Engineering

SIMULATION AND ANALYSIS OF THE MILLING MACHINES RELIABILITY USING THE MONTE CARLO METHOD

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ABSTRACT:
STUDIES ON OPERATIONAL RELIABILITY AND DURABILITY OF MACHINES BECAME AN IMPORTANT ISSUE BECAUSE OF EXIGENCIES IN TERMS OF MAINTAINING ACCURACY WHILE PROCESSING RAPID REPLACEMENT OF WORN MACHINE TOOLS BY NEW ONES. MACHINE TOOLS ARE USED AT THE OPERATING REGIMES MORE INTENSE, WITH AN INCREASING DEGREE OF USE AND REQUIREMENTS FOR WEIGHT REDUCTION AND GAUGE WITH A GREAT EMPHASIS ON PRECISION PROCESSING DURING OPERATION. THIS PAPER DESCRIBES THE STUDY ABOUT INDICATORS OF RELIABILITY OF MILLING MACHINES USING MONTE CARLO SIMULATION BASED ON TIME OF FAILURE.

KEY WORDS: RELIABILITY, MEAN LIFE, MILLING MACHINE, ACCELERATED LIFE TEST, MONTE CARLO SIMULATION

INTRODUCTION

For the concept of reliability of machine tools should be considered both a machine working conditions imposed on as well as term of contents of the safe operating. The reliability of machine tools can be defined as the ability to operate without damage within a given time under certain conditions (precision machining, quality of processed surfaces).[1] This indicator called reliability is particularly important for machine tools that are part of automated manufacturing lines because by their failure the manufacturing processes interrupted[2].

Reliability depends on the machines wear, fatigue and aging. It is important that the machine tool to maintain processing accuracy throughout the exploitation[3]. Accuracy of the processing of machine tool decreases following the action on the mechanisms from the kinematic chains of degradation processes (wear, deformations, vibration of the components). To maintain processing accuracy of the machine tools, it has to be developed a machine tool to

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[1] Scott P. Anderson, *Machine Tools: Design, Reliability and Safety*, (Singapore: Nova Science Pub Inc, 2011), 1–38.
[2] Cristian Silviu Simionescu, *Maintenance and reliability machine*, (Bucuresti: A.G.I.R., 2014), 11–20.
[3] Constantin Militaru, *Reliability and accuracy in manufacturing engineering*, (Bucuresti: Tehnica, 1987), 191–210.

keep the same reliability regardless of the various external factors[5]. Thus, it requires the use of solutions in design, construction and reasonable exploitation that possible deviations: elastic deformations, the amplitude of vibration not to exceed allowable limits of resistance, to reduce the wear resistance of machine parts[4]. Therefore, reliability, durability, reparability and maintaining the processing accuracy of the machine tool are important in the determination characteristics of this goal and therefore the quality of the machine in terms of the functionality. Given the terms of reliability and maintaining the processing accuracy, the output of the operation of the machine tool can be perceived in two ways[5] (figure 1).

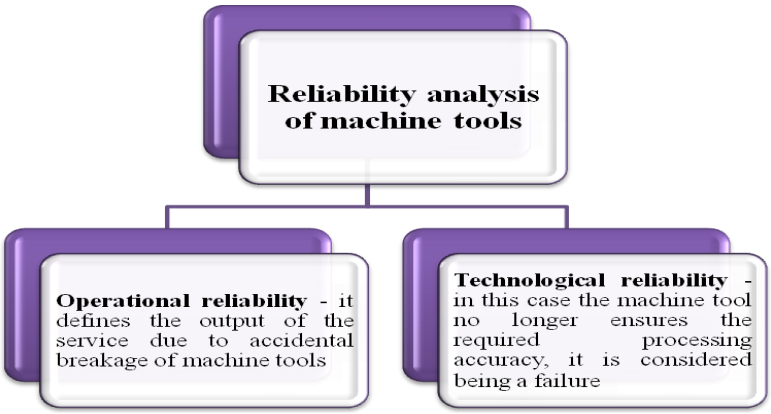

Figure 1. Reliability machine tools classification[6]

RELIABILITY OF MACHINE TOOLS

To study the reliability of milling machines using statistical methods and faultless uptime parameters that are used in this case are: reliability function, unreliability, failure rate, probability density function[7]. For reliability analysis in this paper will be studied universal milling machine described in figure 2.

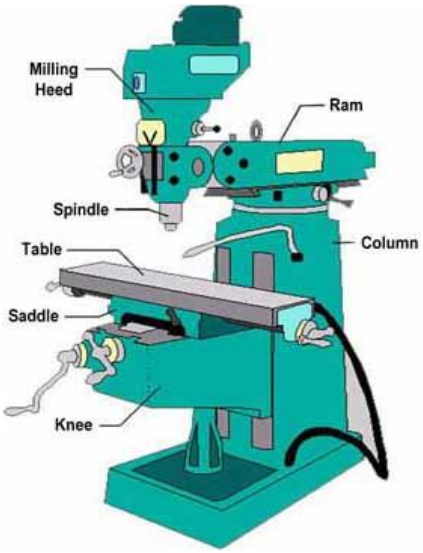

Figure 2. Milling machine

[4] Prakash Joshi, *Machine Tools Handbook*, (New Delhi: McGraw-Hill Education, 2007), 14 – 67.
[5] Richard R. Kibbe et al., *Machine Tool Practices,* (New York: Prentice Hall, 2014), 24 – 45.
[6] Mariana Deliu, *Reliability of machine tools*, (Brasov:Ed. Univeritatii Transilvania, 2002), 78 – 89.
[7] Sebastian Marian Zaharia and Ionel Martinescu, *Reliability tests*, (Brasov: Ed. Universitatii Transilvania Brasov, 2012) 23-34.

The theory of reliability was scarcely used until now in the manufacturing engineering. This situation is caused by many factors (figure 3):

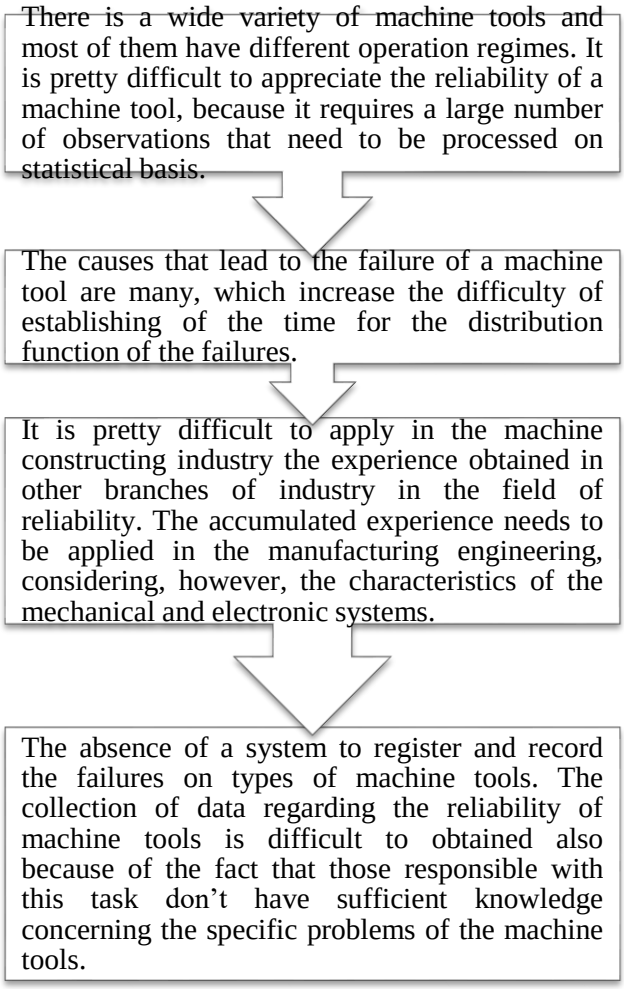

Figure 3. The technological difficulties in estimating the reliability of machine tools

The determination of the reliability indicators for the machine tools, in normal operation conditions, requires a long period of testing. The relatively long period of observation and experiments makes the values of the reliability indicators determined for the type of machines observed, as well as for the other observations made on the operation of some sub-assemblies, unusable by the designer. To obtain the values of the reliability indicators in a relatively short period of time (figure 3), we resorted to experiments made on prototypes or zero series by using a forced or accelerated work regime.

Accelerated life testing (ALT) is experiments in which: the physics (or chemistry) of degradation mechanism (or failure mechanism) is similar to the mechanism in the real operation using a given criteria; the measurement of reliability and durability parameters (time to failure, degradation and service life) have a high correlation with these respective measurements in the real operation a given criteria. Accelerated experiments is used in electronics (resistors, lasers, liquid crystal displays, electronic bounds, switches, relays, cells) in the study of metals and composite materials, but also for certain components and mechanical assemblies (hydraulic components, tools, bearings). The degree of interdisciplinary of research in the field of accelerated experiments is complex and can include the following industries: manufacturing engineering, the aerospace industry, the nuclear industry, the electronic

industry, the dental industry, the pharmaceutical industry and the industry of renewable energy resources.

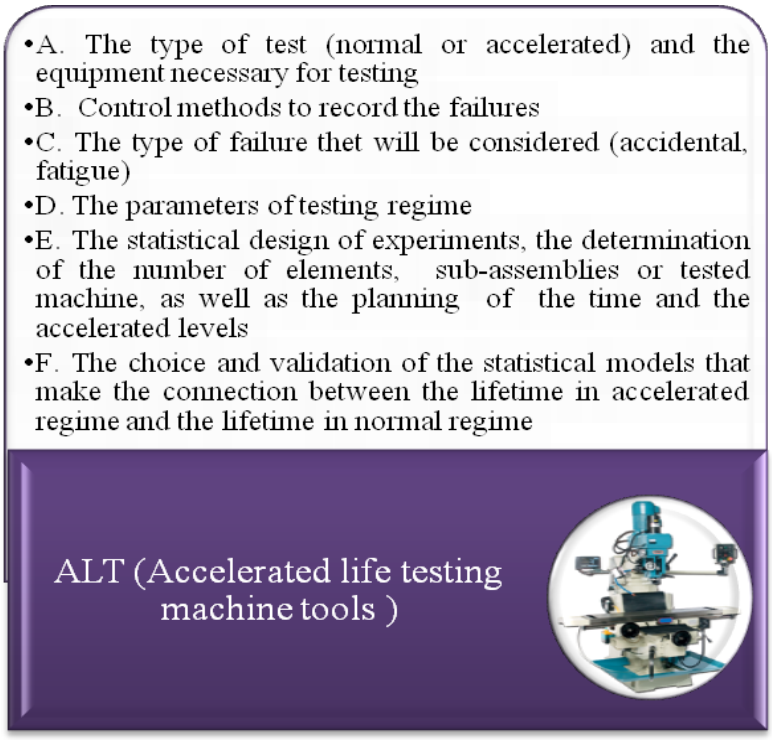

Figure 4. The stages necessary to the realization of the accelerated life testing

The execution of some tests in accelerated regime offers the following advantages:

- It offers the premises of some decisions and of construction and technological measures, applicable before the product goes into mass production;
- The reduction of the testing time and of the material costs afferent to the testing;
- It makes possible the fast detection of elements with a lower reliability and the estimation of the reliability indicators in a shorter amount of time.

MONTE CARLO SIMULATION OF ACCELERATED RELIABILITY TEST

Simulation in system reliability analysis is based on the Monte Carlo simulation method that generates random failure times from each component's failure distribution. The overall system reliability is then obtained by simulating system operation and empirically calculating the reliability values for a series of time values. Through the use of computers, simulation has become a very popular analysis tool. Simulation is simple to apply and it can produce results that can be rather difficult to solve analytically[8].

On milling machines most defects occur in mechanical systems (here including motors, couplings, gears, bearings). In this paper is analyzed the engine reliability of milling machines. The engines will have a more intense regime of operation, namely 2000 and 2500 rpm (the normal is 1700 rpm).

Using the Monte Carlo method we simulated N stages of a product with the help of an acceleration model (Inverse Power Law) and statistical distribution (Weibull) which are suited to the analyzed case study. Using the previously determined parameters (β=13; k=1.34E-10; n=1.61) and the two accelerated levels (2000 rpm and 2500 rpm), we simulated with the help of ALTA7 software the values for the number of cycles to failure in accelerated conditions

[8]ALTA Software, accessed October 25, 2015, http://weibull.com/

(figure 5).

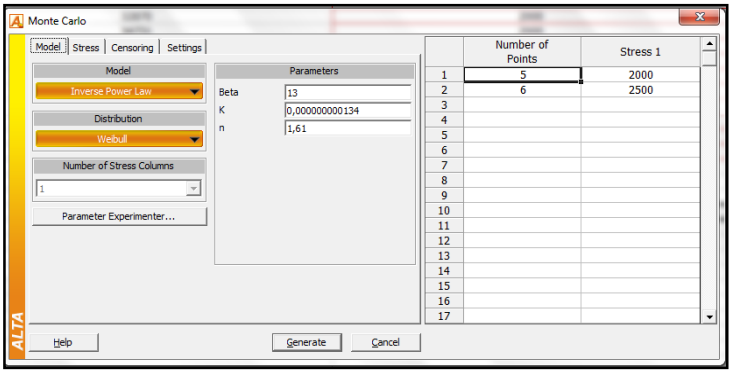

Figure 5. The simulation using the Monte Carlo method of the data in accelerated conditions for the engine from milling machine

Figure 6 shows the determination of failure times for the two accelerated regimes (2000 rpm and 2500 rpm) obtained with Monte Carlo simulation in ALTA 7 software. For the determination of the mean life and of the reliability parameters under normal testing conditions (1700 rpm) for the engines from milling machine, the experimental data resulted from accelerated conditions have been processed using the ALTA7 software

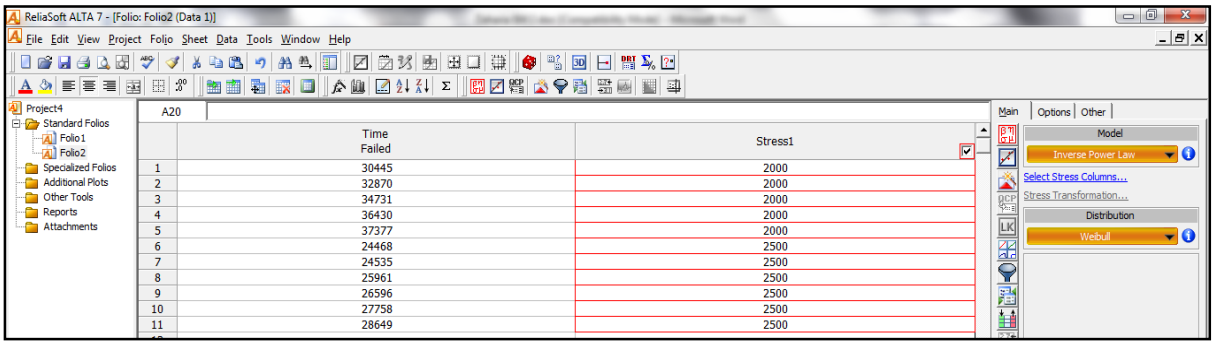

Figure 6. The accelerated test data from Monte Carlo analyzed in ALTA

It was determined the reliability parameters (the reliability function, unreliability and the rate of failure) depending on the number of hours to failure in normal testing condition. Using the calculated values (the number of hours in normal testing conditions), the reliability 3D (figure 7.a) and the unreliability (figure 7.b) were plotted.

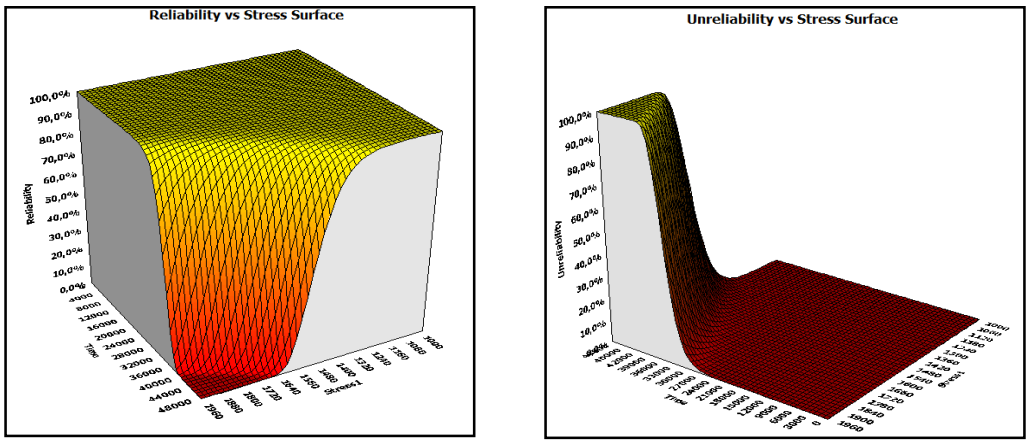

Figure 7. Reliability indicators

a) reliability function b) unreliability function

Using the calculated values (the number of hours in normal testing conditions), probability density function 3D (figure 8.a) and the failure rate (figure 8.b) were plotted.

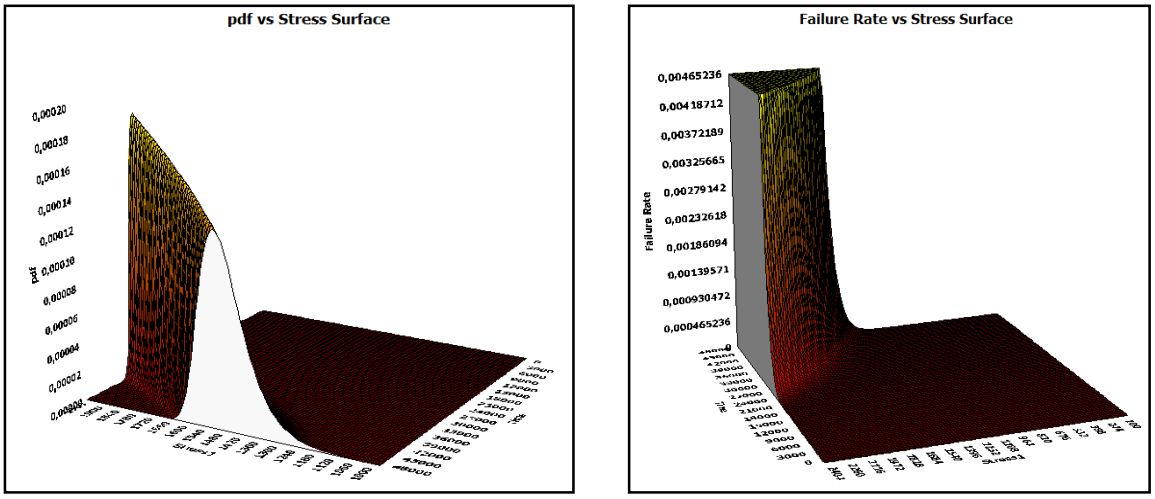

Figure 8. Reliability indicators
a) probability density function b) failure rate

Following the simulation of accelerated data using the Monte Carlo method for the engines from the structure of the milling machine, we obtained the value of 42110 hrs, which represents the mean life of the engines. The Quick Calculation Pad (QCP) provides you with a quick and accurate way of gaining access to some of the most frequently requested reliability results (figure 9).

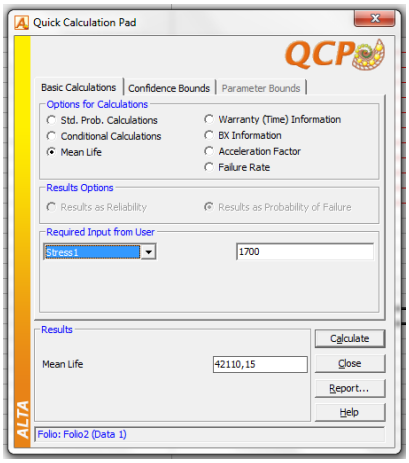

Figure 9. The calculation of the mean life in normal testing conditions for the engines with the Monte Carlo method using QCP

CONCLUSION

The study of reliability has become a matter of major interest for the companies in the field manufacturing engineering. This is due to the use of more intense work regimes, the increase of the intensity of use of the machine tools, the requirements regarding the reduction of the gauge and weight and especially regarding the accuracy of processing obtained during the time of operating. The complexity of the machine tools produced nowadays, the multitude of operation regimes, the rapid replacement of obsolete models with new ones, all of this condition the necessity of a general theoretical approach of the problems regarding the increase of reliability of all machine tools independent of their construction and destination.

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