Engineering

THE ANALYSIS AND DEVELOPMENT OF A MAINTENANCE PROGRAMME FOR THE FUEL SYSTEM

Sebastian Marian ZAHARIA[1]

ABSTRACT:
THE MAINTENANCE IS A COMPLEX ACTIVITY THAT COMPRISES TECHNICAL, ADMINISTRATIVE AND MANAGEMENT MEASURES TAKEN OVER THE LIFECYCLE OF A TECHNICAL SYSTEM – HAVING AS OBJECTIVE MAINTAINING IT OR BRINGING IT BACK IN A STATE IN WHICH IT CAN FULFIL THE NECESSARY FUNCTION. LIKE ANY TECHNICAL SYSTEM, THE AIRCRAFT SUFFERS A CONTINUOUS DEGRADATION PROCESS DURING ITS OPERATION. THROUGH MAINTENANCE OPERATIONS THE MAIN CHARACTERISTICS AND PARAMETERS OF THE AIRCRAFT ARE KEPT IN THE SO CALLED AIRWORTHINESS STATE. IN THIS PAPER HAS BEEN CREATED AND DETERMINED A MAINTENANCE PROGRAMME FOR THE FUEL SYSTEM AND THE TURBOSHAFT ENGINE OF A CS 27 LIGHT CATEGORY HELICOPTER.

KEY WORDS: MAINTENANCE, HELICOPTER, FUEL SYSTEM, MSG MAINTENANCE SCHEDULE, TURBOSHAFT ENGINE

INTRODUCTION

The maintenance is a group of technical, organizing and management activities whose main objectives are: ensures maximum performances are obtained for the technical system considered; resetting a technical system in the good working state; prevention of the technical systems to get out of regular functionality[2].

When planning how maintenance activities take place, important aspects to be considered are the company location, the activity profile, and the characteristics for the available means of production. The systematic approach considers the following maintenance activities' organising forms which, according to the allocated resources and the objectives, are directed to ensure the optimum availability of the technical systems[3]. The maintenance is classified in two categories:

---

[1] Lecturer PhD, Transilvania University of Brasov, Romania, email: zaharia_sebastian@unitbv.ro

[2] Nicoleta Teodorescu, *Mentenanță generală în domeniul ingineriei mecanice*, (Bucureşti: Editura A.G.I.R., 2008), 3–5.

[3] Ion Verzea, Gabriel Marc and Daniel Richet, *Managementul activității de mentenanță*, (Iaşi: Editura Polirom, 1999), 17–23.

a) The preventive maintenance is a group of systematic activities, programmed and repetitive having the goal: to check and maintain the good working state, to prevent the loss of reliability, to reduce the downtime for the technical system. In aviation, where the technical systems are the aircrafts (helicopters, airplanes), the uptime is assumed as airworthiness state (regular operations of: greasing, lubrication, regular testing/check of different systems and equipment, visual inspections, non-destructive tests, maintenance works, replacement works). The preventive maintenance watches the evolution of the working state for a technical system so that an intervention can be scheduled, after a reasonable delay necessary to acquire the replacement parts.

b) The corrective maintenance is a group of maintenance activities that take place after the malfunction of a technical system or after the unpredictable loss of its function. During these maintenance activities the defects are located and a diagnostic is given for the defects then the technical system is restarted with or without alterations. In aviation the corrective maintenance is triggered by: an alarm or a warning message on the instrument panel; abnormal aircraft or system (hydraulic, electric, controls) behaviour; finding malfunctions/anomalies during scheduled maintenance operations.

The main maintenance types are described in figure 1.

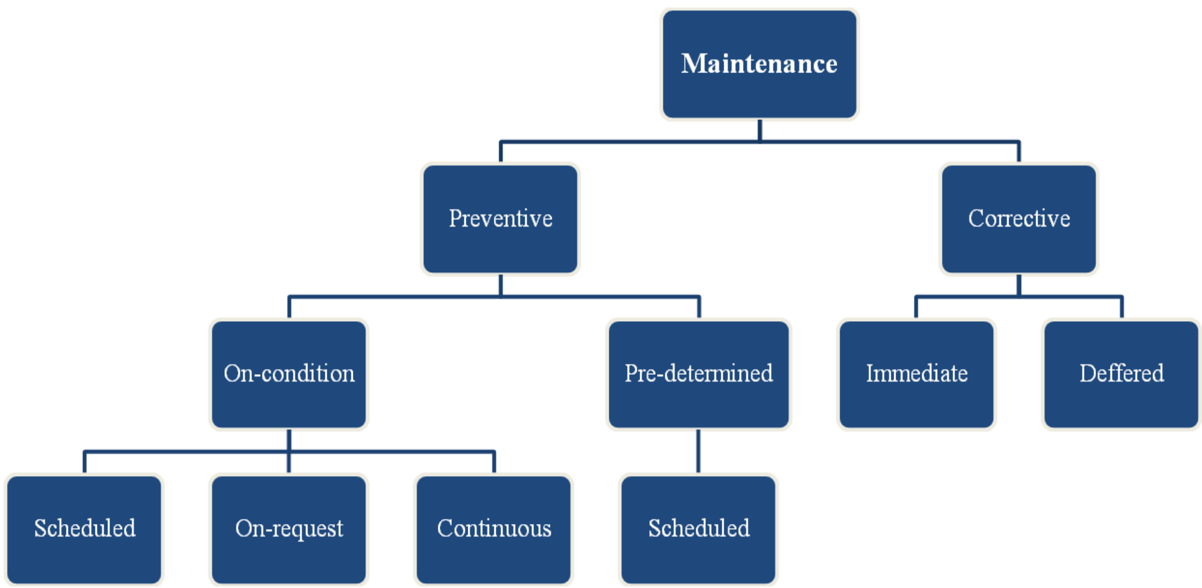


Figure 1. Major maintenance type[4]

The maintenance in each domain determines characteristics specific to the analysed domain. For this reason in aviation industry, the aircraft maintenance represents all of the inspection, check, repair, alteration action, having as a goal to keep the performances, potential and the technical availability of the aircraft with acceptable costs.

In figure 2 the main maintenance processes used in the aviation industry are defined[5]:

[4] British Standards Institution, *BS EN 13306: Maintenance Terminology*, 2001.

[5] Hong Kong Civil Aviation Department, *CAD 418 – Condition Monitored Maintenance:An Explanatory Handbook*, 2012.

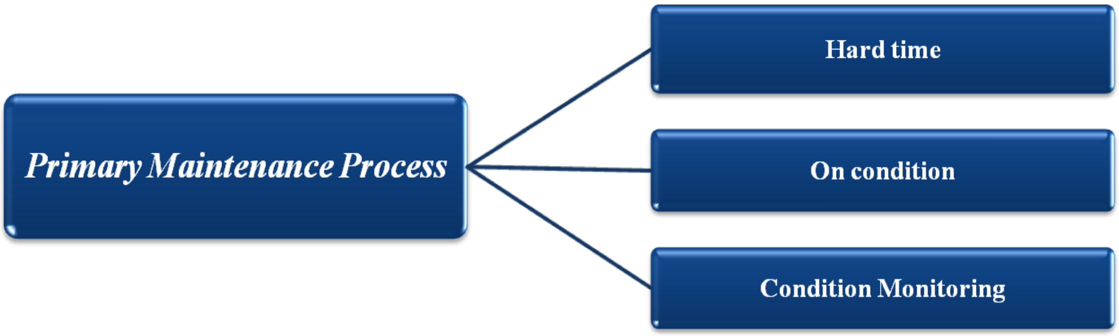


Figure 2. Major maintenance type

a) Hard Time Maintenance Process – a technical system constitutes the object of a time limit maintenance if that system has to be subjected to a maintenance operation before reaching the time limit. This time limitation can be expressed in flight hours, calendar time or number of cycles.

b) On-Condition Maintenance Process – a technical system is maintained after the state if it is subject periodically to state checking operations with the goal of controlling the evolution of certain degrading processes, well defined initially.

c) Condition Monitoring Maintenance Process – a technical system constitutes the object of this type of maintenance if it is subjected to maintenance operations after its failure. It is about failing elements that do not affect the safety of the aircraft.

In this paper the case study was done on a technical system (fuel system and turboshaft engine) from the structure of a helicopter. Further the maintenance programme for the fuel system shall be detailed and developed.

THE DEFINITION AND ANALYSIS OF A MAINTENANCE PROGRAMME

The definition, implementation and application of the maintenance programmes was based on the experience of manufacturers and airlines and proved that the most effective is to use a components' logical analysis for the aircraft's structure, based on the study and analysis of failing modes' consequences and on the main wearing modes observed.

MSG-3 (Maintenance Steering Group) is a document developed by the Airlines For America (A4A) and it objective is to present a methodology to be used for developing scheduled maintenance tasks and intervals, which will be acceptable to the manufacturers, operators and regulators. The main objective behind this concept is to know the inherent reliability of aircraft systems and components, avoid unnecessary maintenance tasks and achieve increased efficiency. MSG-3 is generally used to develop initial maintenance specifications for aircraft which are published as a Maintenance Review Board Report and consist of four essential sections: Aircraft Systems and Powerplant, Aircraft Structures, Zonal Inspections and Lightning[6].

The aeronautic regulations (CS, FAR, JAR) require that the MSG-3 procedure takes place during the type certification and the recommended maintenance program and the maintenance documents are developed and approved before the aircraft delivery. For the MSG-3 procedure to take place, is required an organizing structure formed by: the manufacturing company (structure engineer, engine specialist engineer), the aircraft operator and the aeronautic authority.

Industry Steering Committee establishes: the strategy and the objectives of preventive

[6] SKYbrary. MSG – 3 – Maintenance Steering Group – Operator/Manufacturer Scheduled Maintenance Development, Accessed September 19, 2016. http://www.skybrary.aero/index.php/MSG-3.

maintenance; coordinates the Maintenance Working Groups' activity; collaborates with the aircraft manufacturer and the user; communicates with the aeronautical authority; elaborates the final form of the recommended maintenance programme that needs to be shown to the aeronautical authority. Every work group makes a specific and detailed analysis of the following elements: hydraulic systems, electrical systems, avionics, controls and drives; propulsion systems; aircraft structure; structural areas that interfere with the drive systems, pipes, cabling.

The Maintenance Review Board elaborates the Maintenance Planning Docunent[7]. This document contains the preventive maintenance operations that need to be applied by all aircraft users.

The Maintenance Planning Document represents a minimal platform for the users and customized to each operation situation. The maintenance programme can be altered in time by expanding the time intervals for inspection, simplifying maintenance operations – with the aircraft manufacturer and aeronautic authority's approval[8].

CASE STUDY – FUEL SYSTEM AND TURBOSHAFT ENGINE MAINTENANCE SCHEDULE

To make the fuel system's maintenance programme, the ReliaSoft MPC software was used. This was done together with the Honeywell's Aircraft Engines and Systems division. The software was designed to assist the engineering teams to efficiently and accurately analyse and maintain the aircraft's turbine engine groups and systems.

ReliaSoft's MPC has been designed to assist MSG-3 working groups to perform Systems and Powerplant Analysis, Structural Analysis and/or Zonal-L/HIRF Analysis in accordance with the MSG-3: Operator/Manufacturer Scheduled Maintenance Development guidelines. MPC-3 facilitates the analysis process, provides flexible data management capabilities and offers automated report generation in templates that have been accepted for submission to the aircraft industry maintenance review board[9].

For this paper's case study the maintenance programme was designed and analysed for a CS-27 light helicopter turboshaft engine.

To design the maintenance programme the systems for which the maintenance is done are specified, respectively (figure 3):

---

[7] European Aviation Safety Agency. Maintenance Review Board Process (MRB) And Instructions for Continued Airworthiness, Accessed September 20, 2016. https://www.easa.europa.eu/system/files/dfu/ws_prod-g-doc-Events-2010-jan-19-Ref-9.-MRB-process.pdf.

[8] ReliaSoft Company, MSG-3 Compliant Maintenance Program Creator, accessed September 23, 2016, http://www.reliasoft.com/mpc/features1.htm.

[9] European Aviation Safety Agency, Where Does the Maintenance Planning Document (MPD) Come From?, Accessed September 20, 2016. https://www.easaonline.com/blog/entry/where-does-the-maintenance-planning-document-mpd-come-from.

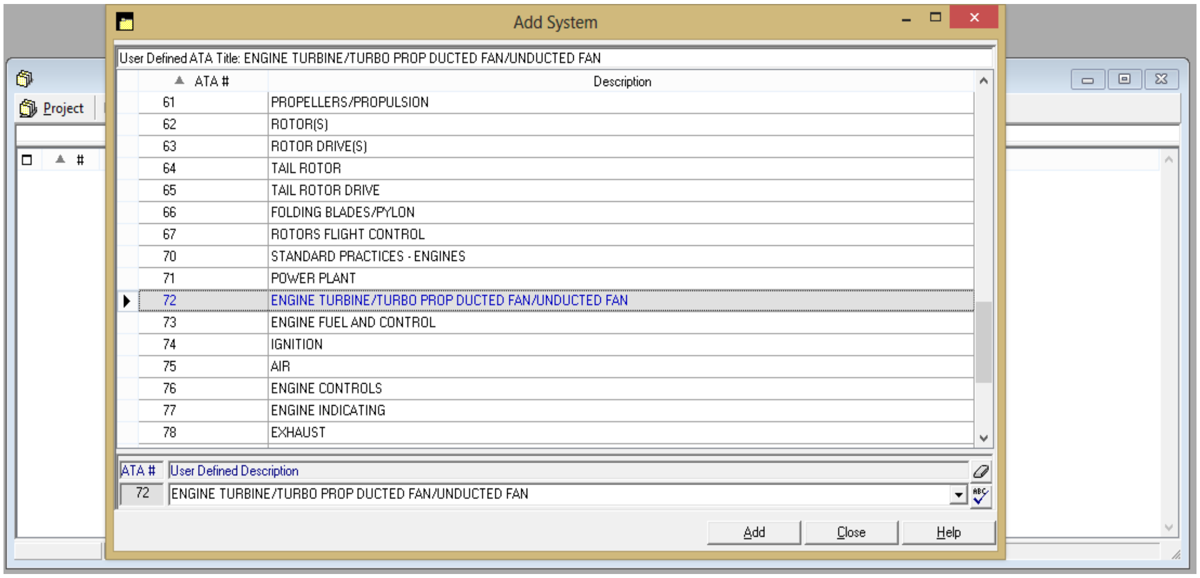
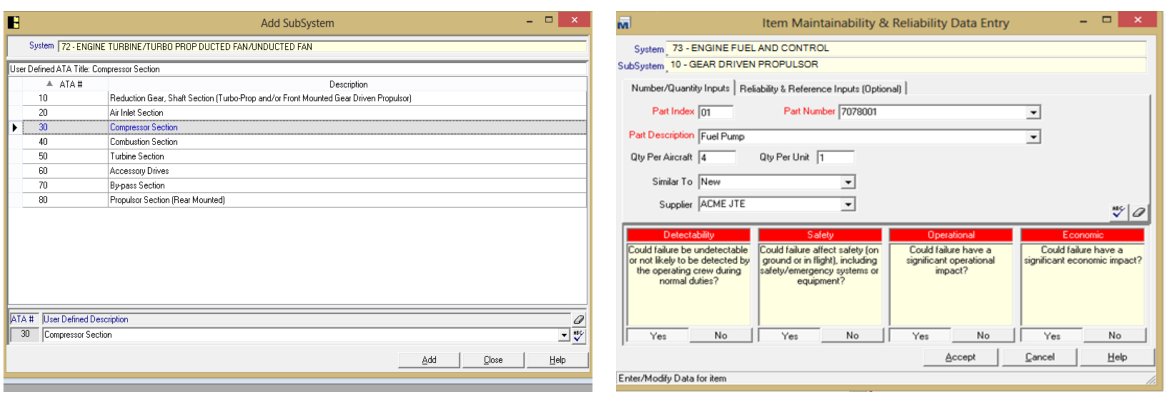


Figure 3. Helicopter components

The next step in the analysis and design of the maintenance programme for the helicopter's fuel system is to define the specific subsystem of every system, with the components and functions specific to each of it.

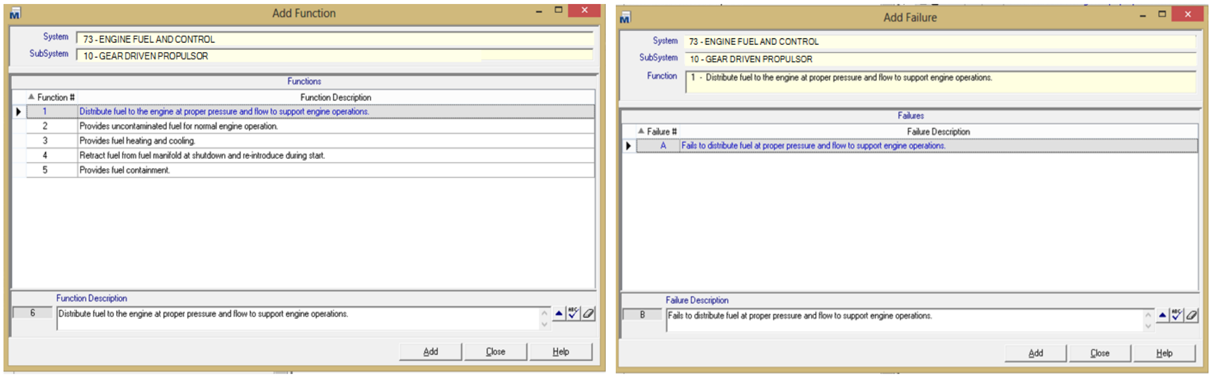
For example a subsystem can be the fuel distribution system, from within the fuel control system. The subsystem is composed, in its turn, from more elements like: fuel pump, fuel collector, pipes, fuel filters (figure 4):



a) b)

Figure 4. (a) The addition of engine's subsystems (b) The addition of components

For each subsystem are specified the functions that it has (figure 5.a), the defects that may appear (figure 5.b), the consequences of these defects being produced (figure 6.a) as well as the producing causes of these defects (figure 6.b).



a) b)

Figure 5. (a) The addition of functions (b) The addition of defects

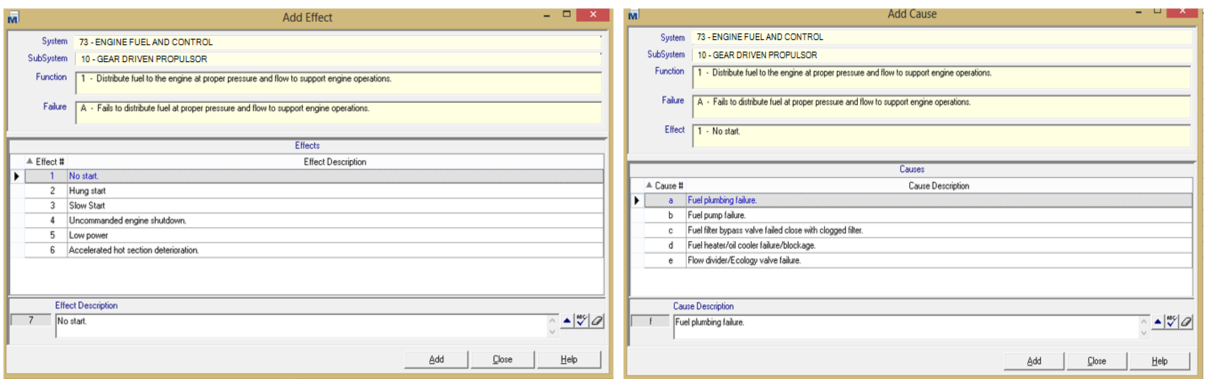


Figure 6. (a) The addition of effects (b) The addition of causes

Thus, in order to avoid these problems, a checking interval is specified, to prevent defect occurrence. This interval depends on each inspected element, being different from one element to another. The interval can be given as number of flight hours or take-off - landing cycles. Both the elements that need to be checked as well as the checking interval are to be found in the report generated by the MPC software. The maintenance programme's report is generated in table format and is shown separate for each component of the fuel system (table 1) and for the entire engine (table 2).

Table 1. The maintenance programme's report for the fuel system

Task Number	Task Description	Interval	Observations
731000-201	Visual general inspection of the fuel system	4000 flight hours	The inspection of the pipes and the state components, safety and leakage signs
731000-202	Detailed inspection of the fuel nozzles (flow check)	7000 flight hours	Sample taking: cleaning, flow checking. Initial interval 1750 h ± 250 cycles

731000-203	Removal of the fuel filtration elements	5000 flight hours	Replacement of the fuel filter when indicates imminent bypass 5000 flight hours, according to which comes first
731000-204	Visual general inspection of the engine's cable equipment harness	4000 flight hours	Area transfer – inspection for friction, breaks, weak connectors and proof of contamination or corrosion.
731000-205	Visual general inspection of the fuel's air cooler.	4000 flight hours	Area transfer – Status inspection, safety and radiator cleaning.
731000-206	Engine oil level check.	100 flight hours	Check for fuel smell and raised level

Tabele 2. The engine's maintenance programme report

Task Number	Task Description	Interval	Observations
723000-201	Engine oil level check	100 flight hours	Check for excessive oil consumption
723000-202	General visual inspection of the engine's leak pole	100 flight hours	Inspection for signs of excessive oil leaks
723000-203	Special detailed inspection of the compressor module	12000 flight hours	Sample taking: Digital visual inspection with borescope Initially: 1750 flight hours

Table 2 (continued). The engine's maintenance programme report

723000-204	General visual inspection of the compressor case	4000 flight hours	Inspection for cracks, dents, weaken or missing equipment.
723000-205	Detailed inspection of the frontal frame, the attachment points of the engine's frontal mounts.	4000 flight hours	Inspection for corrosion signs, loose or missing equipment, having the engine installed on the aircraft.

723000-206	General visual inspection of the fan's exterior frontal duct	4000 flight hours	Inspection for cracks, dents, safety, destruction of the brittle bushings and corrosion signs
723000-207	Operational fan rotor check	500 flight hours	Manual spin of the fan and check for loosening and unusual noise
723000-208	General visual inspection of the fan rotor and stator	500 flight hours	Area transfer – inspection of the fan and stator for breakings and the rotor fan for loosening

CONCLUSION

The maintenance represents an important part of the operation process for an aircraft because of the need to have a high degree of safety for pilots, passengers and of course for the overflown population. This need to maintain a high degree of safety is being satisfied by applying a set of preventive and corrective maintenance procedures to the aircrafts. The design of a maintenance plan determines along the service time a raised economic efficiency and a reduction of the maintenance costs. The analysis and design of a MSG-3 maintenance programme represents a development method for aircraft and aircraft components' maintenance/inspection tasks.

The aircraft engines are vital components and for this reason corrective maintenance (after the malfunction appears) cannot be used. Thus is required to apply preventive maintenance by careful monitoring of the propulsion system's performance state. For different engine components the maintenance works done are visual inspections, performance monitoring, functional checks, planned replacements etc. after a certain number of flight hours or when malfunctions are found (wear, deteriorations, missing parts etc.) according to the maintenance software generated report.

REFERENCES

1. **Teodorescu, Nicoleta;** *Mentenanță generală în domeniul ingineriei mecanice*, Bucureşti: Editura A.G.I.R., 2008;
2. **Verzea, Ion, Marc, Gabriel and Richet,** Daniel; *Managementul activității de mentenanță*, Iaşi: Editura Polirom, 1999;
3. **British Standards Institution**, *BS EN 13306: Maintenance Terminology*, 2001;
4. **Hong Kong Civil Aviation Department**, *CAD 418 – Condition Monitored Maintenance:An Explanatory Handbook*, 2012;
5. **SKYbrary MSG – 3 – Maintenance Steering Group,** – Operator/Manufacturer Scheduled Maintenance Development, Accessed September 19, 2016. http://www.skybrary.aero/index.php/MSG-3;
6. **European Aviation Safety Agency**, Maintenance Review Board Process (MRB) And Instructions for Continued Airworthiness, Accessed September 20, 2016. https://www.easa.europa.eu/system/files/dfu/ws_prod-g-doc-Events-2010-jan-19-Ref-9.-MRB-process.pdf;
7. **ReliaSoft Company**, MSG-3 Compliant Maintenance Program Creator, accessed September 23, 2016, http://www.reliasoft.com/mpc/features1.htm;
8. **European Aviation Safety Agency**, Where Does the Maintenance Planning Document (MPD) Come From?, Accessed September 24, 2016. https://www.easaonline.com/blog/entry/where-does-the-maintenance-planning-document-mpd-come-from;