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The MIT International Conference 2018
12th - 15th September, 2018
Izola, Slovenia

The MIT Conference first began life in 1995. Since then we have been a bi-annual international gathering of industrial practitioners and academics from different disciplines and from all over the world mostly held in Slovenia and a few times in Romania. The conference has brought together a unique dialogue in the fields of management and innovative technologies.

In the MIT conferences people from different countries, disciplinary backgrounds, sectors and interests come together in a deliberate mixing of technical and philosophical conversation. Cross-disciplinary research and inter-disciplinary ways of working form the heart of this dialogue – the sharing of new practices, stories, research challenges, questions and the results of research and experimentation are shared through a blend of presentation, conversation, emergent discussion and workshop activities.

The event blends formal and informal methods of communication. We don't encourage Death by PowerPoint but we do celebrate innovation, passion for our work, and the asking of tough and inspiring questions.

This is an intense event, which takes place in a beautiful setting. Many leave at the end energised in their work, inspired and motivated.

In this journal, selected peer reviewed scientific papers are gathered. Their content represent the eclectic environment of researchers and scientists that facilitate multidisciplinary discussion on this biannual event.

COMPOSITE MATERIAL MANUFACTURING BY 3D PRINTING AND VACUUM RESIN INFUSION

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ABSTRACT:

ADDITIVE MANUFACTURING TECHNOLOGIES, POPULARLY KNOWN AS 3D PRINTING, ARE USED TO QUICKLY CREATE OBJECTS WITH COMPLICATED SHAPES. ONE OF THE TECHNOLOGIES IS CALLED FUSED DEPOSITION MODELLING (FDM) AND OPERATES BY ADDING LAYERS OF FILAMENT ATOP OF ONE ANOTHER TO CREATE OBJECTS. VACUUM INFUSION IS A TECHNOLOGY USED IN THE CREATION OF COMPOSITE MATERIALS THAT CREATES VACUUM IN THE OBJECT IN ORDER TO DRAW THE LIQUID THERMOSET INTO IT. THE ARTICLE EXPLORES THE ADVANTAGES AND THE VIABILITY OF COMBINING THE TWO TECHNOLOGIES TO CREATE A COMPOSITE OBJECT THAT HAS A SHAPE DEFINED BY FDM PRINTED PLA STRUCTURE AND IS REINFORCED WITH EPOXY RESIN THAT IS APPLIED WITH THE PROCESS OF VACUUM INFUSION.

KEY WORDS: 3D PRINTING, COMPOSITES, PLA, EPOXY, VACUUM INFUSION

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INTRODUCTION

Composite materials have been used since the ancient times but it was not until the introduction of composites on the polymer basis that they became widely used in the industry. They are admired for their high strength to weight ratio when compared to metallic counterparts which has led to their adoption in the fields where weight saving is crucial like the aerospace and automotive industries. As the name suggests composites are comprised of at least two different components that when combined provide exceptional mechanical properties. Conventional composites are made by combining the resin with a fiber as a reinforcement material, usually made of carbon, glass or aramid⁸. We created an unconventional composite by swapping traditionally used fibers with a matrix made by additive manufacturing that would be filled with epoxy resin with the process of vacuum resin infusion.

Additive manufacturing technologies are increasing in popularity and FDM printing of polymers is one of the most prevailing. Using these technologies, we can create objects with complex geometries with ease and low cost. The cost per manufactured object is not correlated with the number of objects manufactured thus making it suitable for making low volume parts with unique shapes such as prototypes or medical prostheses⁹.

There is a variety of additive manufacturing technologies on the market that can be divided into several categories based on the underlying process that is being used. Most notable are the Stereolithography (SLA) and Digital Light Processing (DLP) that rely on the light induced polymerization, Selective Laser Sintering (SLS), Material Jetting (MJ) and Fused Deposition Modelling (FDM). This article will be focused primarily on the FDM technology since it was used to manufacture test specimens.

FDM printing works by extruding polymeric filament through a heated nozzle. There it is melted and shaped in a thin strand. CNC control is used to deposit it layer by layer in a shape of the desired object. This is done separately for every layer starting from the ground up. Schematics of the process are shown in Figure 1. It is one of the cheapest and most broadly used of the additive manufacturing technologies. Materials printed with this method are thermoplastics, usually PLA, ABS or TPU.

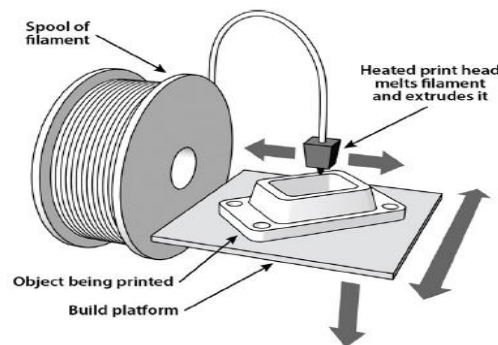


Figure 1: Schematics of FDM printing process¹⁰

⁸ Mazumdar, Sanjay K.; *Composites manufacturing: materials, product and process engineering*: CRC Press, 2002

⁹ Lipson, Hod; Kurman Melba; *Fabricated: The New World of 3D Printing*. John Wiley & Sons Inc, 2012

¹⁰ Barnatt, Christopher; *3D Printing, Third Edition*. Explainingthefuture.com, 2016

Impregnation of the object with the resin can be done in several ways, most popular being hand lamination, resin transfer molding (RTM) and vacuum infusion. We have decided to use the last method due to the accessibility of required equipment and higher quality products¹¹.

The goal of this research is to investigate the benefits and shortcomings of creating a composite of the FDM printed porous PLA specimen that is filled with an epoxy resin by a process of vacuum infusion and comparing it with specimens made of PLA alone. Evaluation was done by comparing the mechanical properties of the materials by conducting the three-point bend test and Charpy impact test.

MATERIALS AND METHODS

Test specimen production consisted of FDM manufacturing of porous specimens, filling them with an epoxy resin using vacuum infusion and if needed post-processing them to fit in the tolerances prescribed by standard. Standard test specimen size for the three-point bend test and the Charpy impact test is the same and measure 80x10x4 mm.

The printing was conducted on Ultimaker 3 FDM printing machine. Cura 3D printing software was used for preparing the 3D model for printing. The build volume is 215x215x200 mm in xyz dimensions or 197x215x200 mm when using both nozzles to manufacture using two different materials. According to the manufacturer the printing resolution is 12.5 μm on xy axes and 2.5 μm on z axis. The large build volume has made possible to print more than one test specimen at a time and shorten the manufacturing time.

Test specimens were made of PLA polymer that is commonly used in FDM printing due to its low cost, good workability and low ecological impact compared to other polymers. The biggest drawback of PLA is the inability to withstand elevated temperatures due to its low glass transition temperature, which may cause it to deform when products are used in warm environment. The test specimen with its details is shown in Figure 2.

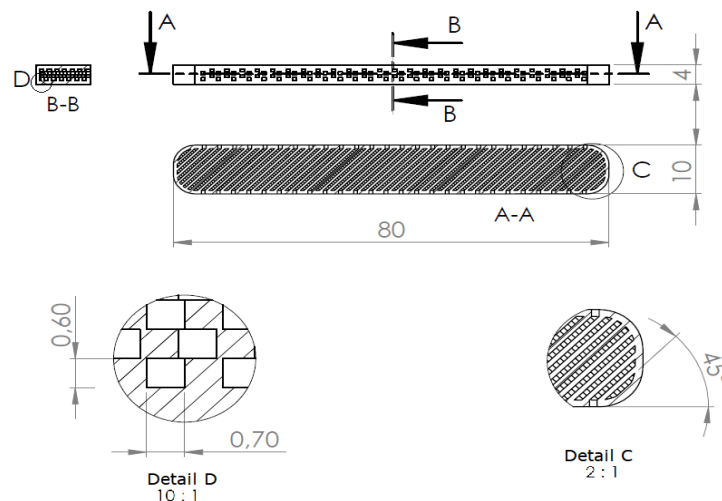


Figure 2: Test specimen. Dimensions were defined according to the standards ISO 179-1:2010 and ISO 178:2010 (80x10x4 mm). The standard does not provide the dimensions of the pores, which were added subsequently

¹¹ Potter, Kevin; Resin Transfer Moulding. Chapman & Hall, 1997

In order to be able to reinforce the material with epoxy resin, the specimen had to be designed in a way that enabled the resin to penetrate into the specimen. Therefore, the specimen had to be designed with less than 100% infill density. The infill density percentage tells us how much of the object's interior is filled with the material. The custom preset had to be created. We used 50% infill density and wall, top and bottom thicknesses of 0.8 mm. To enable the resin to penetrate into the interior of the specimen, the intakes and exhaust holes were incorporated into the walls of the specimen as shown on Figure 2. Resin and PLA were interlaced in each layer to make a homogeneous composite material. The rows of materials were inclined at a 45° angle to provide isotropic mechanical properties in x and y axes. The corners were rounded to avoid bending of the specimen's corners during the printing process.

Test specimens were inspected for any defects that might have occurred during the printing process. The dimensions were checked to insure they comply with the ISO 179-1:2010¹² standard for Charpy impact test and with the ISO 178:2010¹³ for determining of flexural properties with the three-point bend test.

The vacuum infusion takes place in a sealed chamber that is connected by tubes to the epoxy resin on one end and the compressor on other (Figure 3). Sealed chamber was constructed by putting the vacuum foil over specimens and sealing it with a strong adhesive. Sealing has to be done diligently to prevent any leaks in the system. Tube connections are the most critical part when it comes to potential leaks. Vacuum foil was placed over the build area with care to prevent any wrinkles from appearing. Potential wrinkles would be visible on test specimens and the dimensions of test specimens would not be in agreement with the requirements of mentioned standards. The base plate was covered with a separating agent that prevented the epoxy resin from sticking to it and made the removal of the parts simpler. The sealed chamber is shown in Figure 3.

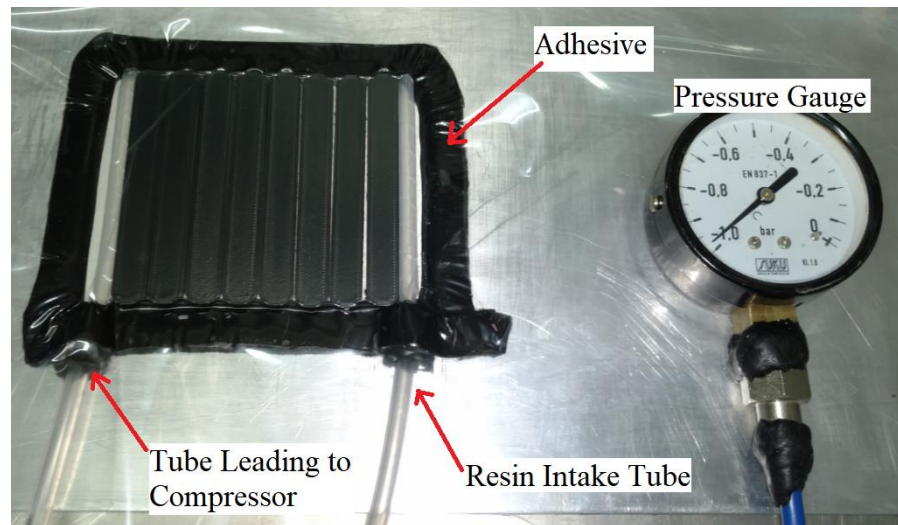


Figure 3: Vacuum infusion system

¹² Slovenski inštitut za standardizacijo; Plastics – Determination of Charpy impact properties – Part 1: Non-instrumented impact test (ISO 179-1:2010), 2010

¹³ Slovenski inštitut za standardizacijo; Plastics – Determination of flexural properties (ISO 178:2010/Amd 1:2013), 2014

To speed up the specimen production process 8 test samples were put in the vacuum infusion system at once. About a millimeter of space was left in between them to simplify the separation of samples as shown in Figure 4. Prior to pumping the resin in the specimens, the infusion system had to be checked for any leaks. This was done by placing a pressure gauge on the resin connection and turning on the pump. The desired value on the gauge was 0.02 bar of absolute pressure. The pump tube was then clenched with a clasp and the system was inspected for possible leaks that would result in an increase in pressure. Upon stable negative pressure reading the specimens were subjected to the epoxy resin infusion.

The epoxy resin used was Araldite LY 564 with the Aradur HY 951 hardener made by Huntsman. Named resin was chosen due to its low viscosity and consequentially higher potential of better impregnation. To further decrease the resin viscosity the build plate temperature was set to 60 °C. This was also the temperature held during the curing process after the infusion.

After the resin curing for 4 hours at 60 °C the specimens were removed from the build plate and were separated from one another. Separation was done by cutting a few millimeters deep in the resin between the specimens and breaking them off. This produced some excessive resin on the sides of specimens that was removed by milling and sanding. The specimens were then inspected whether their dimensions are in agreement with standards ISO 179-1:2010 and ISO 178:2010.

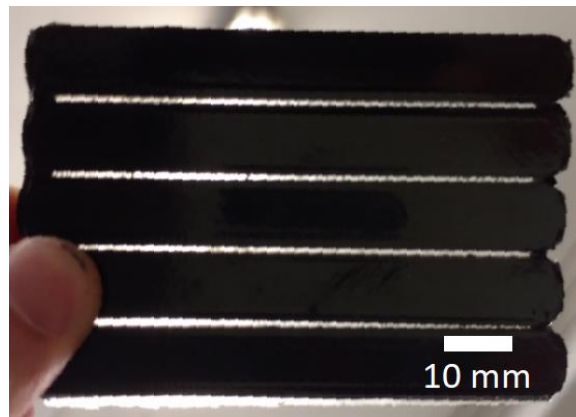


Figure 4: Test samples separated by a thin layer of epoxy resin for easier separation

Properties of specimens were tested using the Charpy test and three-point bend test. All the specimens have been printed on the same Ultimaker 3 FDM printer and are made of the filament from the same spool. 5 specimens of each material were used for the three-point bend test and 10 specimens of each material were used for the Charpy impact test.

RESULTS AND DISCUSSION

The first set of results is from the three-point bend test and is shown in Figure 5. Composite specimens made from the combination of PLA and Epoxy resin are marked as “PLAEPOX”. The reference specimens made from PLA with infill densities of 100% and 50% are marked as “PLA 100%” and “PLA 50%” respectively. Bending tests were conducted in accordance with ISO 178:2010.

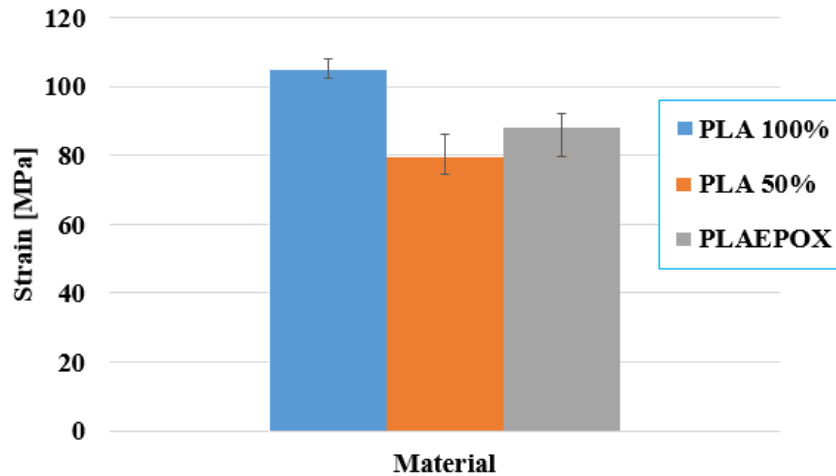


Figure 5: Chart comparing three-point bend test results (ISO 178:2010)

The best results were exhibited by the specimens made from PLA with 100% infill. They topped the chart as they endured the highest applied force and managed to achieve the biggest deformation before yielding. Composite material presented nearly identical characteristics to PLA with 100% infill but had a brittle fracture at lower load. PLA with 50% infill managed the lowest force of the three but endured bigger deformation than the composite material.

When comparing the specimen made of PLA with 50% infill density with the composite, the composite between PLA and epoxy exhibits better tensile strength. It appears as if the added epoxy resin acts like the remaining 50% of the infill due to the similarity with the results gathered from the specimens made from PLA with the 100% infill density. The lack of ductility of the composite material could be explained by the lower ductility of epoxy resin when compared to the PLA. Therefore when the epoxy component breaks the whole strain is transferred on to PLA, which can not bear the load due to its low infill density and the specimen yields.

Charpy impact test was conducted according to ISO 179-1/fU method which prescribes the usage of unnotched test specimen with flatwise blow direction. Material markings are the same as on the three-point bend test chart. The results are shown in Figure 6.

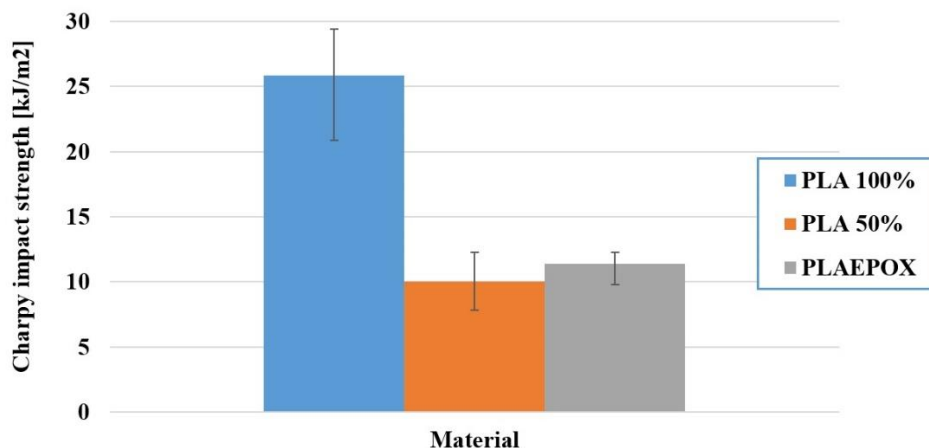


Figure 6: Charpy impact strength (ISO 179-1/fU)

Again, the PLA with 100% showed the best properties with highest Charpy impact strength. It is followed by composite made from PLA and epoxy resin with 11,4% higher impact strength than PLA with 50% infill.

Relatively close performances by the PLA with 50% infill density and the composite material could be explained by the fact that the PLA is more ductile compared to epoxy resin, consequentially absorbing the majority of the dissipated energy. Epoxy component does help by a small amount, resulting in a modest increase in the impact strength of the composite compared to PLA with the 50% infill. PLA with the 100% infill has the most ductile load bearing material and achieves the best result.

CONCLUSION

Gathered results show no benefit regarding mechanical properties of test specimens by going from PLA with 100% infill density to the composite made of 50% PLA and 50% epoxy resin, although it performed better than PLA with 50% infill density.

Given the results there are doubts whether the additional complexity of manufacturing the composite part is worth the trouble. Looking solely at measured values there is no point of creating PLA-epoxy composite, however there might be applications where adding epoxy yields improvements. For example, PLA has low glass transition temperature, becoming soft and potentially deforming at temperatures in excess of 50-60 °C. In that case adding epoxy component might decrease the chance of deformation and increase the rigidity at those temperatures. Presently, the ABS filament is commonly used when better performance at elevated temperatures is desired. Easier to print PLA with added epoxy resin might be justified to use instead due to easier FDM manufacturing process. This should be investigated in further experiments.

The main drawback of using the proposed process chain is the amount of additional time and labour required to make a composite part. If one was able to simplify the production process the PLA-epoxy composite could become an interesting alternative.

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ENHANCED SECURITY AND ALERTING SYSTEM IN THE CONTEXT OF INTERNET OF THINGS AND CLOUD FACILITIES

George CARUTASU¹
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ABSTRACT:

THE PRIORITY OF LIFE AND PERSONAL ASSETS RESCUE, IN THE CONTEXT OF INTERNET OF THINGS AND CLOUD FACILITIES, OPENS NEW OPPORTUNITIES FOR EMERGENCY SYSTEMS DEVELOPMENT. THE ACTUAL ALERTING 112 EMERGENCY MECHANISM IS BASED ON CALLS MADE BY THE HOUSEHOLD OCCUPANTS TO 112. THE PAPER DEBATES THE OPPORTUNITY OF USING SENSORS TO AUTOMATICALLY DETECT FIRES, BURGLARIES AND LIFE IN DANGER SITUATIONS FOR HOUSEHOLD RESIDENTS AND TO BE SENT TO 112 AS DATA PACKAGE. LIKE ECALL SYSTEM, THE ALERTED SITUATION IS DETAILED INTO A MINIMUM SET OF DATA (MSD), CONTAINING THE TRIGGERED SENSORS, OWNER OF HOUSEHOLD, NUMBER OF RESIDENTS PRESENT IN THE BUILDING AND TIME STAMP. IT MUST BE NOTICED THAT ECALL SYSTEM IS DESIGNED FOR CAR ACCIDENTS AND IT IS OPERATIONAL STARTING WITH 2017 AND MANDATORY FOR NEW DESIGNED VEHICLES CLASS M1 AND N1 AFTER 30TH OF APRIL 2018. AFTER THE MSD IS RECEIVED BY 112, THE EMERGENCY SYSTEM WILL USE ALSO USE THE CALL BACK FUNCTION TO CHECK AND REQUEST MORE DETAILS ABOUT THE EMERGENCY EVENT. FURTHERMORE, THE MANUAL TRIGGERING BUTTON IS ALSO PROVIDED TO INITIATE MSD. THE HOUSEHOLD ALERTING SYSTEM COULD ALSO INTEGRATE, BESIDES FIRING, GAS LEAKING DETECTION AND BURGLARIES, NEW INTERNET OF THINGS DEVICES THAT MONITORIES THE HEATH OF RESIDENTS. THE FORESEEN EMERGENCY SITUATIONS, OTHERWISE IMPOSSIBLE TO BE ALERTED ARE: FIRING, GAS LEAKING AND BURGLARIES WHEN NO RESIDENT IS PRESENT AND SEVERE HEALTH ISSUES, LIKE HEART ATTACK WHEN THE RESIDENT IS UNABLE TO MAKE THE CALL TO 112.

KEY WORDS: HOUSEHOLD EMERGENCY, INTERNET OF THINGS, SENSORS, ECALL

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INTRODUCTION

The actual alerting system for emergency situations in Romania, according to 112 website³, is by voice call, SMS (Short Message Service) and eCall for vehicles. The 112 should be alerted when life, property or environment need immediate assistance from Fire Brigade, Police or Ambulance.

From emergency type point of view, there several common situations that consist a 112 indicated calling:

- Criminality against persons (homicide, armed assault, attack, robbery) or property (fire, burglary),
- Traffic accidents (road, train, ship, aviation),
- Extreme weather accidents (landslide, fire caused by thunder, flooding),
- Personal accidents (severe medical problems, electrocution).

As information flow for voice call alerting method, the caller initiates a voice call to 112 and during the call the PSAP (Public Safety Answering Point) operator is questioning the caller, according to internal procedure, regarding the nature of emergency, caller identity, emergency location and severity. From communication point of view, the call is treated as emergency call, having priority against all other calls, using 112 discriminator flag, might using Public Switched Telephone Line (PSTN), mobile network or even Voice over IP (VoIP) call (figure 1). As disadvantages for this alerting method, it can be emphasized:

- High rate of false calls, most emergency agencies report over 50% rate of false calls⁴,
- Inaccurate location of emergency, excluding calls made from PSTN where address is recorded into land phone line client database, but also confusions possible by misinterpreting the address. Furthermore, in case of mobile calls, the accuracy might vary from kilometers to tens of meters, depending on cells density. In case of Voice over IP call, the location is even more unlikely to be established,
- Impossibility of caller identification in some cases like pre-paid SIM or VoIP,
- Lack of emergency severity detection, the dispatched rescue forces are sized according to caller given information and PSAP operator interpretation.

³ Special Telecommunication Service, “112-Sistemul national unic pentru apeluri de urgenta.”. Accessed: August 16, 2018

⁴ EENA, “False Emergency Calls,” 2011

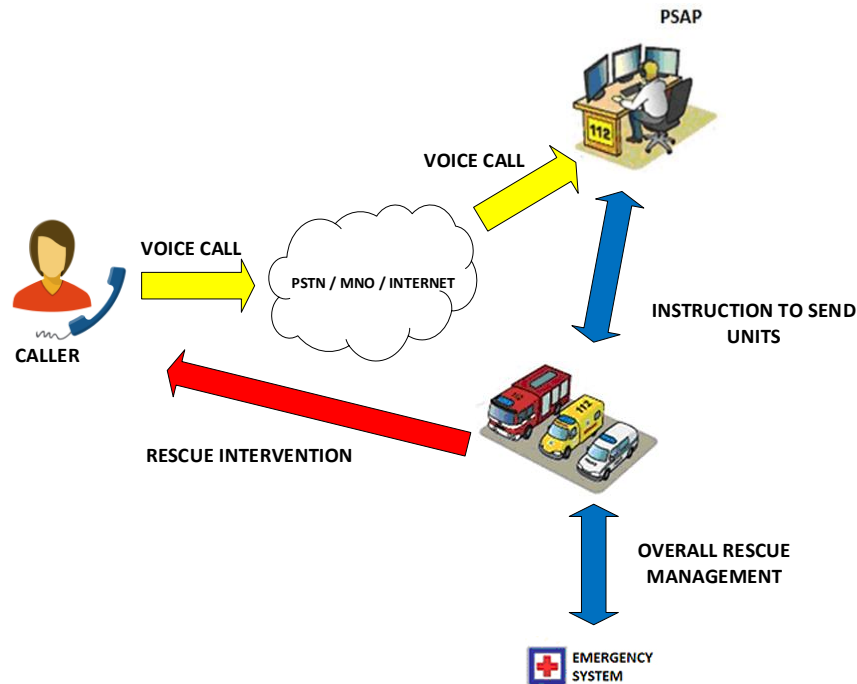


Figure 1. 112 system architecture

The second method of alerting emergency system is using 113 number to send a SMS, which mandatory should contain the nature of emergency and the address (location). The 113 SMS emergency service is operated according the Law 132/2015 for persons with hearing or speech disabilities. As a difference against previous voice call method to 112, the SMS service requires that potential user to be pre-registered to Single National Emergency Calls System (SNECS). The operational flow³ implies that the person with disabilities initiate the call to 112 and receives a message with the text “SEND AN SMS TO 113 WITH THE EMERGENCY AND ADDRESS OF THE INCIDENT”. The caller must reply to 113 with requested information, the two-way communication channel making possible further details requirement from PSAP operator.

What is important to be noticed regarding 113 SMS service is that the communication between caller and emergency agency is made using a two-way channel and the content of emergency is exclusively data. Also, the pre-registered form might be able to enhance the location accuracy.

The last alerting method presented is eCall. The eCall⁵ represents a harmonized free emergency service at European level which makes possible the automatically notification of 112 in case of car accident. The implementation of eCall at PSAP level and most of operational tests

⁵ “The interoperable EU-wide eCall - European Commission.” Accessed: June, 26, 2017

were made under HeERO1⁶ and HeERO2 projects course. The Romanian pilot site and tests are largely exhibited in⁷. In figure 2⁸ is presented the operational flow of eCall service.

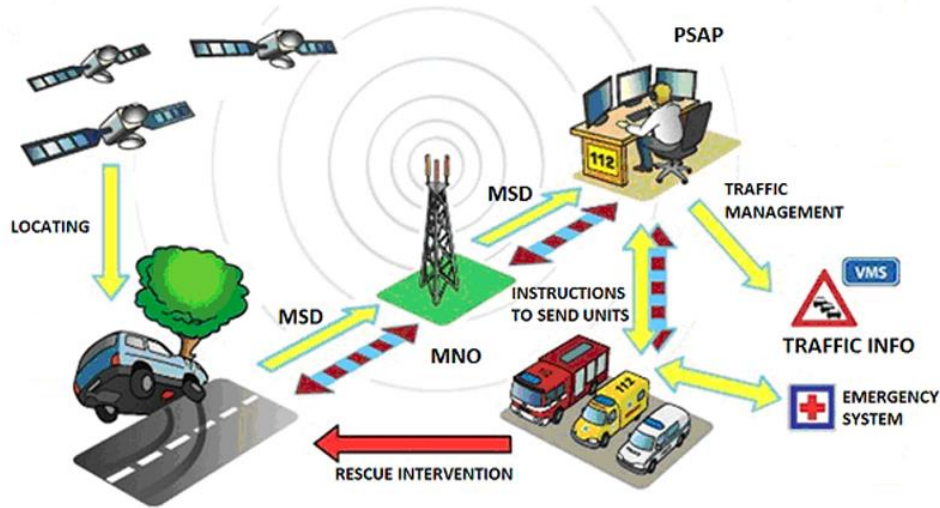


Figure 2. eCall operational flow

The emergency is automatically detected by car embedded sensors or could be triggered manually. The emergency call is started using an Minimum Set of Data (MSD), the content being standardized by CEN EN 15722⁹. However, after the MSD is sent from InVehicle System (IVS) to 112 and it is received successfully, the content of MSD is resolved and proper displayed as meaningful information to PSAP operator. The operator initiates the call back function of the system in pursuit of more detailed information regarding the emergency. Furthermore, in time of calling, the operator already posses the location, using the GNSS coordinates, the car model, by resolving Vehicle Identification Number (VIN) code into the EUCARIS database, all this information being included into MSD. The further action is seized according to call details or procedural standard rescue force are dispatched if no one can answer or is unable to give more details.

As specific to eCall alerting method, it can be underlined several aspects:

- The triggering event is automatically set, but also could be manually, increasing the range of situations that can be used. It covers the situation when driver could be temporarily incapacitated by a hearth attack or stroke when shortening the intervention time is a priority. Also, if an accident or other emergency is seen on the road, the driver could use the hands-free feature of IVS, without stopping or pay attention to phone during of call,

⁶ HeERO Consortium, "HeERO - About HeERO Objectives." Accessed: July 5, 2017

⁷ Dumitrescu, Dorin, Andrei Grososiu, Sorin Dumitrescu, Vioteta Rosu, Germina Ristea, and George Carutasu, "Solution for eCall implementation at national level within the HeERO project - Romania case study," (paper presented in 19th Intelligent Transport Systems World Congress, ITS 2012, 2012)

⁸ EENA, "eCall," 2014. http://www.eena.org/uploads/gallery/files/pdf/2014_10_28_3_1_5_eCall_Update_v2.0_FINAL.pdf

⁹ BSI Stanards, "Intelligent transport systems. eSafety. eCall minimum set of data (MSD)," 2011

- The location is signalized into MSD, avoiding the address misinterpretation and indicating the direction of move, being very useful on highways accidents where dispatching points positioning depends on it,
- The severity of the accident might be evaluated using optional additional data field, where vehicle manufacturer or special vehicles categories are defined. Furthermore, after iHeERO project it possible to implement eCall for two-wheels vehicles, long distances buses and dangerous goods transports¹⁰.

NEXT GENERATIONS EMERGENCY SERVICES AND SMART HOME

After detailing the alerting methods described above, it can be noticed that between today users IT&C usage and emergency services is very serious gap, in terms of type of communications channel used. Furthermore, if we are considering the way that people communicate nowadays, using social media, video calls over mobile networks or internet, sharing location etc. and the possibility of resolve those data into 112 system, reveals a technical impossibility to do so.

There are several reasons, which contributes to this fact, regarding the gap between existing technology and related emergency services:

- Lack of standardization of data format, approved to be used into 112 systems from foreign applications. For instance, in case of eCall service was necessary to implement 11 different standards¹¹ to normalize the communication between IVS and PSAP, starting with discriminator flag implementation, to consider the call back function, where the PSAP calls the IVS, MSD format and finishing with high level applications protocols,
- Harmonization and pan-European feature of the service, because of mobility character of the emergency for car accidents, the service should operate into the same way all Europe and to be able to treat eCalls from foreign cars situated on national territory, which was a huge task to plane the procedure around all PSAP,
- Industry effort to implement the service, beside the PSAP upgrade was necessary to implement the eCall flag discriminator by all MNO's around Europe and car manufacturers to certify and implement IVSs to new car models.

To recover this gap, the European Emergency Number Association published a position document¹², that reveals the main features of NG 112 and also in EMYNOS project¹³:

- Extending the communication option from traditional voice call to VoIP, message text, real time messaging, pictures and video,
- Improve the interoperability between PSAP and other emergency services to facilitate the data transfer,

¹⁰ Carutasu, George, Cristina Coculescu, and Mihai Alexandru Botezatu, "Romanian roadmap for e-call technology adoption and future developments of emergency systems," (paper presented in Annals of DAAAM and Proceedings of the International DAAAM Symposium, 2017)

¹¹ EENA, "eCall and open issues (2018 revision)"

¹² EENA, "Next Generation 112 Long Term Definition," 2014.

¹³ Markakis, Evangelos, Asimakis Lykourgiotis, Ilias Politis, Anastasios Dagiuklas, Yacine Rebahi, and Evangelos Pallis, "EMYNOS: Next generation emergency communication," IEEE Communications Magazine, 55, 139–45 (2017)

- Moving to IPv6 architectures for all services, allowing multiple routing and identification methods to be used instead of CallerID.

As it can be seen above, the 112 is more oriented to manually initiated call rather than automatically alerted situation, the exception being given by eCall. For the main proposal of this paper, to implement an enhanced security and alerting system for households, the legacy of existing 112 system can not be ignored. Regarding the smart home concept, even is present in the literature¹⁴ it traits mainly the energy efficiency¹⁵ in the context of smart metering implementation. However, beyond the real-time sensors based decision systems, the smart home is a concept that use efficiently resources to sustain the indoor living environment. Related to smart home application development, in¹⁶, the authors proposed a framework for further services, presented in figure 3.

The emergencies signalized by an automated system from smart homes should eliminate or reduce at least the disadvantages of traditional voice call. In this case, it will be emphasized as individual:

- High rate of false calls: automated identification of household will discourage the caller to initiate false calls and even so, restriction might be implemented for abusive calls,
- Inaccurate location: the data packet, like MSD will contain the GNSS coordinates of emergency location,
- Lack of emergency severity detection: the sensors triggering the call will be displayed to PSAP operator, indicating the nature of emergency and severity.

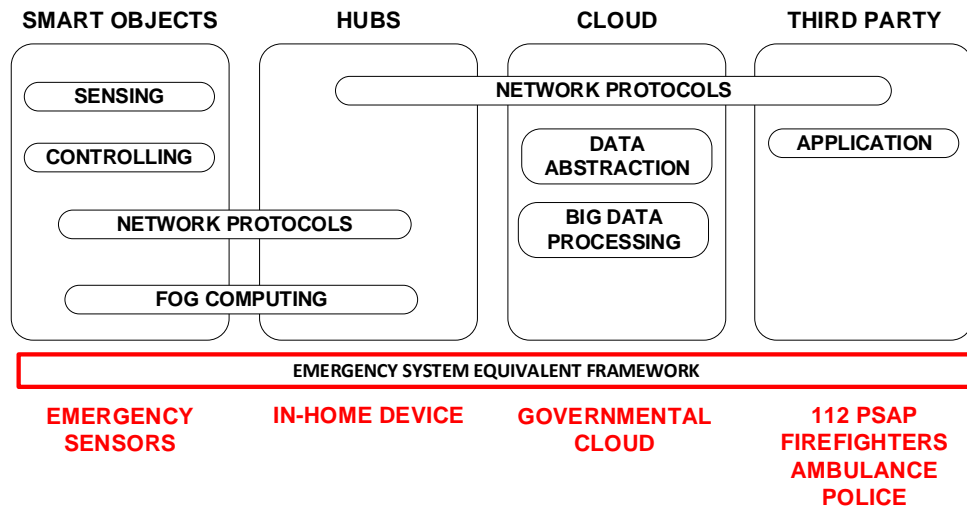


Figure 3. Emergency system architecture for IoT (adapted from¹⁶)

¹⁴ Alaa, Mussab, Aws Alaa Zaidan, Bilal Bahaa Zaidan, Mohammed Talal, and Laiha Mat Kiah, "A review of smart home applications based on Internet of Things," Journal of Network and Computer Applications, 97, 48-65 (2017).

¹⁵ Carutasu, George, Alexandru Pirjan, Cristina Coculescu, and Nicoleta Luminita Carutasu, "Business opportunities for retrofit homes within smart meter implementation context," (presented in Technology and Innovation Industrial Management, 2018)

¹⁶ Risteska Stojkoska, Biljana, and Kire V. Trivodaliev, "A review of Internet of Things for smart home: Challenges and solutions," Journal of Cleaner Production, 140, 1454-14, (2017)

PROPOSED SOLUTION FOR SMART HOME EMERGENCY SYSTEM

As is presented in figure 3, the 112 system architecture adapted for IoT should comprise the next modules:

- Emergency sensors that detects any potential situation that might endanger the live of residents, property or environment and for this purpose are established the potential situations:
 - Criminality against persons or property (attack, burglary) and in this case the system could be used as panic alarm button and immediate alerting systems without being necessary to send all emergency details (e.g. identification, location),
 - Fire (fire condition detection, number of residents, rooms affected),
 - Personal accidents (severe medical problems).
- In-House System, presented in figure 4 with similar function with IVS, integrating home sensors, communication function using PSTN/GSM/GPRS module with GSM antenna if mobile channel is selected and GNSS localization. Unlike vehicles accidents, in case of house emergency location could be stored at initial setting of IHS. The short-term memory function is used to store sensors recorded data a small period (one hour) in 5 minutes series, very useful in establishing the severity of emergency.
- Governmental cloud, structure necessary to integrate data among all emergency agencies but also, with National Agency for Cadaster and Land Registration for building floor plans, Construction State Inspectorate for Construction Authorization details, like type building material, year of construction, type of heating systems, Police for number of residents declared as living in current household etc.
- 112 PSAP, firefighters, ambulance or police, that receive the emergency data crossed the governmental cloud and to forward it to rescue forces.

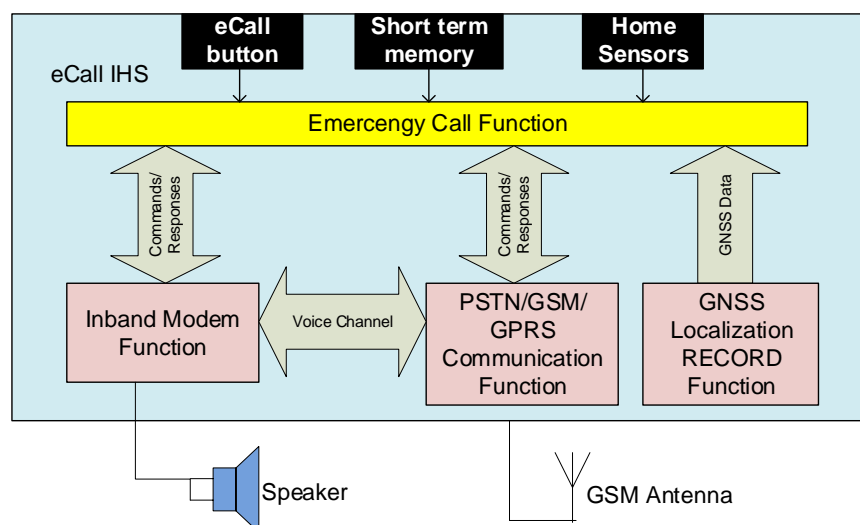


Figure 4. In-House Emergency module architecture

The operational flow (figure 5) for the enhanced security and alerting system follows the rules and procedures of eCall for vehicles. The emergency is triggered automatically or manually, sending MSD from IHS to PSAP through PSTN/MNO/Internet communication channel. The MSD is resolved by PSAP interface, displaying to PSAP operator the significant details of emergency: nature of emergency, location in GNSS coordinates and postal address (useful for multilevel households), unique residency number, which further will allow to interrogate from external agencies database for additional details, number and type of sensors triggered and might access the short-time memory of IHS as history.

After the MSD is received, the PSAP call back to IHS, in attempt of establishing the connection with eye-witness of the event and determine more accurate the severity of emergency. The collected data is sent to emergency rescue forces dispatched to intervene at emergency site.

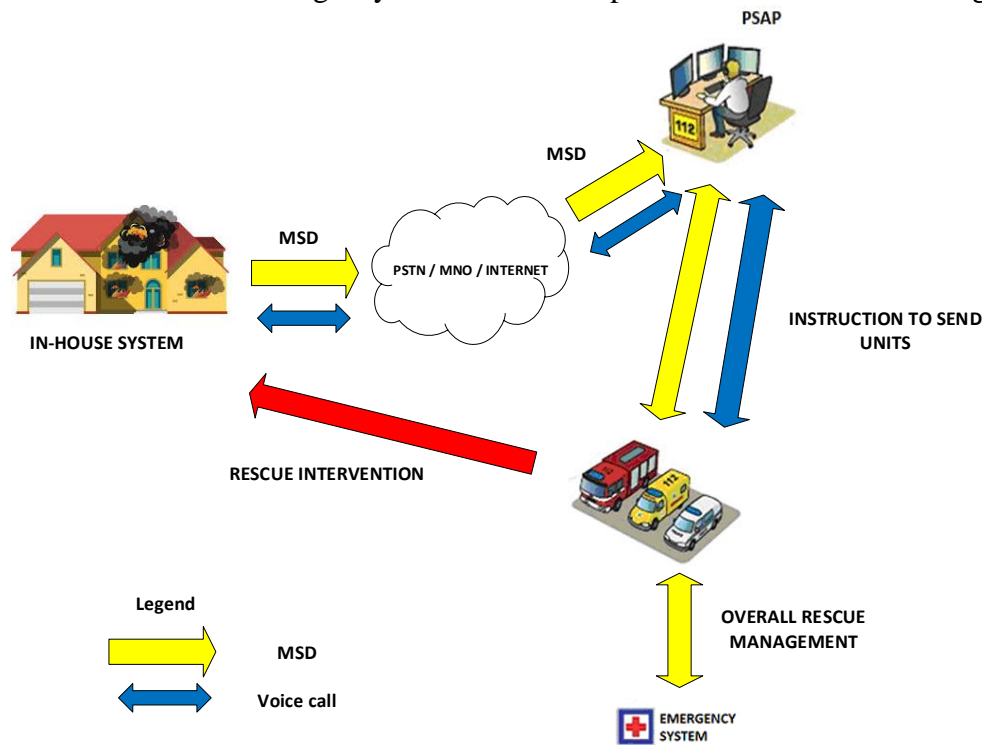


Figure 5. eCall operational flow for households

The content of MSD in case of In-Vehicle Systems is regulated by CEN EN 15722. The comparison between MSD content for vehicles and households is presented in table 1.

Table 1. Comparison between MSD content for vehicles and households

MSD for vehicles	MSD for households
Message identifier: MSD format version	Message identifier: MSD format version
Activation: Automatically / manually triggered	Activation: Automatically / manually triggered
Call type: Emergency or test call	Call type: Emergency or test call
Vehicle type: passenger Vehicle, buses and coaches, light commercial vehicles, heavy duty vehicles, motorcycles	Residential type: Single-family home (SFH), apartment blocks

Vehicle Identification Number (EUCARIS)	Residential Identification Number (National Agency for Cadaster and Land Registration)
Vehicle propulsion storage type: Gasoline tank, Diesel tank, Compressed natural gas (CNG)	Heating systems type: natural gases, electric, pellets etc.
Time stamp: Timestamp of incident event	Time stamp: Timestamp of incident event
Vehicle location: determined by the on-board system at the time of message generation	Residential location: stored at initial setting of IHS and resolved using Residential Identification Number in related database of National Agency for Cadaster and Land Registration
Recent vehicle location (Optional): vehicle's position in (n-1) and (n-2)	Recent sensors values: Reading the recent values of sensors from short-term memory of IHS
Number of passengers (Optional): number of fastened seatbelts	Number of residents: Values obtained by resolving the Police database for determined location and reading values from occupancy sensors disposed in rooms
Optional additional data field that can be used to send additional information to PSAP	Optional additional data

CONCLUSIONS

The novelty of the paper is given by using the existing eCall technology, which now is available for automotive industry, for households. Authors contribution consists in evaluating and foreseen the changes needed to implement eCall technology for wide category, meaning households, with immediate user adoption. The results of study might be used for feature adoption of eCall or other emergency services for households. The existing emergency system features, regarding alerting methods are still behind the technology used in ordinary life by the citizen. Even further efforts were made for implementing combined voice call and data message as communication channel between caller and PSAP, or NG 112 framework is defined, changing the paradigm from CallerID to IPv6. The very long term of implementation, eCall started in 2009 with an impact study, in 2017 PSAP reported the availability for the service and is mandatory only for new car models for class M1 and N2 after May 2018, rise a series of questions regarding the priority of rescue services into EU action plan or budget. The extension of already existent eCall technology to other type of use scenario, like boats, trains or residential building enhance the efficiency of investment for this technology. However, the presented solution is depending on eCall key elements but involves further developments. The first measure is to connect all emergency agencies and other related structures into a governmental cloud structure, able to offer a secure and integrated access for various information that might be useful during on-site emergency intervention of rescue forces. Another issue to discuss is that all residencies should have available for query from PSAP site at least several data explained into table 1, this Residencies Register is already implemented in traditional form, each property having a unique cadaster number. The type and position of sensors should be further evaluated, but a starting pull might consist in smoke detector, temperature, carbon monoxide or dioxide sensors, occupancy for each living space and security sensors for preventing unauthorized entrance on property: broken glass, door and window sensors and motion detectors.

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ENHANCING ENTREPRENEURIAL COMPETENCIES AND LOWERING SOCIAL INEQUITY FOR UNDERDEVELOPED REGIONS IN ROMANIA

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Florina CHISCOP³

ABSTRACT:

THE UNEQUAL DEVELOPMENT OF ROMANIAN REGIONS CONDUCTS TO SOCIAL INEQUALITY REGARDING THE REVENUES, SOCIAL SERVICES AND PERSONAL DEVELOPMENT. THE REMOVING OF SOCIAL INEQUALITY IS ONE OF THE EUROPEAN PRIORITIES REGARDING ASSURING THE SAME LIFE CONDITIONS AND RESOURCE ACCESS. ONE OF THE ACTIONS TAKEN BY EUROPEAN COMMISSION, JOINED TO ROMANIAN GOVERNMENT IS TO ENHANCE THE ENTREPRENEURIAL COMPETENCIES OF UNDERDEVELOPED REGION POPULATION AND TO FINANCE THE ESTABLISHMENT OF NEW SMALL BUSINESS ACCORDING TO LOCAL NEEDS. THE PAPER PRESENTS A RESEARCH MADE IN ROMANIAN MUNTENIA-SUD REGION, REGARDING THE EFFECTIVENESS OF TRAINING CURRICULA AND MODEL USED TO ENHANCE THE ENTREPRENEURIAL COMPETENCIES. FURTHERMORE, THE SYLLABUS, TRAINING METHOD AND ORGANIZATION ARE PRESENTED, TOGETHER WITH THE RECORDED SATISFACTION QUESTIONNAIRE ANSWERS AND THE ACTION PLAN FOR IMPROVING THE TRAINING RESULTS. THE BIZZSMART PROJECT IS DEVELOPED BY UNIVERSITY POLITEHNICA OF BUCHAREST, IN SEVEN SOUTHERN COUNTIES, WITH 400 PEOPLE AS TARGET GROUP. THE PROJECT ACTIVITIES COVER INITIAL TRAINING OF SELECTED PERSONS, ACCORDING TO FINANCING REQUEST, THE INDIVIDUAL BUSINESS PLAN COMPLETION AND EVALUATION AND THE FINANCING AND MONITORING OF 80 SELECTED BUSINESS FOR A TWO-YEARS PERIOD, WITH UP TO 40 000 EUR EACH.

KEY WORDS: ENTREPRENEURSHIP, ENTREPRENEURIAL COMPETENCIES, TRAINING.

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INTRODUCTION

The continuous need to enhance entrepreneurial competencies is established in⁴, to avoid business cycles influences. According to the Romanian National Employment Agency⁵, unemployment statistics on 31th of August 2016, out of 10 counties with the highest unemployment rate, three are from the South-Muntenia Region (RSM), representing 30%, and from the seven counties with the highest rate of unemployed persons without compensation from the total number of unemployed, two counties are from RSM (28.57%). Also, the information included by the National Prognosis Commission in the report "Projection of the main economic and social indicators in territorial profile until 2017"⁶ shows that the unemployment rate projected in 2016 on RSM is 6.6%, and in 2017 it is 6.4%, being just overtaken by South-West Oltenia.

Following the history of sustainable development indicators, according to the reports published by the National Institute of Statistics (INS), turnover in innovation is 5.75% of total turnover in 2012, and innovative enterprises that have introduced new or improved products in 2012 was 149 out of 1216 (12.25%). INS also published a report in 2018⁶, which shows that the number of active enterprises in RSM is 3,108 (11% of the total nationally active enterprises 28,809), a small percentage for the second region as a population. The South-Muntenia Regional Development Agency (RDA) has developed the RSM Intelligent Specialization Strategy (SSI) for 2014-2020⁷. Following the study of this strategy, it was noticed that: RSM has a population of over 3.2 million inhabitants, meaning 15% of the population, being the second most populated region of Romania. With over 53 000 active local units accounting in 2012 12.8% of the turnover achieved by local units at national level and net investment of over 10 billion lei, RSM ranks second in the top regions of Romania to these chapters. Industry accounts for over 42% of the region's total business, but the trend of innovative enterprise development is decreasing (down from 642 to 168 in 4 years).

IMPROVING ENTREPRENEURIAL SKILLS AND BIZZSMART PROJECT

Enhancing entrepreneurial competencies was addressed before, especially for students, using different practices⁸ or tools⁹. In this context, the idea of the project POCU / 82/3/7/105944, "Increasing employment through the support and development of innovative entrepreneurship in South - Muntenia - BIZZSMART", developed by POLITEHNICA University of Bucharest was developed. Thus, the project stimulates the development of entrepreneurship, job creation and the establishment of small and medium-sized enterprises with a non-agricultural profile in the urban

⁴ Christiano, Lawrence J., Martin S. Eichenbaum, and Mathias Trabandt, "Unemployment and Business Cycles," *Econometrica*, 84, (2016): 1523–1569

⁵ Romanian National Employment Agency, "Unemployment rate August 2016 Romania." Accessed: March, 02, 2017

⁶ National Prognosis Commission, "Projection of the main economic and social indicators in territorial profile until 2017" Accessed: September 09, 2017

⁷ The South-Muntenia Regional Development Agency, "RSM Intelligent Specialization Strategy (SSI) for 2014-2020." Accessed: September 09, 2017

⁸ Carutasu, Nicoleta Luminita and George Carutasu, "Collaborative virtual environments using ERP and cloud tools," Paper presented in 10th International Technology, Education and Development Conference, Valencia, 7-9 March, 2016

⁹ Carutasu, Nicoleta Luminita and George Carutasu, "Replicating enterprise environment using Office 365 to enhance graduates' employability," MATEC Web Conferences, 121, (2017)

area, able to capitalize the innovative potential in industry and services. The duration of the project is 36 months starting on 29 December 2017.

The BIZZSMART project aims at eliminating or reducing the negative impact of social inequity on target group members (GT) through:

1. Reducing the high outflow of youth from RSM to other more developed areas;
2. Stimulate the employment of the population in the sectors with high added value;
3. Diminishing the number of unemployed and / or unpaid unemployed;
4. Assistance in drafting patent applications for own ideas;
5. Assistance in identifying and implementing untapped patents;
6. Capitalizing on existing resources and sustainable development;
7. Intensifying the collaboration between business and higher education, research and development and technology transfer units.

The **objectives** of the BIZZSMART team are as follows:

Overall objective. Ensure long-term sustainability in the South-Muntenia development area by supporting and developing entrepreneurship, creating jobs and setting up small and medium-sized enterprises capable of harnessing the innovative potential in industry and services, while responding to concrete needs of the workplace in the areas covered by the project by supporting the implementation of selected business plans to be funded by minimis aid scheme, while providing an entrepreneurial training program and personalized counseling / mentoring / mentoring services.

Specific objective 1. Increase of entrepreneurial abilities and skills unemployed & inactive / employed persons, including self-employed, wishing to start a business by offering an entrepreneurial training program and by providing support in identifying and promoting services in new, high-activity areas of activity or niche (based on inventions or innovations, new or advanced technologies: computer assisted design, computer assisted engineering, assisted manufacturing, 3D printing, medical recovery equipment development, personalized monitoring systems, preventative maintenance, things and others) as well as services in common areas (e.g. franchise business, non-technical services and others) that have market potential.

Specific objective 2. Increase in the number of enterprises and the creation of new jobs by supporting the implementation of the business plans selected to be funded under the minimis in the South-Muntenia Region, addressing unemployed & inactive / employed people, including self-employed persons, offering personalized counseling / mentoring / mentoring services.

Specific Objective 3. Develop a professional networking network (professional networking) between target group members and other individuals or businesses interested in partnerships or funding - both during and after the project, in order to facilitate partnerships and development business.

To achieve the objectives, the indicators and the proposed results, **the activities** carried out within the project are the following:

A1. Professional training in the field of entrepreneurship, with next sub-activities: *informing the potential target group on the training program, the selection methodology and the benefits received by participating in the activities carried out within the project; counseling the target group to select people with entrepreneurship spirit and selecting the target group to participate in the courses organized within the entrepreneurship training program; organizing and running the entrepreneurial training program; selection of business plans to be funded under the project; conducting internships,*

A2. Implementing business plans funded by the ESF, with next sub-activities: *providing personalized counseling / mentoring / mentoring services for selected business plans; monitoring the functioning and development of funded businesses, including using ICT tools;*

A3. Monitoring the functioning and development of businesses funded under their sustainability period, including using ICT tools;

MONITORING THE RESULTS OF THE TRAINING ACTIVITY

Within BIZZSMART, the Satisfaction Assessment process for training activities starts from the moment the members of the target group access the training services through their participation in the training courses and until the training has been completed.

Through the Satisfaction Analysis Questionnaire, we have been looking at the **continuous improvement of the training program**. We also considered a more accurate understanding of learners' needs and expectations, identifying and eliminating the causes of nonconformities, processing and analyzing information provided by learners, objectively assessing quality and improving the training process.

In this way, BIZZSMART team paid maximum attention to the needs of learners, meeting their requirements for quality improvement and a high level of satisfaction. Therefore, the following satisfaction criteria were used to develop the questionnaire:

- Overall degree of satisfaction through participation in the Entrepreneurial Competence course,
- Expectations, in particular,
- Volume of knowledge,
- Teaching methods,
- Attitudes of trainers towards learners,
- The usefulness of the themes, in achieving the objectives of the course,
- The degree of encouragement of participation in the discussions,
- The professionalism of trainers,
- Equipment used for the course,
- Support materials for the course,
- The work of other members of the BIZZSMART team (other than trainers).

Also, the learner was asked to make suggestions to the organizers / trainers to improve the organization and conduct of the course. Concerning the definition of questions, of the three possibilities:

- Closed questions - with a single answer and multiple answer,
- Open questions - with free answer, numerical answer etc.,
- Scoring questions - rankings and sums.

Closed questions were considered for the questionnaire. The way the answers are evaluated is the arithmetic sum of the score for the applicable questions and to calculate the percentage ratio for applicable questions. The analysis questionnaire was applied to a total of 40 trainees (Table 1), representing the graduates of the Entrepreneurial Competence course held between 14.04.2018 - 29.04.2018. Data collection was done on 28th of April 2018, after the completion of the course. Before completing the learner questionnaire, they were explained the role of the questionnaire and the fact that the answers provided were confidential. The average time to complete a questionnaire was 10-15 minutes.

Table 1. Classification based on the education level

Crt. No.	International standard education classification (ISCED)	No. of trainees
1.	ISCED 2 – Lower secondary education ISCED 2	1
2.	ISCED 3 – Higher secondary education ISCED 3	6
3.	ISCED 4 – Non-university tertiary education (post-secondary education)	4
4.	ISCED 5 – Short-term higher education	4
5.	ISCED 6 – License Studies	14
6.	ISCED 7 – Master's degree studies	10
7.	ISCED 8 – PhD degree studies	1

Note: The investigated lot has only indicative, not representative value, providing only an overview of the activity carried out between 14.04.2018 - 29.04.2018.

1. Appreciation of the course in general

To determine the general satisfaction with participation at the *Entrepreneurial Competence* course, the respondents were asked to answer the question: *How do you rate the course in general?* Thus, 22 trainees (55% of 40 respondents) appreciated the course **Good**, 12 trainees (30% of 40 respondents) **Very good** and only 4 (10% of respondents) appreciated the course **Satisfactory**. The results obtained in this question are shown in Table 2 and Figure 1. It is worth mentioning the high share of those who positively appreciated the course - 85% of the respondents (34 students).

Table 2. Results for “How do you rate the course in general?”

	Very good	Good	Satisfactory	Wick	Very wick
How do you rate the course in general?	12	22	4	1	1

How do you rate the course in general?

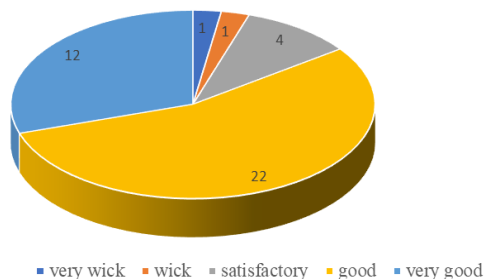


Figure 1. Appreciation of the course in general

2. Fulfilling expectations through this course

To find out how to meet expectations by participating in the *Entrepreneurial Competence* course, the learners were asked to answer the question: *How have your expectations been met by this course?* Thus, for 22 trainees (55% of 40 students) the expectations were met **To a great extent**, for 10 trainees (25% of the 40 trainees) **To a high extent** and only for 4 (10% of the respondents) **Satisfactory**. The results obtained in this question are shown in Table 3 and Figure

2. Also, as in the case of the first question, there is a high share of those who have positively appreciated their expectations by attending the course - 80% of the students (32 respondents).

Table 3. Results for „How have your expectations been met by this course?”

	To a high extent	To a great extent	Satisfactory	Very little	None
<i>How have your expectations been met by this course?</i>	10	22	4	3	1

How have your expectations been met by this course?

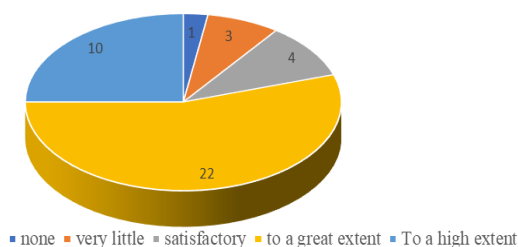


Figure 2. Fulfilling expectations through this course

3. The volume of knowledge

To determine the amount of knowledge passed, the respondents were asked to express their opinion by answering the question: *How do you appreciate the amount of knowledge?* As a result, 18 trainees (46.15% of 40 respondents) appreciate a **Good** knowledge, 16 trainees (41.03% of 40 respondents) **Very good** and only 3 (7.69% of respondents) appreciate the course as **Satisfactory**. It is worth noting that 34 students (87.18% of the respondents) positively appreciate the amount of knowledge assimilated by attending the course. The results obtained in this question are shown in Table 4 and Figure 3.

Table 4. Results for „How do you appreciate the amount of knowledge?”

	Very Good	Good	Satisfactory	Unsatisfactory	Unacceptable
<i>How do you appreciate the amount of knowledge?</i>	16	18	3	1	1

How do you appreciate the amount of knowledge?

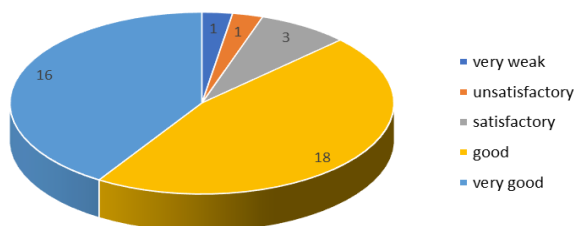


Figure 3. The volume of knowledge

4. Teaching methods

To the question *How do you appreciate the teaching methods?* used by trainers in the training process, respondents stated 71.80% (28 trainees) that the methods were **Good** and **Very Good**, for 23.08% (9 students) were **Satisfactory** and only for 2.56% the methods were **Unsatisfactory** (1 learner) or **Unacceptable** (1 learner). The results obtained in this question are shown in Table 5 and Figure 4.

Table 5. Results for „How do you appreciate the teaching methods?“

	Very Good	Good	Satisfactory	Unsatisfactory	Unacceptable
<i>How do you appreciate the teaching methods?</i>	14	14	9	1	1

How do you appreciate the teaching methods?

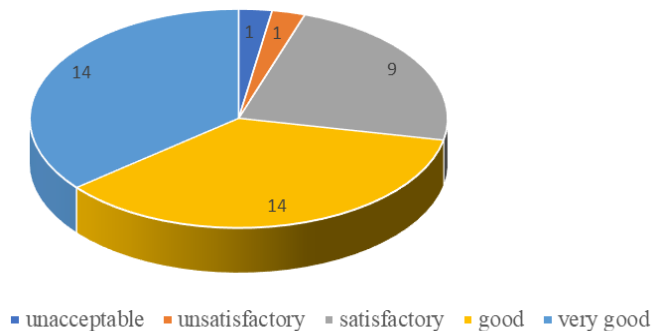


Figure 4. Teaching methods

5. Attitudes of trainers towards learners

To find out the attitudes of the trainer's trainers, they were asked to answer the question: *How do you appreciate the attitudes of the trainers towards learners?* Nearly all trainees, representing 95% of the respondents, positively appreciated the attitudes of trainers (32 trainees - **Very good**, 6 trainees - **Good**) and only 5% of respondents (2 trainees) **Unsatisfactory**. The results obtained in this question are shown in Table 6 and Figure 5.

Table 6. Results for „How do you appreciate the attitudes of the trainers towards learners?“

	Very high	High	Average	Low	Unacceptable
<i>How do you appreciate the attitudes of the trainers towards learners?</i>	32	6	0	2	0

How do you appreciate the attitudes of the trainers towards learners?

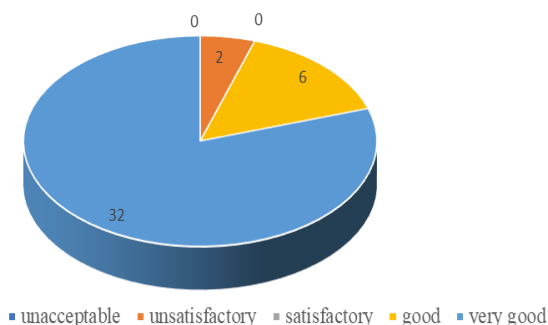


Figure 5. Attitudes of trainers towards learners

6. The usefulness of studied themes

To measure the degree of achievement of the course objectives, respondents were asked to answer the question: *How do you consider the usefulness of studied themes in achieving the objectives of the course?* Among them, 19 respondents (47.50% of the students) appreciated the usefulness of the themes as **High**, 11 respondents (27.50% of the students) with **Very high**, 7 respondents (17.50% of the students) with **Average** and only 3 respondents (7.50% of learners) respectively **Low** and **Unacceptable**. The results obtained in this question are shown in Table 7 and Figure 6.

Table 7. Results for „How do you consider the usefulness of studied themes in achieving the objectives of the course?”

	Very high	High	Average	Low	Unacceptable
<i>How do you consider the usefulness of studied themes in achieving the objectives of the course?</i>	11	19	7	1	2

How do you consider the usefulness of studied themes in achieving the objectives of the course?

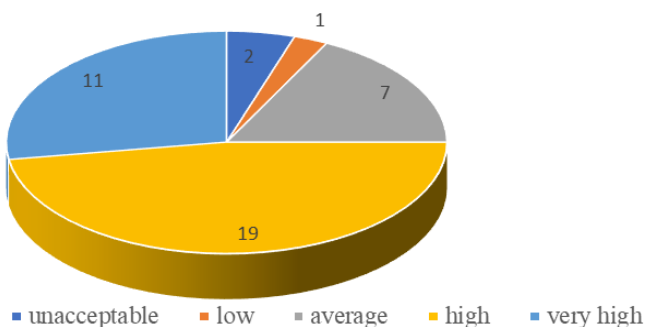


Figure 6. The usefulness of studied themes

7. Degree of encouraging participation into discussions

Determining the degree of encouragement to participate at discussions that were generated during the course was achieved by asking: *How do you rate the degree of encouragement of participation in discussions?* Thus, 14 trainees (35% of 40 respondents) appreciate encouraging discussions **Over average**, 21 trainees (52.5% of 40 respondents) **High** and only 5 trainees (12.5% of respondents) **Average**.

It is worth mentioning the high share of those who positively appreciated the degree of encouragement of the participation in the discussion - 87.5% of the respondents (35 students). The results obtained in this question are shown in Table 8 and Figure 7.

Table 8. Results for „How do you rate the degree of encouragement of participation in discussions?“

	Excellent	Very good	Good	Satisfactory	Unsatisfactory
<i>How do you rate the degree of encouragement of participation in discussions?</i>	21	14	5	0	0

How do you rate the degree of encouragement of participation in discussions?

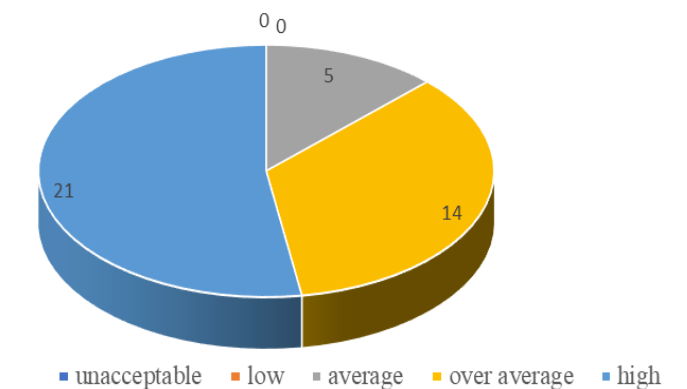


Figure 7. Degree of encouraging participation into discussions

8. Degree of professionalism of trainers

To find out the professionalism of trainer trainers, they were asked to answer the question: *How do you appreciate the professionalism of trainers?* Nearly all trainees, representing 90% of the respondents, appreciated positively the professionalism of trainers (24 students - **Excellent**, 12 trainees - **Very good**) and only one trainee (2.5% of respondents) **Unsatisfactory**. The results obtained in this question are shown in Table 9 and Figure 8.

Table 9. Results for „How do you appreciate the professionalism of trainers?“

	Excellent	Very good	Good	Satisfactory	Unsatisfactory
<i>How do you appreciate the professionalism of trainers?</i>	24	12	3	0	1

How do you appreciate the professionalism of trainers?

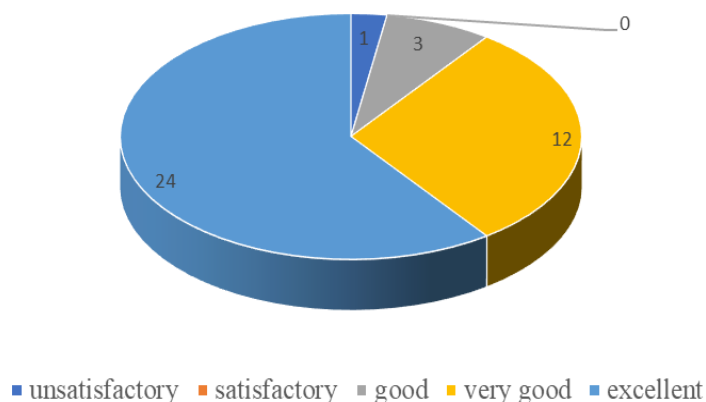


Figure 8. Degree of professionalism of trainers

9. The facilities used for the course

To the question: *How do you appreciate the equipment used for the course?* in the training process, the students stated that 52.5% (21 respondents) said that the facilities were **Good** and **Very good** for 32.5% (13 students) **Satisfactory** and only for 15% **Unsatisfactory** (4) students) and **Very poor** (2 trainees).

The results obtained in this question are shown in Table 10 and Figure 9.

Table 10. Results for „How do you appreciate the equipment used for the course?“

	Very good	Good	Satisfactory	Unsatisfactory	Very poor
<i>How do you appreciate the equipment used for the course?</i>	7	14	13	4	2

How do you appreciate the equipment used for the course?

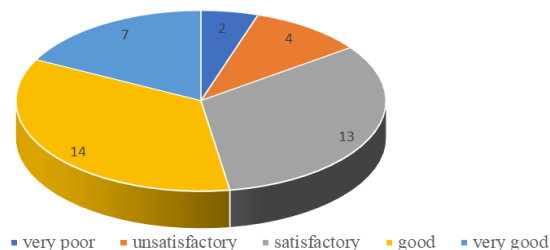


Figure 9. The facilities used for the course

10. Support materials for the course

To determine the quality of course support, the respondents were asked to answer the question: *How do you rate course support materials?* Thus, 23 students (57.50% of 40 respondents) appreciate the support materials for the course **Very good**, 10 trainees (25% of 40 respondents) **Good** and only 3 (7.5% of respondents) **Satisfactory**. The results obtained in this question are shown in Table 11 and Figure 10.

Table 11. Results for „How do you rate course support materials?”

	Very good	Good	Satisfactory	Unsatisfactory	Very poor
<i>How do you rate course support materials?</i>	23	10	3	3	1

How do you rate course support materials?

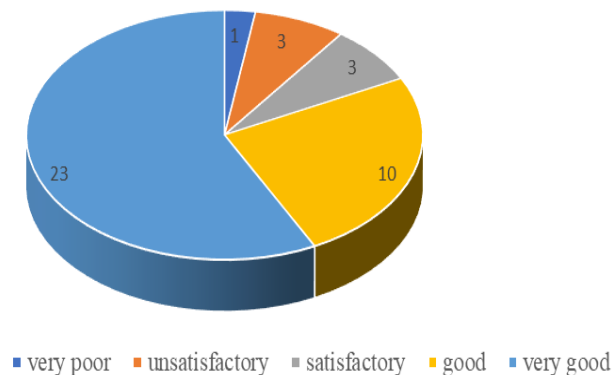


Figure 10. Support materials for the course

11. The work of the other members of the BIZZSMART team

To the question *How do you rate the activity of other BIZZSMART members (other than trainers)?* the trainees selected 57.5% (23 respondents) the **Very Good** rating, 27.5% (11 trainees) the **Good** grade and only 7.5% **Unsatisfactory** (1 trainee) or **Very Poor** (2 trainees).

The results obtained in this question are shown in Table 12 and Figure 11.

Table 12. Results for „How do you rate the activity of other BIZZSMART members (other than trainers)?”

	Very good	Good	Satisfactory	Unsatisfactory	Very poor
<i>How do you rate the activity of other BIZZSMART members (other than trainers)?</i>	23	11	3	1	2

*How do you rate the activity of other
BIZZSMART members (other than trainers)?*

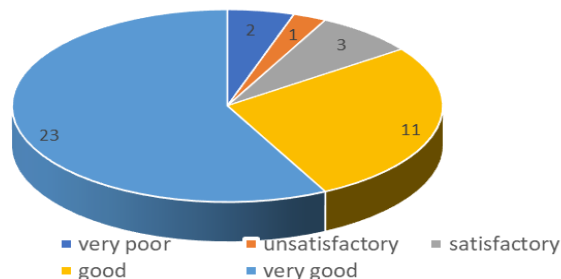


Figure 11. The work of the other members of the BIZZSMART team

CONCLUSIONS

The evaluation questionnaire included 11 questions designed to collect data on different aspects of the entrepreneurial training program. Some were focused on collecting data on the effectiveness of the training session in achieving the stated objectives (e.g. knowledge volume, course support material, methods of teaching, the usefulness of the themes, encouraging participation in discussions, etc.) and others on collecting data on how to organize (e.g. the equipment used, etc.). Responses indicate that an average of over 80% of respondents agreed that the training objectives were achieved and that they are very pleased with the quality of the learning and teaching experience provided during the training sessions.

In general, the answers indicate a high level of satisfaction among learners, the investigated group having an indicative value, not representative, giving only an overview of the activity carried out between 14.04.2018 - 29.04.2018. From the analysis of the evaluation questionnaires, it is obvious that the training activity was carried out with professionalism, the course materials have been well-developed. Also, the themes were well-prepared and appropriate for the objectives of the training and the proportion of presentations and work activities was well balanced and appropriate to achieve the training objectives. Furthermore, the formative and summative learning has been well integrated and ICT tools have been used to organize and assist the teaching-learning process. A detailed set of recommendation is presented in table 13.

Table 13. Detailed recommendation for organizers and trainers

	Recommendations:	Appreciations:
Recommendations and appraisals for the	<ol style="list-style-type: none"> 1. Being the first two groups, it is normal to need different improvements, some examples in this regard would be: hardware infrastructure improvement, time management and more practical examples, 2. A higher period for the course, 3. More flexibility towards learners, 4. More hours / knowledge / counselling is needed to make a proper and complete business plan. 	<ol style="list-style-type: none"> 1. I have learned to work in a new program, having access to textbooks and explanatory material, 2. Very dedicated people; 3. People who know what and how to do, able to send us the appropriate message, 4. Actively involved, respond quickly to emails, 5. I have accumulated much knowledge even if the amount of information was high and at a high level, 6. I learned new things in a relaxing atmosphere, 7. I learned new and interesting things that will help me to realize my project.

<i>Recommendations and appraisals for trainers</i>	<ol style="list-style-type: none"> 1. Several examples for designing and implementing the business plan, 2. The rotation of trainers from one group to another within the same series, 3. More concrete synthesis of information, 4. Presenting as clearly as possible the criteria on which funding is granted, 5. Provide more time for training courses. 	<ol style="list-style-type: none"> 1. Interest, academic quality, 2. I appreciated the fact that the trainers had the patience to explain what we did not understand, very involved, 3. Modern, interesting and useful methods, 4. All chapters were explained to everyone, although the time was short for the area covered, 5. Professionally trained, moral and physical trainers, 6. The materials have included all the necessary information and very well elaborated, 7. Only words of praise and positive attitude.
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SOCIAL VIRTUAL REALITY COLLABORATIVE PLATFORM

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Georgescu CRINA-NARCISA²
Costel EMIL-COTET³
Ghinea MIHALACHE⁴

ABSTRACT:

THIS PAPER DESCRIBES SOME RESULTS OF AUTHORS' RESEARCH FOR DEVELOPING A SOCIAL VIRTUAL REALITY COLLABORATIVE PLATFORM. THE PLATFORM PROVIDES USERS WITH A WEALTH OF COLLABORATIVE TOOLS THAT MAKE IT POSSIBLE TO INTERACT AND RUN COMPLEX ACTIVITIES REMOTELY IN A VIRTUALLY IMMERSIVE ENVIRONMENT.

KEY WORDS: VIRTUAL REALITY, SOCIAL PLATFORM, COLLABORATIVE WORK

INTRODUCTION

Virtual Reality (VR) is a technology that allows the user to interact with a computer simulated environment, via Head Mounted Display (HMD) or through CAVE stereoscopic projection systems, to experience a world that is not physically and is not real⁵. Some environments include additional sensory information, such as audio, tactile information - used by haptic systems - known as force feedback. Users interact with the virtual environment through standard input devices such as mouse, keyboard, multimodal devices (wired glove, extension arm - arm boom, omnidirectional treadmill, Leap Motion Controller or Nimble VR). Simulated environments can be like the real world (flight simulation exercises for astronauts, flight training for pilots or military training) or may be different from the real world (VR games). If we include concepts of real life in the virtual world, we can talk about a new concept - augmented virtuality⁶. Our research has

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⁵ Hype Cycle for Emerging Technologies, Gartner Research, August 2008

⁶ Burdea G., Coiffet Ph., La realite Virtuelle, Ed. Hermes, Paris, 1995

focused on expanding the capabilities that a virtual reality platform makes available to create an immersive, truly collaborative work environment.

MAIN TEXT

To develop such a complex platform, we needed first to select a proper engine to start with. After a study of the options currently available on the market, we have selected the High-Fidelity engine, an open-source engine that enables the expansion and development by exposing the engine core by java script and qml⁷. This engine allows the importing of 3D models in FBX and OBJ format^{8,9} and fully support PBR materials and procedural textures. The engine allows also importing of rigged 3D characters as avatars and have a good physics engine for complex simulations and interaction.

From the facilities developed by our team on the virtual platform, we mention:

- 3D animated product layouts and animated 3D CAD model visualization. This tool allows importing and visualization of complex animated CAD models, exported as baked FBX from the 3D designing application. This tool allows an easy way to import and study the models and trigger various animations based on some developed scripts.
- Live audio communication. The platform includes a high-fidelity audio interface with a surround mixer, that allows a realistic communication between users. The mixer compute automatically the attenuation based on the distance between the users and spatial surround panning base on the angular position in the domain (fig.1). Based on this existing interface, we have developed some applications for sound recording and playing, that allows us to integrate an audio messaging system into High Fidelity platform and to play multichannel sound tracks in sync, the sound for each channel coming from a specific point in 3D space.

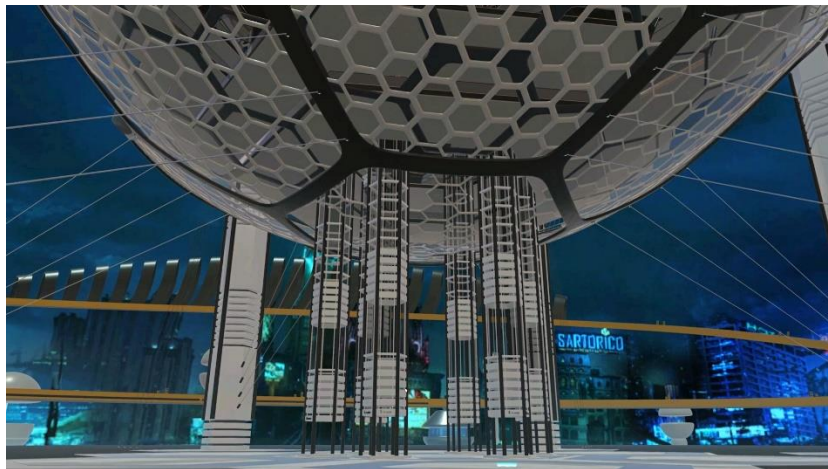


Figure1 – ImproMedia domain main building

⁷ www.highfidelity.com

⁸ Chaillou C., Froumentin M., La Synthese d'images, 1997, École Universitaire d'ingénieurs de Lille, France

⁹ Ștefănescu B., Tehnici moderne de generare a mediilor virtuale prin sinteză grafică asistată de calculator

- customizable 3D avatars with VR tracking system and default gesture desktop interface (fig.3). The platform includes a realistic physics simulation system for avatar movement and 3D tracking of user movement, based on HTC Vive and Oculus Rift trackers or Leap-Motion controller.

To enhance the nonverbal communication and body language, the platform includes also an advanced gesture interface for the users that use this platform in desktop mode and don't have trackers. Users can select some predefined animations like dance, clap, wave, rise hand, sit, point at, by pressing the application buttons. The default avatar animation will be override for a short time with the selected animation.

Starting from this existing implementation, we have integrated a Real-time Speech Emotion Recognizer based on Tensor Flow. This application can do the feature extraction, build the classification model and based on this model can detect the human emotions based on the voice inflexions. This recognized emotions, based on a scoring system (fig.2) are used to drive the blend shapes of the avatar and reflect in real time the emotions of the real user into the avatar face. The model was trained on Berlin Database of Emotional Speech¹⁰ but can be trained based on each specific user audio recordings.

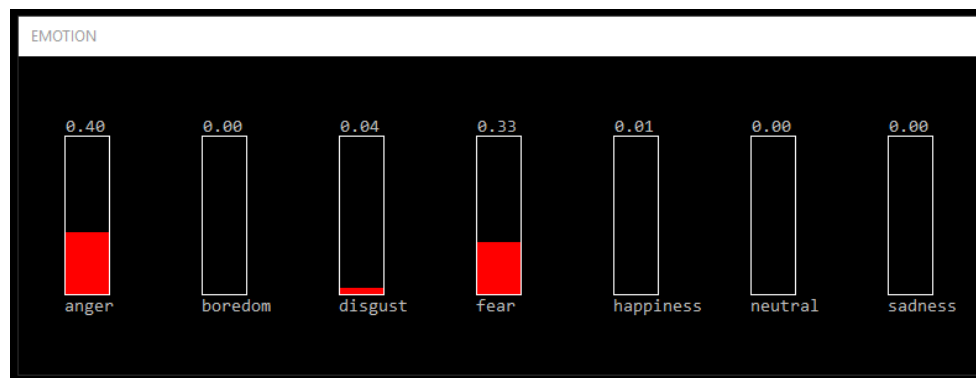


Figure 2. Detected emotions scoring



Figure 3 - Customizable 3D avatars

¹⁰ Berlin Database of Emotional Speech, <http://emodb.bilderbar.info>

- contact list. The platform allows users by a simple handshake to exchange contacts and add friends. Starting from this implemented feature we have created a business card exchange application. Users can exchange business cards that can be visualized inside the platform and also on an external web application.
- Interactive teleportation system. The platform allows users to teleport inside a domain and from one domain to another using a go to application. We have developed some scripts for portal droppers in order to do this navigation in a collaborative way. When a user wants to invite other users to go on a specific location, this user opens the portal dropper interface, select or type the destination and press the drop button. A portal will be included in 3D space and all the users that will enter in this portal will be redirected to that specific location.
- chat text – application based on JavaScript and Node.js that allows text-based and cross domain communication between users.
- video conferencing – JavaScript, WebRTC multiuser application that allows audio-video communication for the users inside VR or between VR and real world. The application allows also screen sharing and video sharing from YouTube and Vimeo.
- display system for brochures, web pages, business cards, videos, catalogs, which visitors can collect and view in the VR environment or through a web interface. This tool is based on a MySQL database and a JavaScript client application.
- The platform allows the access of web applications inside a Web Entity, which is a chromium-based web browser. We have integrated many web applications for collaborative working using this option for text editing, project planning, whiteboard, CRM, ERP etc.
- snapshots using this app the users can create photos in the virtual environment and share them in their network of friends on Facebook or twitter. The snapshots can be printed also in VR as 3D framed photo.
- Camera - Virtual video camera that shoot in the VR environment and export videos and 360 panoramas. We have created some scripts for camera movement, in order to make the shooting process more natural and effective. Using this scripts the camera can automatically follow an avatar or can be remote controlled having smooth motion.
- multimedia presentation system (fig.4), including slides, video, polls, live webcam streaming. A Node.js WebRTC application that allows the uploading of slides and videos to be presented in sync to the users.



Figure 4 - Multimedia presentation system

- screen share (possibility to display live PC screens in VR) and also do remote desktop connections.
- simultaneous audio language translation system. A WebRTC JavaScript application using google API for translation, that allows instant translation from / to 200 different languages in real time. The presenter will talk in his native language and the translation is automatically screened as a text to each user in his preferred language (fig.5).



Figure 5. – Aula with multimedia and automatic translation system

- augmented reality system (by scanning with the VR phone of augmented images, 3D objects, animations, information or video files will be displayed)
- WebRTC live streaming that allows live broadcasts in the VR environment from VR to Web and from outside to VR
- user monitoring system (detailed traffic, username, date, access time, collected promotional materials)

Based on these tools, we can think of many applications where we can integrate an unlimited number of tools and features. Here's some possible applications:

- Virtual office
- E-Learning
- Virtual Exhibitions (fig.6)
- Webinar
- Product launch
- Training
- Recreational events
- Scientific sessions and conferences
- Videoconference from / to VR and real world
- Live streaming from VR to real world



Figure 6. – Virtual Exhibition stands

CONCLUSION

Using the JavaScript and qml API of the HighFidelity platform we have succeeded to extend his capabilities in order to create a truly social collaborative and immersive VR environment. The platform can be accessed by installing the HighFidelity engine interface from: <https://highfidelity.com/download/thanks#client>

After the installation you can access the platform, pushing the GOTO button and typing the domain name called impromedia.

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VIRTUAL REALITY BROADCASTING STUDIO

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Costel Emil COTET⁵

ABSTRACT:

IN THE PAPER, RESEARCH RESULTS FOR DEVELOPING A VIRTUAL REALITY BROADCASTING STUDIO ARE PRESENTED. THE PROPOSED PLATFORM PROVIDES USERS WITH A FULLY AUTOMATED TELEVISION STUDIO, INCLUDING TOOLS LIKE AUTOMATED CAMERA SYSTEM, MULTI VIDEO SWITCHERS, PROPS AND TEXT PROMPTERS. THE STUDIO ALLOWS THE PRODUCTIONS OF VIDEO SHOWS EXCLUSIVELY IN VR USING AVATARS IN A COMPLETE VIRTUAL IMMERSIVE SPACE AND LIVE BROADCASTING OF LIVE OR PRERECORDED MATERIALS TO THE VR DOMAINS OR OUTSIDE TO THE REAL WORLD.

KEY WORDS: VIRTUAL REALITY, BROADCASTING STUDIO, LIVE STREAMING

INTRODUCTION

The rapid evolution of hardware technology in recent years, especially in the game industry has made possible to achieve real-time rendering of very complex 3D virtual spaces where more users can interact⁶. This use goes beyond the sphere of entertainment, with applications in many fields and becomes a part of modern technological civilization. Technological development has made possible in recent years to relaunch the development of equipment and applications for virtual reality and the development of augmented reality technologies.

Virtual Reality (RV) is a state-of-the-art computer-based interface that involves real-time simulations and interactions across sensory channels such as visual, tactile, smell and taste, as

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⁶ Burdea, G.; Coiffet, Ph.; *La realite Virtuelle*, Ed. Hermes, Paris, 1995

defined in⁷. More and more users will access the VR environment in the next years, and this immersive medium will become part of their lives⁸.

Nowadays, there are several VR platforms which makes possible to construct a variety of scenarios and use cases, that can be editable or created by the user by the mean of some editors, not requiring a special VR experience and 3D graphic expertise. But, also, there are some of them which allow users to extend the open source platform capabilities, by own code developing, writing in diverse programming languages or augmenting the graphics look and feel. Thus, the look can be improved by importing graphics and special textures like physical based rendering materials (PBR), which assign different textures for material properties like: colors, normal map, metallic, roughness, ambient occlusion and emission.

One example is the platform Amazon Sumerian, where the user can design the scene directly using a browser application, having a Sumerian's WebGL and a WebVR based editor. These interfaces make it easy to import 3D objects (FBX and OBJ) and to place them in scenes, to add animation and script the logic that commands how the objects behave⁹. The platform also surprises with Sumerian Hosts, which create 3D characters, called Hosts, that talk to users in a variety of languages, narrate the users scenes, recognize speech and guide users through them by answering questions, by having an administrable input text and allowing customize the Host's appearance, clothing, voice and language⁹. Sumerian platform comes with a library of pre-built objects and also gives the possibility to download or import objects from third-party 3D asset repositories such as Sketchfab or Turbosquid, for those users that doesn't create their own objects. The interaction across the scene is made by using Sumerian's visual workflow or JavaScript editors. If the Sumerian platform enchants with easy construction of the scene and user-host interaction, though, it presents an disadvantage: it doesn't allow multi-user collaboration and interaction, only one session: one user - hosts is possible. This feature is instead possible in another VR platform, High Fidelity.

High Fidelity, which is an open-source engine, allows building virtual communities, it is a multiuser VR environment that allow users to interact remotely, just as they would on a real-life¹⁰. So users can not only interact with robots, the Hosts present in Sumerian platforms, but also can meet real users around the globe. They can enterprise different actions in the virtual environment, interacting with the virtual spaces, creating actions together, learn together or discuss, they can meet together inside a virtual conference or in a collaborating office work. Even if this platform hasn't associated pre-created libraries, as Sumerian platform does, it allows experienced users to create dynamic interactions using the JavaScript and QML language.

Taking this in consideration, our team has decided to push forward the limits of this technology and develop as an experiment a fully automated TV station with many studios and a lot of tools that made possible to create professional looking TV shows exclusively in Virtual Reality and broadcast them inside VR or to the real world. This approach has a lot of advantages, the production price being very low and regarding the diversity and complexity of props the only limit is the imagination. The users can operate cameras, mixer consoles and can be a moderator, a

⁷ Jason, Jerald; *The VR Book: Human-Centered Design for Virtual Reality*, Morgan & Claypool, 2015

⁸ Daniel, Shafer; Corey, Carbonara; Michael, Korpi; *Exploring Enjoyment of Cinematic Narratives in Virtual Reality: A Comparison Study*, The International Journal of Virtual Reality, 18 (01): 1-18, 2018

⁹ Amazon Sumerian VR Platform; <https://aws.amazon.com/sumerian/features>

¹⁰ High Fidelity; www.highfidelity.com

presenter or an actor sharing the same collaborative space but being in different part of the real world.

THE VIRTUAL REALITY BROADCASTING STUDIO

To develop the VR platform, we have selected the High-Fidelity engine, an open-source engine that enables development based on some API for java script and qml (<https://highfidelity.com>)¹⁰. This engine allows the importing of 3D textured models in FBX and OBJ format and fully support PBR materials and procedural textures. The engine allows also importing of rigged 3D characters as avatars^{11;12}.

The engine can also import rigged 3D characters as avatars. The avatars can be driven by real users or robots that can include animations and speech to text NLP conversation modules and text to speech, in order to interact with real user in a natural way. The avatars driven by users follow the user movements from real life using the tracking systems and also the engine have a good physics based on Bullet for complex simulations.

In order to make more natural the movement of avatars and allow users which are using the platform in Desktop mode, without HMD glasses, to express themselves, we created scripts that allow the selection of different animations for interaction and non-verbal expression, like applause, surprise, dance, point at, and various other emotional states.

The platform includes a very good spatial audio mixer in which each user's live voice and ambient sounds included in the platform are amplified or attenuated and directed into the surround channels, depending on the spatial position of the user's avatar in relation to them.

The platform also allows the creation of spatial audio areas with different sound attenuations. For example, to create a scene and an audience, the sounds generated by the users on the stage are amplified and transmitted without mitigation to all users in the audience area. In reverse, audience generated sounds are diminished more intensely, depending on their relative position relative to the scene, so as not to disturb the performance of the users on the stage.

This system, although very advanced, is not suitable for professional television production, so we created scripts of selective amplification and individual mixing of avatars performing independently of space areas, avatars can speak or be recorded, as if they were wearing lavalier. This is a major improvement we've added to the High Fidelity platform through this app from an audio perspective.

¹¹ Chaillou, C.; Froumentin, M.; *La Synthese d'images*, École Universitaire d'ingenieurs de Lille, 1997

¹² Daniel, Shafer; Corey, Carbonara; Michael, Korpi; *Exploring Enjoyment of Cinematic Narratives in Virtual Reality: A Comparison Study*, The International Journal of Virtual Reality, 18 (01): 1-18, 2018



Figure 1. The lobby of the Studio

We have started by creating the domain environment and the main building of the TV studio (figure 1). On the first floor one can find some meeting rooms and a News Studio. The News Studio have two fixed cameras and three mobile cameras. On the ceiling it is included a teleprompter text tool for presenters. The teleprompter allows editing the text, changing the font size and scrolling speed. In the back of the studio, there are three big automated screens, that can be switched from control room.

The platform allows during the avatars evolution, switching a single user camera in three distinct ways: first, person-view, third person view, and mirror. These view modes are not enough for professional video production, so we extended the platform with scripts that allow us to generate an unlimited number of camera-type entities (Figure 2) that can be placed in any position in the virtual environment. They can be fixed, mobile, or automated to automatically track the evolution of certain avatars.

The picture provided by these cameras can be selected using the keypad or a button interface in the virtual master control room. This creates the possibility of recording a very qualitative and dynamic video productions, even much easier than in reality.

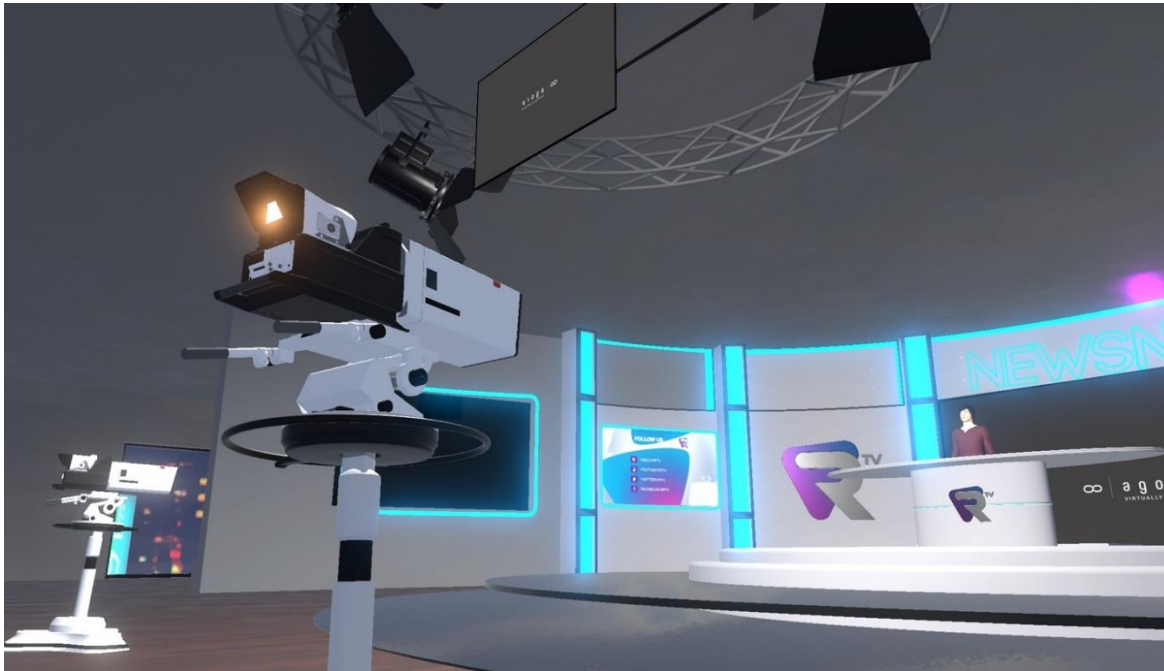


Figure 2. Multiple Camera Studio

The platform allows the creation of light, light-spot and omni-like entities, as well as color and intensity assignment. Since video productions sometimes require a live change of light parameters and timing of their evolution, we have extended the platform with scripts which allow easy access to all the studio light set parameters and their modification using a graphical console. At the same time, we have connected these lights to physical projectors or spot entities that can be easily manipulated in the virtual space manually by users, or using programmed scripts to follow predefined trajectories.

The High Fidelity platform allows video to be viewed in Chromium-based web entities, but as each user runs their own simulation in the client application, each will view the video independently. An important contribution we have made to the High Fidelity platform is to create the possibility of synchronous viewing of video files as if users present at a certain time in the same simulation would watch the same video monitor. Thus, any user's actions on the video player (play, pause, stop, scroll, or change video content) are captured using web APIs and using a NOD JS and Socket.io server to be transmitted in real time to the players videos of other users so that a synchronous view of the video is obtained.

The High Fidelity Platform allows video content to be viewed in WebM format using VP8 and VP9 video codecs and Opus audio codecs, while not allowing the use of mp4 format with H264 video codec and AAC for audio, for licensing reasons of these codecs, which makes it impossible to include live streaming systems in the platform because they exclusively use these codecs through the RTMP protocol.

A major contribution was the development of a scalable live streaming system based on RTMP, where, at the streaming server level, we included a live transcoding of the media format from H264 / AAC to WebM / Opus. Thus, any live RTMP broadcast can be included in the platform, in the web browser, in the supported format.

We have also tried WebRTC-based solutions that are wholly based on WebM /Opus, but they have the disadvantage of scalability because the web browser allows a maximum of 100 simultaneous connections.



Figure 3. Virtual Studio Set

Regarding the virtual studio sets (Figure 3), we have created the ability to remotely manage their different animations, from the technical room, as well as to change colors or background images for them, to create the best environment for live video production. Images, video, live images taken by virtual cameras as well as real-world live images can be included.

For best communication between technical team members, we created virtual intercom systems, so that user lists can be created, such that team members can communicate independently, listening to each other.

For the best presentation of moderators and presenters, we have created and included teleprompter systems, whose text content can be edited, and the scrolling speed and font size can be set live. These teleprompter systems can be configured to be visible to all users or just to certain users, so they do not appear in virtual cameras' images, which is impossible in the real world.

For the technical room, we have included command interfaces for all of these elements, so control panel virtual operators can provide technical direction in a much easier way than in the real world: they can control decors, lights, audio mixer, switching live virtual cameras, video and graphics (lower thirds, logos, texts), and control recording or live video production.

In this project, we have started by creating the domain environment and the main building of the TV studio (Figure 3). On the first floor we have some meeting rooms and a News Studio. The News Studio have two fixed cameras and three mobile cameras. On the ceiling it is included a teleprompter text tool for presenters (Figure 4). The teleprompter allows editing the text,

changing the font size and scrolling speed. In the back of the studio, there are three big automated screens, that can be switched from control room.

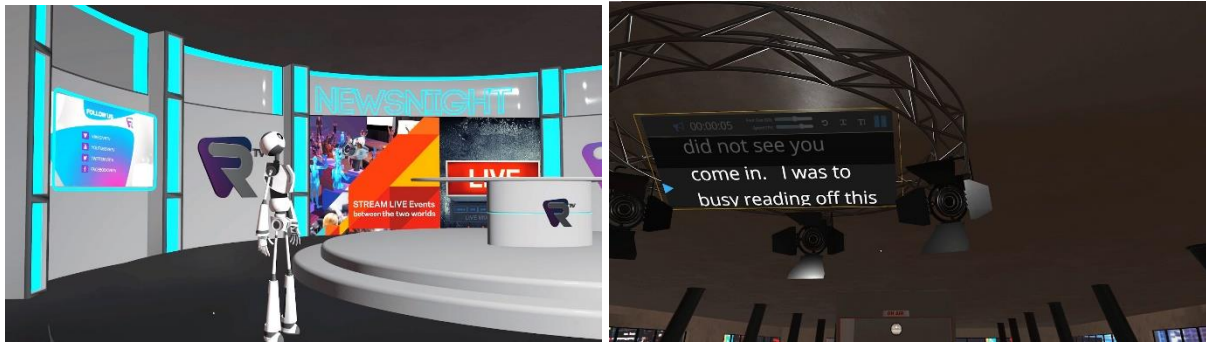


Figure 4. The News Studio and Prompter application

On the first floor, there is also a control room that includes the switching screens application, based on Node.js and the video switcher, that allows real time switching of cameras and prerecorded materials. This switcher also allows the using of video graphic overlays (logos, lower thirds, and the using of visual identity materials bumpers, tv schedule etc.).

The switcher application is based on Web sockets and use as a backend the open source OBS Studio application. From the control room the users can operate the recording application and the live broadcast application. The broadcast application is based on JavaScript and WebRTC.



Figure 5. Studios, stage and aula



Figure 6. The Control Room

On the lobby there is integrated an NPC, a robot that act as a virtual guide to take the tour of the studio. This NPC uses a TTS (text to speech) application to talk to the users.

On the second floor there are two studios for talk show and entertainment productions (figure 7), a stage with a big video screen and an aula with chairs (figure 5) and a fully equipped control room (figure 6).

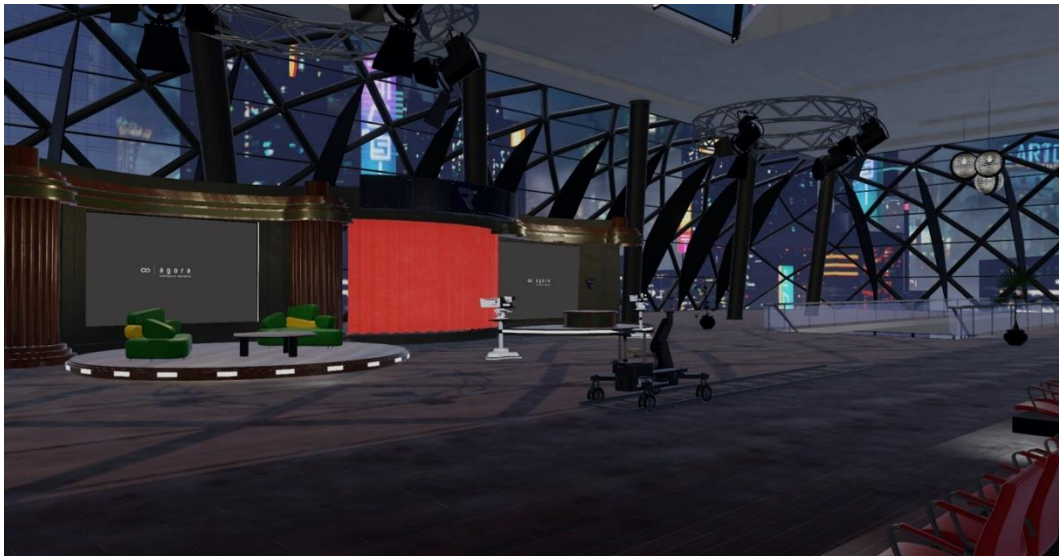


Figure 7. Talk Show Studio, Stage

CONCLUSION

Using the JavaScript and qml API of the HighFidelity platform we have succeed to create a fully functional TV Broadcasting Studio. The platform can be accessed by installing the HighFidelity engine interface from: <https://highfidelity.com/download/thanks#client>

After the installation one can access the platform, by pushing the GOTO button and typing the domain name called *VRTV*.

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AN ELEMENTARY DERIVATION OF THE COEFFICIENT OF DYNAMIC VISCOSITY BASED ON THE PRINCIPLES OF STATISTICAL MECHANICS

Enej ISTENIČ¹
Viktor ŠAJN²

ABSTRACT:

VISCOSITY IS A PHENOMENON WHICH IS OF GREAT IMPORTANCE TO THE THEORY OF FLUID MECHANICS AND KEY TO UNDERSTANDING MANY PHENOMENA IN NATURE. USING THE FORMALISM AND METHODS OF STATISTICAL MECHANICS, WE HAVE COMPLETED AN INTUITIVE DERIVATION OF VISCOUS SHEAR STRESS IN A FLUID BY CONSIDERING MOMENTUM TRANSPORT OF PARTICLES CONSTITUTING SAID FLUID AND OBTAINED AN EXPRESSION FOR DYNAMIC VISCOSITY WHICH DEPENDS ON PARTICLE PROPERTIES AND STATE VARIABLES. WE COMPARE THEORETICAL PREDICTIONS MADE BY THE MODEL WITH EXPERIMENTAL DATA.

KEY WORDS: VISCOSITY, INTERMOLECULAR FORCE, MEAN FREE PATH, PROBABILITY DENSITY FUNCTION

1. INTRODUCTION

A common method of understanding phenomena happening in complex systems is by considering the behavior of its individual constituents and then adding up their contributions into a whole which represents the system. With this mechanistic approach we can explain various properties pertaining to fluids, as well as numerous phenomena which show up in fluid dynamics, e.g. viscosity.

The purpose of this article is to analytically derive an expression for the coefficient of dynamic viscosity by utilizing the formalisms of classical and statistical mechanics. We derive said expression on the basis of a model, which predicts the exchange of linear momentum through binary particle collisions and takes into account all of the parameters which describe the properties associated with constituent particles.

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2. METHODOLOGY AND THEORETICAL ASPECTS

2.1. THEORY OF BINARY PARTICLE COLLISIONS

Particles, such as molecules, experience various forces, which arise as a consequence of particle interaction potential. Forces between molecules are either classical, i.e. electromagnetic, or quantum mechanical in origin. We can separate these interactions into long and short-range interactions. A comprehensive overview of the theory describing intermolecular forces can be found in ref.^{3,4}. Because analytical expressions for inter-particle forces usually have quite complicated forms, we often use simpler mathematical models for the purposes of calculation, which can be a good enough approximation of analytical models and have a basis in reality. One such commonly used model is the Lennard-Jones model, which describes the potential energy field pertaining to a pair of atoms or molecules and takes the following form:

$$U = \varepsilon \left(\left(\frac{\delta}{r} \right)^{12} - \left(\frac{\delta}{r} \right)^6 \right). \quad (1)$$

Here r represents the particle separation, ε the depth of the potential well and δ the distance of zero potential energy and is in essence equal to the diameter of a particle. This model combines the aspects of an attractive long range interaction, which becomes stronger as the particle separation decreases, and a highly repulsive short range interaction which is similar to a hard sphere model.

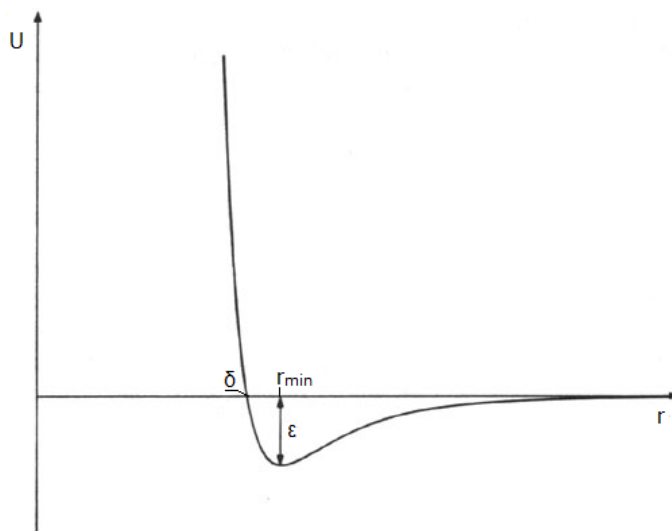


Fig. 1: Potential energy field of interparticle interaction according to the Lennard-Jones model.

Figure 1 displays a diagram which shows the potential energy of interaction as a function of particle separation according to the Lennard-Jones model. Parameter r_{\min} denotes the

³ Stone, Anthony; The Theory of Intermolecular Forces, Second Edition. Oxford: Oxford University press, 2013.

⁴ Buckingham, David; Utting, D.B.; Intermolecular forces, Annual Review of Physical Chemistry, no. 21 (1970), p. 287-316.

interparticle separation value where the interaction force due to potential energy of interaction is at its lowest value.

Forces between particles exert significant influence on various thermodynamic properties, such as the mean free path, which represents the average distance a particle travels between two separate collisions. The mean free path is equal to the following expression:

$$l_{mfp} = \frac{1}{\sqrt{2}\pi nd^2}, \quad (2)$$

where d is the particle collision diameter and n is the number density, defined as the number of particles per unit volume. The collision diameter is equal to the minimal lateral distance between the centers of pair particles, at which the two particles collide. A derivation of the expression above can be found in ref.⁵.

For a non-interacting particle, such as a particle approximated with a hard sphere, its collision diameter is exactly the same to its actual diameter. However, in most physical cases, the collision diameter also depends on the particle interaction potential. For example, an attractive force between two particles will cause them to alter their trajectories and start approaching each other until they collide. We can expect the attractive force to exert more influence and cause collisions to be more likely if the two particles travel at lower velocities.

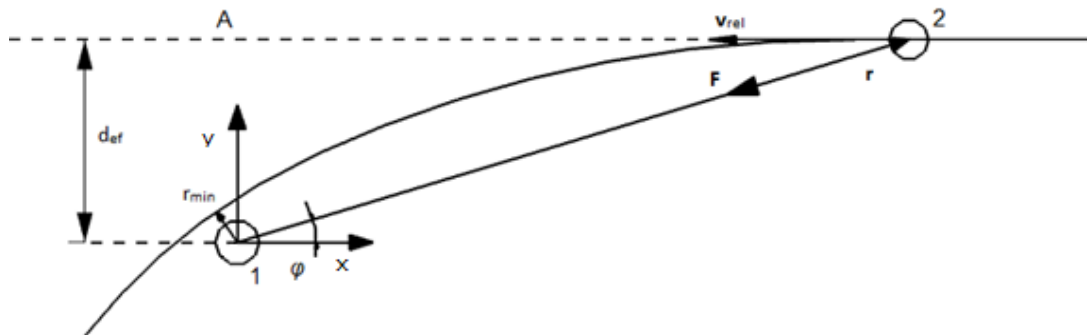


Fig. 2: Graphical representation of the effective collision diameter.

Figure 2 located above shows the motion of two particles in a plane, where the centre of the frame of reference is located at the centre of one of the particles, which means that the particle in question stands still for the purposes of this analysis. Furthermore, d_{ef} represents the effective collision diameter, v_{rel} represents the average relative velocity and r_{min} represents the distance of the closest approach (not to be confused with the distance defined in figure 1). The force acts on the particle in radial direction only, so we can describe the dynamics of one particle relative to another in polar coordinates with the following expression:

⁵ Serway, Raymond; Physics for Scientists and Engineers, Third Edition, Saunders College Publishing, 1990.

(3)

$$\mathbf{F}(\mathbf{r}) = m(\ddot{\mathbf{r}} - r\dot{\phi}^2)\mathbf{e}_r.$$

We then introduce an expression for angular momentum of particle 2 about particle 1, which takes the form $L = mr^2\dot{\phi}$. The angular momentum of the particle is constant, because the force exerted on the particle has no tangential component and there is no torque exerted on the particle. For the purposes of the derivation we use an expression for specific angular momentum, i.e. angular momentum per unit mass: $\sigma = r^2\dot{\phi}$.

To establish a link between relative velocity and effective collision diameter, we integrate the differential equation over the variable r , with the lower limit being equivalent to particle diameter d , as it is twice the particle radius, and the upper limit approach infinity. Since we simultaneously also integrate over velocity, with the lower limit being zero and upper limit being average relative velocity. In this manner, we arrive at the following expression:

$$\int_0^{v_{rel,a}} m\dot{r}d\dot{r} = \int_d^\infty \left(F(r) - \frac{\sigma^2}{r^3} \right) dr. \quad (4)$$

When we solve the integral, we make use of the fact that specific angular momentum is equivalent to the product of average relative velocity and the effective collision diameter: $\sigma = v_{rel,a} \cdot d_{ef}$. We understand the latter as the minimal lateral distance between a pair of particles, at which the two begin to move towards one another due to attractive forces. From this, it is possible to arrive at the following expression:

$$d_{ef} = d \sqrt{1 - \frac{2}{mv_{rel,a}^2} \int_d^\infty F(r) dr}. \quad (5)$$

A formal derivation of the expression above is given by ref.⁶⁷. Interparticle force, which appears in the integral above, is equal to the gradient of Lennard-Jones potential, shown by equation 1. When solving the integral we leave out the first term of the interaction potential, since it represents the action of repulsive forces which contribute negligibly to the value of the integral for values of the integration parameter larger than d . It should be noted that parameter δ from the Lennard-Jones model is equivalent to the particle diameter d . Following on from that, we consider the average relative velocity of particles which is equal to: $v_{rel,a} = \sqrt{2}v_a$, where v_a represents the mean of the magnitude particles' velocity and is equal to:

⁶ Loeb, Leonard; The Kinetic Theory of Gases, Third edition. Mineola: Dover Publications, 1961, p. 221-224.

⁷ Sutherland, William; The viscosity of gases and molecular forces, Philosophical magazine series 5, 36:223, p. 507-531.

$$v_a = \sqrt{\frac{8k_B T}{\pi m}}, \quad (6)$$

where k_B is the Boltzmann constant. We can subsequently introduce the expression for the effective diameter into the expression for the mean free path and obtain accordingly:

$$l_{mfp} = \frac{1}{\sqrt{2} \pi n d^2 \left(1 + \frac{\pi m}{8k_B T}\right)}. \quad (7)$$

From the expression above, we can observe that the particle mean free path decreases at greater number densities, since this means that there are more neighbouring particles which it might collide with, and increases with greater temperature, since this means a particle has greater kinetic energy and is more likely to resist the attractive interparticle potential.

2.2. THEORETICAL TREATMENT OF MOMENTUM TRANSPORT

In order to obtain an expression for dynamic viscosity, we make certain assumptions. We form a model describing the behavior of gas at low enough pressure, so that we can treat the gas as being rarefied, and low enough temperature, so that collisions between constituent particles do not cause energy transfer into particles' rotational and vibrational degrees of freedom. We also assume that particles are isotropic, which means that its diameter and potential energy field remain constant in all directions. With that in mind, it should be stated that this model will give less accurate results at higher temperatures if we apply it to diatomic and polyatomic molecules. We also assume that intermolecular forces act on particles and affect their motion in space.

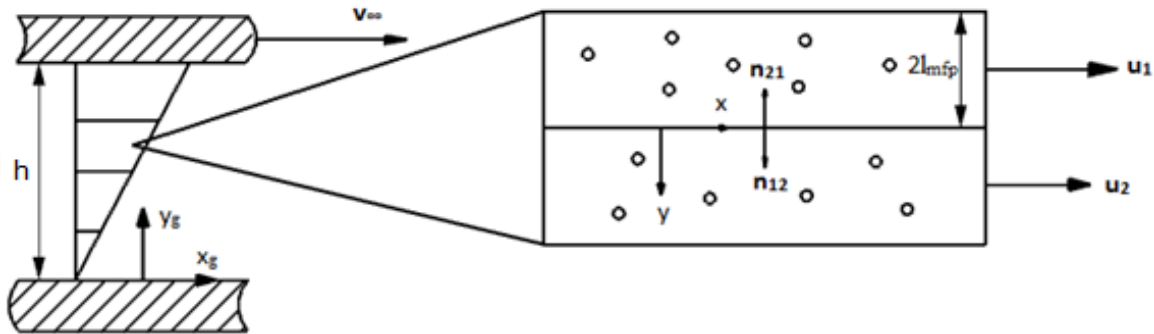


Fig. 3: Graphical representation of particle dynamics in a Couette fluid flow.

Figure 3 shows the physical system on which we base our model. We can observe that it consists of a fixed lower and moving upper plate with fluid in between. It is noted that x - y is the local, while x_g - y_g is the absolute frame of reference. We assume that fluid is undergoing a two-dimensional Couette flow, which is caused by a force acting on the upper plate moving with

velocity v_∞ , therefore acting as the cause of shear stress. The image also describes motion of particles at the length scale of individual particles in a fluid flow. Comparing the motion of matter at different length scales, we can see that individual particles move about in a random way, while at larger scales fluid moves as a set of layers moving at a different velocities. We can write a generalized expression for particle velocity in the following way:

$$v_i = c_i - u_i, \quad (8)$$

where v_i is a velocity component as viewed from a stationary absolute frame of reference, c_i is a velocity component as seen by an observer moving together with the local reference frame and is probabilistic in its nature, while u_i is a component of the local reference frame velocity and accordingly a velocity component of the layer of fluid relative to the absolute reference system. It is assumed that individual fluid layers move only in the horizontal direction. Kinematics of fluid layers in this particular case can be described by this expression:

$$u_2 = u_1 - \frac{\partial u}{\partial y} \delta y, \quad (9)$$

with u_2 and u_1 being velocities of two different fluid layers, $\partial u / \partial y$ the velocity gradient with respect to vertical distance as shown in figure 3 and δy the thickness of each individual layer. We then propose that individual particles, which cross the interface between two distinct layers, eventually collide with a different particle in a way described in the previous section. Such collisions are of course elastic, as linear momentum and kinetic energy remain conserved in such a collision. These collisions represent an underlying mechanism causing the momentum flux between the two fluid layers, resulting in a force acting on the two fluid layers. This causes the shear stress experienced by the fluid. We then propose that each distinct layer of fluid has a thickness δy which is twice the size of particle mean free path l_{mfp} because we expect particles which transfer momentum between adjacent layers to originate from the centre of each such layer.

Following on from that, we can define as the ratio between the derivative of transferred momentum with respect to time and the surface area:

$$\tau_{yx} = \frac{F_{yx}}{A} = \frac{1}{A} \frac{d}{dt} (G_{12,yx} + G_{21,yx}). \quad (10)$$

In this expression, $G_{12,yx}$ and $G_{21,yx}$ represent macroscopic averages of particles' x axis components of linear momentum, transferred along the y axis from layer 1 to layer 2 and likewise from layer 2 to layer 1 due to binary collisions, with temporal derivative of the two representing a net macroscopic momentum flux. We can define a macroscopic value of a transferred property as a statistical average over all the possible values of that property that the constituent particles, which contribute to the transfer of that property, might carry. This is shown by the following expression:

$$\Psi = \int_{\partial c} \int_{t_1}^{t_2} dt \iint_A v_i \hat{n}_i \psi f(c_i) dA dt d^3 c_i. \quad (11)$$

In this equation, Ψ is the transferred property, $v_i \hat{n}_i$ represents the dot product of the particle velocity (as seen in an absolute frame of reference) and the unit normal, ψ is a property we can attribute to a particle (e.g. mass or momentum), $f(c_i)$ is the probability density function, dA is the surface differential and d^3c_i is the product of the velocity components' differentials over which we integrate. Since we are dealing with transport of momentum, variable ψ shall represent linear momentum carried by a particle. We can define it in the following way:

$$g_{12,i} = m_p v_{12,i} = m_p (c_{1,i} - u_{1,i}), \quad g_{21,i} = m_p v_{21,i} = m_p (c_{1,i} - u_{1,i}). \quad (12)$$

Here, variable m_p denotes the mass of a single particle. The probability density function $f(c_i)$, which appears in equation 11, is a function of a continuous random variable which attributes a relative likelihood to each possible interval of values this random variable can have. In this case, it describes relative likelihood of particles having a velocity component in the range of some interval, or in other words, the fraction of the total number of particles whose velocity component is in this range. In our case, we can expect that particle velocity components in the y direction follow the single velocity component Maxwell – Boltzmann probability distribution, shown below:

$$f(v_i) = n \sqrt{\frac{m_p}{2\pi k_B T}} e^{-\frac{m_p v_i^2}{2k_B T}}. \quad (13)$$

In this expression, v_i represents a velocity component of a particle, m_p represents its mass, T represents the temperature and n the number density (number of particles per unit volume), while k_B stands for Boltzmann's constant. A formal derivation of the Maxwell – Boltzmann distribution can be found in ref.⁸.

An expression for macroscopic transfer of momentum is obtained by averaging horizontal components of particle momenta over the probability density function of the particle vertical velocity, since the horizontal momentum transferred over the boundary depends on particles' vertical velocity components. Combining eqs. 10, 11, 12 and 13 with respect to the local frame of reference, as seen in figure 3, and through proper definitions of quantities $v_{12,i}$, $v_{21,i}$, $\hat{n}_{12,i}$ and $\hat{n}_{21,i}$, we arrive at the following expression for shear stress:

$$\tau_{yx} = \rho \sqrt{\frac{m_p}{2\pi k_B T}} \left((c_{1,x} - u_1) \int_0^\infty c_{1,y} e^{-\frac{m_p c_{1,y}^2}{2k_B T}} dc_{1,y} - (c_{2,x} - u_2) \int_0^\infty c_{2,y} e^{-\frac{m_p c_{2,y}^2}{2k_B T}} dc_{2,y} \right), \quad (14)$$

with density ρ being the product of particle mass m_p and number density n . By solving the two integrals above, we obtain the following expression for shear stress:

⁸ Sethna, James; Statistical mechanics: Entropy, Order Parameters, and Complexity. Oxford: Clarendon press, 2011, p. 41-43.

$$\tau_{yx} = \rho \left((c_{1,x} - u_1) - (c_{2,x} - u_2) \right) \sqrt{\frac{k_B T}{2\pi m_p}}. \quad (15)$$

Since probabilistic parts of horizontal velocity components $c_{1,x}$ and $c_{2,x}$ do not differ significantly between two adjacent layers, we can assume that the two are equal, which means that they in turn cancel out. We also take into account the fact that we conducted our derivation in a left-handed local reference frame, which means that the velocity gradient in equation 9 changes its sign when viewed from the global frame of reference, which is right-handed. The result of our derivation is the following expression for the coefficient of dynamic viscosity:

$$\mu = \frac{\sqrt{\frac{m_p k_B T}{\pi}}}{\pi d^2 \left(1 + \frac{\pi \varepsilon}{8 k_B T} \right)}. \quad (16)$$

A more thorough and rigorous procedure of this derivation can be found in ref.⁹.

3. RESULTS

We can compare predictions made by our theoretical model with experimental data for a diatomic gas, because we can expect diatomic molecules to behave somewhat similarly to isotropic particles. We compared our predictions with experimental data for molecular hydrogen H_2 . Parameters in expression 16 therefore take on these values: $m_p = 3.35 \cdot 10^{-23}$ kg, $d = 292$ pm and $\varepsilon = 5.24628 \cdot 10^{-22}$ J. Data for Lennard-Jones model parameters is taken from ref.¹⁰ 8. Boltzmann constant is equal to $k_B = 1.3806 \cdot 10^{-23}$ J/K.

⁹ Istenič, Enej; Deduction of the fluid dynamic viscosity coefficient based on statistical mechanics, B.Sc diss., University of Ljubljana, 2016. p. 28-33.

¹⁰ Ahren, Jasper; Miller, James; Lennard-Jones parameters for combustion and chemical kinetics modeling from full-dimension intermolecular potentials, Combustion and flame 161, no. 1 (January 2014): p. 101-110.

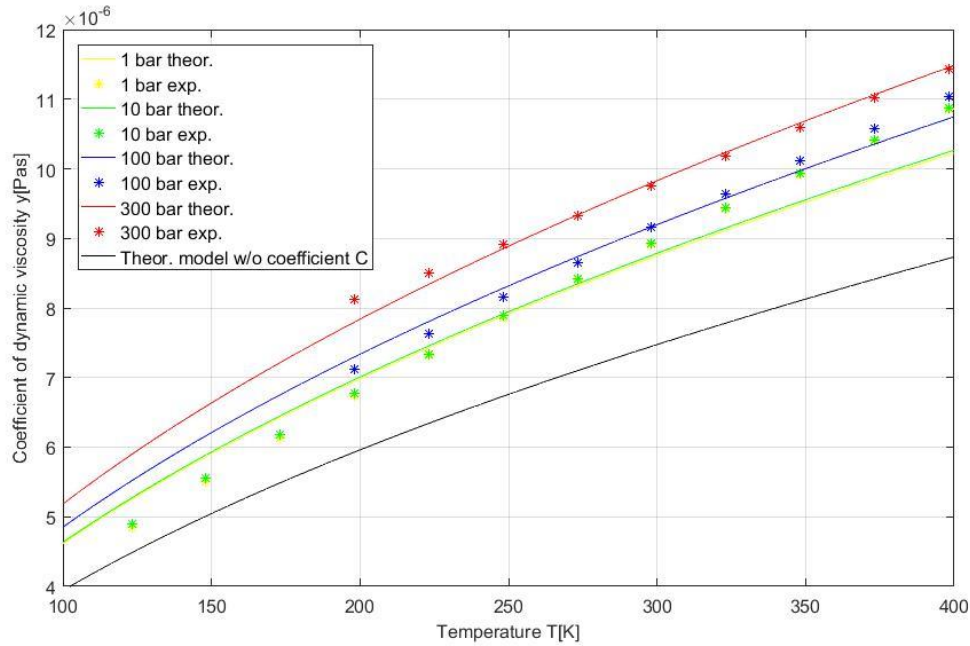


Fig. 4: Dynamic viscosity of molecular hydrogen H_2 as a function of temperature as predicted by eqs. 16 and 17 compared to experimental data.

Figure 4 shows how the coefficient of dynamic viscosity depends on temperature, as predicted by equation 16, and experimental results, adapted from ref.¹¹ 9. It is evident that the analytical model we developed does not quite match experimental data at hand, although it apparently manages to express the fact that the dynamic viscosity coefficient depends on an exponent of temperature, with the exponent being equal to $3/2$. Experimental data shows that the dynamic viscosity coefficient is a function of pressure as well, since it appears to be greater at higher values of pressure. For that reason we multiply our model with a dimensionless coefficient C , which takes into account discrepancies between experimental data and our original model. We determined this coefficient C numerically with the method of least squares regression. The improved version of our model has the form:

$$\mu = \frac{C \sqrt{\frac{m_p k_B T}{\pi}}}{\pi d^2 \left(1 + \frac{\pi \epsilon}{8 k_B T}\right)}. \quad (17)$$

Once again examining figure 4, we can see that coefficient C improves the accuracy of our prediction, although it does not entirely match the slope indicated by the experimental results. It can also be noted that dynamic viscosity increases with pressure. We postulate that this fact,

¹¹ U.S. Department of Energy, Hydrogen analysis resource center; Hydrogen Viscosity at different temperatures and pressures. accessed August 1, 2016. <http://hydrogen.pnl.gov/hydrogen-data/hydrogen-viscosity-different-temperatures-and-pressures>.

observed in figure 4, is caused by our assumptions about the fluid layer thickness and the way molecules interact. Firstly, we assumed that the thickness of a fluid layer is twice the size of the mean free path, which we had no justification for, although it is very certainly true that the layer thickness is of the order of the mean free path. Secondly, if pressure and consequently number density are high enough, the particle mean free path becomes comparable in length to the mean particle separation, which means that particles are in close proximity of one another at all times.

It is likely that under such conditions, a collision of two particles is influenced not only by their respective potential energy fields, but also by fields pertaining to nearby particles, which likely changes the dynamics of collisions. It also probably holds true that simultaneous collisions of multiple particles become more frequent under such conditions. Furthermore, if mean particle separation becomes low enough, we can expect attractive forces to prevent particles from even dispersing after an event of interaction, which happens at values of pressure and temperature close to conditions where a phase transition occurs.

4. CONCLUSION

Our derivation has shown that the coefficient of dynamic viscosity is a function of temperature as well the properties we can ascribe to constituent particles, such as their mass, diameter and the depth of the potential energy well. It also depends on pressure, although we were not able to quantify its influence on viscosity through theoretical methods. We created this model by assuming that an ensemble of particles behaves as a rarefied gas and that intermolecular forces act between pairs of particles. Consequently, the model gives most accurate predictions at values of parameters where these two assumptions hold true.

We could have improved our model of viscosity by describing the influence of interparticle forces on interactions more accurately, while we also could have accounted for the influence of neighbouring particles on a binary collision and simultaneous collisions of more than two particles.

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ANALYSIS OF IMPLEMENTATION OF MBD AND STEP AP242 STANDARD INTO MODERN CAD TOOLS

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Nikola VUKAŠINOVIĆ²

ABSTRACT:

THIS PAPER PRESENTS AN OVERVIEW OF RECORDING DATA ON TOLERANCES AND PRODUCT SURFACES, USING THE MODEL BASED DEFINITION (MBD) METHOD, AND THE TRANSFER BETWEEN VARIOUS MODERN CAD MODELERS, USING THE STEP AP242 STANDARD. WITH MBD IMPLEMENTED IN DESIGN PROCESS, WE PLACE 3D MODEL IN THE CENTER OF DEVELOPMENT. REFERRING TO THAT, THERE IS NO NEED FOR SEPARATE 2D DRAWING FILES AND THAT MAKES SIMPLER MANAGEMENT WITH ALL PROJECT DOCUMENTATION. USING MBD INSTEAD OF 2D DRAWINGS CAN BE TIME SAVING, WHEN WE ARE DESIGNING COMPLEX MODELS WITH A LOT OF PRODUCT MANUFACTURING INFORMATION (PMI). BY PRODUCING THE SAME MODEL IN DIFFERENT MODELERS, ADDING PMI TO MODELS AND CONVERTING MODELS INTO STEP AP242, WE REVIEWED THE RELEVANCE OF CONVERSIONS AND MODELERS. THE RESULTS HAVE SHOWN THAT MODERN MODELERS OF THE LATEST GENERATIONS ARE COMPATIBLE WITH THE ISO 10303-242: 2014 (STEP AP242) STANDARD AND ALLOW RELIABLE TRANSFER OF PMI BETWEEN DIFFERENT MODELERS USING THE MBD METHOD.

KEY WORDS: MBD, MODEL BASED DEFINITION, PMI, PRODUCT MANUFACTURING INFORMATION, STEP AP242

INTRODUCTION

Model based definition (MBD) stands for cataloging components or assemblies, using only a 3D model. This includes geometry, dimensional and geometric tolerances, materials and surface quality. Traditionally, cataloging these data included, and still does, transforming 3D models into 2D views and making technical drawings. With MBD the designers place PMI directly on 3D model in the process of designing. An example of a combination of a 2D drawing and a 3D model is shown in Figure 1. Being the most accurate and universal language for providing information on what to do and how to do it, 2D technical drawings are generally still being used for industrial communication. The basic purpose of technical drawings is to transfer, control and preserve

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product information in a way that eliminates misinterpretations and false assumptions³. The purpose of MBD is to place the 3D model at the center of development. The model can be accessed by anyone who needs information about this model, editing is allowed only to the users, that have access to the editing and that is set by PDM (Product Data Management) system. This allows better tracking and control and easier understanding of the product for those who are less skilled in reading 2D documentation.

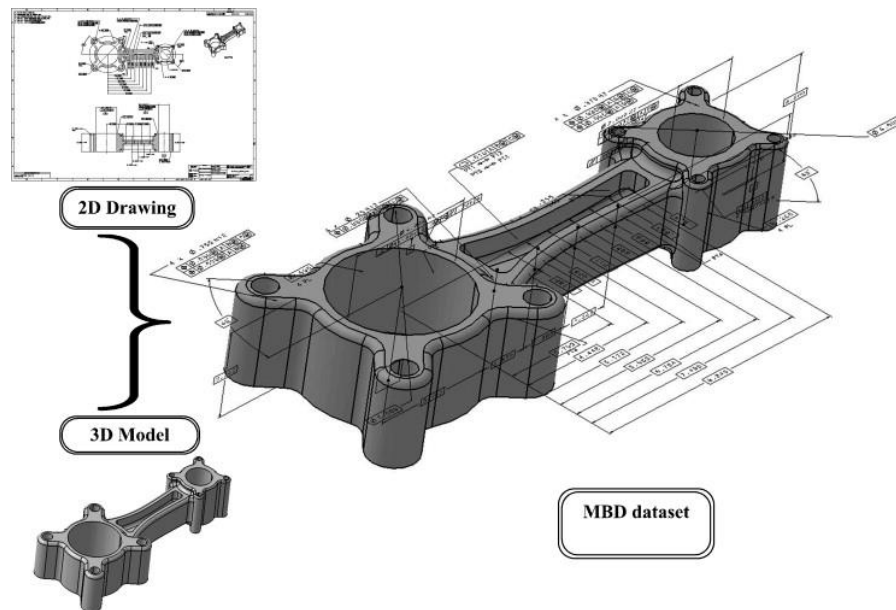


Figure 1: MBD as a combination between a 2D technical drawing and a 3D model⁴

MBD is standardized by several standards. It has been standardized by both ISO and ASME and the United States Department of Defense. The American Society of Mechanical Engineers (ASME) standardized MBD for the first time in ASME Y14.41-2003 in 2003. In 2012, the standard was improved and re-published as ASME Y14.41-20012. The International Organization for Standardization (ISO) standardized MBD with the ISO-16792: 2006 standard.

Advantages of using MBD

The method is appreciated in engineering environments where people deal with complex products that are incorporated into even more complex structures, while facing a wide variety of product and manufacturing information. Typical examples of this area are the aviation and automotive industries, as they need more than just a description of geometries (e.g. geometric and dimensional tolerances) and surface treatment and other properties. Combined with the development and design process, excluding 2D documentation saves a lot of time. On the other

³ Quintana, V.; Rivest, L.; Pellerin, R.; Venne, F.; Kheddouci, F.; *Will Model-Based Definition replace engineering drawings throughout the product lifecycle? A global perspective from aerospace industry*, Computers in Industry, Volume 61, Issue 5, p. 497-508, 2010

⁴ Quintana, V.; Rivest, L.; Pellerin, R.; Venne, F.; Kheddouci, F.; *Will Model-Based Definition replace engineering drawings throughout the product lifecycle? A global perspective from aerospace industry*, Computers in Industry, Volume 61, Issue 5, p. 497-508, 2010

hand, the MBD approach is not practical when developing simple products, e.g. reinforcing ribs for structures, supports, etc. Such products are usually simple because no high precision is required, and geometric tolerances and surface quality are not specified, and therefore there are no time savings. Most development time is saved by the fact that engineers are no longer required to choose between different sections and views, as was the case on 2D technical drawings, because all the necessary information is given on the model. This does not exclude choosing views onto which they would like to place their dimensions; it only means that their choice is not limited by placing these views on a limited paper format. In practical terms, dividing the views is similar to drawing each view on a separate drawing and thus not limiting the engineer by space. By eliminating the need to generate 2D drawings, the costs and time of development are reduced⁵. Savings are also reflected in immediate information transfer. Because anyone in need of product information has access to one single model, this means that they can view the current status of the project without delay. This reduces the information transfer time between the stages from development to sale.

Another advantage is that with appropriate approaches to MBM (Model-Based Manufacturing), CAD-CAM transformation can automatically create CAM manufacturing strategy, which has so far been done by production engineers. With an appropriate database of cutting tools and their properties, and with the data on processing, provided on the 3D model, appropriate decision algorithms can be used to automatically generate the CNC code, where all the necessary processing characteristics, including the choice of tools, are specified⁶.

Since tolerances can be determined during the development of a product in a 3D model, discrepancies can be detected more quickly, as opposed to converting to 2D views, where the sense of functionality of the model is lost. Often it also happens that a 2D technical drawing lacks some information. For example, if in the case of a blind hole with a certain depth you forget to specify this dimension on a 2D drawing, a through hole will be drilled.

In assemblies, errors occur in the preparation of 2D documentation for larger systems, also due to incorrect recording of the number of elements on 2D technical drawings and the fact that component drawings are not updated together with changes to the CAD model. Since additional communication is needed between production engineers and designers, a lot of time is wasted. According to the Scania company, using MBD saved them approximately 18% of the time precisely due to the reduction of the extra communication, caused by errors⁷.

In the manufacturing of products, constant control over the quality of production is of vital importance for competitiveness reasons. Much of this is done by sensor-equipped instruments, capable of measuring dimensions by multiaxial movement, which cannot be measured with conventional instruments; such instruments are also very accurate. Being guided similarly to CNC machines, the path of the sensor is determined according to the product. In a traditional way, the instrument would measure the product and display the readings, while the engineer would verify

⁵ Quintana, V.; Rivest, L.; Pellerin, R.; Venne, F.; Kheddouci, F.; *Will Model-Based Definition replace engineering drawings throughout the product lifecycle? A global perspective from aerospace industry*, Computers in Industry, Volume 61, Issue 5, p. 497-508, 2010

⁶ Wardhani, R.; Xu, X.; *Model-based manufacturing based on STEP AP242*, 12th IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications (MESA), Auckland, New Zealand, p.p. 1-5, 2016

⁷ Lundqvist, T.; Phillips, F.; *Model Based Definition: The Main Effects of Implementing Model Based Definition in an Automotive Manufacturing Industry*, master thesis, Stockholm, Sweden, 2016

that the dimensions meet the required regulations. The MBD method has already provided the instrument with the requirements that the product should meet, so you can immediately know whether or not the machine is working within the appropriate tolerance limits⁸.

The process from development to sale involves people who are not skilled in reading and understanding technical documentation, however, they are important for transferring the product from the idea to the market. These are people from the sales, purchasing and other financial areas. The ability to observe a product in a 3D view is very suitable for them, since it can give them a proper idea of it. The user can easily understand geometry as well as geometric and dimensional tolerances by simply manipulating the model (translation, rotation, zooming, etc.)⁹.

Archiving data

It is also important for the proper management of product data to keep all product data and to be able to access them freely throughout the life cycle and beyond. On the other hand, CAD tools are constantly changing and being upgraded, so it often happens that after a few years, the tools that can read old documents properly are no longer available. The purpose of standardization is also to ensure the continuity and sustainability of a record for archiving purposes. Converting 3D models with all the PMI data into the neutral STEP AP242 format will result in a computer format that will be readable in the future and will allow independence from the user environment in which the model was made. By doing so, companies can make sure that their current knowledge will not become useless even in the case of a new software provider. They will be able to open everything they have available today in the future if they only keep the STEP file.

Drawbacks and challenges of MBD

The key disadvantage of using MBD is that it is first necessary to teach the engineers how to properly transfer information onto a 3D model. The main thing is to learn how to master the software and get used to a new approach of communicating information. It is also important that engineers learn the transparency of communicating information and selecting appropriate views.

A suitable method should be provided that will allow proper communication and notification of possible changes on the model, so that everyone who has access to the model will be informed of any changes. This is crucial in order not to make any changes that would lead to the purchase of wrong elements in the assembly, because people in charge of purchasing would not know that changes were made. This is also important in order to avoid mismanagement, as production engineers would not know that changes in surface quality and other things were introduced on the 3D model. Informing the production is important, as it is necessary to create appropriate CAD-CAM transformation once a change in the model has been approved.

⁸ Fang, F. Z.; Li, Z.; Arokiam, A.; Gorman, T.; *Closed Loop PMI Driven Dimensional Quality Lifecycle Management Approach for Smart Manufacturing System*, 9th International Conference on Digital Enterprise Technology – DET 2016 – »Intelligent Manufacturing in the Knowledge Economy Era«, Nanjing, China, p.p. 614-619, 2016

⁹ Carvajal, A.; *Quantitative comparison between the use of 3D vs 2D visualization tools to present building design proposals to non-spatial skilled end users*, Ninth International Conference on Information Visualisation (IV'05), London, UK, p.p. 291-296, 2005

STEP AP242

Neutral CAD formats have been developed in order to provide a single language that can be read by different CAD systems (CAD packages) and other CAx systems (Figure 2). Because companies use different CAD systems, it is a neutral form of some sort that allows the exchange of data, which is important both for data exchange within companies as well as between different companies. Neutral formats are necessary because, for example, a company develops a CAD model, another company carries out analyses, and a third party produces end products.

The neutral format should include a description of all product information over the life cycle, it should be independent of hardware and software, it should allow upgrading and updating, it should be stable over a long period of time, and in addition to reliable file sharing, we need shared access to a common database¹⁰.

The basic conversion process involves geometric information (shape and dimensions), while newer versions also allow the storage of non-graphic data, information on manufacturing, tolerances and assemblies in the structure of a STEP file. These are also basic requirements that should be fulfilled if the neutral format is to be used for the MBD method for communication between different CAD packages.

STEP or ISO 10303 is an international standard that prescribes a neutral file transfer format. It was developed by the International Organization for Standardization. Different areas use different versions of the standard, distinguished by the number that comes after STEP. At the beginning, only a number was used behind the acronym, and later the AP symbol, standing for Application Protocol, was added. Each application protocol is intended for a particular type of industry and is adapted to its requirements. STEP thus covers different areas, but basically it is divided into three major parts – development, manufacturing and support of a product life cycle.

STEP is used in industry for sharing 3D CAD geometric models with organizations that use different CAD software with various primary file formats. More importantly, it is used to transfer files to the control, manufacturing and assembly departments in the companies themselves¹¹.

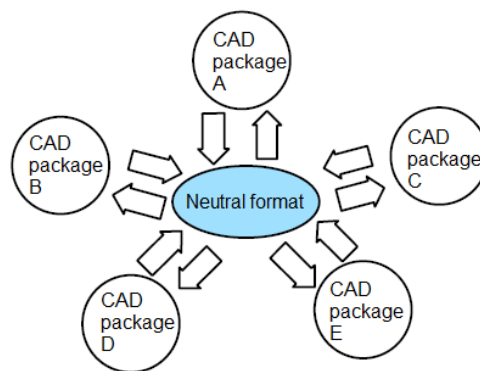


Figure 0: A neutral format is the common point between different CAD packages¹²

¹⁰ Duhovnik, J.; Tavčar, J.; Elektronsko poslovanje in tehnični informacijski sistemi: PDMS-Products data management systems, University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, 2000

¹¹ Fischer, B. R.; *A step up: a neutral file format brings more information into play*, Mechanical Engineering-CIME, Vol. 137, Issue 3 p.p. 42-45, 2015

¹² Duhovnik, J.; Tavčar, J.; Elektronsko poslovanje in tehnični informacijski sistemi: PDMS-Products data management systems, University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, 2000

STEP AP242 is a standard for the exchange of product data, introduced by the International Organization for Standardization in 2014 in ISO10303-242. It is referred to as Managed Model-Based 3D Engineering. ISO10303-242 was created as a product of joint development of two previous standards. These are standards for the automotive industry (STEP AP214) and the aviation industry (STEP AP203)¹³. STEP AP214 is managed by ProSTEP iViP and SASIG, while PDES is responsible for AP203. Both standards are used in a wide range of global industries and have similar basic structures, however, there are also differences. In order to reduce the costs of parallel development and maintenance, joint development was proposed. The new STEP AP242 standard also offers the possibility of unified increase in STEP support from stronger industries. The basic purpose of the standard was to combine the functionalities of AP214 and AP203 into a model that would define a structured general-purpose approach, develop a semantic data model that would represent product and manufacturing information and other external references to elements, assembled parts and kinematics in assemblies¹⁴. Development also focused on the ASME Y14.41 and ISO16792 standards, which describe MBD. In order to make it possible, it is important to keep data on the 3D model even after conversion into a neutral format. STEP AP242 allows preserving semantic data on dimensions and dimensional tolerances, geometric tolerances and other data on surface treatment. This makes STEP AP242 a step towards eliminating 2D formats from the industrial environment, and constant use of data, defined on 3D models, as it allows information to be provided along the product development chain by means of a uniform binding to a 3D model.

The STEP AP242 standard focuses on the presentation of data to support CAD/CAE (Computer Aided Engineering) and PDM in data exchange, system integration, visualization and long-term storage of data and information.

The main areas covered by AP242:

- MBD (Model Based Development),
- integration of PDM,
- LTA (Long Term Archiving),
- integration of the supply chain,
- exchange of development data with included composite elements,
- advanced product and manufacturing information (PMI).

AP242 records product and manufacturing information in two ways. The first one is graphical, which is also referred to as presentation. Since the standard allows storing graphic information, the information given on the model is displayed graphically as lines and points. This was already possible in the STEP AP214 standard. The graphic part is intended for visual presentation and is not the key to subsequent processing, however, it allows the modeler to graphically display the processing information on the screen.

The second one, referred to as semantic mode, is more important. However, it is usually not visible to the user but the software can read it. It is called representation. This is a record in a file that determines the geometric and dimensional tolerances and surface treatment. It is in fact

¹³ STEP AP242 Project: <http://www.ap242.org>, last accessed: 19. June, 2019

¹⁴ Fischer, B. R.; *A step up: a neutral file format brings more information into play*, Mechanical Engineering-CIME, Vol. 137, Issue 3 p.p. 42-45, 2015

bound to the elements of the solid model. On solid models that we open in modelers, this information does not appear.

METHODOLOGY

The computer programs were compared from the viewpoint of MBD support and their ability to export models into STEP AP242. They were selected on the basis of the availability of software package licenses and their usability in industry. The selected programs include Siemens NX 11, SolidWorks 2018, Autodesk Inventor 2018 and PTC Creo 5.0.

In order to be able to compare different modelers with respect to their ability to perform MBD, it was necessary to first create a reference model. For the purpose of describing the shape, the reference model was required to allow capturing as many dimensional and geometric data and tolerances as possible. The model used is shown in Figure 3.

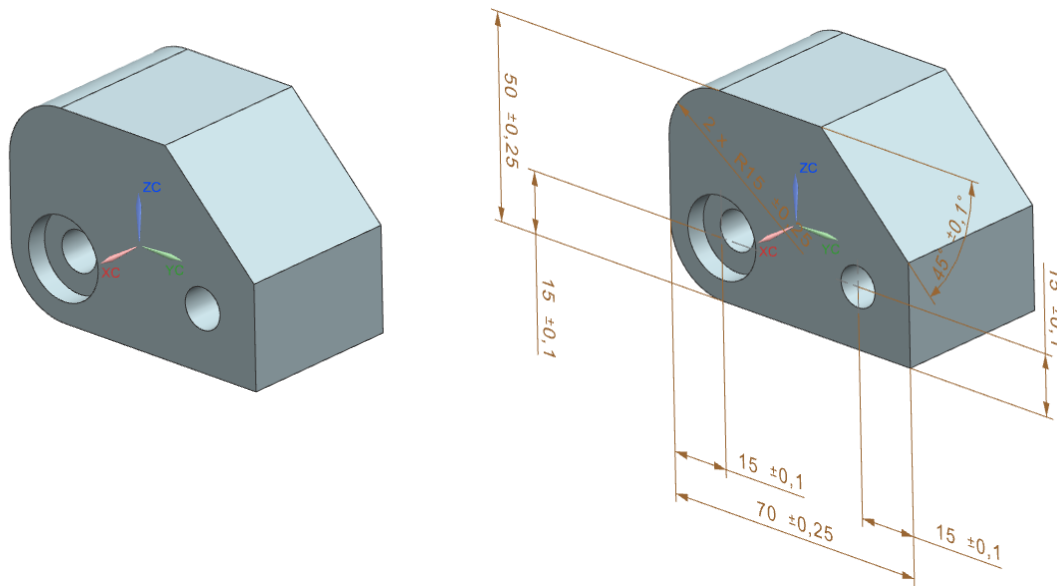


Figure 0: Reference model and model with added PMI (dimensions only)

RESULTS

Table 1 shows whether or not we get a solid model when importing STEP files. The far left column shows from which modeler the file was exported, and the adjacent one shows which extension the exported file received. Because modelers allow for different file exports, the number of options varies from modeler to modeler. Beginning with the second column, you can see for each modeler whether a solid model appeared upon opening, whether the file could not be opened, or the file could be opened but there was no solid model.

Table 1: Opening solid models

Export modeling software	Exported file extension	Import modeling software			
		Siemens NX 11	SolidWorks 2018	Autodesk Inventor Professional 2018	PTC Creo 5.0
Siemens NX 11	.stp	+	+	+	+

Legend: + opens a solid model, o opens a file but no solid model, - does not open a file

The .stp file overview shows whether or not the file contains product and manufacturing information. In addition, you could already see in the first part of the file (file information) whether the STEP AP242 standard was used for transformation. The results are shown in Table 3, where the modelers from which the STEP file was imported are presented on the far left, while the other two columns show separately whether the information was included and whether STEP AP242 was used.



		Opening modeling software			
Export modeling software	Exported file extension	Siemens NX 11	SolidWorks 2018	Autodesk Inventor Professional 2018	PTC Creo 5.0
Siemens NX 11	.stp	+	-	-	+
	.stpz	-	o	-	o
	.stpx	o	o	o	o
	.stpxz	-	o	o	o
SolidWorks 2018	.stp	-	-	-	-

Autodesk Inventor 2018	.stp	-	-	-	+
	.stpz	-	o	-	o
PTC Creo 5.0	.stp	+	-	-	+

Legend: + PMI displayed, o no solid model, - no PMI displayed

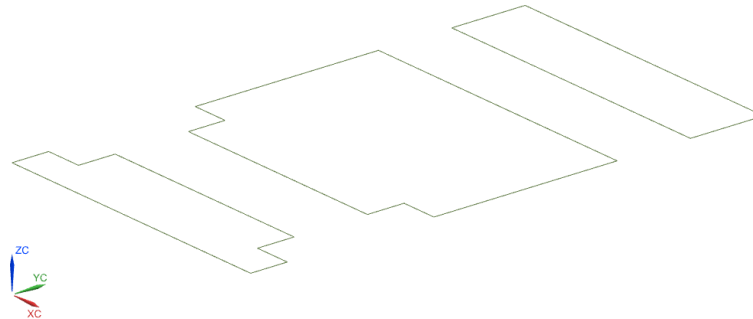


Figure 5: File in .stpx format opened in Siemens NX 11

Table 2: Results of .stp files validation

Modeling software	Information preservation	Use of AP242
Siemens NX 11	+	+
SolidWorks 2018	+	+
Autodesk Inventor Professional 2018	+	+
PTC Creo 5.0	+	+

Legend: + information included, - information not included

The size of the converted models on the disk is shown in Table 4. The left column shows the modeler from which the STEP file was exported, the adjacent column contains the file extension of the exported file, and the far right column shows file size on disk.

Table 0: File size on disk

Modeling software	Exported file extension	File size on disk [kB]
Siemens NX 11	.stp	1161
	.stpz	270
	.stpx	7
	.stpxz	2
SolidWorks 2018	.stp	1758
Autodesk Inventor Professional 2018	.stp	478
	.stpz	141
PTC Creo 5.0	.stp	1587

CONCLUSION

Table 1 reveals that modelers have no problem opening ordinary .stp files. Other than the basic versions of STEP files cause problems. The biggest problem is that some modelers are unable to import specific file formats.

Considering that two modelers (Siemens NX 11 and Autodesk Inventor Professional 2018) out of the four compared have the option of exporting and opening a compressed .stpz file, this would be a desirable option also in other modelers. Especially due to the fact that in the case of the exported file from Siemens NX 11, the compressed file takes up only 25% of space, compared to the ordinary non-compressed STEP file.

.stpx and .stpxz files are XML types of STEP files. The difference between them is that the latter is a compressed version of the former. These files are capable of being both exported and opened only in the Siemens NX 11 modeler, where it is interesting that a solid model is obtained when opening a compressed file type, but when opening a non-compressed file, displayed are only the lines of the sections where the model was cut when views were created.

Looking at the results, presented in Table 2, you can see that the display of PMI on solid models is not so common. Similarly, when displaying this information, some confusion may occur, as all the data are displayed on one model, which makes them unclear. Displaying different graphic elements is one of the possibilities, provided by STEP AP242.

In principle, the display of PMI is not crucial for the manufacturing process to continue because CAM programs do not require graphical information, they only need the representative part. The graphical display is important for the production engineers to be able to see what the requirements on the model are, but for this purpose, it is easier to use some other dedicated file. One of the options includes a 3D .pdf file that can be easily opened in Adobe Acrobat Reader. It can be exported from all of the compared modelers, except Siemens NX 11, which uses JT files for this purpose. For viewing these files, Siemens also provides free software for computers, as well as for smartphones and tablets running Android or iOS.

Reviewing .stp files in the text format and the results obtained from Table 3 show that conversions from solid models into STEP files are appropriate. This is evident from the fact that the information, required by the software that is used in the phases that follow development, is preserved. Even if the information is invisible to the eye, a file still contains it. This fact makes it the key information transmitter between different software environments.

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SMARTPHONE USER TESTS FOR USER CENTERED DESIGN

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ABSTRACT:

THESE LAST DECADES SOME NEW INFORMATION AND COMMUNICATION TECHNOLOGIES BECOME POORLY ADAPTED TO ELDERLY, WITH THE INCREASE IN LIFE EXPECTANCY. IN PARTICULAR, THIS IS THE CASE OF DEVICES WITH SMALL SIZE AS SMARTPHONES FOR INSTANCE. IN THIS CONTEXT, IN ORDER TO PREDICT AND IMPROVE THE ACCESSIBILITY OF PEOPLE WITH LIMITED FOREARM MOTOR CAPACITY THIS PAPER DEALS WITH THE STUDY OF INTERACTION MODALITIES BASED ON EMG (ELECTROMYOGRAPHY) FOR HUMAN-COMPUTER INTERACTION, FOR A MORE TOLERANT INTERACTION IN THE FACE OF VAGUENESS OF THE GESTURE. FOR THIS PURPOSE SERIES OF TESTS FOR FINGER ACTIVITY ESTIMATION WERE PERFORMED ACCORDING TO AN APPROPRIATED BIO-MEDICAL PROTOCOL WHILE MANIPULATING A SMARTPHONE IN TWO CASES: WITH AND WITHOUT ERGONOMIC STRAP USED. THE EMG SIGNALS OF THE THREE MOST INVOLVED MUSCLES OF THE THUMB ARE RECORDED AND ANALYZED. THE RESULTS SHOW THAT: I). THE FINGER'S EMG SIGNALS FOR THESE MUSCLES ARE INTERDEPENDENT, II). THE RELATIONSHIPS BETWEEN POSITIONS OF TOUCH, FOR THREE LAYOUTS DOTS DISPOSED ON THE SMART PHONE SCREEN, AND APPLIED FORCE ARE NO LINEAR. USING LINEAR REGRESSION ANALYSIS THE QUANTITATIVE RELATIONSHIPS BETWEEN FORCE AND FINGERS' DISPLACEMENTS HAVE BEEN EXTRACTED. BY COMPARING FORCE-DISPLACEMENT RELATIONSHIPS, IT IS OBSERVED THAT THE THUMB INDUCES LESS ACTIVATING FORCE THAN THE OTHER FINGERS. IT WAS ALSO FOUND THAT THE RELIEF OF THE FINGER MUSCLES INVOLVED IN THE GRIPPING OF THE SMARTPHONE ALLOWS TO REDUCE THE MUSCULAR ACTIVITY OF THE THUMB AND THUS TO DELAY THE APPEARANCE OF MUSCULOSKELETAL DISORDERS.

KEY WORDS: USER CENTERED DESIGN, ERGONOMICS, ACCESSIBILITY, BIOMECHANICS

INTRODUCTION

Today our world is becoming more and more "*connected*" thanks' to new information and communication technologies allowing us access to information by the emergence of the Internet,

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and its enabling tools. Smartphones, for instance, are ones of the most effective ways to navigate in this virtual world. Their small size and intuitive interface have made them familiar, indispensable and ubiquitous devices. These devices offer a variety of possibilities through an increasingly large touch screen. If the interaction with the phones of yesterday was done mainly by means of a keyboard located under the screen, in today designed phones the whole surface of the devices are used thus increasing their functionalities. However, people with limited hand mobility can experience fatigue-related problems when using such devices ^{4,5}. More generally, the long-term effects of everyday use of a smartphone (including young people) are still unknown, but it is reasonable to suppose that illnesses may appear, such as tendinitis ^{6,7}. These specially designed devices are mainly based on interaction with gesture or touch: which requires specific gestures especially for elderly ^{8,9}. Thus, scientific and technological advances have to be proposed to take this reality into account. To this end a question arises, namely: *How to improve the accessibility for this class of devices?*

A two-step touch method (*Press and Flick*) for website navigation on smartphones was presented in ⁸. It consists of finger press and flick motions: *i*). a target hyperlink is selected by a finger press motion; *ii*). a finger flick method is conducted for error correction if the initial interaction (press) failed. Authors comprehensively examined its effectiveness using the goals, operators, methods, and selection rules (GOMS) model and user testing. For this purpose they compared the two-step touch method with the current touch method through the GOMS model and user testing. The results show that the two-step touch method is significantly superior to the current touch method in terms of error rate and subjective satisfaction score. However, it seems that its superiority in terms of number of interactions and touch time is vulnerably affected by error rate. Recently new ergonomic solutions were available on the market. The designed ergonomic keyboards “*Word Flow*” from Microsoft was an example. Supposed to do writing easier and faster, it was abandoned last year. The smartphones with classical “*QWERTY*” and “*AZERTY*” keyboards seem not to be obsolete anymore and are still predominant on the market today. For this reason our study concerns the manipulation of these widely used classical devices.

An extended review of control with hand gestures by older users was presented in ⁴. Authors first reviewed issues about age and its related characteristics. Then two major

⁴ S-F. M. Liang, Y-J. B. Lee; *Control with Hand Gestures by Older Users: A Review*, Lecture Notes in Computer Science book series (LNCS, volume 9754), International Conference on Human Aspects of IT for the Aged Population, ITAP 2016: Human Aspects of IT for the Aged Population. Design for Aging, pp 350-359

⁵ H. Hwangbo, S.H. Yoon, B.S. Jin, Y.S. Han; *A Study of Pointing Performance of Elderly Users on Smartphones*, pp. 604-618 (2012), International Journal of Human-Computer Interaction, Volume 29, 2013 - Issue 9, Pages 604-618

⁶ S.C. Lee, M.C. Cha, H. Hwangbo, S. Mo, Y.G. Ji; *Smartphone form factors: Effects of width and bottom bezel on touch performance, workload, and physical demand*, Applied Ergonomics 67 (2018) 142–150

⁷ I. Bautmans, S. Vantighem, E. Gorus, Y-R. Grazzini, Y. Fierens, A. Pool-Goudzwaard, T. Mets; *Age-related differences in pre-movement antagonist muscle co-activation and reaction-time performance*, Experimental Gerontology, 46 637–642 (2011).

⁸ K. Jung, J. Jang; *Development of a two-step touch method for website navigation on smartphones*, Applied Ergonomics 48 (2015) 148e153

⁹ I. G. Motti, N. Vigouroux, F. Gorce; *Improving accessibility of tactile interaction for older users: lowering accuracy requirements to support drag-and-drop interaction*, Procedia Computer Science, Elsevier, vol. 67, 366-375, (2015).

applications of gestural user interfaces, “gesture-on-surface” and “gesture-in-midair,” are investigated. It is shown, that *while gesture-on-surface refers to gesture control on touchscreens, gesture-in-midair denotes that hand gestures are performed without touching anything.*

A study of pointing performance of elderly users on smartphones was presented in ⁵. Pointing performance was measured by the time taken to complete the pointing task and the number of errors during a task. For this purpose authors conducted two experiments. For the first one (three target sizes and two target spacings), they analyzed whether touch screen pointing performance is dependent on the location of the target. For the second experiment (three types of feedback; auditory, tactile, and audiotactile) the results show that: *i.)* pointing performance of elderly was significantly influenced by size, spacing, and location of target, and *ii.)* the performance was higher in audio tactile feedback condition.

Recently an investigation of the effect of two smartphone form factors (width and bottom bezel) on touch behaviors with one-handed interaction was presented in ¹⁰. For this purpose, authors performed user experiments on tapping tasks for four widths (67, 70, 72, and 74 mm) and five bottom bezel levels (2.5, 5, 7.5, 10, and 12.5 mm). In order to examine the touch behavior, authors collected: task performance measures (success rate and task completion time), electromyography, and subjective workload data (NASA-TLX method).

The performance of two scrolling techniques (*flick* and *ring*) for document navigation in touch-based mobile phones using three input methods (*index finger*, *pen*, and *thumb*), with specific consideration given to two postures: *sitting* and *walking* were examined by Huawei et al. in ¹¹. The authors find out that: *i.)* in both sitting and walking postures, for the three input methods, *flick* resulted in shorter movement time and fewer crossings than *ring*, suggesting *flick* is superior to *ring* for document navigation; *ii.)* for sitting posture, regarding pen and thumb input, *ring* led to shorter movement time than *flick* for large target distances. In ¹² authors relate age and muscle mobilization during a prolonged reaction-time (RT) test. For this purpose they studied the evolution of reaction time with relief of the muscles involved in the gripping of a smartphone by young and older subjects.

Note that other studies dealt with improving the accessibility of tactile interaction for older users by lowering accuracy requirements to support drag-and-drop interaction ¹³. Some of them deal with electromyography (EMG) signal processing, and the flourishing use of smartphones. It was proven that the peak value of EMG signals after root mean square (RMS) processing is an index of fatigue ¹⁴ when subjects are performing the task at the same level of force when

¹⁰ S.C. Lee, M.C. Cha, H. Hwangbo, S. Mo, Y.G. Ji; *Smartphone form factors: Effects of width and bottom bezel on touch performance, workload, and physical demand*, Applied Ergonomics 67 (2018) 142–150

¹¹ T. Huaw, R. Xiangsi, T. Feng, F. Wang; *Evaluation of Flick and Ring Scrolling on Touch- Based Smartphones*, International Journal of Human–Computer Interaction , Vol. 30, 2014 - Issue 8: Human Computer Interaction in the Asia-Pacific Region, pp. 643-653, <https://doi.org/10.1080/10447318.2014.907017>

¹² S. Vantieghem, E. Gorus, E. Lauwers, Y. Fierens; A. Pool-Goudzwaard, I. Bautmans; *Age-related differences in muscle recruitment and reaction-time performance*, Experimental Gerontology, Volume 70, October, 125-130 (2015).

¹³ I. G. Motti, N. Vigouroux, F. Gorce; *Improving accessibility of tactile interaction for older users: lowering accuracy requirements to support drag-and-drop interaction*, Procedia Computer Science, Elsevier, vol. 67, 366-375, (2015).

¹⁴ S. Boyasn, A. Guenel, R. Naik Ganesh; *Endurance time prediction using electromyography*. In Applications, Challenges, and Advancements. In Electromyography Signal Processing: Bd. v. 219-233: IGI Global, ISBN 978-1-4666-6090-8 (2014).

manipulating daily used devices as smartphones. In this optic, the speed of motions of the thumb and the intensity of segmental muscular EMG activity of the *abductor pollicis longus* (APL) muscle of the hand during an upward writing test were investigated in ¹⁵.

Interesting results concerning the optimal range of smartphone form factors for one-handed interaction, which could contribute to the design of new smartphones, were obtained in ¹⁰ where the EMG signals of two thumb muscles, namely the first *dorsal interosseous* and *abductor pollicis brevis*, were observed. It seems that: *i). the task performances deteriorated with increasing width level; ii). the subjective workload and electromyography data show similar patterns with the task performances; iii). the tasks became increasingly difficult as the bottom bezel level decreased.*

After reviewing and analyzing some studies related with the subject of this paper, a part of which was presented here above, seems that they partially improved accessibility of smartphones touch screen. However, they do not take into account of the vagueness of the gesture thus limiting the performances of the proposed solutions.

Thus, our aims is to show the interdependencies amongst the work done by the thumb and the others fingers while gripping the phone, via the experiments to measure the muscular activity of the thumb. The results obtained on the decrease of muscular activity of the thumb with strapped phone are interesting and encouraging. They can contribute to the design of new generation mobile touch screen devices and application button layout in the frame of user centered design. As designers of current smartphones try to include a lot of information and input control in the same display, the latter often include too much information. As a result elderly users with osteoarthritis of the thumb as rhizarthrosis (or trapeziometacarpal) experience pain during and after using such devices.

The materials and the methods are detailed in Section 2. Then, the results are presented and discussed in Section 3. Conclusions and future work are suggested in Section 4.

METHOD

To carry out a complete study of human limb's movements it would be necessary to study the functionality of a lot of muscles. In fact, the movements of a human limb are possible thanks to a complex network of muscles and tendons, and interaction amongst them. Studying all the hand muscles while manipulating a smartphone seems to be a very complicated task. For the sake of accessibility, we studied the behavior of three out of eight more loaded and involved muscles of the hand namely: *adductor pollicis* (AP), *abductor pollicis brevis* (APB) and *interossei dorsal muscles* (DIM). (Fig. 1.a).

The main points of the proposed methodology are: *i). performing experiments to measure the muscular activity of the thumb during two tests for each subject while manipulating a smartphone in both ergonomic cases: with and without a strap used; ii). comparing the data retrieved on each of the tests in order to evaluate the activities of the three more involved muscles of the thumb in these both cases.*

¹⁵ G. Thérèse Simard, P. Esem Cerqueira; *Fine motor control: An EMG study of ability of the thumb in healthy hands of adult subjects*, Journal of Electromyography and Kinesiology, 2 (1), 42-52 (1992).

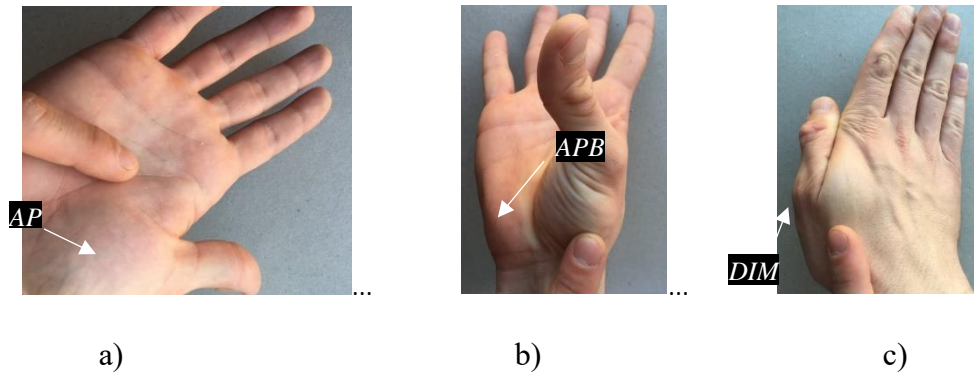


Figure 1: Locations of: a). adductor pollicis (AP), b). abductor pollicis brevis (APB), c) interossei dorsal muscles (DIM).

According to the proposed methodology, during the tests, subjects had to use the thumbs of their predominant hands when touching the smartphone screen as shown in Fig. 2.

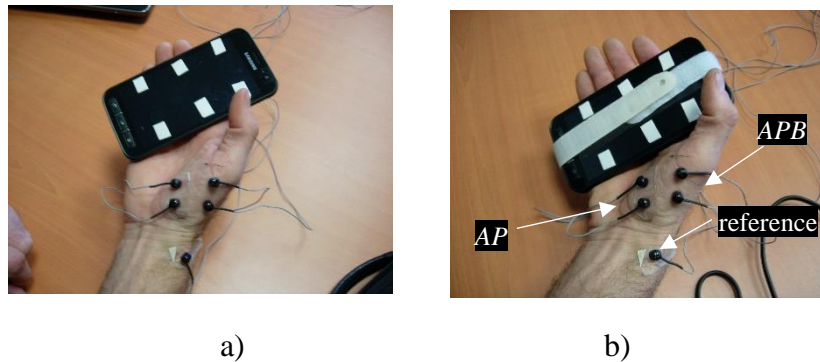


Figure 2: Test bench for the experiments carried out: positions of the sensors for target dots on the Smartphone screen; manipulation of the Smartphone without a strap (a) and with a strap (b).

BIOPAC EL503 Vinyl 1-3/8" electrodes were used to record the EGM signals of *adductor pollicis* (AP), *abductor pollicis brevis* (APB) and *dorsal interossei muscles* (DIM) according to the SENIAM (surface EMG for non-invasive assessment of muscles recommendations)¹⁶ and analyzed with four channel EMG-BIOPAC MP150 system, the fourth channel being the reference one. The smartphone used in the performed experiences was an iPhone 4S. On the touch screen (3.5 in., 88.89 mm) six square visual indicators were spaced from their center regularly (Fig. 2a) to crisscross the entire screen in three different trajectories (layout types) as shown in Fig. 3.

Prior to the three-order Dot disposals tests, a familiarization session consisting of five trials was dedicated for each participant. After 5 minutes of recovery, the participants performed the tests. According to the proposed medical protocol, during the tests, subjects (in sitting position)

¹⁶ H.J. Hermens, B. Freriks, C. Disselhorst-Klug, G. Rau; *Development of recommendations for SEMG sensors and sensor placement procedures*. Jour. Electromyogr. Kinesiol. 10 (5), 361–374 (2000).

had to only use their predominant thumb finger when touching the screen. The first phalange of the little finger was placed on the table and remained in this position throughout the experience.

Two tests, of 3 minutes each, are performed according to the bio-medical protocol. During the first one, subject held the smartphone in his agile hand, resting elbow and wrist on a fixed support (table). While squeezing the smartphone with his supporting hand, the subject had to touch the six visual markers with the thumb in a specific order (Fig. 3) for 180 seconds, changing the orders every 60 seconds. In order to maintain the same speed of action for all subjects, for both tests, a metronome set at *60 bpm* (beats per minute) gave the tempo to touch the indicators with a frequency of *1 Hz*. During the second test, the subjects have to repeat the same movement as in test one. However, a strap passing in the back of the hand and in front of the smartphone screen was attached, as shown in Fig. 2b, so that the muscles involved in the gripping by the fingers were completely relieved. In other words, in this configuration the subject does not need to actively hold the phone while in the first case it must tighten it.

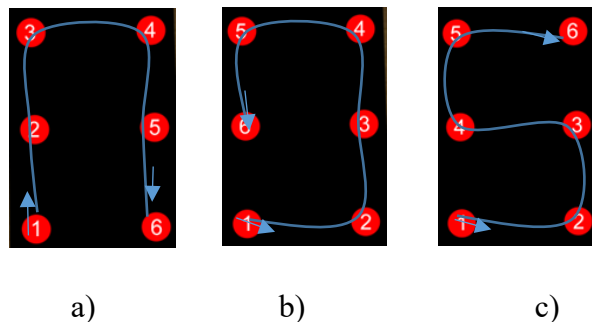


Figure 3: Three-order Dot disposals (layouts) on the Smart phone screen.

Eight unpaid, voluntary and healthy subjects (all males, two of them left-handed), aged from 20 to 62 participated in the experiments. All subjects have declared not having: *i*). corrected visual impairment; *ii*). impairments of haptic sensitivity (sensitivity of touch, numbness of the fingers and loss of finger location perception); *iii*). diseases or symptoms which induce hand movement disorders. All subjects declared also being naive to the purpose of the experiment. The study was approved by the Ethics Committees of the University Grenoble Alpes and all participants gave written informed consent. After a briefing about the experiment, participants filled out a background survey.

During the test, finger involvement, is estimated by the treatment of EMG signals emitted by the three more involved muscles of the thumb, while manipulating the Smartphone, in the two cases: without and with a strap. In Figure 4 the EMG row signals of muscles *APB* (channel 2) for subject *Corsel* and *AP* (channel 1) for subject *Michel* are presented. However, these signals require treatments in order to be analyzed and compared after then for biomechanical analysis of the finger movement.

For this purpose, first, all raw sEMG signals were simultaneously sampled at *1250 Hz* and filtered with Butterworth 2-nd order, band-pass 10–5000 Hz and notch-filtered as in ¹⁷ using

¹⁷ J.F. Stins, M. E. Michielsens, M. Roerdink, P. J. Beek; *Sway regularity reflects attentional involvement in postural control: Effects of expertise, vision and cognition. Gait & Posture, 30(1), 106–109 (2009).*

MATLAB (MATLAB 2014a, MathWorks) software in order to erase the various parasites. Note, that the low frequencies are trained parasites due to external factors such as: cable movement, blood passing in the hand, while the high frequencies represent often the parasitic movements of the hand. Then sEMG signals are RMS (root mean square) processed over a short 2 s period and the maximum RMS values obtained between the different tests are compared. Consequently the absolute values of those signals are taken. Finally those modified signals of the three muscles for each subject are compared in order to find the more leaded one, while manipulating the Smartphone, with and without a strap. Here, it is assumed that the subject is not tired and therefore the EMG/force relationship remains constant.

Concerning the statistical analysis, first, Shapiro-Wilk method has been applied to verify the normality of the EMG data. Then, a *two-way* Analyses of variance (ANOVA) were performed to test changes on RMS-EMG (i.e. dependent variable) while manipulating the smartphone in both cases: with and without a strap separately for the three muscles. Significance was set a priori $p < 0.001$. All the statistical analyses were performed under the MATLAB Software (MATLAB 2014a, MathWorks). The standard error of mean (SEM) of finger's pressing forces of all subjects were calculated as well.

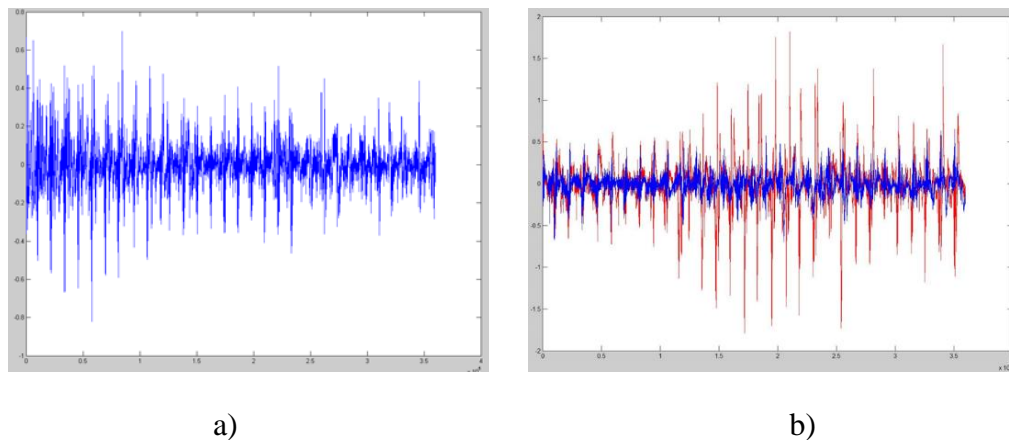


Figure 4: EGM raw signals: a). APB muscle (subject Corsel) without a strap) and AP muscle (subject Michel) red without a strap, blue with a strap

RESULTS AND DISCUSSION

Recall that, for each subject, after filtering, the RMS value of the EMG data were compared and averaged (Matlab Software) to get the overall value of the activity by averaging the differences of the three channels in both cases: with and without a strap. Then the average difference for each muscle and for all three muscles on seven subjects were calculated in both cases (without a strap 1 and with a strap 2). The results are presented in Table.

From Fig. 4, is seen that muscle activities are less important while manipulating the strapped phone. This is confirmed also by the values reported in Table 1. It is seen, that the overall muscle activity of the thumb decreased for all the subjects (over 27%). For all of them, the average activity decreased: for AP muscle (over 25%), for APB muscle (over 19%) and even significantly for DIM muscle (over 36%). However, it seems that this trend is not followed by some muscles

because the *APB* activity of *Subject Corcel* and *AP* activity of *Subject Issam* increased. This may be due to a wrong electrode location for these subjects or a specific muscle involvement associated to the great variability in muscle involvement across subjects. However, it can be assumed that the strap helps the subject significantly if properly used because it keeps the phone without the need for great muscle intervention.

After then the muscle activities in the Points 1,2...6 for each orders Dots disposals, (called *Trajectory 1*, *Trajectory 2* and *Trajectory 3*) were compared in order to estimate the difficulty to reach a specific zone of the touch screen. For this purpose, after filtering the row EMG signals with a *BP filter* (20-500 Hz) the RMS values over small periods (2 s) are calculated in order to visualize the contractions of the muscles in these points (Fig. 4a). Finally the RMS value are filtered to smooth the curve.

For the right handed subjects the major peaks correspond while touching the bottom left side of the smartphone screen corresponding to the surrounding zone of *Point1* of the three Trajectories (Fig. 3 a, b, c). While, for the left handed subjects the peaks correspond while touching the bottom right side of the smartphone screen corresponding to the surrounding zone of *Point 6* for *Trajectory 1* (Fig. 2.a) and *Point 2* for *Trajectories 2* and *3* (Fig. 3b, et Fig. 3c respectively). Thus, the effort to reach these points is more important, which requires most muscle activity.

Table 1: Average RMS signals values (*Voltage*) for the three muscles of each of the eight subjects (without a strap 1, with a strap 2)

subject	muscle AP	muscle APB	muscle DIM			muscle AP	muscle APB	muscle DIM
Corcel1	3,47177551	7,58794676	2,53623998		Lionel1	7,87464349	7,10201037	4,12083936
Corcel2	3,31416386	8,08006639	1,02878253		Lionel2	4,56768518	4,51699047	1,39810742
diff in %	-4,53979949	6,48554414	-59,4367041		diff in %	-41,9950225	-36,3984247	-66,0722659
average		-19,1636531			average		-48,1552377	
	muscle AP	muscle APB	muscle DIM			muscle AP	muscle APB	muscle DIM
Luc1	6,25185035	6,68975272	2,97198872		Jean1	10,0463538	14,571706	2,0908563
Luc2	5,37178183	5,16745813	1,37723244		Jean2	6,36098922	10,604789	1,89201241
diff in %	-14,0769288	-22,7556182	-53,6595671		diff in %	-36,6836048	-27,2237924	-9,5101655
average		-30,164038			average		-24,4725083	
	muscle AP	muscle APB	muscle DIM			muscle AP	muscle APB	muscle DIM
Michel1	5,89589763	8,64893855	2,4830159		Mathieu1	3,95967805	17,9435117	5,32956626
Michel2	2,66544547	4,15390582	2,10543955		Mathieu2	2,88711538	16,9567801	2,6993981
diff in %	-54,7915256	-51,9720738	-15,2063604		diff in %	-27,0871185	-5,4991018	-49,3505107
average		-40,6566533			average		-26,3122439	
	muscle AP	muscle APB	muscle DIM			muscle AP	muscle APB	muscle DIM
Issam1	4,02060217	8,18008688	3,35028364		Rami1	10,0386407	13,2771558	2,58657936
Issam2	4,02512539	8,04445975	3,24546592		Rami2	4,42064565	5,44199848	2,04368046
diff in %	0,11250093	-1,65801581	-3,12862215		diff in %	-55,9637036	-59,0123178	-20,0989068
average		-1,55804567			average		-45,0249763	
average/8 subjects								
total	-29,3137791							
muscle AP	-29,378151							
muscle APB	-21,0141327							
muscle DIM	-34,5775878							

In summary, *Trajectory 1* (Fig. 3a) requires more muscular effort than the other ones. In contrary *Trajectory 3* (Fig. 3c) requires less effort. These findings suggest that it can be interesting to investigate on these displacements to create the smartphone's interface most ergonomic possibly. SEM) of finger's pressing forces of all subjects were calculated as well.

CONCLUSION

In this study we investigate the behavior of muscle thumb EMG during manipulation of a Smartphone in two cases: with and without a strap. Through experiments (EMG signal processing) which involve the three more loaded muscles of the thumb finger, subjects' pressing involvement have been recorded and analyzed while touching the smartphone screen for three different trajectories. The results shown that the finger's EMG signals for the three most involved muscles are interdependent thus increasing the difficulties for a precise finger force analysis. They also shown that: *i*). the relationships between positions of touch, for these three-order dots disposed on the smart phone screen (layout, trajectories), and EMG level were no linear; *ii*). the EMG decreases significantly while manipulating strapped phone.

In the near future the study will be deepened in order to determine strap's true utility and if so to optimize its ergonomics. Thus, it is expected that through further study about people interaction with electronic devices, they will fill more comfortable while using these new technologies. At this stage of the study it may be stated that the use of the strap seems to bring significant help to the thumb for smartphone use by people with limited fingers' mobilities.

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EXPERIMENTAL STUDY ON SHRINKAGE OF NARROW PARTS PRODUCED BY LASER CUTTING PROCESS

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Joško VALENTINČIĆ⁴

ABSTRACT:

THE EFFECTS OF DIMENSIONS OF NARROW PARTS ON LENGTH SHRINKAGE WERE INVESTIGATED. BASED ON TAGUCHI APPROACH TO DESIGN OF EXPERIMENTS (DOE), AN EMPIRICAL MODEL WAS BUILT TO CALCULATE THE SHRINKAGE OF X5CrNi18-10 STAINLESS STEEL CUT BY CO₂ LASER USING N₂ AS AN ASSIST GAS. THE EXPERIMENTAL DESIGN WAS PERFORMED ACCORDING TO TAGUCHI L16 ORTHOGONAL ARRAY WITH A MIXED LEVEL DESIGN FOR SHEET THICKNESS, NOMINAL SAMPLE LENGTH AND NOMINAL SAMPLE WIDTH. WITHIN THE LIMITS OF ANALISED VALUES, SHEET THICKNESS HAS NO SIGNIFICANT EFFECT ON SHRINKAGE AND THE HIGHEST EFFECT HAS THE NOMINAL SAMPLE LENGTH. THE RESULTS ARE IN LINE WITH THE HYPOTHESIS THAT THE SHRINKAGE OCCURS DUE TO THE RESIDUAL STRESSES INDUCED IN RESOLIDIFIED LAYER. DERIVED EQUATIONS CAN BE USED TO PREDICT THE SHRINKAGE AND CONSEQUENTLY TO MODIFY THE CUTTING HEAD TRAJECTORY THAT LENGTH OF THE PART AGREES WITH THE NOMINAL VALUE.

KEY WORDS: SHEET METAL, LASER CUTTING PROCESS, SHRINKAGE, DOE, TAGUCHI METHOD

INTRODUCTION

Austenitic stainless steels and nickel based super-alloys as well as titanium and its alloys are the most popular difficult to cut sheet materials used in the manufacturing industries due to their exceptional mechanical and physical properties. Cutting these materials by using conventional processes are difficult with plenty of disadvantages. Therefore, advanced processes

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like plasma beam cutting, abrasive water jet cutting and laser beam cutting are mostly used to machine such materials⁵.

Laser cutting is one of the leading industry technology for cutting a wide variety of materials. Compared to other advanced cutting technologies, laser cutting process offers significant advantages and possibilities such as the ability to cut complex geometries, achieving tight tolerances, high cutting speeds, localized head affected zone, ease of automation, computer control, integration into assembly lines, etc.^{6,7}. Mastering the influence of process parameters to cutting performances is a key not only to improve the quality of cut and cutting efficiency, but also to lower the production costs⁶. A lot of researches to master the technological process parameters have been conducted using Design of experiments (DOE) techniques. The Taguchi method is one of them. It is a well-known technique for improving the quality of products and processes. It represents a simple and efficient method of planning the experiment, it is not limited to specific problems and is most often used for experimental analysis and optimization of products and processes⁶.

A large number of recent scientific studies dealing with the problem of the laser cutting process mainly describe the variation of the laser process parameters for different types of materials and their impact on the measured variables. However, there are almost no studies indicating the influence of geometric features and dimensions on processing errors and the discrepancy between the finished product dimensions and the nominal dimensions defined by the cutting head trajectory. Additionally, it was practically observed that narrow and long parts are shorter than nominal length defined by the cutting head geometry. The shrinkage in the direction of part length is most probably caused by the residual stresses induced by the formation of resolidified layer on the surface of the cut, which is formed due to the thermal material removal mechanism. The shrinkage could be calculated by mastering the formation of resolidified layer (especially its depth) and connect it with the expected shrinkage.

In this paper, the effects of the sample thickness, sample nominal width and sample nominal length on length shrinkage are determined using Taguchi method. The results are analysed from the point of view of residual stresses. The sample thickness is defined by the sheet thickness whereas nominal sample width and nominal sample length are defined by the laser cutting head trajectory.

EXPERIMENTAL SETUP AND PROCEDURE

The experimental studies were performed by using a 5 kW continuous wave mode CO₂ Power Laser Platino (Prima Power, Italy) as shown in Figure 1. The samples of various dimensions were cut out of three plates of various thickness. All cuts were performed by the fixed laser machining parameters given in Table 1, thus eliminating the variance of the laser cutting parameters (cutting speed, gas pressure, laser power, focal point position, etc.) as influential parameters to shrinkage. Assuming that the mutual relations of the selected sizes and

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⁶ Madić, Miloš; Antuceviciene, Jurgita; Radovanović, Miroslav; Petković, Dušan; Determination of laser cutting process conditions using the preference selection index method, Optic and Laser Technology

⁷ Fetene, N. Besufekad; Kumar, Vikash; Dixit, S. Uday; Echempati, Raghu; Numerical and experimental study on multi-pass laser bending of AH36 steel strips, Optics and Laser Technology

experimentally measured sizes are complex and nonlinear, four values (levels) of thickness and lengths were defined as well as two sample widths. The samples of high alloyed steel X5CrNi18-10 were measured on a flat table using Digital height and marking gauge (Vogel, Germany) with maximal total accuracy of 0.03 mm. Each dimension was measured at least two times, and the mean values were taken into consideration.



Figure 1. Cutting of samples

As shown in Table 2, nominal sample width has two values and nominal sample height and sample thickness have four values. In order to perform full factorial analysis, $4 \cdot 4 \cdot 2 = 32$ experiments are required without counting the repetitions. By using the Taguchi method based on the $L_{16} (4^2 \times 2^1)$ orthogonal array, the number of experiments is reduced to half (Table 2). Each experiment was repeated three times, therefore the total number of experiments is 48. The summary of experimental conditions are listed in Table 2. When applying any DOE method, the experimental parameters, in this case sample dimensions, are denoted as *control factors* or shortly just *factors*.

Table 1. Laser process parameters

Process parameter	Symbol	Unit	Value
Cutting speed	v	mm/min	1900
Gas pressure	p	bar	12.8
Focus	f	mm	-4.5
Used gas	-	-	N ₂

Table 2. Control factors and their levels

Symbol	Control factor	Notation	Unit	Level values			
				1	2	3	4
A	Sheet thickness	t	mm	2	3	4	5
B	Nominal sample length	l	mm	150	250	350	450
C	Nominal sample width	w	mm	10	20	-	-

RESULTS AND DISCUSSIONS

The experimental parameters (factor levels) and the experimental results are given in Table 3. The mean value of the shrinkage is calculated by Eq.1.

$$\bar{Y} = \frac{1}{N} \sum_{i=1}^N Y_i \quad (1)$$

Since all the measured values are either greater or smaller than the nominal values (in our case smaller) and the smallest value of means is the best result, the “smaller-is-better” type characteristic (Eq. 2) may be used to obtain S/N value for each experiment⁸.

$$S/N = -10 \cdot \log \left(\frac{1}{N} \cdot \sum_{i=1}^N Y_i \right) \quad (2)$$

In both cases N is the number of repetitions, in this case 3.

Table 3. Taguchi orthogonal array $L_{16} (4^2 \times 2^1)$ with experimental results

No	Factor levels			Experimental results						
	A	B	C	Measured sample length, mm			Shrinkage Y, mm			S/N ratio, dB
				I	II	III	I	II	III	
1	1	1	1	149.87	149.81	149.81	0.12	0.19	0.19	15.33
2	1	2	1	249.66	249.70	249.71	0.34	0.30	0.29	10.15
3	1	3	2	349.80	349.74	349.78	0.20	0.26	0.22	12.84
4	1	4	2	449.61	449.76	449.74	0.39	0.24	0.26	10.34
5	2	1	1	149.83	149.87	149.68	0.17	0.12	0.31	13.19
6	2	2	1	249.82	249.16	249.59	0.18	0.84	0.41	5.19
7	2	3	2	349.70	349.70	349.86	0.29	0.29	0.14	11.90
8	2	4	2	449.90	449.79	449.66	0.10	0.21	0.34	12.47
9	3	1	2	149.81	149.78	149.79	0.18	0.22	0.20	13.81
10	3	2	2	249.82	249.75	249.86	0.18	0.25	0.14	14.18
11	3	3	1	349.61	349.67	349.52	0.39	0.33	0.48	7.85
12	3	4	1	449.37	449.46	449.43	0.63	0.54	0.57	4.71
13	4	1	2	149.77	149.75	150.00	0.23	0.25	0.00	14.14
14	4	2	2	250.00	249.81	250.00	0.00	0.19	0.00	19.19
15	4	3	1	349.53	349.56	-	0.47	0.44	-	6.83
16	4	4	1	449.28	449.15	449.45	0.72	0.85	0.55	2.88

According to the Taguchi method, the response table for the means \bar{Y} and S/N ratios were used to determine the factor effect on the difference between the nominal and measured sample length (Table 4). Each value given in the table is the average value of means \bar{Y} or S/N ratios in which the observed factor was on the observed level⁹. Greater the difference between minimum and maximum value, greater the factor effect on the measured results. Therefore, nominal sample length has the greatest effect whereas the sheet thickness has the smallest effect in the range of the factor levels. These data may be presented as main effects plot for the factors. The plots are very helpful in visualizing the magnitudes of the investigated parameters on the response variable (Figure 2 and Figure 3).

⁸ Tosun, Nihat; Pihtili, H.; Gray relational analysis of performance characteristics in MQL milling of 7075 Al alloy, Int. J. Adv. Manuf. Technol.

⁹ Phadke, Madhan Sridhar; Quality Engineering Using Robust Design, Prentice Hall PTR Upper Saddle River

Table 4. Response table for S/N ratios and means

Means \bar{Y} , mm				S/N ratios, dB			
Level	A	B	C	Level	A	B	C
1	0.25	0.18	0.41	1	12.16	14.12	8.27
2	0.28	0.26	0.20	2	10.69	12.18	13.61
3	0.34	0.33	-	3	10.14	9.85	-
4	0.34	0.45	-	4	10.76	7.60	-
Delta	0.10	0.27	0.21	Delta	2.02	6.52	5.34
Rank	3	1	2	Rank	3	1	2

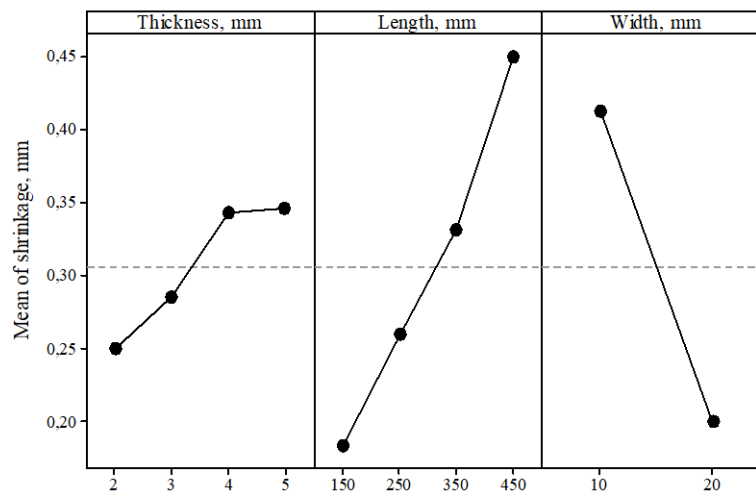
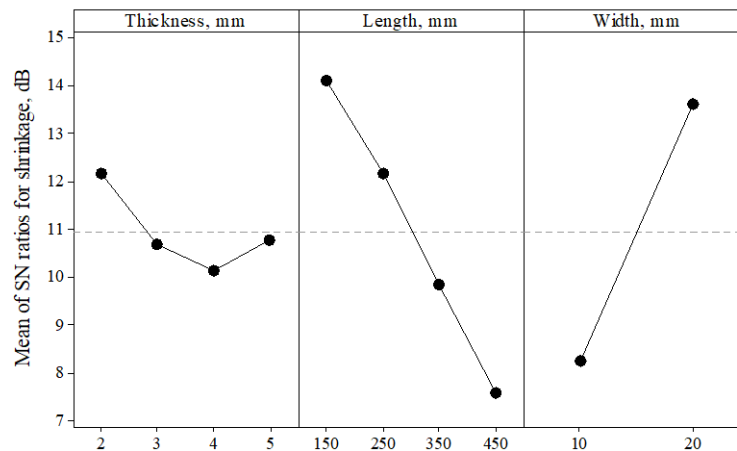


Figure 2. Main effects plot of means for shrinkage



Signal-to-noise: Smaller is better

Figure 3. Main effects plot of S/N ratios for shrinkage

In order to confirm the statistical significance of the factors, the analysis of variance (ANOVA) is used. The results of ANOVA are given in Table 6 and are showing that the sheet thickness t , that was varied in the range from 2 mm to 5 mm, has no statistical significance on the shrinkage, since the p -value exceeds the significance level of 5% ($p > 0,05$). Thus, the model to predict the shrinkage encompass only sample nominal width and length (Eq. 3). The calculated shrinkage \hat{Y} can be further used to modify the cutting head trajectory in order to produce parts that have the required length. The model is valid for the given laser process parameters (Table 1), stainless steel X5CrNi18-10 as the workpiece material and for the samples that have the thickness t in the range from 2 mm to 5 mm, nominal width w in the range from 10 mm to 20 mm and nominal length l in the range from 150 mm to 450 mm. According to the values $R^2 = 87.01\%$, $R^2_{adj} = 83.8\%$, $R^2_{predicted} = 78.5\%$, Figure 4 and Figure 5, the model is satisfactory accurate.

$$\hat{Y} = -0,119 + 0,00248 \cdot l + 0,01095 \cdot w - 0,000107 \cdot l \cdot w \quad (3)$$

Table 6. The effects of sample nominal dimensions on shrinkage determined by ANOVA.

Source	Degrees of freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	F-test F	p-value p
Thickness (mm)	3	0.026	0.009	0.80	0.528
Length (mm)	3	0.154	0.051	4.7	0.036
Width (mm)	3	0.181	0.181	16.6	0.004
Error	8	0.087	0.011		
Total	15	0.448			

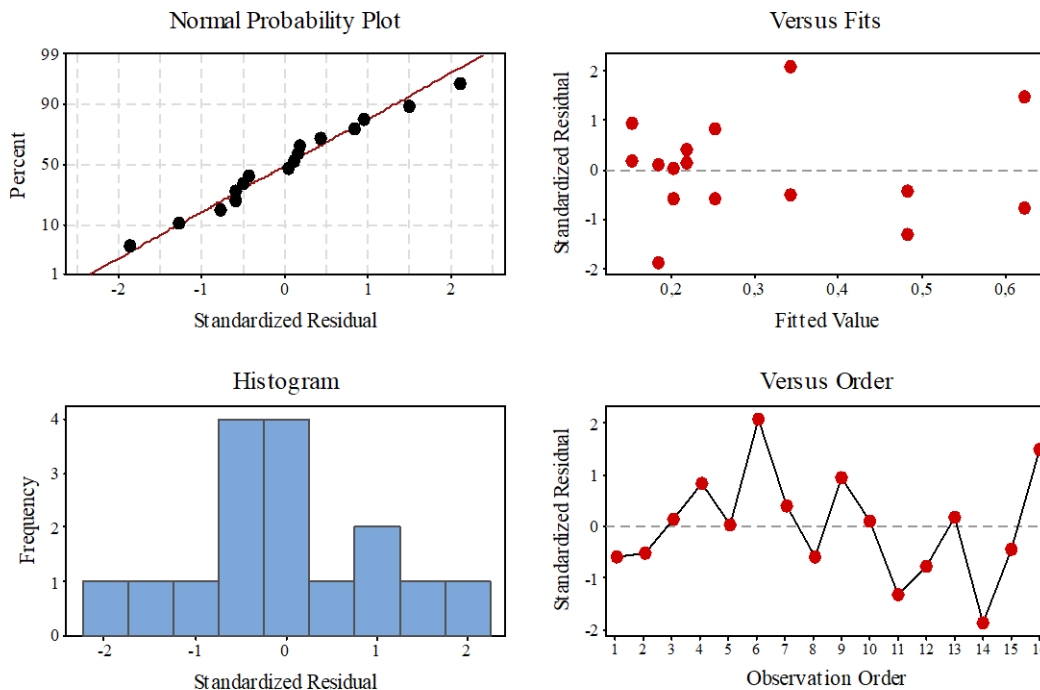


Figure 4. Residual plots of the linear model to predict shrinkage

The shrinkage of parts calculated by the derived model are compared to the measured values and given on Figure 5. The biggest difference between the calculated and measured values is 0.135 mm, which is acceptable for most industrial applications.

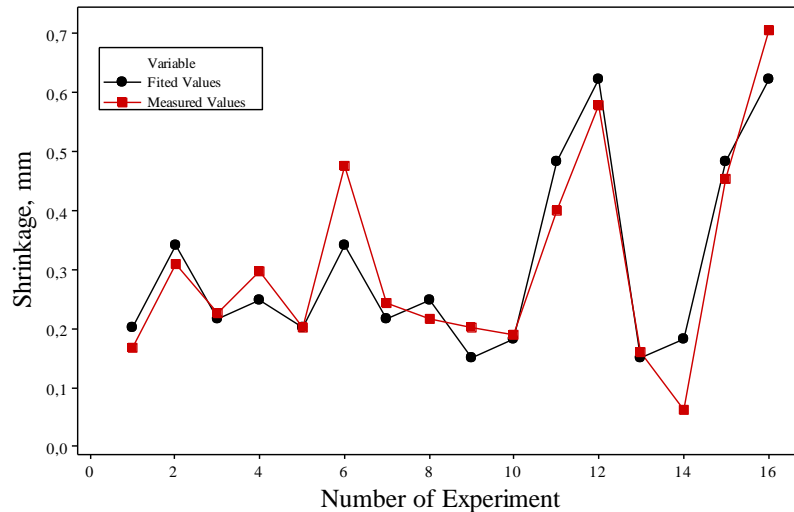


Figure 5. Experimentally measured and predicted shrinkage by the linear empirical model

The results are in agreement with hypothesis that residual stress in resolidified layer is causing the shrinkage. The tensile stresses in resolidified layer are causing the compressive stresses in the thermally unmodified material. Since the cutting parameters are constant for all experiments, the thickness of resolidified layer must be the same in all experiments. Thus, the surface area ratio of resolidified layer and the base material measured in the cross section perpendicular to the sample length depends only on the sample width. Sample thickness and sample length have no influence on the surface area ratio. Greater the sample width, smaller the volumetric ratio and thus smaller the shrinkage (Figure 2). The material thickness has no influence on the volumetric ratio therefore its effect on shrinkage is not significant (Table 6). Although the sample length has no influence on volumetric rate it affects the shrinkage, since the shrinkage of any material due to residual stresses depends on the nominal dimensions. The sample length has the strongest effect on the shrinkage (Figure 3).

CONCLUSION

In this study, the Taguchi technique was used in order to determine the shrinkage of narrow X5CrNi18-10 stainless steel parts machined by the laser cutting process. All experimental results were evaluated using the S/N quality characteristic and ANOVA. The following conclusions are valid for the given laser process parameters (Table 1), sample material stainless steel X5CrNi18-10 and for the samples that have the thickness t in the range from 2 mm to 5 mm, nominal width w in the range from 10 mm to 20 mm and nominal length l in the range from 150 mm to 450 mm.

- (1) According to the response table for S/N ratios and data means it was found that the order of importance of the control factors (sample dimensions) to the measured output variable (shrinkage in length) is the following: sample length, sample width and sheet thickness.
- (2) Based on the results of ANOVA, the sample length and the sample width have effect on the shrinkage, but not the sample thickness.
- (3) The derived model is accurate enough. The highest discrepancy between the measured and calculated shrinkage is 0.15 mm, which is sufficiently accurate for practical use.
- (4) Through the variation of the sample dimensions in the laser cutting process, despite the constant laser cutting process parameters, the heat input into the material influences the shrinkage due to variations of a volumetric ratio between resolidified layer and the base material. The obtained results are in agreement with hypothesis that residual stress in the resolidified layer is causing the shrinkage.

The model describes the phenomena of shrinkage well enough. In further work it will be tested for different machining parameters. The most significant parameters affecting the thickness of resolidified layer are cutting speed, laser beam power and assist gas flowrate. By adding these parameters into the model will make a model significantly more general, it will enable to better understand the phenomena of shrinkage and last but not least, it will be ready for practical use.

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AN OVERVIEW OF PAST AND CURRENT ENGINEERING ETHICS RESEARCH TRENDS

Diana Mariana POPA¹
Diana POPESCU²

ABSTRACT:

THIS ARTICLE PRESENTS AN EXPLORATIVE LITERATURE RESEARCH OF THE PAST AND CURRENT TREND OF ENGINEERING ETHICS RESEARCH AND ENGINEERING ETHICS EDUCATION RESEARCH. MAJOR SUBTHEMES ABOUT ENGINEERING AND ETHICS ARE IDENTIFIED AND THE MOST INFLUENTIAL ARTICLES IN THIS FIELD ARE CONSIDERED. THE DISCUSSIONS ON RESEARCH TRENDS ARE BASED ON INFORMATION GATHERED USING BOTH QUANTITATIVE AND QUALITATIVE METHODS. RESEARCH DATA SHOWED AN INCREASING INTEREST IN APPROACHING ETHICS FROM THE ENGINEERING PERSPECTIVE. THE PURPOSE OF THIS ANALYSIS IS RELATED TO THE NECESSITY OF INCORPORATING ETHICAL ASPECTS IN ENGINEERING STUDENTS EDUCATION FOR MAKING THEM AWARE AND RESPONSIBLE OF THE IMPLICATIONS OF MODERN TECHNOLOGIES.

KEY WORDS: ETHICS, LITERATURE REVIEW, ENGINEERING, RESEARCH, EDUCATION

INTRODUCTION

Together with the steps taken by mankind on the path of technological development, new ethical dilemmas arose about the implications of using these technologies. At the forefront of the technological development, engineers are the ones shaping technology and having an active role in guiding the ethics behind the technology. Several codes of ethics or ethical guides for the engineering profession have been developed in time and in different countries³, however internalizing their principles is no one stop shop for (future) engineers. On the other hand, the engineering field is so vast and intertwined with numerous other fields of research that it can hardly be called one single field anymore. Thus, one single code of ethics for the engineer cannot possibly be comprehensive for all contexts. For example, passive and active responsibility, engineers versus

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³ The Royal Academy of Engineering; *Engineering ethics in practice: a guide for engineers*, London. 2011. Available at: www.raeng.org.uk/ethicsinpractice

managers and whistle-blowing are general themes discussed in most textbooks on engineering ethics⁴.

Engineering ethics is a subject of interest to us from the point of view of the educator needing to incorporate ethical aspects in the educational paths of engineering students and raising ethical awareness of the students while educating them about a certain technology. Students must be taught to evaluate the risks and the implications of developing or using different scientific approaches, technologies or information over peoples' life, economy, business practice, etc. For instance, the ethical aspects related to conducting experiments, performing tests and using their results, to legal issues on using digital data, safety aspects, intellectual property rights⁵, etc. should all be taken into account by engineers as technology developers. Therefore, in order to identify the main issues already or to be included in the educational development of engineering students, an explorative literature research of the past and current state of ethics research and ethics education research was conducted. This article presents the first findings of this explorative literature research. Used methods and findings are detailed in the following.

METHOD AND FINDINGS

The interest in conducting this explorative literature review about engineering and ethics was twofold: first to map the research field concerning engineering and ethics based on identification of research subthemes, and second to explore in particular the subtheme of education, meaning those articles addressing the issue of ethics in the context of the engineering education. As data source, Web of Science Clarivate Analytics^(C) (WoS) database was mainly used for the quantitative and qualitative analyses. A second resource source was the Scopus^(C) database, but this was used only in the first instance quantitative analysis and served the purpose of validating the main quantitative trends. Data was extracted from Web of Science Clarivate Analytic^(C) (WoS) and Scopus^(C) in August 2018 and it was valid at this date. The explorative analysis contained three steps, described in the following.

In the first step, a search in WoS and Scopus was run for collecting necessary data. In WoS, a first search on ethics and engineering in the title (TI) or in the topics (TS) of the articles (TI=(ethics) OR TS=(ethics) AND TS=(engineering) OR TI=(engineering)) resulted in 251,939 items. These results were refined with search string in the advanced search option from WoS: (TI=(ethical) OR TS=(ethics)) AND (TS=(engineering) OR TI=(engineering)), thus obtaining 2536 results. In this step the instruments available in WoS were used to look at the articles depending on the number of citations, affiliation and geographical interest. In this phase we also compared these aspects with the data available in Scopus.

Based on the number of published articles about ethics and engineering, an ascending trend was observed (as shown in Figure 1) demonstrating the growing interest of researchers in different ethical aspects of the engineering field. As technology evolves it brings new ethical dilemmas that both society and scientists must face and solve.

⁴ Van de Poel, Ibo; Royakkers, Lamber; *Ethics, Technology and Engineering. An Introduction*, Wiley-Blackwell, 2011.

⁵ Daly, Angela, *Socio-Legal Aspects of the 3D Printing Revolution*, ISBN 978-1-137-51555-1 Springer, 2016

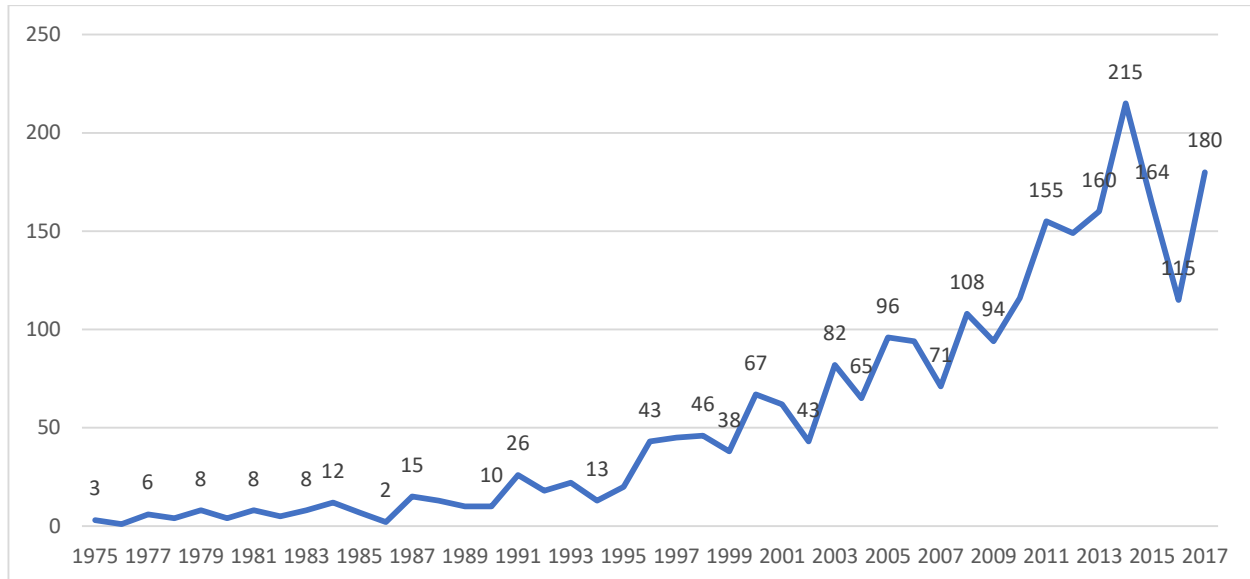


Figure 1. Trend for number of articles in the Web of Science Clarivate Analytics database containing *Ethics* in the title or the topic and *Engineering* in the title of the topic. Time frame 1975-2017

Using the search options from the Web of Science Clarivate Analytics database, additional interesting information were found. The most prolific writer, with 25 articles is Michael Davis, whose most cited article (67 citations) is *Thinking like an engineer - the place of a code of ethics in the practice of a profession*. The Journal that has published the most articles on the subject is *Science and Engineering Ethics* (with 290 results) with an impact factor of 1.859 in 2017, in Q1 in the Ethics section and in Q2 in Engineering multidisciplinary.

Almost half of the results (1229) have USA as country/region registered in the Web of Science Clarivate Analytics. However, the organization most mentioned as affiliation of authors is Delft University of Technology (Netherlands), followed by Purdue University (USA). This could show the high localised interest in the subject of engineering ethics of researchers from Delft University of Technology and the spread interest of US researchers, resulting in US researchers publishing from many US universities/research institutions, etc.

Refining the 2536 paper titles based on the topic "Education", as it is classified in WoS, a list of 754 results was obtained. There is a similar ascending trend for the published papers regarding ethics engineering education, peaking between 2013 and 2015. The average number of citations for the articles in this category is 4. If we look at the category engineering ethics, there are 580 articles registered in this WoS category.

In the Scopus database, when looking for "ethics" AND "Engineering" in title, abstract and keywords, 7738 documents were generated, with the number of articles per year increasing and peaking in 2017 (Figure 2). The same trend was found also in WoS Clarivate Analytics. Here we find the same name as being the most prolific author - Davis, Michael. The same article as in Clarivate is the most cited one *The ABET "Professional skills" - Can they be taught? Can they be assessed?*⁶. The first 2 affiliation institutions have switched places, with Purdue University ranking

⁶ Shuman, LJ.; Besterfield-Sacre, M.; McGourty, J.; The ABET "Professional skills" - Can they be taught? Can they be assessed? Journal of Engineering Education. Volume: 94, Pages:41-55, 2005.

first and Delft University of Technology second, with the USA still being the most mentioned geographical area.

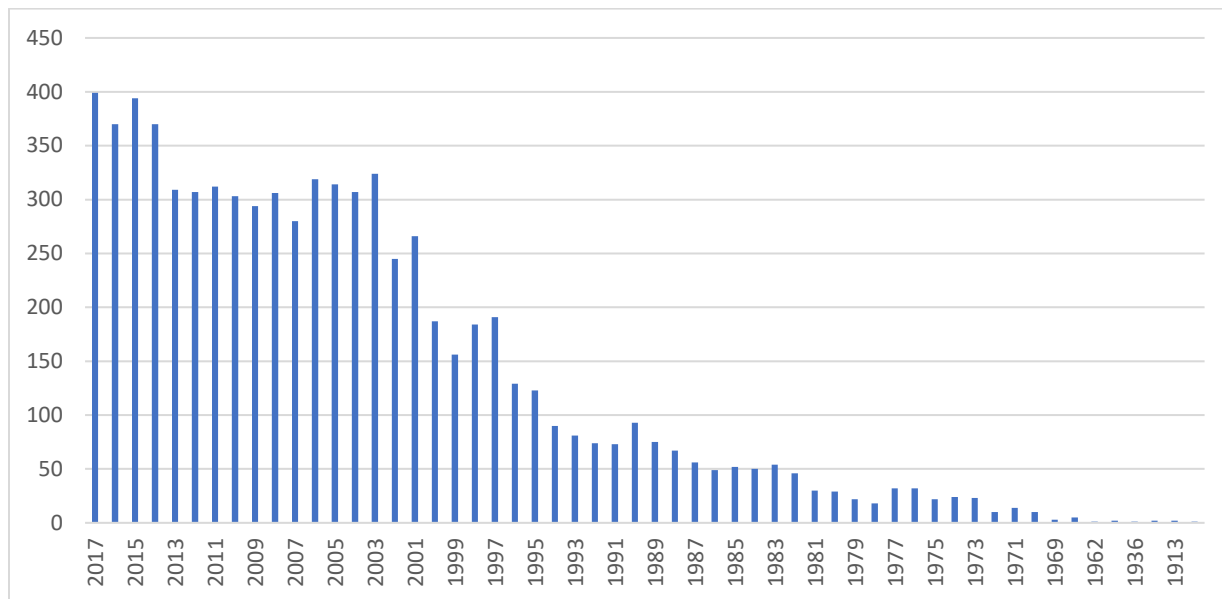


Figure 2. Trend for articles in the SCOPUS database containing Ethics* and Engineering* in the title, abstract or keywords. Time frame 1909-2017

In the second step of the analysis, the results were exported in a spreadsheet format, which contained 2493 cases. Duplicate cases were searched for exclusion. The automated function found 59 such cases. However, after a first analysis, not all of these resulted in actual duplicate cases, as some articles had the same title but different authors and publication source. The second step contained the main qualitative analysis of the articles. We classified articles in different subthemes based on their title. Where the title was not conclusive, we looked at the summary available in WoS. If no summary was available or if from the summary it resulted that the article was not mainly about engineering and ethics, the article was removed from the analysis.

We first looked at the all the articles and classified them in subthemes. The largest identified subthemes (and their classification algorithm) are the following:

- Education: students, education, curriculum, teaching, training, classroom, learning, university etc.
- Artificial Intelligence (AI): Artificial Intelligence, robots, Self-Driving/autonomous vehicles, intelligent machines etc.
- Bioethics/bioengineering: GM food, biology etc.
- Medicine: genetic⁷, tissue, clinical, stem cells, hospital, pharmaceutical, mitochondrial, embryo, vaccine etc.
- General: ethics/ethical + engineers/engineering (+ code of/framework), (social) responsibility⁷, moral, challenges etc.
- Animal welfare: animal (and examples of) etc.

⁷ *and derivatives of

- Environment: sustainable*⁷, renewable, climate, solar, water, green etc.
- Case studies.

By far the largest subtheme is that which was labelled Education. The second largest subtheme is that which was labelled General, containing articles mostly regarding codes of ethics or discussions of ethical dilemmas of engineers. One of the most controversial and debated ethical aspect of engineering products is found at the crossroad between engineering and the medical field. For instance, the implications of using Additive Manufacturing technology in medical applications (3D printing of biomaterials, organs, etc.) represent a new subject of debate in the field^{8,9}. Another discussed subject around the ethics of engineering is found in connection with AI. Here, questions about how to incorporate ethical decisions making in a machine has been both the subject of scientific research and of science fiction.

We also looked at the Web of Science Categories that these articles were classified under. In WoS, one article can be classified under more than one category, and this is the case of the majority of the articles we looked at about engineering and ethics. It was seen that the existing classification overlaps the category identified as the largest one – Education, but it is divided into two subthemes: Education scientific disciplines and Education educational research. The WoS Categories are narrower than our classification. For example, the identified “Medical” subtheme is divided in: Medical ethics and Medicine research experimental.

In the first 15 years of published research on engineering and ethics, in the 1975-1990 timeframe, the titles of the articles suggest the exploration of general, broader aspects of ethics in the engineering field, when compared to the titles from the third timeframe. The titles of the published articles are shorter: “*Engineering Ethics*”, “*Engineering and Ethics*”, “*Morals and Engineering Ethics*”, “*Ethical Engineering*”, “*The Search for Engineering Ethics*” etc. In the 2000-2017 timeframe, articles have become more focused, with many subdomains specific case studies, prevailing subthemes relating to genetic research or AI research.

In the third step, we looked at the first 10 most cited papers from WoS based on the search terms ethics and engineering in the title or the topic of the article and we analyzed on how they connect with the subthemes identified in the previous step. In this third step we also used CiteSpaceIII app for looking at the citations trends found in our data.

The 10 most cited articles in WoS based on the search terms ethics and engineering in the title or the topic of the article are presented in Table 1. They show the wide range of subthemes

⁸ Gilbert, F, O’Connell; CD; Mladenovska, T; Dodds, S; Print me an organ? Ethical and regulatory issues emerging from 3D Bioprinting in medicine, Science and Engineering Ethics, vol. 24, issue 1, Pages 73-91, 2018

⁹ Neely, E; The risks of revolution: ethical dilemmas in 3D printing from a US perspective, Science and Engineering Ethics, vol. 22, issue 5, DOI 10.1007/s11948-015-9707-4, 2016

that are found under engineering and ethics, from education¹⁰, medicine/health^{11;12;13;14}, environmental aspects¹⁵, and behaviour sciences¹⁶.

The top cited article¹⁷ analyses several engineering curricula, advocating the integration of professional (soft) skills in the education trajectory of engineering students. Among these skills the authors mention communication, teamwork, and the ability to recognize and resolve ethical dilemmas¹⁷. The authors show that effective educational activities should be based on fidelity (to the actual future work environment) and on complexity (which includes task interdependency and cognitive effort)¹⁷. Following a meta-analysis of different ethics educational programs, the effectiveness of case based and interactive ethics education has been underlined by¹⁸ also, even if the authors draw a less positive conclusion about the success of ethics instruction, the results being characterized as rather “modest”.

Regarding the other subthemes of the most cited articles, in ¹⁹ a comprehensive approach on geoengineering is presented, including some of its ethical implications. In the medicine category we have found articles ^{20;21;22} dedicated to genetics and genetic engineering. General ethical aspects of technology and engineering and design ethics are discussed in ²³. In Harding et al.²⁴ we found a comparative research on professional and academic dishonesty among engineering students that we classified under the theme behaviour sciences.

¹⁰ Shuman, LJ.; Besterfield-Sacre, M.; McGourty, J.; *The ABET "Professional skills" - Can they be taught? Can they be assessed?* Journal of Engineering Education. Volume: 94, Pages:41-55, 2005.

¹¹ Frewer, LJ; Howard, C; Shepherd, R. *Public concerns in the United Kingdom about general and specific applications of genetic engineering: Risk, benefit, and ethics.* Science Technology & Human Values, 1997

¹² Bhargava, Saurabh; Patterson, Jacob M.; Inman, Richard D.; MacNeil, Sheila; Chapple, Christopher R. *Tissue-engineered buccal mucosa urethroplasty - Clinical outcomes.* European Urology, 2008

¹³ Sadler, TD; Zeidler, DL. *The significance of content knowledge for informal reasoning regarding socioscientific issues: Applying genetics knowledge to genetic engineering issues.* Science Education, 2005

¹⁴ Schilling, AF; Linhart, W; Filke, S; Gebauer, M; Schinke, T; Rueger, JM; Amling, M. *Resorbability of bone substitute biomaterials by human osteoclasts.* Biomaterials, 2004

¹⁵ Keith, DW. *Geoengineering the climate: History and prospect.* Annual Review Of Energy And The Environment, 2000

¹⁶ Harding, TS; Carpenter, DD; Finelli, CJ; Passow, HJ. *Does academic dishonesty relate to unethical behavior in professional practice? An exploratory study.* Science And Engineering Ethics, 2004

¹⁷ Shuman, LJ.; Besterfield-Sacre, M.; McGourty, J.; *The ABET "Professional skills" - Can they be taught? Can they be assessed?* Journal of Engineering Education. Volume: 94, Pages:41-55, 2005.

¹⁸ Antes, Alison L.; Murphy, Stephen T.; Waples, Ethan P. Mumford, Michael D., Brown, Ryan P., Connelly, Shane & Devenport, Lynn D., *A Meta-Analysis of Ethics Instruction Effectiveness in the Sciences*, Ethics & Behavior, 19:5, 379-402, 2009.

¹⁹ Keith, DW.; *Geoengineering the climate: History and prospect.* Annual Review Of Energy And The Environment, 2000

²⁰ Frewer, LJ; Howard, C; Shepherd, R.; *Public concerns in the United Kingdom about general and specific applications of genetic engineering: Risk, benefit, and ethics;* Science Technology & Human Values, 1997

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²² Sadler, TD; Zeidler, DL.; *The significance of content knowledge for informal reasoning regarding socioscientific issues: Applying genetics knowledge to genetic engineering issues;* Science Education, 2005

²³ Verbeek, PP.; *Materializing morality - Design ethics and technological mediation.* Science Technology & Human Values, 2006

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Table 1. The 10 most cited articles in WoS based on the search terms ethics and engineering in the title or the topic of the article

Author(s)	Title	Journal/ Publication name	Publ. year	Nr. of citations in WoS
Shuman, LJ; Besterfield-Sacre, M; McGourty, J	The ABET "Professional skills" - Can they be taught? Can they be assessed?	Journal of Engineering Education	2005	368
Keith, DW	Geoengineering the climate: History and prospect	Annual Review of Energy and the Environment	2000	249
Frewer, LJ; Howard, C; Shepherd, R	Public concerns in the United Kingdom about general and specific applications of genetic engineering: Risk, benefit, and ethics	Science Technology & Human Values	1997	167
Verbeek, PP	Materializing morality - Design ethics and technological mediation	Science Technology & Human Values	2006	133
Bhargava, S.; Patterson, J.M.; Inman, R.D.; MacNeil, S.; Chapple, C.R.	Tissue-engineered buccal mucosa urethroplasty - Clinical outcomes	European Urology	2008	120
Sadler, TD; Zeidler, DL	The significance of content knowledge for informal reasoning regarding socioscientific issues: Applying genetics knowledge to genetic engineering issues	Science Education	2005	119
Schilling, A.F; Linhart, W; Filke, S; Gebauer, M; Schinke, T; Rueger, J.M; Amling, M	Resorbability of bone substitute biomaterials by human osteoclasts	Biomaterials	2004	111
Sparrow, R.; Sparrow, L.	In the hands of machines? The future of aged care	Minds and Machines	2006	110
Harding, T.S; Carpenter, D.D; Finelli, C.J; Passow, H.J	Does academic dishonesty relate to unethical behavior in professional practice? An exploratory study	Science and Engineering Ethics	2004	108
Roco, M.C; Bainbridge, WS	Societal implications of nanoscience and nanotechnology: Maximizing human benefit	Journal of Nanoparticle Research	2005	102

In this step of our exploratory researched we also used CiteSpaceIII, a free tool used for visualization of a knowledge domain based on relevant publications^{25; 26; 27}. Based on the files exported from WoS, we looked at the citation bursts in the 1996 - 2018 time period. The results are presented in Figure 3.

Top 15 Keywords with the Strongest Citation Bursts

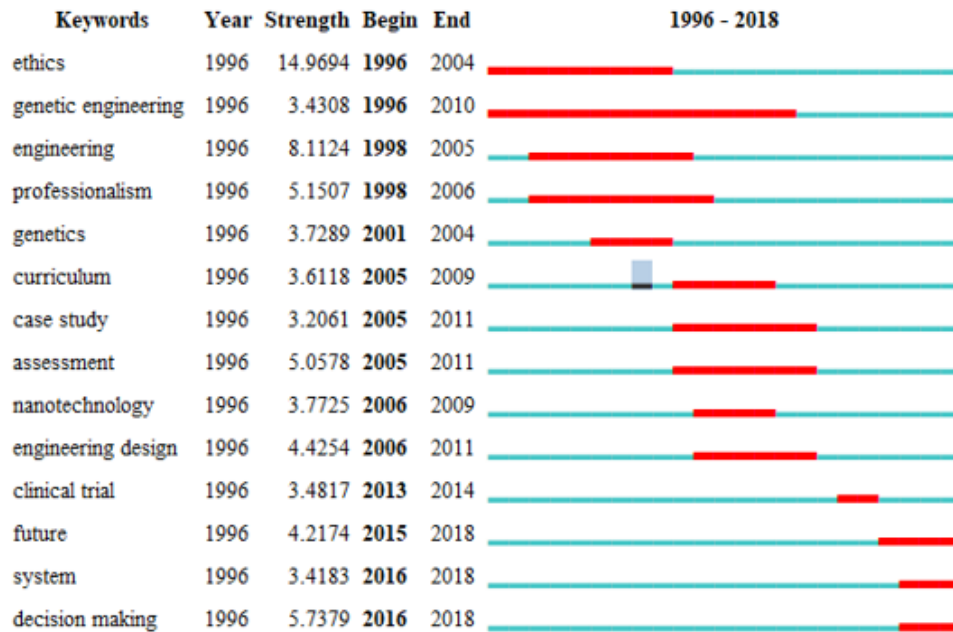


Figure 3. Trend for citation bursts using CiteSpace on WoS indexed articles about engineering and ethics

We see again that the genetics is one of the most discussed themes, the educational theme, represented here under curriculum, being also of high interest. As a matter of fact, how to incorporate ethics into engineering curriculum is a shared and long-term matter of scientific inquiry. During time, new aspects and subjects related to engineering ethics were added to these curriculums referring, for instance, to data ethics, digital ethics, robotics and artificial intelligence, drones, environment and sustainability, genetics, bioprinting etc. The emerging technologies are raising new ethical and regulatory issues, most of them representing real challenges for society.

CONCLUSIONS AND FURTHER WORK

²⁵ Chen, Chaomei. *Searching for intellectual turning points: Progressive knowledge domain visualization*. Proceedings of the National Academy of Sciences of the United States of America, 101, 5303–5310, 2004.

²⁶ Chen, Chaomei. *CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature*. Journal of the American Society for information Science and Technology, 57, 359–377, 2006.

²⁷ Chen, Chaomei. *The CiteSpace Manual*. 2014. Available at: <http://cluster.ischool.drexel.edu/~cchen/citespace/CiteSpaceManual.pdf>

The ethical questions in the engineering field have evolved in light of the technological developments. The interest in engineering ethics research and engineering ethics education research has been constantly growing and scholars continue to study the most effective ways of incorporating ethics training in the educational engineering programs. There are several ethical codes of conduct for the engineering profession, but our class experience has shown that these are for the most part unknown by students. In this article we looked at the major subthemes that could be identified in research about engineering and ethics. We found that the ways of how to include ethics in the education of future engineers is one of the major interests of scholars in this field. Our future work includes a systematic review of papers about the way ethical principles and critical thinking about ethical dilemmas can be included in the engineering curriculum and the effective ways they can be internalised by students.

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AMPLIFYING PERFORMANCE IN VIRTUAL TEAMS OPTIMIZING COMMUNICATION STRATEGIES

Ionut SAVU¹

ABSTRACT:

INTERNATIONAL COMPANIES, IN RESPONSE TO A HIGH EXPECTATION OF GAINS AND EFFICIENCY, HAVE STARTED IMPLEMENTING VIRTUAL TEAMS TO COMBAT GEOGRAPHICALLY SCATTERED RESOURCES. THESE STRATEGIES HAVE OFFERED SIGNIFICANT SAVINGS AND INCREASED PRODUCTIVITY AS WELL AS MANY ADVANTAGES AND OPPORTUNITIES FOR EMPLOYEES. ALTHOUGH TECHNOLOGY HAS BEEN THE MAIN ENABLER IN THE VIRTUALIZATION OF TEAMS BY OFFERING MANY DIVERSE FORMS OF COMMUNICATION WHICH VARY FROM TELEPHONY SERVICES, EMAIL, TELECONFERENCING, ELECTRONIC WHITEBOARDS, COLLABORATIVE SOFTWARE, GROUP CHATS TO CLOUD/INTRANET DATA SHARING, IT IS ALSO ONE OF THE DEFINING DIFFERENCES WHICH HAS TO BE TACKLED WHEN CREATING A STRATEGY FOR LEADERSHIP. RESEARCH SUGGESTS THAT FACE TO FACE AND ON-SITE MEETINGS, VIRTUAL ROUND TABLES AND ELECTRONIC YEARBOOKS SHOULD BE TAKEN INTO ACCOUNT TO ENCOURAGE COMMUNICATION AS NOT ALL CHANNELS ARE AS EFFICIENT IN SENDING NONVERBAL CUES. THE PURPOSE OF OUR PAPER IS TO DISCOVER THE EXTENT OF PREVIOUS RESEARCH REGARDING COMMUNICATION IN A VIRTUAL TEAM AS WELL AS GAIN INSIGHT INTO THE RELATIONSHIP BETWEEN DIFFERENT FORMS OF DIGITAL COMMUNICATION AND HOW THEY IMPACT PERFORMANCE.

KEY WORDS: VIRTUAL TEAMS, COMMUNICATION, LEADERSHIP STRATEGIES, TEAM PERFORMANCE

1. INTRODUCTION

Efficient teams have become vital for performance in the management of the fight against the growing complexity and uncertainty of today's business which led to a restructure of organizations and the birth of international teams whose members are scattered across geographic locations. Virtual operations have offered significant savings and increased productivity to companies as well as better working conditions, terms of recruitment and an increased balance of professional/personal lives to employees. Rapid development of technology has enabled virtual teams and organizations to become more prevalent. Even so, not even the best of IT&C has saved

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companies from the occasional rough patches due to the specifics of the virtual way of operation: problems regarding trust and a sense of belonging due to impersonal forms of communication or leadership that does not take into account the particulars of the virtual environment.^{2 3 4 5 6}

An efficient team fosters healthy relationships which can only be mediated by strong communication. The most efficient teams are those that have members which combine their talents, individual experiences and abilities by means of meaningful processes and work relationships. Communication can become problematic even in a traditional team where meetings are held in person. The problems persist and are exacerbated when linguistic, temporal and cultural variables are introduced by the nature of virtual teams.

Even though research in virtual teams has increased in recent years and studies in communication are prevalent, these vectors haven't been synergized enough in a way that can contribute to a working model. Although team communication is often defined and described in different ways it has still been integrated into studies of virtual team efficiency. This has led to a less relevant understanding of the dynamics of this issue and its relationship to team efficiency. The connection between the level of communication and performance of teams, be they virtual or traditional, has been proven but less research has been done on how the different ways of communication available compare and contribute to overall team goal achievement, trust, comprehension or effectiveness.^{7 8}

The purpose of this paper is to discover the extent of previous research regarding communication in a virtual team environment, how it compares to the findings of our research as well as gain insight into the relationship between different types of communication and efficiency. Furthermore, we aim to find what future recommendations can be made on the topic. We decided to focus our attention on how different communication channels impact performance in a virtual team as to create a guideline upon which communication strategies can be made as well as guide the focus of leadership.

2. VIRTUAL TEAMS

Below we'll firstly try to broadly define virtual teams and their inherent advantages and disadvantages after which we'll tackle a general definition of communication with a focus on its verbal and nonverbal components. We'll continue by taking a look at how communication is used

² Alpaender, Guvenc G., and Carroll R. Lee. "Culture, strategy and teamwork: the keys to organizational change." *Journal of Management Development* 14, no. 8 (1995): 4-18.

³ Hoefling, Trina. *Working virtually: Managing people for successful virtual teams and organizations*. Stylus Publishing, LLC, 2012.

⁴ MacGregor, Steven P. "Working Virtually: Challenges of Virtual Teams by Robert Jones, Robert Oyung, and Lisa Pace." *Journal of Product Innovation Management* 24, no. 1 (2007): 95-97.

⁵ Katzenbach, Jon R., and Douglas K. Smith. *The wisdom of teams: Creating the high-performance organization*. Harvard Business Review Press, 2015.

⁶ Powell, Anne, Gabriele Piccoli, and Blake Ives. "Virtual teams: a review of current literature and directions for future research." *ACM SIGMIS Database: the DATABASE for Advances in Information Systems* 35, no. 1 (2004): 6-36.

⁷ Cooke, Nancy J., Preston A. Kiekel, Eduardo Salas, Renée Stout, Clint Bowers, and Janis Cannon-Bowers. "Measuring team knowledge: A window to the cognitive underpinnings of team performance." *Group Dynamics: Theory, Research, and Practice* 7, no. 3 (2003): 179.

⁸ Mesmer-Magnus, Jessica R., and Leslie A. DeChurch. "Information sharing and team performance: A meta-analysis." *Journal of Applied Psychology* 94, no. 2 (2009): 535.

in virtual teams and carry on with our case study. Our conclusions and limitations we'll end the paper.

2.1 Defining Virtual Teams

Virtual teams are the group of individuals united by a common goal but spread geographically, culturally, linguistically or, ethnically. As defined by Powell, Piccoli and Ives, virtual teams are described 'as groups of geographically, organizationally and/or time dispersed workers brought together by information and telecommunication technologies to accomplish one or more organizational tasks.'⁹ Virtual teams mainly meet the demand for flexibility and agility in the delivery of services or products in a marketplace with increased competition and a decentralized and globalized work processes. The need for talent and competency has lead organizations to look to structures which leverage available talent across boundaries. More and more organizations are adopting the virtual team approach to reduce their operating costs, encourage knowledge sharing among their employees, promote organizational learning and expand their business hours to 24/7 by utilizing the different time zones of virtual team members.¹⁰ Human relationships draw their power from the proximity of the individuals but due to the fact that virtual team members have limited personal interaction this creates a myriad of issues. For a virtual team to be productive it is important to overcome the cultural differences, communication barriers, power struggles and conflict to build trust, collaboration and commitment among the individuals. By using the right strategies, tools and processes, organizations can benefit greatly from this new-age trend of virtual teams.^{11 12}

2.2 Advantages and Disadvantages of Virtual Teams

Regarding the advantages and disadvantages of virtual teams we can contextualize them from three perspectives, individual, organizational and societal. Below we will summarize the attribute, positive and negative, of virtual teams so that a clear pathway to identifying constructive solutions can be uncovered.

ADVANTAGES:

Cost savings - Organizations can optimize real estate costs by using virtual teams as well as utility or travel expenses. Most outsource operations in low-cost regions to also take advantage of lower wages of the employees.

Global Talent - By leveraging human capital from around the world, organizations can bring in the fold greater understanding of local markets as well as benefit from specialist and experts that increase innovation and knowledge sharing.

⁹ Powell, Anne, Gabriele Piccoli, and Blake Ives. "Virtual teams: a review of current literature and directions for future research." *ACM SIGMIS Database: the DATABASE for Advances in Information Systems* 35, no. 1 (2004): 6-36.

¹⁰ Prachi Juneja "Virtual Team - Management Study Guide." *managementstudyguide.com*, from <http://www.managementstudyguide.com/virtual-team.htm> retrieved September 3rd, 2018

¹¹ Prachi Juneja "Virtual Team - Management Study Guide." *managementstudyguide.com*, from <http://www.managementstudyguide.com/virtual-team.htm> retrieved September 3rd, 2018

¹² Savu, Ionut, Cicerone Laurentiu Popa, and Costel Emil Cotet. "MITIGATING FRICTION IN MULTICULTURAL VIRTUAL ORGANIZATIONS/TEAMS." *Annals of DAAAM & Proceedings* 28

Increased Productivity - As opposed to local teams, virtual teams tend to have a greater focus on the objectives dealt with as they benefit from a flatter structure of organization. This translates into increased productivity and greater profits for the company.

Decreased Time to Market - Virtual teams can leverage the different time zones that the members span and run the project continuously 24/7. This greatly speeds up development as well as response time.

New Opportunities - Any tasks that do not require physical presence are now obtainable by candidates that formerly were restricted by availability thus opening the doors to new potential talent.

DISADVANTAGES:

Cost of Technology - One of the main costs in running virtual teams comes from the necessary technology required to run them. Without the use of multiple communication technologies it is either impossible or impractical to run such teams.

Conflicts, Lack of Trust & Collaboration - One of the main reasons for conflict in virtual teams is the cultural divide as well as the different styles of communication which give rise to mistrust and difficulties in collaboration that are intrinsic to their success. Other challenges come from the lack of direct interaction as most communication is done through non-verbal interactions.

Social Isolation - Although collaboration in the virtual space has many advantages, on a personal level, the lack of direct contact with coworkers may lead to an adverse effect on the psychological welfare of team members and consequently on productivity.¹³

As we can see, two of the disadvantages of virtual teams stem from improper communication or are a direct result of it which lead to friction and loss of efficiency in the organization or team.

3. COMMUNICATION

Going forward we'll take a broad look at how communication is defined, the importance of verbal vs nonverbal communication and how it applies to teamwork.

3.1 Defining Communication

"Communication" means any transmission of information, ideas and emotions from a social entity (person, group, community) to another via messages.

Communication can be:

Verbal - Information is transmitted through articulated language (written or oral);

Nonverbal - Information is conveyed through facial expressions, posture, tone, etc.¹⁴

Verbal communication concerns only words, verbalization, symbolic language, and not the voice that speaks them or the tone, the modulation and the rhythm of the speech. Verbal communication is a component of a oral communication. Written communication is also a verbal communication, because everything is based on the language of words, only that the oral

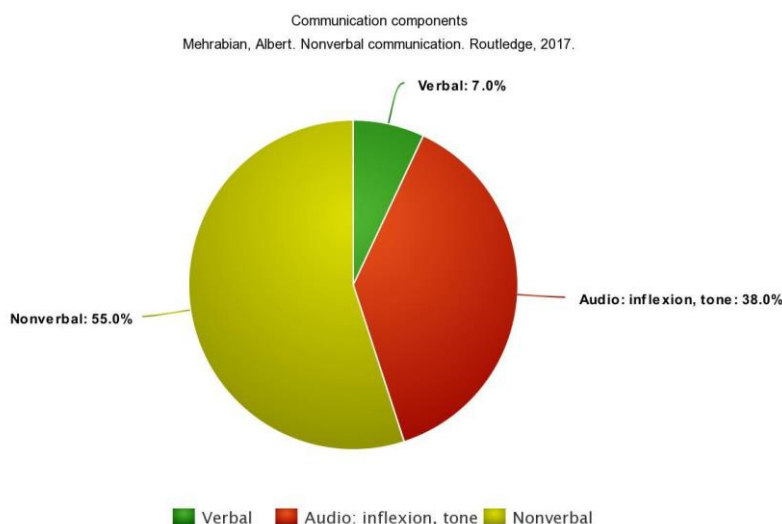
¹³ Prachi Juneja "Virtual Team - Management Study Guide." managementstudyguide.com, Advantages and Disadvantages of Virtual Teams, from <http://www.managementstudyguide.com/virtual-teams-advantages-and-disadvantages.htm>

¹⁴ Chelcea, Septimiu, Loredana Ivan, and Adina Chelcea. Comunicarea nonverbală: gesturile și postura: cuvintele nu sunt de ajuns. Comunicare. ro, 2005.

expression is replaced by the graphic expression of the written word. Thus, verbal communication is transmitted by speaking and deciphering the symbolic meaning of words.¹⁵

Nonverbal communication involves the sum of stimuli (except verbal) present in the context of a communication situations, generated by the individuals and containing a potential message. The definition includes the intentional and unintentional component as part of the process of communication. As one speaks, one reveals a huge amount of information about oneself, but not only by words (verbal communication) but also by voice (paraverbal language) and by body language, gestures, mimic etc. (nonverbal communication). This also requires a definition of the paraverbal language concept. The paraverbal language is what is communicated by voice (volume, intonation, rhythm, accent, breaks, etc.) and by nonverbal vocal expressions: tone of the voice, laughter, coughing, shouting, sighing, screaming and so on.

Also in a conversation 45% are the verbal and audio components, while nonverbal communication occupies 55%. Most research gives similar percentages to verbal communication at a maximum of 10% in message communication. There are a multitude of similarities and differences between verbal and nonverbal communication, which we will outline below.¹⁶



3.2 Verbal vs Nonverbal Communication

Consciously or unconsciously, intentionally or unintentionally, we send and receive nonverbal messages, we make judgments and make decisions. This observation is all the more relevant as in 90% of cases, the impression of the interlocutor is formed on the basis of nonverbal information in the first 10 seconds of a meeting, so that the first messages, mostly nonverbal, affect and determine subsequent perception.¹⁷

We can summarize the similarities as being:

¹⁵ Prutianu, Ștefan. Manual de comunicare și negociere în afaceri: Comunicarea. Polirom, 2000.

¹⁶ CHIRU, Irena. Comunicare interpersonală. Irena Chiru. ed. a 2-a: București: Tritonic, 2009. 192 p.; 20 cm.(Comunicare. Media). Vol. 316. ISBN 978-973-733-357-5. II 38610.

¹⁷ CHIRU, Irena. Comunicare interpersonală. Irena Chiru. ed. a 2-a: București: Tritonic, 2009. 192 p.; 20 cm.(Comunicare. Media). Vol. 316. ISBN 978-973-733-357-5. II 38610.

Both verbal and nonverbal communication can be modeled in the following terms: transmitter-message-receiver, communication channel, effect, feedback and context of the act of communication;

Both types of communication are produced by individuals and are subjective messages;

Mostly, the meanings attached to verbal and nonverbal cues are similar;

Both verbal and nonverbal communication is based on a set of symbols culturally accepted;

The differences though are what we are interested in as they can give us insight into performance applied in practice:

Verbal communication makes use of language as a form of human specific relationship; nonverbal communication makes use of facial expressions, posture, body language in a more or less conscious manner;

Verbal communication uses oral language, written language while nonverbal communication is represented by the tone of the voice, the breaks in speech, the vocal characteristics, gestures, movements, physical presence, facial expressions etc .;

Verbal communication is voluntary, while nonverbal is involuntary, in most cases;

Nonverbal language is taught before the verbal (innate, imitation, etc.) and is also practiced on a much broader scale than verbal communication;

Nonverbal communication is generated by biological factors, and therefore more difficult to control (in connection with the involuntary nature of this type of communication);

Nonverbal communication is continuous; while verbal communication is composed of segmented units: any sentence has a distinct start and end;

4. COMMUNICATION IN THE VIRTUAL ENVIRONMENT

The exchange of information in and out of organizational boundaries is one of the most important functions of teams. The constant exchange of knowledge necessitates daily face to face meetings, common norms, trust and a strong social bond. In the case of virtual teams this is also valid but mediated by technology with little to no personal interaction.¹⁸ Today the technology used in virtual teams varies from telephony services, email, teleconferencing, electronic whiteboards, collaborative software, group chats and cloud/intranet data sharing. It is also suggested that face to face and on-site meetings, virtual round tables and electronic yearbooks should be taken into account to encourage communication.^{19 20}

These types of technology also allow asynchronous communication for team members that are location or temporally dispersed. Although CMAC (computer-mediated asynchronous

communication) systems are an improvement for agents that can choose their own time to contribute to the conversation, they lack the nonverbal component of communication, facial cues, body language, tone, etc. This inherently leads to a slower process of creating relationships and

¹⁸ Kauppila, Olli-Pekka, Risto Rajala, and Annukka Jyrämä. "Knowledge sharing through virtual teams across borders and boundaries." *Management Learning* 42, no. 4 (2011): 395-418.

¹⁹ Kostner, Jaclyn. *Virtual leadership: Secrets from the round table for the multi-site manager*. Grand Central Publishing, 2010.

²⁰ Fisher, Kimball, and Mareen Fisher. *The distance manager: A hands on guide to managing off-site employees and virtual teams*. McGraw-Hill Professional, 2000.

trust among team members.²¹ Some types of communication have been shown to be more personal, have better clarity and leave a definite impression on the parties engaged whereas others are more suited for creative work.²² As a general rule Nemiro suggests that “communication tools high in social presence and information richness” should be used “to transmit complex, non-routine and ambiguous messages”.

5. TRUST

Trust is the willingness to increase one’s vulnerability towards another person whose behaviour one cannot control in a situation where the potential gain is lower than the possible loss in case the other person abuses one’s vulnerabilities.²³ Trust plays a major role in the performance of any team, when team members are able to trust each other they will complete their tasks more efficiently and with less friction. Trust building is difficult enough in traditional team, the same endeavour is even more of a challenge when visual elements of trust are missing in the case of geographically dispersed teams. Interactions in the virtual environment gives many advantages like bringing together talent from around the world but the main disadvantage is the way team members communicate, they cannot meet face to face which induces a feeling of isolation and destroys trust.

6. CASE STUDY

The case study consists of interviews with seven people managers and two information managers of virtual teams from three BPOs (business process outsourcing), one international telecommunications company and one database technology and software company as well as a questionnaire for 14 team members, two from each of the managers. All the managers had at least 5 years of team lead experience and the team members a minimum of 4 years. Since the nature of their work and their respective employment contracts have non disclosure agreement clauses their names and those of their companies of employment have been anonymized. We decided to interview the managers as opposed to the questionnaire as it could allow a more open ended discussion regarding the qualitative aspects of the study.

For the purpose of this research we constructed an interview (for the managers) that consisted of open ended questions which gave the respondents the opportunity to be more flexible in their answers and go into more detail. We have also used closed ended questions for performance related parameters. For the team members we developed a questionnaire based on the same format as the interview but disregarding empirical performance related questions(as they did not have direct access to that information).

The aim of the case study was to test two hypotheses:

1. How influential is communication in regard to virtual team performance.
2. Is team performance affected by the channel of communication used.

In the first part of the study we tried to identify the main barriers that impede performance in a team that is geographically dispersed. The answers had a great degree of convergence especially among the managers. We can summarize the answers as follows:

- Comprehension issues/Language barriers

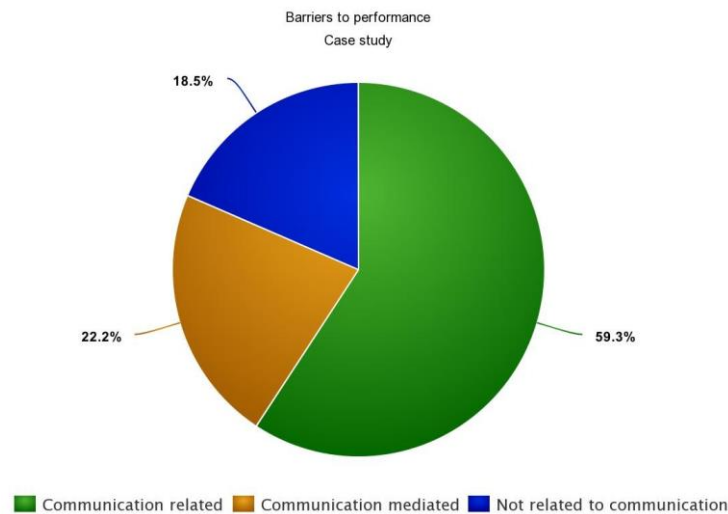
²¹ Berry, Gregory R. "Enhancing effectiveness on virtual teams: Understanding why traditional team skills are insufficient." *The Journal of Business Communication* (1973) 48, no. 2 (2011): 186-206.

²² Nemiro, Jill Creativity in virtual teams: Key components for success Vol.6. John Wiley & Sons, 2004.

²³ Gignac, Francine. Building successful virtual teams. Artech House, 2004.

- Lack of trust
- Lack of follow-up and follow-through
- Information dilution in long threaded asynchronous written communication
- Lack of team atmosphere

The questionnaire answers and interview discussions related to these issues revealed that performance was being impacted by not adapting communication needs to the most suited form of technologically mediated transfer of information. Furthermore most managers agreed that fostering a sense of team belonging was crucial to team efficiency.



Going forward we asked the managers if they tried to attenuate these problems once they had identified them and what effect did it have on the performance of the team. Efficiency and performance after procedural reform was a closed ended question and it was measured year over year on the basis of: median time to task completion and project deadline adherence. Fortunately, all of the managers had been tracking these variables as part of their business process.

All parties in the study agreed that, as much as logistically possible, the team needs to have at least one onsite meeting to “put a face to the name” of their teammates and to get to know one another on a more personal level. Of the nine managers interviewed, seven of them used either an onsite meeting or a virtual town hall at the beginning of each year or at the formation of a new team as a rule throughout their respective organizations.



Common Reforms with Positive Impact on Performance



Meetings

Periodic onsite meetings or a virtual town halls



Conflict resolution

Prioritizing synchronous communication channels with nonverbal components in conflict resolution



Visual aids

Telepresence used in knowledge transfer to aid presentation with visual cues



Team building

To improve trust and relationships, regular team building exercises are being used

The other two (although the companies did not require them to) implemented similar measures to foster team belonging. Other changes that had been applied include prioritizing calls in conflict resolution as opposed to written communication; if knowledge transfer is required all the parties now use telepresence technology to aid the presentation with visual cues and two of the teams periodically have virtual team building exercises. In all cases, performance of the teams increased year over year after these measures were implemented.

Being separated from your coworkers can lead to a feeling of isolation and at times neglect, revealed the questionnaire. When managers were asked how they deal with the issue they suggested that regular contact, especially via phone is important and if possible they organize face to face or virtual face to face (teleconference) meetings in order to keep the team close to each other. Furthermore it was indicated that communication outside business issues was a good way to develop fruitful relationships. One of the managers even used the World Cup matches as a way to bring the team closer together, he used a combination of streaming technology, telepresence and virtual presentation software to make a team building event.

As stated above we found that language barriers pose an issue and can create misunderstandings in the team. Culture dictates our biases and perceptions and this is still evident even when communication is done via a common language, even so these issues can be moderated if the parties involved are aware of them and the leadership works around them by tailoring communication strategies that take advantage of technologies that can transmit nonverbal signals. Some of the respondents quoted long email threads as a hindrance on their productivity. The asynchronous nature of the technology, in some cases, developed a minor misunderstanding or request for clarification into unnecessarily long conversations. Managers tackled these kinds of problems by limiting the use of email to factual information exchange and incorporating audio and visual communication into the workflow. Four of the nine managers interviewed organize weekly group calls or video calls where problems are discussed. These meetings allow the use of nonverbal

cues which alleviate misunderstandings, builds trust and interacts team members in a more direct way.

7. CONCLUSION

Although the small number of respondents limits any hard conclusions, our study provided some insight into the inner workings and strategies used by virtual teams to ease the issues that come out of the particularities of virtuality. Managers and team leads can incorporate these findings into their team's workflow, for example, by taking into account the strengths and weaknesses of each communication channel and tailoring their communication strategies in accordance. Although management is similar in virtual and onsite teams, leaders might need to consider that technology mediated communication does not convey meaning on all levels at the same time and should suitably alter their approaches.

The study was conducted in Bucharest, Romania and all respondents were romanian but worked in multicultural virtual teams. Although our main focus was communication in a virtual team the cultural makeup of our respondents should be taken into account as it might skew the results to one perspective. Future research should incorporate cultural differences into the proposed guidelines for virtual team communication management.

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THE REVIEW OF THE ACHIEVEMENTS IN THE FIELD OF INCREMENTAL FORMING

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Tomaž PEPELNJAK²

ABSTRACT:

INCREMENTAL FORMING PROVIDES SIGNIFICANTLY HIGHER FLEXIBILITY OF FORMING IN COMPARISON TO CONVENTIONAL FORMING PROCESSES. SINGLE POINT INCREMENTAL FORMING (SPIF) REPRESENTS THE MOST SIMPLE FORM OF INCREMENTAL FORMING, WHERE FORMING OF THE SHEET METAL IS ENABLED USING A WIDE VARIETY OF TOOLS. THE MAIN DISADVANTAGE OF INCREMENTAL FORMING IS LOWER ACCURACY OF FORMING COMPARED TO OTHER CONVENTIONAL PROCESSES. THE AIM OF MANY STUDIES IN THE PAST REGARDING INCREMENTAL FORMING WAS TO INCREASE THE ACCURACY, REDUCE FORMING FORCES AND IMPROVE THE FORMABILITY OF THE SHEET METAL. THIS ARTICLE COVERS SUMMARIES OF STUDIES REGARDING INNOVATIVE APPROACHES TO IMPROVE ALL OF THE ABOVE-MENTIONED ASPECTS OF INCREMENTAL FORMING. IT ALSO ATTEMPTS TO PRESENT THE MAIN PARAMETERS OF INCREMENTAL FORMING AND THEIR INFLUENCE ON THE CHARACTERISTICS OF THE FORMED PRODUCT. IT IS ALSO DISCUSSED, WHY THE FORMABILITY IN INCREMENTAL FORMING IS SIGNIFICANTLY HIGHER THAN THAT OF CONVENTIONAL FORMING PROCESSES, SUCH AS STAMPING. A NUMBER OF OTHER INCREMENTAL FORMING APPROACHES AND THEIR MAIN CHARACTERISTICS ARE PRESENTED, AS ARE AREAS OF INCREMENTAL FORMING IN TODAY'S INDUSTRY AND AREAS OF POSSIBLE IMPROVEMENT IN THE FUTURE.

KEY WORDS: SINGLE POINT INCREMENTAL FORMING, FORMABILITY, GEOMETRIC ACCURACY, TECHNOLOGY ASSESSMENT

INTRODUCTION

The requirements for more flexible production of sheet metal parts dictated the development of new unconventional forming processes. One such process is also single point incremental forming (SPIF). The latter enables forming of the initial sheet metal step by step into

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desired shape³. The tools, of various shapes, are usually installed on the CNC machine, which is shown in (Figure 1). The mentioned process is slow compared to other conventional sheet metal forming processes, which produce a part of a similar shape (e.g. deep drawing). But on the other hand it allows higher flexibility in forming, because the equipment used may stay unchanged for various formed shapes.

Machines that can be used in incremental forming are usually CNC milling machines, robots or specially designed devices. The main advantage of robots is their flexibility and larger working area. They also have many disadvantages, such as enabling smaller maximum forces, less precise positioning of the tool and thus less precise forming process. On the other hand, CNC machine is a better choice if we reach higher forces during forming, as they have higher stiffness. CNC machine also enables an easy mounting of holding frame, which allows fixing of the sheet metal, on its working table.

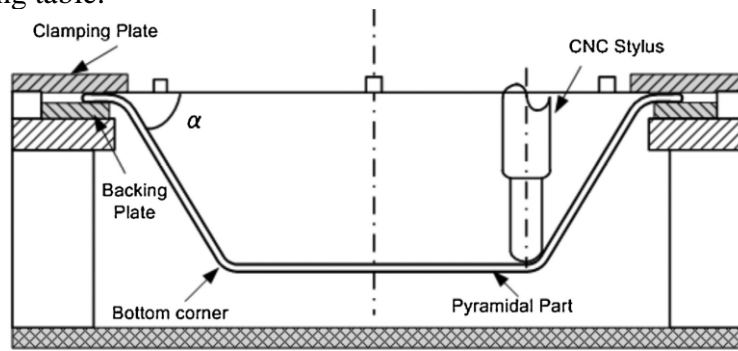


Figure 1: Schematic representation of single point incremental forming (SPIF)⁴

When in contact with the tool, the sheet is being formed in the desired shape and simultaneously also thinning. Excessive thinning of the sheet metal leads to its rupture, which indicates the forming limit. The failure of the sheet metal occurs at a maximum wall angle, which is affected by the material selection, the initial sheet thickness and numerous other forming parameters, among which the diameter of the tool and the forming step can be highlighted. In comparison to other processes, the main limitation of incremental forming is the shape of the formed part, more specifically its wall angle. However, the tearing of sheet metal can also be influenced by other design features, such as quick transitions in wall orientation, forming of narrow channels or small radii in the corner⁵. In addition to certain design constraints of products formed with incremental forming, we can also point out an additional limitation of incremental forming that is the long production time of one piece, which is longer than that of conventional processes^{6,7}.

³ Behera, Amar Kumar et al.; *Single point incremental forming: An assessment of the progress and technology trends from 2005 to 2015*, School of Mechanical Engineering, University of Leeds, 2017;

⁴ Behera, Amar Kumar et al.; *Single point incremental forming: An assessment of the progress and*

⁵ Afonso, Daniel et al.; *Integration of design rules and process modelling within SPIF technology-a review on the industrial dissemination of single point incremental forming*, Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro, 2017;

⁶ Jeswiet, Jack; *Single point and asymmetric incremental forming*, Department of Mechanical and Materials Engineering, Queen's University, 2015;

⁷ Petek, Aleš et al.; *Economical and ecological aspects of single point incremental forming versus deep drawing technology*. Aedermansdorf: Trans Tech Publications, 2007, vol. 344, p. 931-938;

TECHNOLOGY OVERVIEW

Single point incremental forming (SPIF) does not need a die, which means a more cost efficient solution of forming and a more flexible approach to forming of many different types of products without changing the required equipment. In the case of SPIF, the sheet of the material must be clamped and properly supported, as this prevents its movement, thereby reducing the inaccuracy of the forming process⁸. One of the main problems of this forming process is its inaccuracy. The latter is influenced by parameters such as sheet thickness, the slope of the wall, the depth of the forming step and also the size of the tool. By reducing the depth of the step, in any case, we have a positive effect on the accuracy. The latter can be improved by using smaller tools in the case of larger wall angles and using larger tools in the case of smaller wall angles⁹. To improve the accuracy, the thickness of the sheet metal and the forming force must be appropriately controlled during the forming process¹⁰. The type of sheet metal, with its mechanical properties, directly influences the value of the forming force¹¹. We should not neglect the influence of the thickness of the used sheet metal or the size of the tool. The increase in both the thickness of the sheet metal or the size of the tool increases the value of the forming force¹². The latter also depends on a number of other process parameters, among others on the wall angle. The maximum value of the wall angle, before the fracture occurs, is in the literature often equated with the formability of a particular material. With a reduction of tool diameter and depth of the increment step the formability of the process can be increased. The latter is also affected by sheet thickness and the material type. In addition to increasing the formability, we also want to improve the surface roughness, which is again under great influence of the tool diameter, step depth and also the type of the material being formed¹³. By increasing the step depth the surface hardness can also be increased. Additional, increase of feed rate of the used tool also has a significant effect on the increase of the surface hardness of the final product¹⁴.

The forming of sheet metal in incremental forming is limited by a fracture that occurs at a specific wall angle. In the literature the maximum wall angle that can still be reached before fracture is often equated to formability. The formability in incremental forming is influenced by numerous process parameters, including the selected sheet material. In order to determine the formability of the particular material or to determine the effects of specific parameters on formability itself, incremental forming of specially designed test pieces is conducted. Such tests

⁸ Bansal, Ankush et al.; *Prediction of forming forces in single point incremental forming*, Department of Mechanical and Aerospace Engineering, Indian Institute of Technology Hyderabad, India, 2017;

⁹ Hussain, Ghulam et al.; *Improving profile accuracy in SPIF process through statistical optimization of forming parameters*, College of Mechanical & Electrical Engineering, Nanjing University of Aeronautics and Astronautics, China, 2010;

¹⁰ Bansal, Ankush et al.; *Prediction of forming forces in single point incremental forming*, Department of Mechanical and Aerospace Engineering, Indian Institute of Technology Hyderabad, India, 2017;

¹¹ Aerens, Richard et al.; *Advances in force modelling for SPIF.*, Catholic University of Leuven, Belgium, 2009;

¹² H. Mostafanezhad et al.; *Optimization of Two-point incremental forming process of AA1050 through response surface methodology*, Measurement, Accepted manuscript, 2018;

¹³ Mulay, Amrut et al.; *Experimental investigations into the effects of SPIF forming conditions on surface roughness and formability by design of experiments*, Mechanical Engineering Department, National Institute of Technology, India, 2016;

¹⁴ Mulay, Amrut et al.; *Performance evaluation of high-speed incremental sheet forming technology for AA5754 H22 aluminum and DC04 steel sheets*, Mechanical Engineering Department, National Institute of Technology, India, 2017;

include incremental forming of conical or pyramidal parts with specified wall angle values, that are shown in (Figure 2-a) and (Figure 2-b). The wall angle is gradually increased for each further test piece with a fixed wall angle until the formed sheet is torn. In order to shorten the testing procedure a test piece with changing wall angle can be used, the geometry of which is shown in (Figure 2-c). In the latter geometry, we simply measure the formed part depth where the fracture occurs and determine the wall angle at this depth, which is shown in (Figure 2-c)¹⁵.

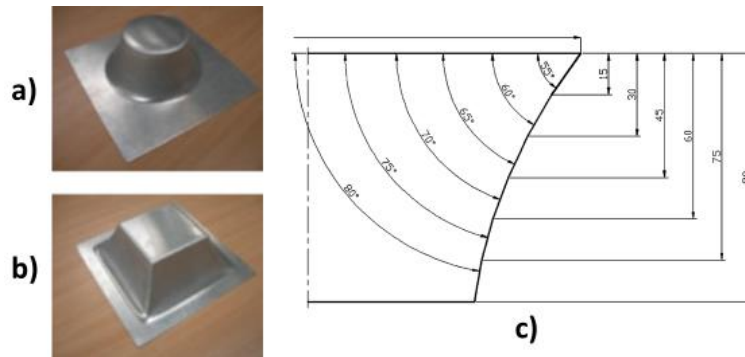


Figure 2: a) Truncated conical shape, b) truncated pyramidal shape and c) geometry of a cross section with variable wall angle used on shapes a) or b)¹⁶

In the case of SPIF process, the fracture occurs in two possible ways. According to the literature^{16,17}, localization can occur prior to the break or a tear occurs without prior localization. For tools with a diameter larger than 15 mm localization occurs and consequently there is a drop of the formability level¹⁶. The difference in failure mechanism is the main reason for the larger formability of SPIF compared to conventional forming processes like stamping. With SPIF forming the delamination of laminated materials is reduced¹⁸ due to localized deformation under relatively small tool. The latter was shown in the study by Al-Ghamdi and Hussain¹⁹, where a comparison was made between SPIF forming and stamping of the steel-Cu composite, the components of which were merged with rolling.

Formability can also be increased by local heating of the sheet metal¹⁸. The easiest way to achieve this is by rotating the tool. In the study by Buffa et al.²⁰ the temperature of the sheet metal was increased by increasing the tool rotational speed, which also increased the formability or the maximum wall angle of all formed parts. **Error! Reference source not found.** shows a diagram o

¹⁵ Silva, Maria B. et al; *Failure mechanisms in single-point incremental forming of metals*, Mechanical Engineering Department, Instituto Superior Tecnico, TULisbon., 2010;

¹⁶ Silva, Maria B. et al; *Failure mechanisms in single-point incremental forming of metals*, Mechanical Engineering Department, Instituto Superior Tecnico, TULisbon., 2010;

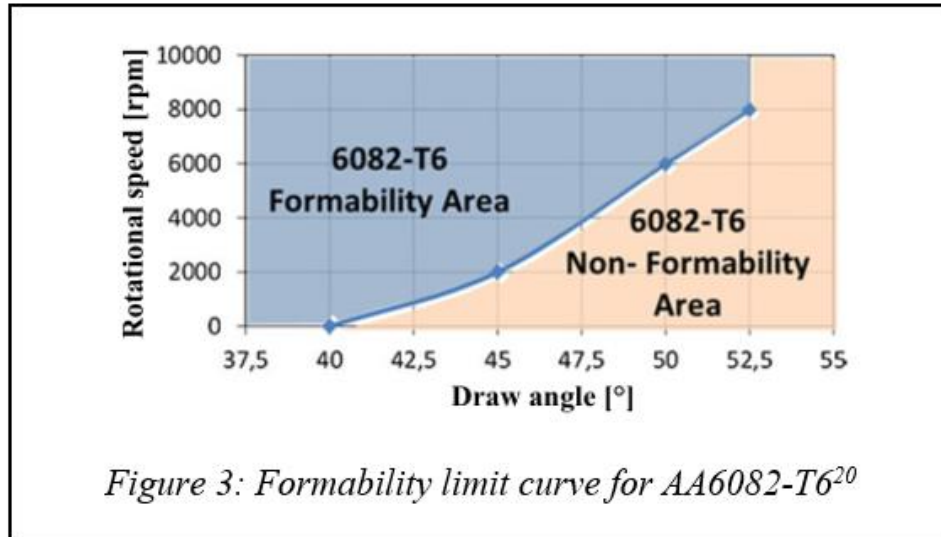
¹⁷ Petek, Aleš; *The definition of stable technological window by incremental sheet metal forming: dissertation*. Ljubljana: [A. Petek], 2008, p. 139;

¹⁸ Petek, Aleš et al.; *Particularities of an incremental forming application in multi-layer construction elements*. Strojniški vestnik, 2009, vol. 55, no. 7/8, p. 423-426;

¹⁹ Al-Ghamdi, Khalid and Hussain, Ghulam; *On the comparison of formability of roll-bonded steel-Cu composite sheet metal in incremental forming and stamping processes*, Department of Industrial Engineering, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia, 2016;

²⁰ Buffa, Gianluca et al.; *On the improvement of material formability in SPIF operation through tool stirring action*, Department of Chemical, Management, Computer Science and Mechanical Engineering, University of Palermo, 2012;

f rotational speed of the tool in correlation with the maximum draw angle at the fracture for a conical test piece formed from aluminium 6082-T6.

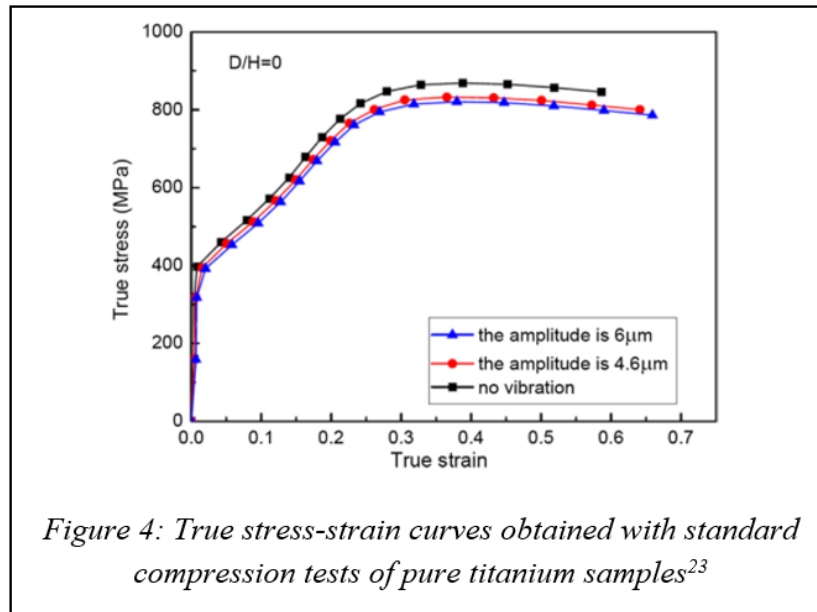


As the main reason for increasing the formability or the maximum angle with increase in the rotational speed of the tool, dynamic recrystallization was exposed. This results in the decrease in grain size following by the consequential drop in micro hardness, which is one of the weaknesses in this approach of improving the formability. By rotating the tool during SPIF forming, in addition to formability, we can also influence roughness, as demonstrated in the study by Liu et al.²¹. From the results of the mentioned study it is clear that with increasing tool rotational speed roughness always improves compared to the state of the surface of the part formed without tool rotation. The SPIF forming always worsens the surface roughness compared to the initial sheet metal.

Preheating of the sheet metal prior to the process has similar effect as the rotation of the tool analysed by Shrivastava et al.²², where aluminium alloy AA1050 was preheated to different temperatures. Increasing the temperature of the preheating process improves the geometric accuracy of the manufactured workpiece and reduces the wall thickness. Generally, by the material heating a reduction of the forming force is achieved. The latter is valid regardless of whether local warming or preliminary global warming of the entire sheet is carried out²².

²¹ Liu, Zhaobing; *Friction stir incremental forming of AA7075-O sheets: investigation on process feasibility*, School of Mechanical and Electronic Engineering, Wuhan University of Technology, China, 2017;

²² Shrivastava, Parnika; *Improvement in formability and geometrical accuracy of incrementally formed AA1050 sheets by microstructure and texture reformation through preheating, and their FEA and experimental validation*, Department of Mechanical Engineering, PDPM Indian Institute of Information Technology, India, 2018;



Material formability can also be improved by supplementing ultrasound vibrations during the forming process. Liu et al.²³ made a study on the effect of ultrasound vibration on the friction and deformation resistance during standard compression test of pure titanium samples. As shown in (**Error! Reference source not found.**), the increase in the amplitude of the vibration causes the decrease in flow stress and also yield stress, but minimally affects elastic deformations. The increase in the vibration amplitude also influences the reduction of the average grain size, but on the other hand has a minimal effect on the temperature rise inside the material.

Ultrasound vibrations can also be used in the field of SPIF forming to increase the formability. In the study by Li et al.²⁴ the SPIF forming with ultrasound tool vibrations was achieved with a specially designed module providing the ultrasound vibrations. The module was mounted between the CNC machine and the tool. Numerical analyses with Abaqus software package delivered diagrams (Figure 3) showing the influence of the vibration amplitude and vibration frequency on the axial force during forming. From the diagram (Figure 3-a) it is evident that the axial force decrease until the frequency of 40 kHz and starts to rise again. The reason for the increase of the axial force is rapid tool hitting against the material and consequential material vibration. Similarly, the influence of the vibration amplitude is evident on (Figure 3-b). The latter diagram is obtained with a simulation of the SPIF forming process with a fixed frequency of vibration of 20 kHz. Despite the tool vibrations the influence of the tool size on the formability remains as well. The study of Li et al.²⁵ shows the influence of the tool size and the tool vibration frequency on the perpendicular force according to the part forming in the SPIF process with the

²³ Liu, Tao et al.; *Effects of ultrasonic vibration on the compression of pure titanium*, Key Laboratory for Liquid-Solid Structural Evolution & Processing of Materials (Ministry of Education), Shandong University, China, 2018;

²⁴ Li, Pengyang; *Evaluation of forming forces in ultrasonic incremental sheet metal forming*, *Evaluation of forming forces in ultrasonic incremental sheet metal forming*, China, 2017;

²⁵ Li, Yanle et al.; *Effects of ultrasonic vibration on deformation mechanism of incremental point-forming process*, School of Mechanical Engineering, Shandong University, China, 2017;

additional ultrasound vibrating of the tool. It can be seen, that with a larger tool the vertical forces are larger, when there is no added vibration. When the vibration amplitudes are large enough, we achieve larger vertical forces with a smaller tool compared to a larger one. The value of the amplitude, where the reversal occurs, depends on the material being formed.

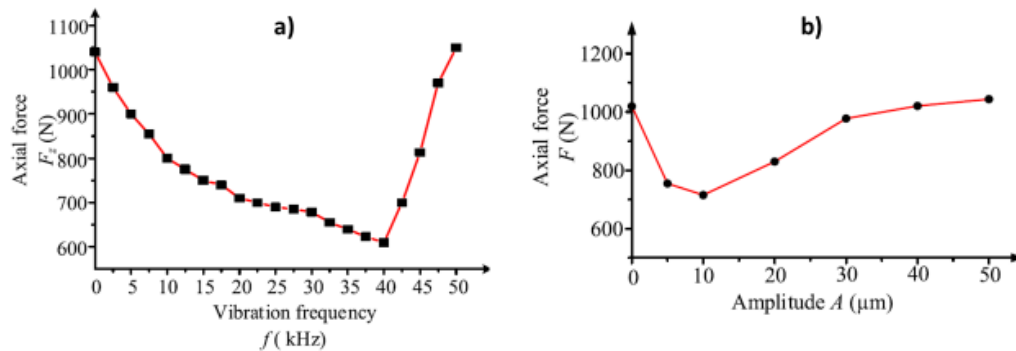


Figure 3: a) Values of the mean axial force at different vibration frequencies and b) values of mean axial force at different vibration amplitudes²⁶

In the study by Lu et al.²⁷ the vibration due to the rotation of the tool was investigated on the magnesium sheet. SPIF forming was performed using three basic tools. Figure 4-a shows a classical hemispheric tool with a diameter of 5 mm, that does not cause vibration while rotating and is used for comparison with newly developed tools. The new tool, shown on (figure 4-b), has a diameter of 4.5 mm and an offset from the rotational axis by 0.5 mm. While rotating, the latter tool provides cyclic hitting on the surface of the material and thus ensuring vibration. Inside the study they also developed a tool with an elliptical head, shown in (Figure 4-c). With such type of tool, that hits the sheet twice per rotation, the frequency of the vibration can be increased. With this the value of the horizontal force was reduced during forming and, above all, the temperature.

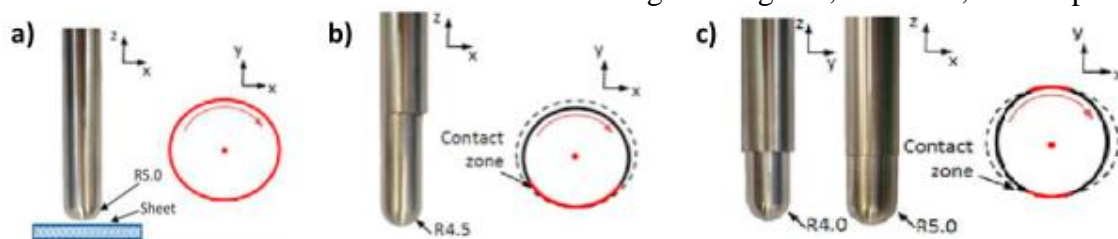


Figure 4: Three types of forming tools used: a) conventional hemispheric tool, b) single-offset tool and c) dual-offset tool²⁷

In order to improve design accuracy of the product obtained with SPIF forming, we can resort to multi-stage SPIF forming. Thus, with a larger number of tool passages, we gradually change the shape and thus achieve the desired angle of the walls with better accuracy. Furthermore,

²⁶ Li, Pengyang; *Evaluation of forming forces in ultrasonic incremental sheet metal forming*, Evaluation of forming forces in ultrasonic incremental sheet metal forming, China, 2017;

²⁷ Lu, Bin et al.; *Microstructure refinement by tool rotation induced vibration in incremental sheet forming*, Department of Mechanical Engineering, The University of Sheffield, United Kingdom, 2017;

at the same time more even distribution of sheet metal thickness is achieved. In addition to the larger number of tool passages of SPIF, a specific stage can also be replaced with other forming processes. Thus, in the study by Shamsari et al.²⁸ the authors present a hybrid two-stage SPIF forming process, where the first stage of the forming is represented by hydraulic bulging of the sheet metal and the second stage by classical SPIF forming process. As shown in (Figure 5), with the first stage of forming the required height of the dome is achieved by applying the required pressure. The dome is then turned before the start of stage two of the forming process, properly re-clamped and formed into specific shape.

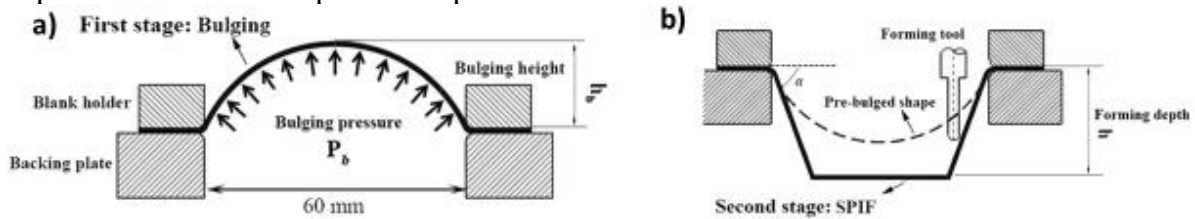


Figure 5: Two forming stages in the hybrid two-stage incremental forming process: a) hydraulic bulging and b) subsequent SPIF forming²⁸

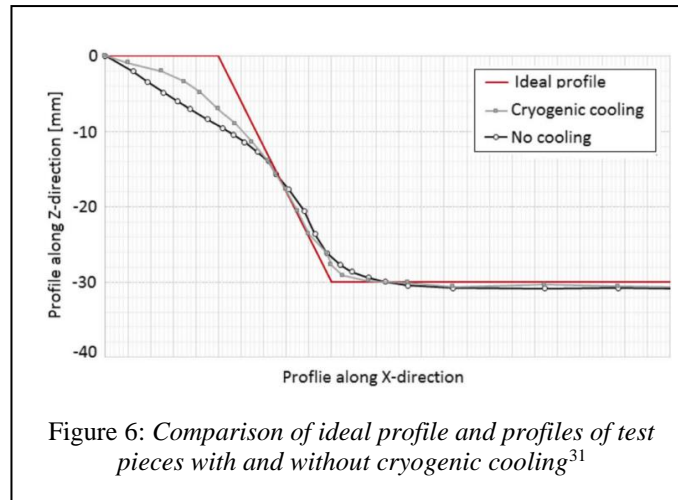
With the hybrid two-stage forming, a greater depth of forming and better sheet thickness distribution in the wall area of the product are achieved compared to one-stage or even conventional two-stage SPIF forming²⁸. The main weakness of the hybrid two-stage SPIF forming is the convex bottom surface after bulging, which limits the use of the presented process combination. In general, the multi-stage SPIF forming enables an improvement in formability in terms of attainable wall angles and also forming depths, but with this approach we may strongly influence the time and consequently the price of forming.

In addition to workpiece warming, the precision of formed SPIF products can also be improved by appropriate subsequent cooling. In a study by Ambrogio et al.²⁹ the SPIF forming process with induction heating and addition of cryogenic cooling with liquid nitrogen of formed pieces was carried out on titanium alloy Ti-6Al-4V. Cryogenic cooling reduces the elastic springback of the unclamped sheet and with this better accuracy of the forming process is achieved. Figure 6 shows a comparison of the geometric accuracy for the test piece formed with and without added cryogenic cooling and their deviation from the ideal profile.

²⁸ Shamsari, Mohsen et al.; *Formability improvement in single point incremental forming of truncated cone using a two-stage hybrid deformation strategy*, Mechanical Engineering Department, Babol Noshirvani University of Technology, Iran, 2017;

²⁹ Ambrogio, Giuseppina et al.; *Induction heating and cryogenic cooling in single point incremental forming of Ti-6Al-4V: process setup and evolution of microstructure and mechanical properties*, Department of Mechanical, Management and Manufacturing Eng, University of Calabria, Italy, 2016;

SPIF enables forming of both metals and polymeric materials. Marques et al.³⁰ presented forming of four polymeric materials, namely PET, PC, PA and PVC. Using standard bulging tests and tensile tests, general mechanical properties were determined and it was realized that PET has



the best formability of all in the study tested materials. The latter was also confirmed by the classical SPIF forming tests, where the fracture of the cone made out of PET occurred at the wall angle of nearly 90°. Forming of polymeric materials is limited by the formation of cracks on the periphery of the product or by wrinkling on its bottom radius being similar to metallic materials. The SPIF forming of polymeric materials may change their density, which is not the case in forming of metals. The latter characteristic is a major problem with PVC products, where the density drops as the wall angle of the product increases. When processing polymers, the wall of the product can also become completely white. This is connected with the aggregation of cracks inside the polymer. Maximum attainable wall angle for polymer products is similar to that of metal products³⁰. The difference between the standard SPIF tests for polymeric materials and those for metals is evident influence of the initial wall angle when the polymer samples with variable wall angles are analysed³⁰. Nevertheless, the use of polymers opens new possibilities for SPIF forming in the field of prototype development.

CONCLUSION

Conventional SPIF forming can be improved with different approaches enabling an increase in the formability or improvement of forming accuracy. The formability can be improved in a simple way by heating the sheet. Such an approach is particularly suitable for materials with low ductility, such as magnesium and titanium³². By heating, additional slip planes are activated

³⁰ Marques, Tania A. et al.; *On the potential of single point incremental forming of sheet polymer parts*, IDMEC, Instituto Superior Tecnico, Technical University of Lisbon, Portugal, 2011;

³¹ Ambrogio, Giuseppina et al.; *Induction heating and cryogenic cooling in single point incremental forming of Ti-6Al-4V: process setup and evolution of microstructure and mechanical properties*, Department of Mechanical, Management and Manufacturing Eng, University of Calabria, Italy, 2016;

³² Dufloy, Joost R. et al.; *Single point incremental forming: state-of-the-art and prospects*, Department of Mechanical Engineering, KU Leuven, Belgium, 2017;

within the microstructure of the material, which in turn means an increase in the formability. Forming at elevated temperatures also reduces the springback and forming forces. Due to all above mentioned reasons, in literature we encounter various ways of heating the sheet metal, which is being heated on the local area beneath the small tool or globally, where the whole sheet of metal is heated at once. Local heating can be divided into laser heating, electric heating and also heating by rotating the tool^{33,34}. In addition to rotation, vibration of the tool is one promising approach that decreases the value of the forming force³⁵. The correct choice of vibration frequency and amplitude is important. Cyclic hitting of the tool against the sheet metal can be achieved with a frequency generator and other necessary additional equipment, or only with the appropriate shape of the tool and its rotation³⁶.

The main advantage of SPIF is its flexibility in forming of different products and the ability to perform the forming itself on a conventional CNC milling machine or on a robot. The main disadvantage of incremental forming compared to conventional forming processes is the long lead time of a specific product. Thus, the incremental forming, including SPIF, is mainly aimed at the small batch production. The SPIF investment justification limit is usually between 100 and 1000 products³⁷. Because the shape of a convex product formed with SPIF derogates from the desired shape below 1 mm, the mentioned forming process can be used in many fields such as biomedicine, architecture, thermoforming mould production and, above all, prototyping, where the above mentioned flexibility of incremental forming plays a vital role³⁷. In addition to improving the accuracy of incremental forming, the lead times for products can be shortened, while retaining or even further increasing the formability level with many different innovative approaches.

³³ Liu, Zhaobing; *Friction stir incremental forming of AA7075-O sheets: investigation on process feasibility*, School of Mechanical and Electronic Engineering, Wuhan University of Technology, China, 2017;

³⁴ Shrivastava, Parnika; *Improvement in formability and geometrical accuracy of incrementally formed AA1050 sheets by microstructure and texture reformation through preheating, and their FEA and experimental validation*, Department of Mechanical Engineering, PDPM Indian Institute of Information Technology, India, 2018;

³⁵ Li, Yanle et al.; *Effects of ultrasonic vibration on deformation mechanism of incremental point-forming process*, School of Mechanical Engineering, Shandong University, China, 2017;

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PRODUCTION OF MICROMIXER USING UNCONVENTIONAL TECHNOLOGIES

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ABSTRACT:

TECHNOLOGIES FOR MICROPRODUCTION ARE BECOMING MORE DIVERSE AND PRECISE. THE NEED FOR SMALL PRODUCTS IS INCREASING AND THERE ARE MANY OPTIONS TO PRODUCE DEVICES WITH ACCEPTABLE PROPERTIES. APPROPRIATE CHOICE OF MATERIALS AND PROCEDURES CAN BE BENEFICIAL BOTH FROM COST AND SPEED OF PRODUCTION POINT OF VIEW. IN THIS PAPER PROCESS CHAIN FOR PRODUCING MICROMIXER IS PRESENTED. TECHNOLOGIES USED ARE: WATER JET (WJ) AND ABRASIVE WATER JET (AWJ) CUTTING, DIE-SINKING ELECTRICAL DISCHARGE MACHINING (EDM) AND GRAVITY CASTING OF POLYDIMETHYLSILOXANE (PDMS). MAIN SOURCE OF ERROR AND DEVIATION WAS CUTTING WITH WJ, SINCE IT PRODUCED HIGH TAPER. AWJ WAS BETTER, BUT WIDTH OF CUT WAS NOT ACCEPTABLE FOR NARROW CUTS. OTHER TWO PROCESSES PERFORMED ADEQUATE TO MICROPRODUCTION STANDARDS, BUT CAN BE GREATLY IMPROVED AS WELL.

KEY WORDS: MICROMIXER, EDM, WATER JET, PDMS

INTRODUCTION

In recent years the demand for small and precise products has greatly increased. Not only the electronics and computer industry but most of other important branches of mass production are trying to make their products as small and as cost effective as possible². New materials require different procedures for producing such small products with high accuracy and narrow tolerances.

Micro product is by definition of 4M association (Multi-Material Micro Manufacture) a product that contains geometries with 2 dimensions of less than 1 mm. Technologies for manufacturing such products vary greatly and depend on what the product will be used for. Rapid prototyping methods are used to quickly evaluate if the geometry and procedure are appropriate or not³.

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² Whitesides, "The origins and the future of microfluidics", 368.

³ Sabotin et al., "Repeatability and limitations", 151.

Microfluidics is one of the most important branches where products on micro scale are used. First applications of microfluidics were used in substance analysis. Small dimensions enable very good flow and temperature control, which results in high accuracy process control⁴. Possibility of analyzing substances with microfluidic devices and therefore needing just a fraction of quantity, which is usually needed when using conventional methods of analysis, is very cost and time effective⁵. If you needed 1 L of substance for analysis with conventional methods, this number drops down to 1 nL or even less for microfluidic devices. In the last two decades there has been great demand for so called LOC – lab-on-a-chip microfluidic devices, which enable very effective analysis and complex chemical reaction on very small scale.

The goal of the research was to investigate how accurately can micromixer be produced using technologies that are not yet established as parts of production chains and are mainly suited for machining macro parts. Two unconventional technologies for machining were used: water jet and EDM. Maximum amount of time that was supposed to elapse from start to finished product was less than 1 day.

MATERIALS AND METHODS

Proposed production process chain was: use of water jet (WJ) or abrasive water jet (AWJ) cutting to make electrodes from 1 mm thick copper plate suitable for EDM, EDM machining of stainless steel workpiece and finally casting liquid polymer PDMS over the tool to produce the final product.

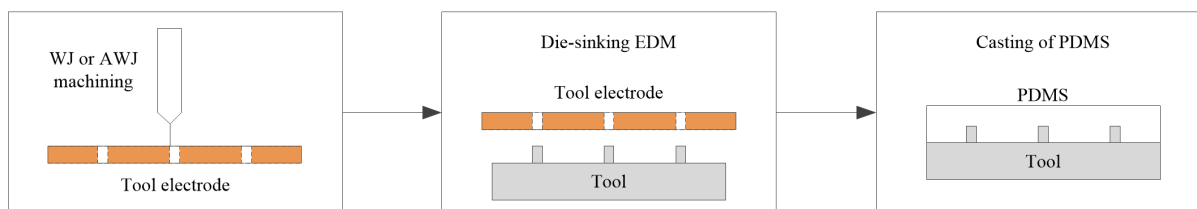


Figure 7: Production chain of micromixer

Electrodes, workpiece - tool and the final product – micromixer were measured using pictures taken with CCD camera which were analyzed in MATLAB. The main goal was to find out how do the geometries and dimensions change along the process chain. The proposed geometry of the micromixer can be seen in Figure 8. It is commonly known as Slanted Groove Micromixer (SGM). It consists of multiple grooves with desired width and spacing. Grooves are arranged in sequence with 45° angle in relation to main channel. Grooves cause lateral displacement of the fluid due to its entrainment. The effect of this is exponential increase of interface surface between two reactants, which through diffusion greatly enhances mixing⁶. Even though this is not optimized geometry of a micromixer, it was suitable for purposes of our research.

⁴ Sia, "Microfluidic devices fabricated in poly(dimethylsiloxane)", 3563.

⁵ McDonald, "Poly(dimethylsiloxane) as a material", 491.

⁶ Sabotin et al., "Optimization of a bottom grooved", 196.

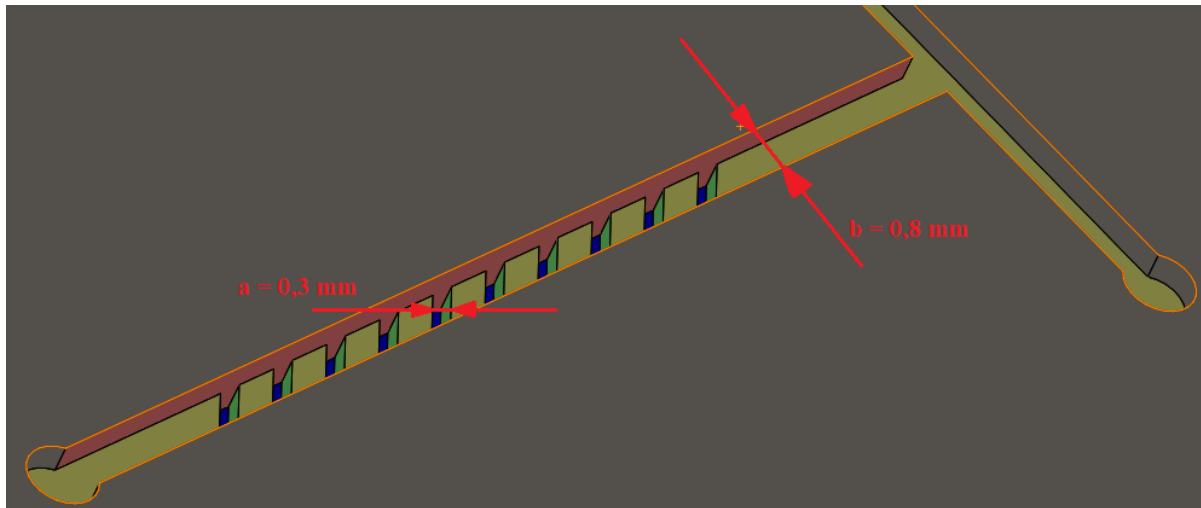


Figure 8: Proposed micromixer geometry

The arrows with numbers on Figure 9 present proposed measuring spots and are translated throughout the production chain. At numbers 1-4 only width of the channel was measured, but on numbers 5-14 width of ribs (on the tool) or grooves (on micromixer) was also measured.

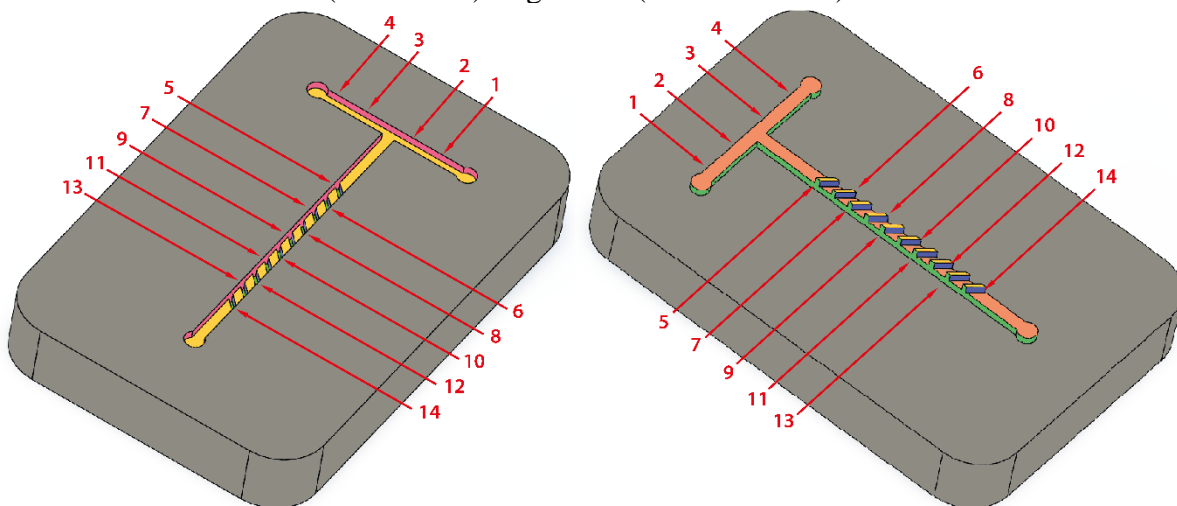


Figure 9: Model of micromixer (left) and tool (right)

WJ AND AWJ MACHINING

With known proposed geometry of micromixer, first step in process chain was possible. Machine tool used for WJ and AWJ machining was OMAX type 2652A/20HP with Böhler Ecotron 403 hydraulic intensifier capable of reaching 410 MPa water pressure. Water nozzle Type 91 from Allfi (Switzerland) with 0.3 mm inside diameter and focusing nozzle with 0.8 mm inside diameter from same manufacturer were used. Tool paths for cutting were programmed in 2D as seen on Figure 10. The difference between WJ and AWJ is in cutting speed and width of cut. Therefore, it was decided that 2 pairs of electrodes should be made, one with WJ and the other using AWJ. The electrode on Figure 10 (a) was named electrode A and was intended for EDM of the side and main channels. Electrodes on Figure 10 (b) and (c) were named electrode B, but the first electrode had

only 6 cuts and the second one, which was later optimized and only cut with WJ, had 10 cuts. As seen on Figure 10 (c) lead-in and lead-out tool paths had to be made in order to move the point of piercing as far away from middle as possible, while still keeping it close enough for shorter time of cutting⁷. For cutting with WJ, water pressure was set to 300 MPa and the cutting speed was set to 5 mm/min. Cutting speed with AWJ was much faster at about 800 mm/min [6].

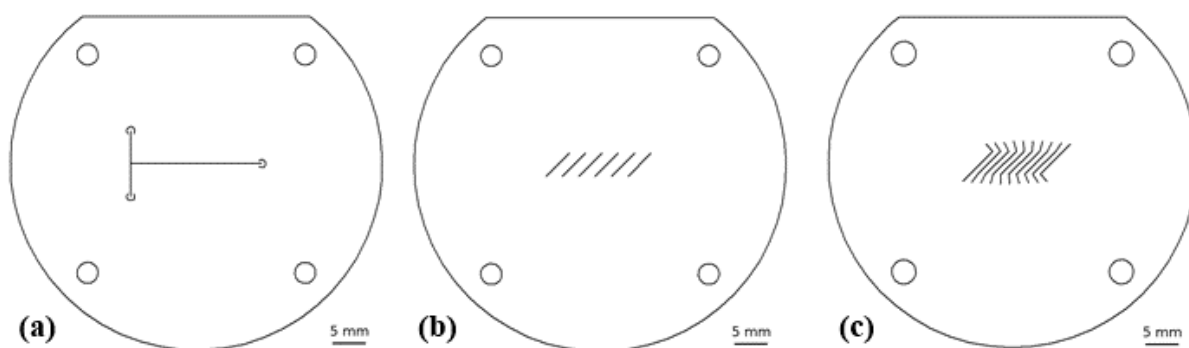


Figure 10(a) toolpath for cutting electrode A, (b) toolpath for cutting electrode B, (c) toolpath for cutting optimized electrode B

ELECTRICAL DISCHARGE MACHINING

Die-sinking EDM was used to machine stainless steel workpiece with electrodes shown in Figure 9. IT Elektronika 200M-E EDM machine was used. Special holder was used to fix the electrode and provide flow of dielectric fluid from inside. This meant that the gap flushing was very good. First, electrode A was used to machine the side and main channels. Depth of machining was set to 1 mm. Since a lot of material had to be removed it was decided that rough machining should be used first and later switch to fine machining. Parameters used for both settings are presented in Table 1.

Table 1: Machining parameters for electrode A

EDM setting	Peak current [A]	Voltage [V]	Pulse on time [μ s]	Pulse off time [μ s]
Rough	16	280	350	50
Fine	5	280	60	18

With the use of fine machining parameters, gap reduces and so does the heat affected zone. Low material removal rate (MRR) was also consequence of fine machining parameters, which meant longer time of machining. Fine parameters were used as late as possible.

⁷ Valentinčič et al., “Alternativne tehnologije: učbenik za tretji letnik”, 102.

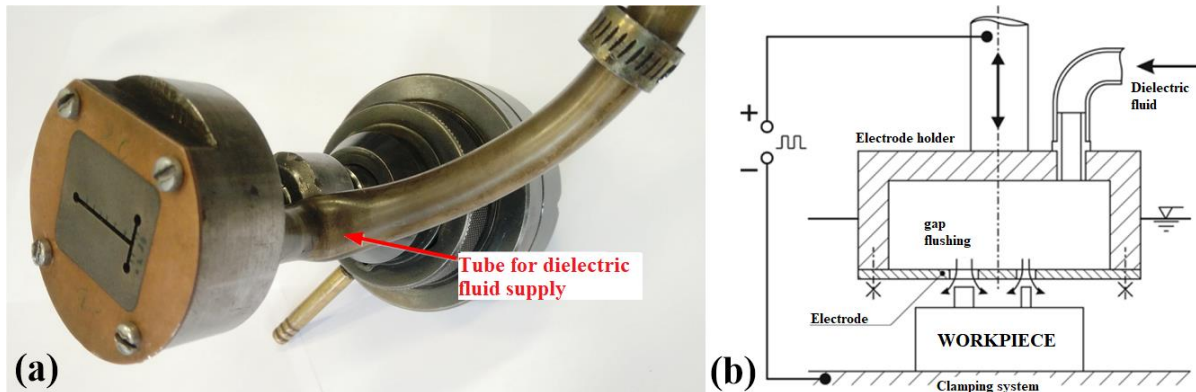


Figure 11: (a) holder with mounted electrode, (b) cross section of the holder

Seen on Figure 11 is the special holder and cross section of the same holder. Gap was flushed from the inside. Since very small geometries were machined, it was of great importance to avoid disturbances during discharges. Machining with electrode B was always done with fine machining parameters, because the eroding surface was very small. Parameters for machining with electrode B are presented in Table 2.

Table 2: Machining parameters for electrode B

EDM setting	Peak current [A]	Voltage [V]	Pulse on time [μ s]	Pulse off time [μ s]
Fine	2	280	45	18

With some testing it was concluded that electrode A cut with AWJ and electrode B (with 10 cuts) cut with WJ shall be used for machining the tool needed for further manufacturing. Final result of the machining was tool insert seen on Figure 12.

GRAVITY CASTING OF POLYDIMETHYLSILOXANE (PDMS)

PDMS is a two-component polymer which consists of base material and curing agent. We used QSil216 from ACC Silicones (United Kingdom). Special casting device was manufactured from aluminum which enabled to firmly secure and cast the machined side of the tool. Two components of the polymer were first mixed in a cup and then exposed to 70 mbar vacuum for 15-30 minutes to remove air bubbles from the mix. Once most of the air was removed, liquid polymer was poured into the device and then exposed to vacuum again. When the polymer had appropriate properties in terms of air content, it was exposed to 100 °C for about 1 hour, which allowed the polymer to cure. Final product was easy to remove from the device. In total, 5 micromixers were produced.

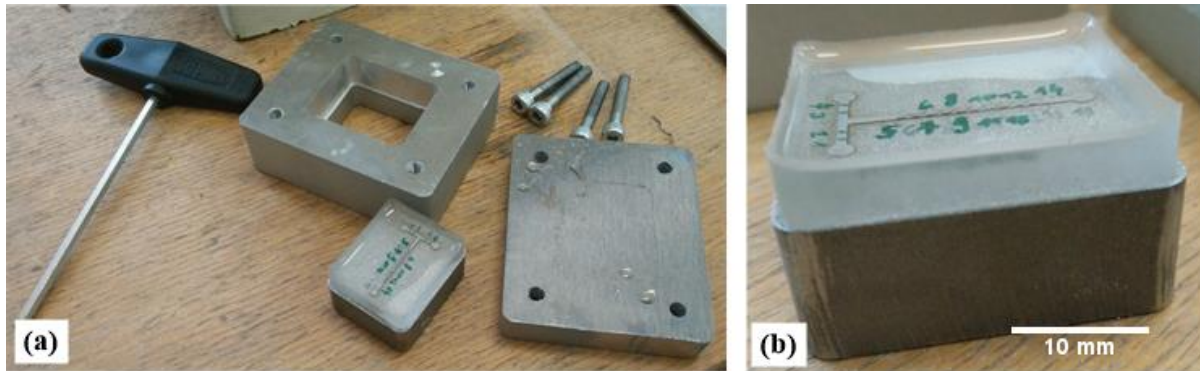


Figure 12: (a) disassembled casting device and tool, (b) cured final product on the tool

RESULTS AND DISCUSSION

As expected, cuts made with AWJ were wider than those made with WJ only. AWJ provided better repeatability in terms of cutting kerf, because the standard deviation was much smaller. Both procedures performed well when cutting electrode A and electrode B with 6 cuts. In case of electrode B with 10 cuts (only WJ), the cutting process was far more difficult. With slower cutting speed this meant that there was a lot of taper present. It was discovered that brand new water nozzle had to be used, otherwise WJ would become too wide and would erode or rip off material between cuts. With brand new orifice, the cuts could be as close as 1.2 mm apart and had less taper.

While machining with EDM, minor electrode wear was observed. Wear resulted in decrease of taper and its deviation on both A and B electrodes cut with WJ as well as AWJ. Comparison of width is shown on Figure 13. In case of AWJ, taper is much smaller by default, because of mechanism by which material is removed. Width of cuts on electrodes A and B was increased after use on the EDM machine. Width increased by less than 10%, but again, deviation of the cut decreased as well. This was present on electrodes cut with WJ and AWJ almost proportionally to width of the cut. Width of cut on the electrodes increased mostly after 1st use of the electrode on EDM machine. After further use of electrodes, wear was barely perceptible. Deviation kept decreasing with more electrode use, which was expected.

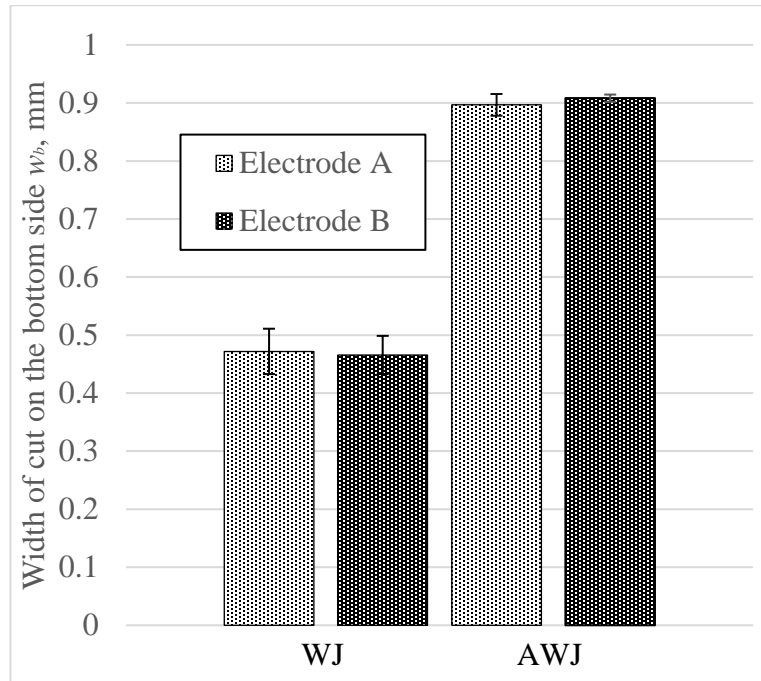


Figure 13: Width of cuts on the bottom side of electrodes

Final tool was machined with electrode A, cut with AWJ and electrode B (with 10 cuts) which was cut with WJ. Where electrodes had cuts, material was left on the tool and presented negative of the final product. Some differences in dimensions were expected, since a gap between the electrode and the workpiece is always present. The difference was in range of few hundredths of a millimeter. Features on tool are therefore of smaller dimension due to gap. Width of the gap depended on operating parameters. Fine parameters resulted in smaller gap and therefore smaller difference in dimensions.

With 5 micromixers produced, it was possible to compare measurements. It is known that polymer shrinks about 1% during transition from liquid to solid. Measurements were conducted on each micromixer and averages for main channels and features were calculated respectively. Main channel widths were always narrower than 0.8 mm. Widths of grooves were expected to be greater than theoretical value of 0.3 mm. It turned out that width was around 0.4 mm. Eventhough dimensions were acceptable, the deviation between separate micromixers was too high for mass production. There are many factors for differences between micromixers' dimensions including deformation during curing, not using clean room for casting, not curing at constant temperature, when removing products from the tool it is possible to use too much force and deform micromixer.

Changes in dimension throughout the production chain were greater in case of main channel as seen on Figure 14. More significant changes were present because of different EDM parameters used in machining. Electrode wear was clearly visible on electrode A. So much wear was caused by discharges which were far more powerful than those with electrode B. Difference in surface area was extensive as well. Wear was not noticed in case of electrode B. Dimensions on the tool were smaller in both cases, but decreased less with electrode B, that is again due to fine machining parameters, which caused much narrower gap during machining and therefore less

difference in dimensions between the electrode and the tool. Difference in dimensions on tool and micromixer were about the same in both cases which means that PDMS material shrunk evenly.

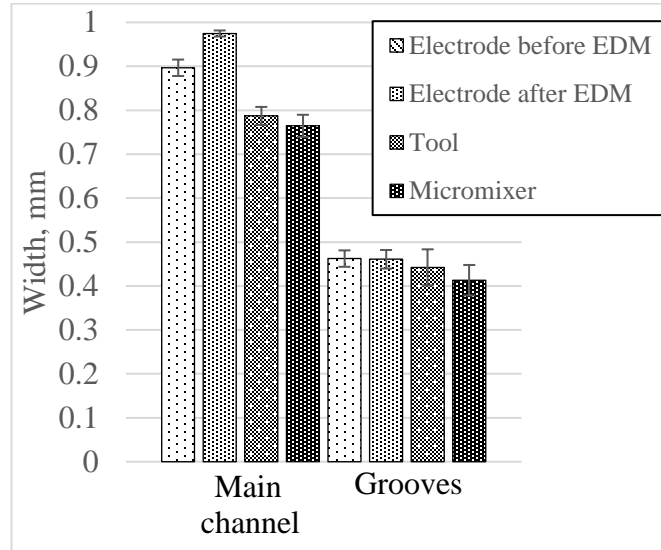


Figure 14: Comparison of dimensions throughout production chain

Final dimension of grooves in the main channel changed less and decreased in every step of production chain to final dimension of around 0.41 mm. Average dimension difference between electrode and micromixer was 0.06 mm. On main channel dimensions changes were greater and mostly due to rough machining parameters on EDM machine. Overall difference in width of main channel was 0.14 mm, starting with 0.9 mm on electrode and ending with 0.76 mm on micromixer. Width on micromixer was smaller even if electrode was significantly widened due to wear. Deviations did not show any trend of becoming smaller through production chain.

CONCLUSION

Presented production process chain is relatively simple and reliable, but for more precision better machines and more fine parameters should be used. At present state the production process chain would not be appropriate for mass production. It is obvious that precision mostly depends on how good AWJ and WJ processes are. Especially in WJ, where deviation of width and taper are significant. A lot of error is due to sapphire orifice which could be replaced with a diamond one. Diamond orifice starts showing signs of wear after longer time than the sapphire one and retains its shape much longer, therefore it would be more suitable. Precision of machining with EDM depends on machining parameters. For this research we tried to optimize time of machining, but sacrificed some precision because of it. For more precise tool insert, we would have to use fine machining throughout the EDM process and try to decrease them even further when machining with electrode B, since its surface area is very small. Replication with PDMS proved to be suitable, but differences between each micromixer were present and obvious after measurements. Even so, the PDMS replication of the tool insert was so good that separate craters created by EDM machining were visible on micromixers surface. For more precision, casting should be performed in more controlled environment and parameters should be closely monitored (humidity,

temperature, time). Deviations between micromixers were too great to consider using this process for mass production.

It was proved that this production process chain can be used to manufacture micromixers, but accuracy must be improved. Machines with greater accuracy should be used for further research as well as appropriate room for handling with PDMS. It would be possible to produce acceptable products with existing production chain, but repeatability must be improved greatly.

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INDUSTRIAL NEEDS FOR MODERN ENGINEERING KNOWLEDGE IN CENTRAL EUROPEAN REGION – SURVEY RESULTS

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ABSTRACT:

IN ORDER TO PROVIDE COMPANIES WITH A COMPETITIVE ADVANTAGE, IT IS NECESSARY TO CONSTANTLY INVEST IN NEW CAPACITIES OF THE STAFF ENGINEERS WHO DEVELOP NEW PRODUCTS, AS WELL AS OF NEW GENERATIONS OF STUDENTS. IN ADDITION TO BASIC ENGINEERING SKILLS, THEY SHOULD ALSO BE PROVIDED WITH SKILLS WHICH WOULD HELP THEM TO DEAL WITH CONTEMPORARY CHALLENGES IN PRODUCT DEVELOPMENT. THE MAIN TRENDS IN THIS RESPECT INCLUDE DEVELOPMENT OF SMART PRODUCTS AND TRANSITION FROM THE PRODUCT AS AN OBJECT OF SALE TO THE PRODUCT AS AN OBJECT TO SUPPORT THE SALE OF A SERVICE. IN THIS PAPER, THE AUTHORS PRESENT RESULTS OF A RESEARCH CARRIED OUT AMONG THE INDUSTRIAL PARTNERS IN CENTRAL EUROPE. THE OBJECTIVE OF THE RESEARCH IS TO IDENTIFY THE DEMAND OF INDUSTRY FOR NEW STAFF, THEIR CAPACITIES AND SKILLS. OUR FINAL AIM IS TO PREPARE AN INTERNATIONAL JOINT STUDY PROGRAM OF THREE UNIVERSITIES.

THE RESULTS HAVE SHOWN THAT COMPANIES IN CENTRAL EUROPE ARE AWARE OF AND FOLLOW GLOBAL TRENDS AND THEY ARE ADAPTING THEIR STAFF ACCORDINGLY. AS THEIR MAIN CHALLENGE, MANUFACTURING COMPANIES PERCEIVE THE GROWING NEED FOR INTERDISCIPLINARY SKILLS AND THE INTRODUCTION OF NEW BUSINESS MODELS THAT BECAME POSSIBLE BY INCREASED SMARTNESS OF PRODUCTS.

KEY WORDS: ENGINEERING SKILLS, ENGINEERING KNOWLEDGE, SMART PRODUCTS, SMART ENGINEERING, SMART PRODUCTION

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INTRODUCTION

Academic partners from the University of Ljubljana, Faculty of Mechanical Engineering (UL-FME), Universities in Zagreb, Faculty of Mechanical Engineering and Naval Architecture (UZ-FMENA), and TU Wien recognized the need for a joint master's degree program, tailored to the needs of industry for engineers with interdisciplinary knowledge that is required for the development of new smart products. To identify the key capacities and skills that industry expects from students, and to identify where the greatest knowledge and skills mismatch occurs, the authors of this paper and their colleagues have reviewed the literature and carried out a research among the industrial partners in the Central European region.

Early results of the literature review have shown that the needs of industry are often different from what students bring from the academic sphere, and that some key skills are under-developed and that there is a gap between how industry and students, respectively, perceive them. It is also of some interest that the results of different studies from different parts of the world are similar and as such, they are not tied only to a specific geographical area.

In an Australian study⁶, Nguyen found that “the most essential generic skills and attributes of a modern engineer are technical knowledge, skills and attitudes. The emphasis given to personal and professional attitudes by the industrial sector was interesting and indicates that engineers are not only expected to be technically proficient in the field but also to know how to behave and operate within an organization”. On the other hand, May and Strong⁷ have found that in Canada, “three of the four skills that students perceive as their strongest points are identified by industry as the greatest weaknesses in engineering education. It is clearly demonstrated by student’s perception of having sound professional design skills, contrasted with the evident unfulfilled needs and wants of industry that there is a significant disconnect between stakeholders”.

Most studies have also recognized the need to improve communication and organizational skills of engineering students. This is crucial for a rapid integration of individuals into development teams and for successful professional collaboration. For example, Ramadi et al⁸ found that “an area where graduates appeared to have substantial deficiencies was the ability to manage time. Additionally, substantial improvements appeared to be needed in engineering graduates’ communication skills.” In a study, conducted in China, Peng et. al.⁹ came to this conclusion: “The curriculum should be expanded to cultivate the competencies of Communication and Coordination as well as Organizational Management. Student collaboration with enterprises and industry engineers should be maintained and further strengthened.”; which reflects the findings of Spinks et. al.¹⁰, who argue that “there was also strong support amongst the interviewees for ensuring that

⁶ Nguyen, Duyen Q.; *The Essential Skills and Attributes of an Engineer: A Comparative Study of Academics, Industry Personnel and Engineering Students*, Global J. of Engineering Education, 2(1), p.p. 65-75, 1998

⁷ May, Elizabeth; Strong, David S.; *Is Engineering Education Delivering What Industry Requires?*; Proceedings of the Canadian Design Engineering Network (CDEN) Conference, Toronto, Canada, p.p. 24-26, 2006

⁸ Ramadi, Eric; Ramadi, Serge; Nasr, Karim; *Engineering graduates’ skill sets in the MENA region: a gap analysis of industry expectations and satisfaction*; European Journal of Engineering Education, DOI: 10.1080/03043797.2015.1012707; 2015

⁹ Peng, Lijun; Zhang, Shulin; Gu, Jibao; *Evaluating the competency mismatch between Master of Engineering graduates and industry needs in China*, Studies in Higher Education, 41(3), p.p. 445-461, DOI: 10.1080/03075079.2014.942268, 2016

¹⁰ Spinks, Nigel; Silburn, Nicholas L. J.; Birchall, David W.; *Making it all work: the engineering graduate of the future, a UK perspective*, European Journal of Engineering Education, 32(3), p.p. 325-335, DOI: 10.1080/03043790701278573, 2007

undergraduates gained relevant industry experience, including vacation work, prior to graduation.”.

Two of the three partners in the development of the new study program (UL-FME and UZ-FMENA) had already previously recognized the above observations and successfully addressed them a decade ago in a joint European Global Product Realization¹¹ course of study. Developing a joint master's degree program in cooperation with TU Wien, their objective now is to raise the experience to a new, higher and more comprehensive level.

METHODOLOGY

In this paper we present the main findings of the industrial survey, performed by project partners as a part of intellectual output. The survey was designed for the purposes of preparing a new master study curriculum in order to identify the needs for new engineers in Austria, Croatia and Slovenia.

After the initial research of higher education trends in engineering, preliminary discussion with industrial partners and a comprehensive analysis of existing product development MSc courses, we prepared a set of questions to identify the industrial needs for new knowledge in the field of the development of new, smart products. The survey was created by four question categories: (1) demographic category; (2) three sets of selective (Likert scale) questions and one open question to investigate the field of existing and needed engineering knowledge and expertise; (3) a set of selective questions about product development in the companies; (4) and a set of questions about the position and role of “smartness” of new products in the company’s portfolio.

The questionnaire was put online as an anonymized web-based questionnaire, however, accessible only to the invited respondents. The selection of respondents was among professional profiles who have clear vision of company strategy and direct impact on future R&D trends in companies. These profiles are mostly executive staff and R&D personnel.

In the research, 58 people have participated – 24 from Austrian based companies, 24 from Croatian based companies, 9 from Slovenia, and one from Germany as well. They are from various fields of knowledge and company positions, but mostly from different fields of mechanical engineering (Figure 1).

¹¹ Žavbi, Roman; Tavčar, Jože; *Preparing undergraduate students for work in virtual product development teams*; Computers & Education: an international journal, ISSN 0360-1315, 44(4), p.p. 357-376, 2005

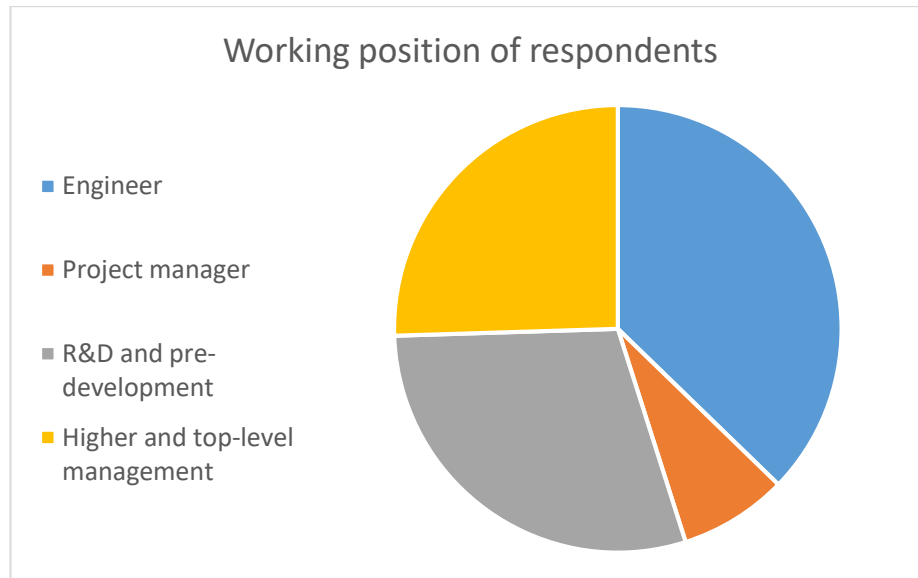


Figure 1: professional positions of respondents

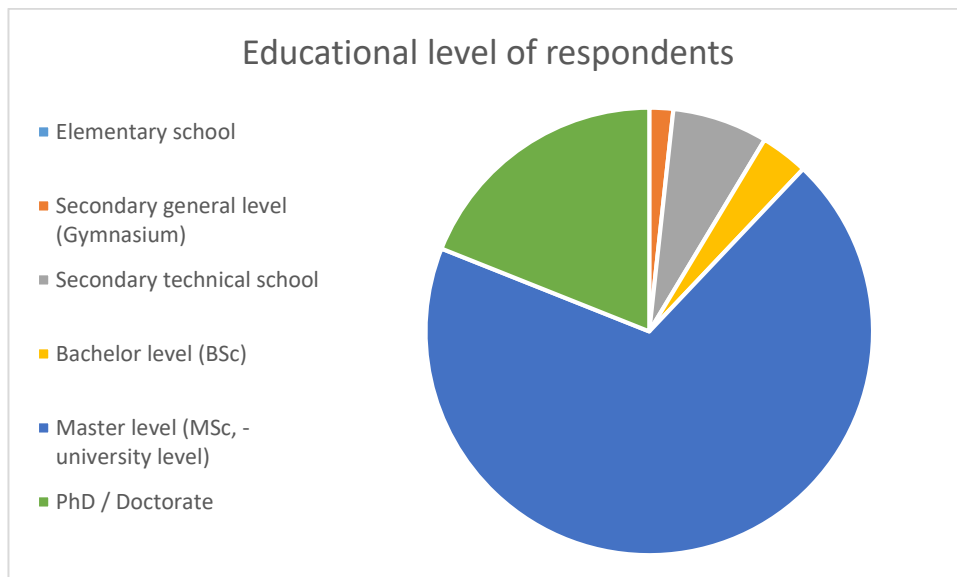


Figure 2: educational level of respondents

The educational level of respondents showed, that more than 88% of respondents are highly educated, having achieved a master's or even PhD level. Almost three quarters of all respondents hold a master's degree, which shows there is a large pool of population that requires the master's level for their job positions. Particularly interesting is also a large number of PhDs, showing the trend and needs for this level of knowledge and experience. We believe that both these shares will only increase in the future.

Unfortunately, the unbalanced gender representation in engineering is reflected also in this survey, where only 6.9% of respondents were female.

Age distribution chart shows that approximately half of the respondents are within their first decade of working experience in engineering. Since education programs do not change rapidly, it can be concluded that half of the respondents can critically evaluate the knowledge provided by universities at the master's level, while at the same time the younger generations are usually more familiar with new trends and technologies.

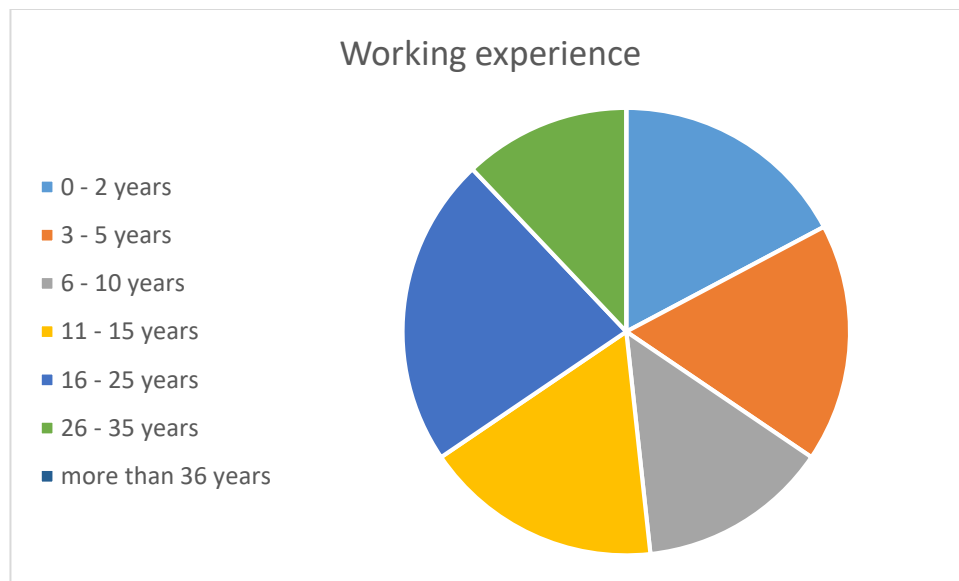


Figure 3: Working experience of respondents

The respondents were asked to answer three thematic sets of questions:

- questions about competences of new master engineers
- questions about the trends in product development process
- and questions about smartness of the products

The answers are presented on the following pages, together with our interpretation of the results.

RESULTS

Competences of newly graduated master's level engineers

The first set of questions asked participants of the survey about their opinion on the quality of the competences of newly graduated engineers in different traditional and emerging engineering skills, as well in some basic transverse skills, e.g. legal basics and business analytics. The selection of subjects mentioned in this survey was based on subjects (and their equivalents) currently being taught at all three universities, subjects that are included in competitive joint master courses around the world and enriched with some topics that are emerging in the field of development of smart and web-based products.

As expected, the traditional knowledge was well represented, especially the knowledge of machine elements and various CAD technologies. Both subjects are usually taught at the bachelor's level, so making a new engineering curriculum would not have a negative effect on the results. There are also some traditional engineering subjects, which should be reorganized or changed as

they do not perform well: material science in particular. This subject usually provides very fundamental knowledge about materials, with a huge emphasis on steel, however the engineers who are dealing with product development need deeper knowledge on the principles of proper material selection and availability and properties of different construction materials.

There was a significant lack of transitive knowledge; therefore, we emphasize improvements in that field – especially by implementing subjects about entrepreneurship, innovation, legal basics, management and business.

The third field of emphasis is new and multidisciplinary knowledge: both of which are only seldom taught at traditional mechanical engineering master courses. This knowledge should cover at least: big data, machine learning, Internet of Things, and cloud base solutions, robotics, electronics, product data management and automation.

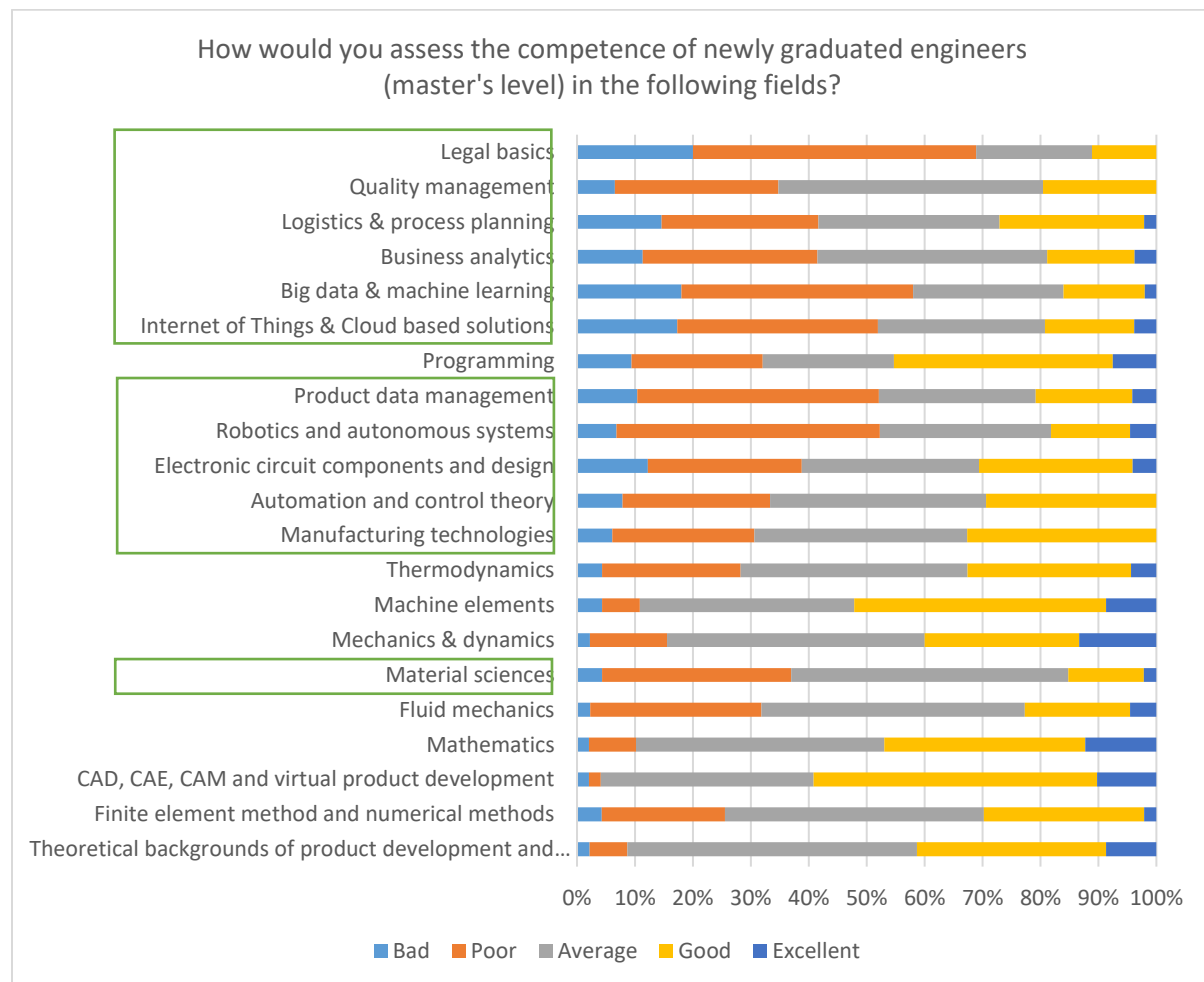


Figure 4: Skills and competences of newly graduated engineers according to industrial perception.

Trends in product development process

The second set of questions investigated how the product development process has changed in the past 10 years. The purpose of this question set is to identify the trends in product development, so the newly developed curriculum would properly address these changes. There are

two main identified shifts in the product development process: (1) the increased interdisciplinarity of the process; (2) and the shortened development cycle. Both shifts result in needs for outsourcing different sub-tasks and in the need to gather and analyze more data in a shorter time. Successful tools and methods exist to address these changes, however, students usually meet them for the first time only during their first industrial experience. Other research also showed a trend when a product is no longer in the focus of a company's business model and a source of income; instead it is the service the company can provide with these products (i.e. product service systems). The survey showed that less than 50% respondents agree with that, but the share of those who do not agree with this statement is less than 20%. This suggests that engineers are becoming aware of this trend (Figure 5).

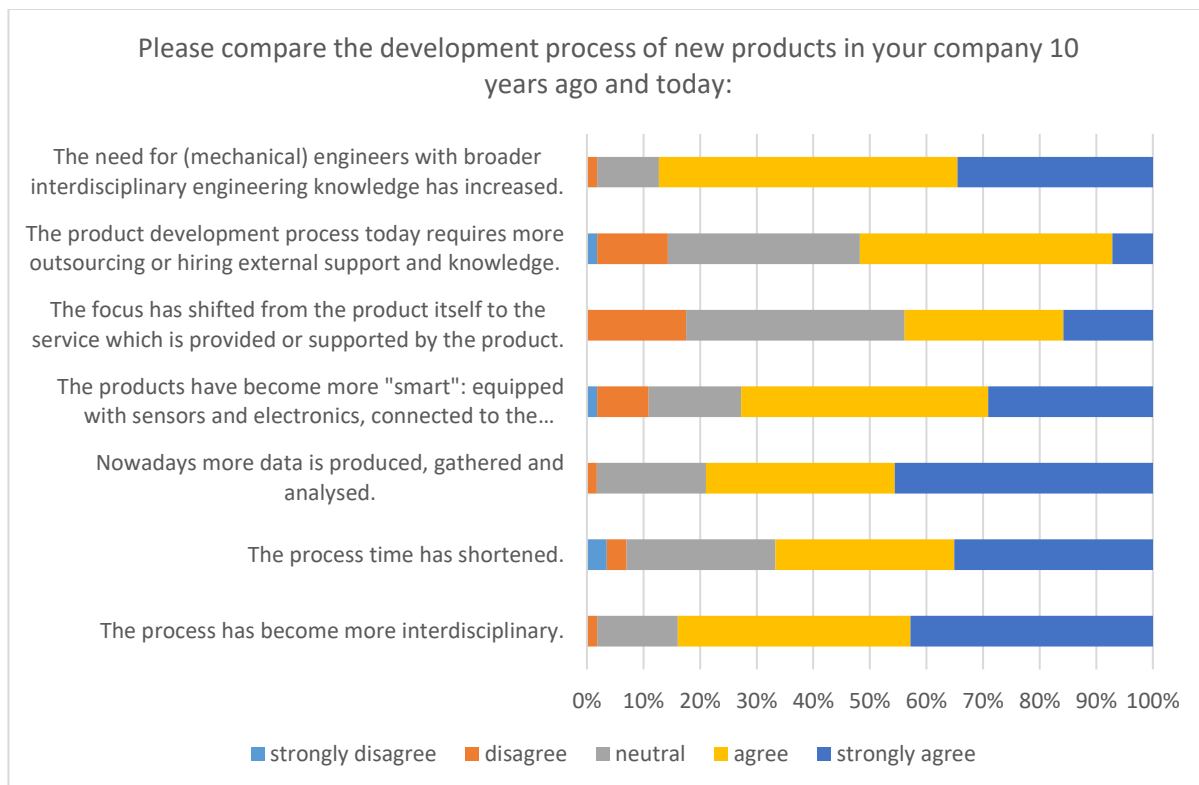


Figure 5: Trends in new product development in the past 10 years.

Smartness of the products

The third set of questions explored how the companies adapt to increasing smartness of the product. The respondents are strongly aware that smart technologies are inevitable for the improvement of their products in the future. Almost 50% strongly agree with the statement, while almost 90% agree or strongly agree that this will be the future. Furthermore, almost 50% of respondents admit that their products already include some level of smart technologies and 60% of respondents say their companies have a strategy to add value to the products by implementing smart technologies.

These results show positive trends in the observed industry. On the other hand, there are some concerns how to implement them. Namely, more than 50% of respondents say the companies

will have to reorganize their development teams and processes, while 40% think this will require also the reorganization of the business model and the organization of the company. The answer that the company does not have capacities to implement smart technologies is of particular concern. Only 20% of respondents think so, while more than 50% think the opposite.

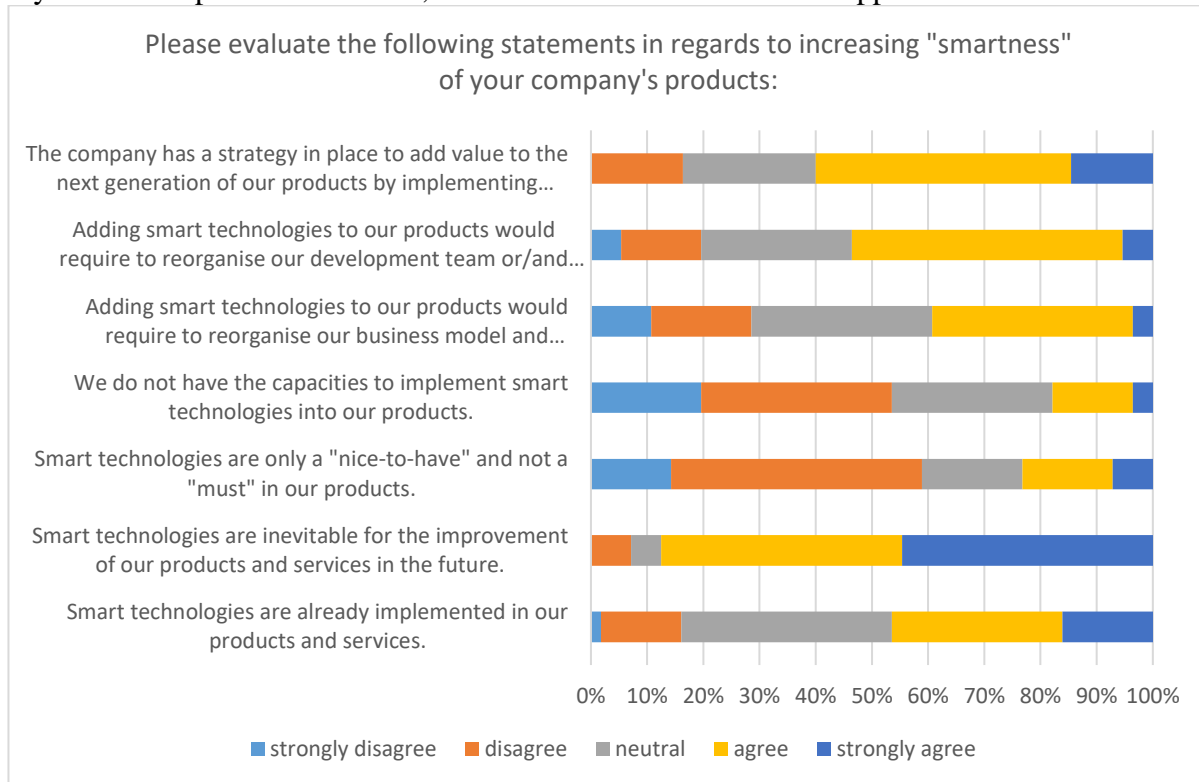


Figure 6: Perception of engineers about the »smartness« of their company's products

CONCLUSION

The paper presented the results of a research, performed by the authors among the industrial partners in Austria, Slovenia, Croatia and Germany. In the research, we tried to identify the skills and competences that industry will need in the next decade when new "smart" content will be increasingly expected from new products.

The results have shown that companies in Central Europe are aware of and follow global trends, and they are adapting their staff accordingly. As their main challenge, companies perceive the growing need for interdisciplinary skills and the introduction of new business models, made possible by smart products. In the future, the authors of this paper intend to produce even more in-depth analyzes in this field, and they are also working on a curriculum that will give young engineering graduates the skills and competences that industry needs in the fight on the competitive global market.

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