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FAILURE ANALYSIS OF TURBOPROP MEDIUM COURIER AIRCRAFTS

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The criticality and the probability of occurrence of a failure are evaluated quantitative to allow the choice of corrective actions that are required and determining their priorities, as well as setting the boundary between accepted and unaccepted risk. In this paper, the effect of failures of a medium courier aircraft are analyzed, using the failure mode, effects an criticality analysis. The defects are ranked according to the severity and frequency of occurence, as well as the possibility of detecting them.

Key words: aviation, critical parts, turboprop aircraft, failure, maintenance, reliability

1. Introduction

Logistics management in the context of a system involves the planning, directing, organizing, and controlling of all activities necessary to accomplish all the requirements of the sustaining maintenance and support of the system throughout its period of utilization and later during retirement as materials are phased out, recycled or subject to disposal [1]. In approaching the systems, experience has shown that their complexity has increased in many cases with the introduction of new technologies, efficiency, and quality aspects for many of the systems have decreased and the costs associated with their operation and maintenance have increased significantly [2, 3]. When we approach cause-effect relationships, a large percentage of the high costs of operating and supporting the system is attributed to engineering and management decisions taken in the early stages of conceptual and preliminary system design [4]. Decisions in the system design stage, associated with the selection of technologies, equipment/systems packaging systems, two or three levels of maintenance and the use of automation compared to manual performance of functions, have a large impact on logistical support and of total life cycle cost [5, 6]. Reliability centered maintenance, RCM, is the set of actions and measures carried out in order to establish the program and

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content of maintenance to be performed to maintain and possibly restore, when necessary, the technical condition of the system, using analyzes of failures, safety analysis, functional analysis, etc. [7].

RCM requires a specific process used to identify policies to be implemented in order to control failure modes that may lead to functional defects of any equipment operating in a particular operational context [8]. The Failure Mode, Effects and Criticality Analysis, FMEA, for RCM application is an effective method that can provide answers to system failure. The method consists in identifying the possible failures of each component of the system, the causes of the identified defects, and the consequences that the defect has on the subsystems or the whole system [9, 10]. The originality of the method consists in the possibility of ranking the defects according to the severity and frequency of occurrence, as well as the possibility of detecting them [11]. Simplified failure and effects analysis is a model used in US industry [12].

2. Defining parameters and the calculus of the risk priority number

The failure analysis in the present study is with respect to the risk priority number, RPN, as part of FMEA, and RCM, respectively. For each mode of failure, a potential effect of the failure is anticipated as the gravity (or severity) that the failure could have in the system functioning objective (the mission for which it was designed) [13]. The associated index/ rank, G, and the significance of the failure gravity are proposed as presented in Table 1.

Table 1

Gravity of the failure

G	Significance
1	Insignificant effect, corrected immediately by the technician.
2	Insignificant effect, corrected immediately by maintenance personnel.
3	Minor effect, the component element will suffer a gradual degradation if not intervened. The mission is not affected.
4	Moderate effect, mission may be affected. A repair may be required along the way.
5	Moderate effect. Surely repairs will be needed, and the mission is partially damaged.
6	Moderate to high effect. A certain part of the mission cannot be accomplished. Delays in restoring function.
7	High effect. An important part of the mission cannot be accomplished. Significant delays in restoring function.
8	High effect. The mission cannot be accomplished. Significant delays in restoring function.
9	Effects on operational safety, consequences for crew health and the environment. The operation is stopped with the warning of the crew.
10	Effects on operational safety, consequences for crew health and the environment. The operation is stopped without warning the crew.

The next step is to evaluate the frequency of failure. In general, this indicator must be established for each fault mode taking into account the maintenance activity history for the last three years. The associated index/rank, F, reference value and the significance of the failure frequency are proposed as presented in Table 2.

Frequency of the failure *Table 2*

D	Reference atribute	Significance
1	1/10000	Very low failure rate. We should not expect the defect to occur.
2	1/5000	Low failure rate. The fault is unlikely to occur.
3	1/2000	Low failure rate, similar to that of products already checked.
4	1/1000	Moderate to low failure rate, previously checked.
5	1/500	Moderate failure rate, previously verified.
6	1/200	Moderate to high failure rate, previously verified.
7	1/100	High verified failure rate.
8	1/50	High failure rate. It can cause problems.
9	1/20	Very high failure rate. Problems will almost certainly arise.
10	1/10+	Very high failure rate. Surely problems will arise.

Detectability of failure is a parameter that considers the possibility of detecting the defect [14], if it occurred. The associated index/ rank, D, reference attribute and the significance of the failure detectability are proposed as presented in Table 3.

Detectability of the failure *Table 3*

D	Reference atribute	Significance
1	Almost sure	Automatically detected fault.
2	Very high	Most likely the fault is detected very quickly.
3	High	Most likely, known control operation will detect the fault.
4	Moderately high	There is a moderately high probability that known control operations will detect the fault.
5	Moderate	There is a moderate probability that known control operations will detect the fault.
6	Low	There is a low probability that known control operations will detect the fault.
7	Very low	There is a very low probability that known control operations will detect the fault.
8	Hard to detect	In some cases, known operations may detect the fault.
9	Improbable	Known control operations are unlikely to detect the fault.
10	Almost impossible	No control operations are known to detect the occurrence of the fault.

The effective failure data have to be registered, for example as presented in Table 4.

Table 4

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

where, in principle: 1 is the component name, 2 - failure date, 3 - failure discovery date, 4 - function, 5 - functional defect, 6 - failure identification method, 7 - failure causes, 8 - failure effects, 9 - G value, 10 - F value, 11 - D value, 12 - RPN value, 13 - improvements, 14 - new F value, 15 - new D value, 16 - new RPN value.

The risk priority number, RPN, is calculated as product of indices G, F, and D, i.e.

$$RPN = G \times F \times D \quad (1)$$

RPN is analyzed with the main purpose to optimize its value, by improving the preventive maintenance and the monitoring system. The necessary improvements will be made, as additional predictive maintenance that could, for example, detect misalignments, imbalances, etc. Frequency and detectability indices will be reevaluated, in order to obtain the new RPN.

The failure mode and effects simplified analysis results are referring to three evaluating criteria:

(1) The impact of the defect on the functioning capacity of the technical system;

(2) The probability that a specific mode of failure will occur, probability given by previous experience or existing statistics in the literature;

(3) The probability of detecting the defect before production, but with the means of maintenance that are available at that time.

3. FMEA analysis of a medium courier turboprop aircraft

Two aircrafts, generically named as Aircraft A and Aircraft B, were analysed during two years of operating, 2016 and 2017. A total of 308 defects resulted, of which 170 - on plane A and 138 - on plane B.

The main elements associated to the considered analysis are as follows.

3.1. Failures of aircraft structure components

Most structure components failures were detected during the preliminary flight preparation, as 26 out of 54 total cases (Fig. 1, a). It is to remark that preventive maintenance and the monitoring system are highly efficient.

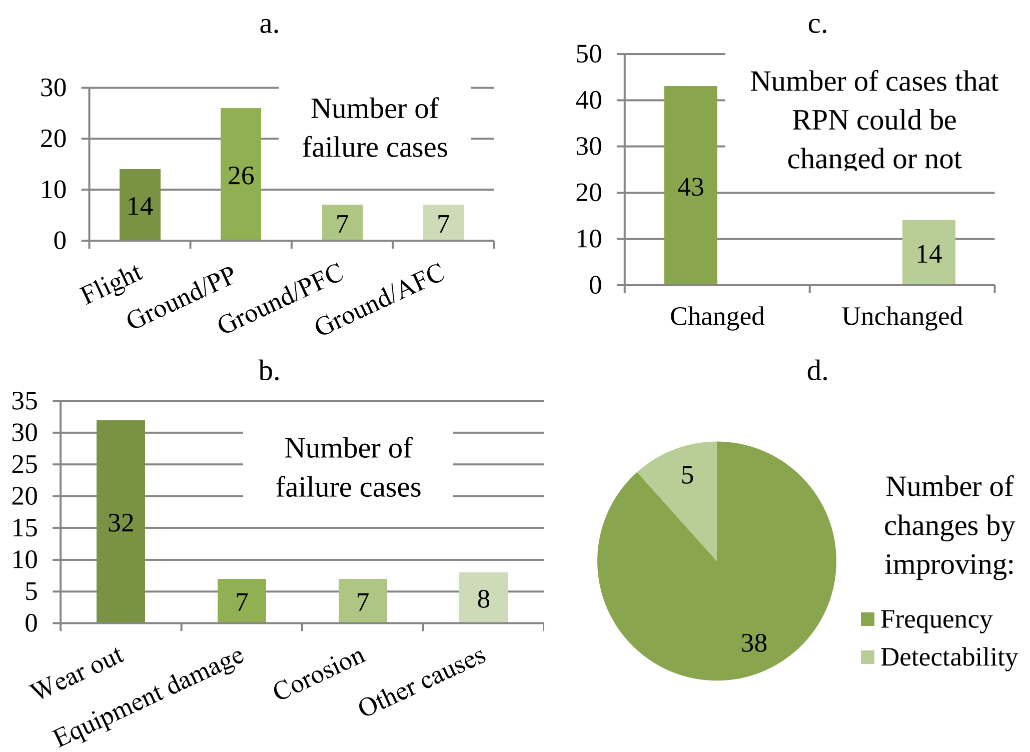

Fig. 1. Data associated to structure components failures – place/ type of preparation where these were discovered (a), causes (b), RPN changes (c), number of changes by improving the frequency or detectability (d)

The main cause of defects is the wear, as 32 out of 54 total cases (Fig. 1, b), most likely due to their age and the vibrations that affect the cell and its aggregates. The RPN could be considerable modified, as 75% (Fig. 1, c), mainly by decreasing the failure frequency, i.e., index F. Thus, it can be deduced that the detection methods have a high yield, but initial F is characterized by a high value; the critical situations can be reduced by identifying as accurately as possible the aggregates with a high risk of failure and replacing them with some with higher reliability, adapted to the operating conditions (temperature, vibration, corrosion, etc.). This entails additional maintenance costs, but it is justified by higher aircraft availability and increased operational safety.

Existing methods for monitoring the system are sufficient to detect faults before they occur, in most cases. In some cases, the defects are caused by the relatively low reliability of the parts, but this can increase and lead to a decrease in the frequency of defects, even involves additional costs.

3.2. Failures of aircraft engine components

The charts (Fig. 2) present that most of the failures occurred during the flight and were mainly caused by clogging of the injectors and filters (from the lubrication system, fuel and hydraulics), which leads to the conclusion that preventive maintenance and monitoring system in technical systems of the engine type it is not carried out at maximum efficiency. Another important factor is the wear of the components, a somewhat normal situation, due to their age and the stress to which they are subjected under to high vibrations and temperatures inside/outside the engine, which decisively affect them.

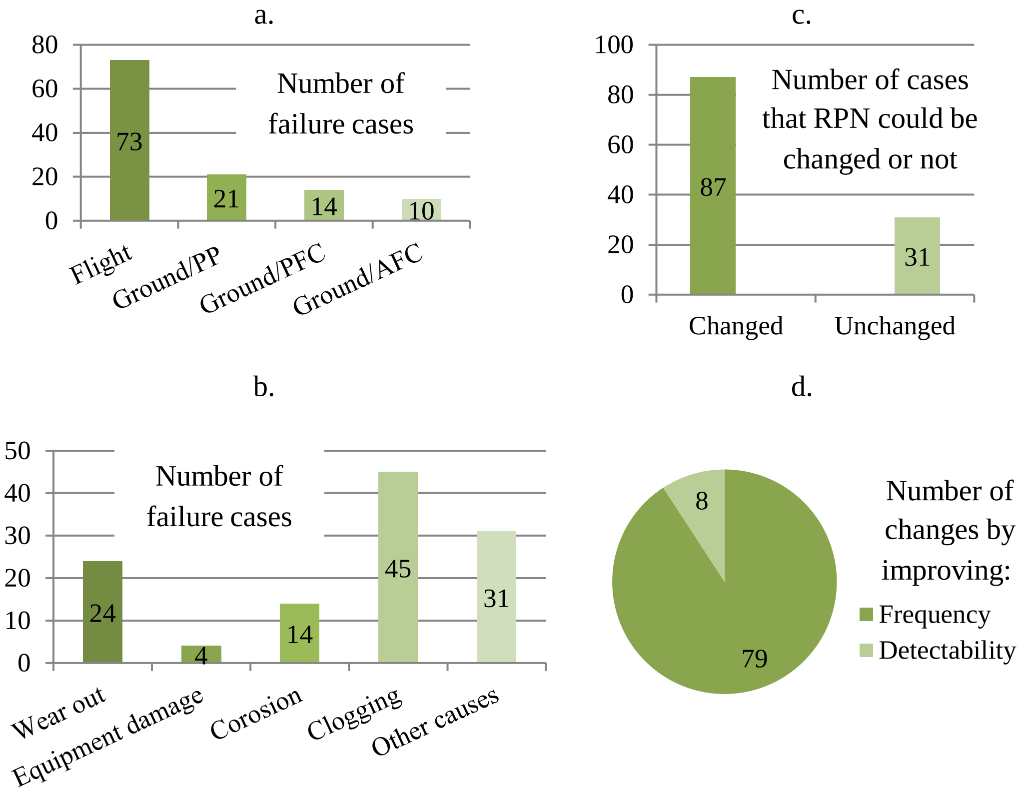

Fig. 2. Data associated to engine components failures – place/ type of preparation where these were discovered (a), causes (b), RPN changes (c), number of changes by improving the frequency or detectability (d)

It was possible to improve the RPN, in a large percentage, 74%. Like the analysis for structure technical systems, the engine-type systems involve the necessity to identify components with a high risk of failure and replace them with more reliable ones, adapted to operating conditions, with additional costs to ensure a proper maintenance.

It is necessary to streamline preventive procedures in order to reduce the probability of failure, by implementing predictive detection methods by using statistical detection methods and by compiling databases with defects found in the operation and highlighting the occurrence of new defects.

3.3. Failures of aircraft radio components

Among the causes underlying the occurrence of failures, it is observed (Fig. 3) that wear is by far the main reason, having the highest percentage compared to other specialties. Radio parts are sensitive to vibrations with high amplitudes and exposed for a long time (taking into account their age).

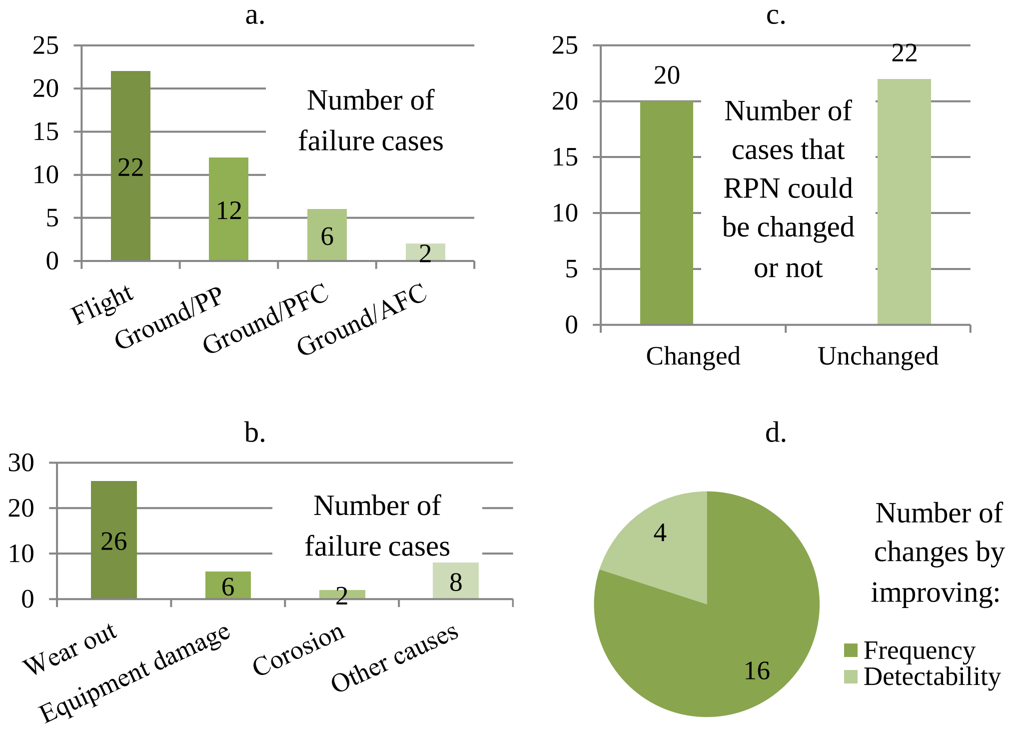

Fig. 3. Data associated to radio components failures – place/ type of preparation where these were discovered (a), causes (b), RPN changes (c), number of changes by improving the frequency or detectability (d)

The RPN could be changed in a lower percentage compared to other specialties, but the rule of improvement is maintained, optimizing it by reducing the frequency of failures in most situations. This can be influenced both by identifying the aggregates prone to damage, wear, corrosion, condensation, etc. as well as by replacing them with some with a high reliability, purchased directly from the manufacturer.

Detection methods can also be improved by specializing maintenance personnel in order to be able to identify in the structure of the aggregates, the components with lower reliability. It should be emphasized that the method entails additional maintenance costs, the adoption of which is dictated by the value of the investment.

3.4. Failures of aircraft special systems

According to the chart (Fig. 4), most of the defects were identified during the flight (60%), a result which is the same as in the case of radio-type systems because some of the aggregates start only after take-off, for example the wing and empennage deicing installation. Almost a third of defects were detected during preliminary preparation and pre-flight inspection, indicating that preventive maintenance and the monitoring system have a good efficiency. It is therefore necessary to streamline preventive procedures in order to reduce the number of inflight failures.

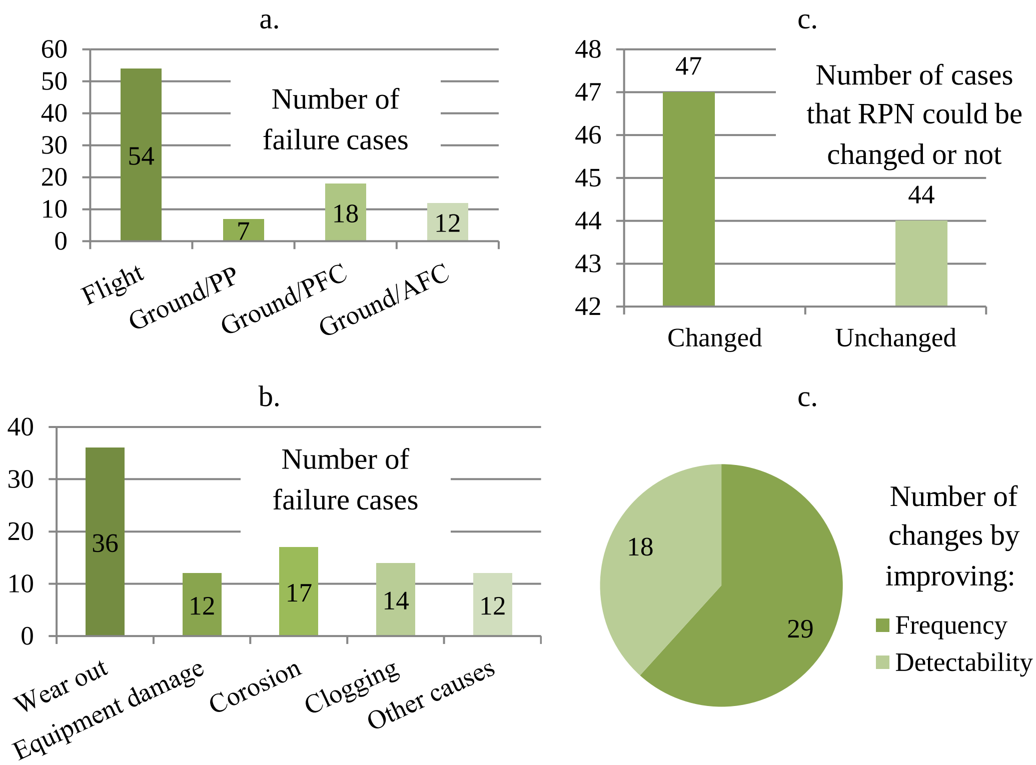

Fig. 4. Data associated to special systems failures – place/ type of preparation where these were discovered (a), causes (b), RPN changes (c), number of changes by improving the frequency or detectability (d)

The main factor leading to failures is again wear, especially due to the age of the aircraft and thus the aggregates.

The RPN could be improved, by reducing the frequency in most of the cases, and proper measures can be imposed that can influence it both by identifying the aggregates prone to wear, corrosion, etc., and replacing them with more modern ones. and technically superior.

4. Conclusions

Applying FMEA analysis for the medium courier tourboprop aircrafts and studying the equipment technical documentation, the main causes of the failures and few ways to improve the system reliability could be noted.

RPN has been analyzed with the main purpose to optimize its value, by improving the preventive maintenance and the monitoring system. The necessary improvements were made, as additional predictive maintenance that could, by detecting misalignments, imbalances, frequency, and detectability indices have been reevaluated, to obtain the new RPN.

Finally, existing preventive and corrective maintenance methods are sufficient to detect faults before they occur, in most of the situations. In some cases, the failures are caused by the relatively low reliability of the parts, but this can be increased and lead to a decrease in the frequency of defects, involving additional costs. FMEA analysis demonstrates again that it is a verified method of identifying equipment maintenance and support activities, performed to increase its availability by reducing the severity and frequency of failures. Although solving the technical problems encountered in performing the FMEA analysis is not easy, the main obstacles identified in implementing this strategy are related to the human factor and the management of the organization.

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