Identification of the critical parts for a medium courier turboprop aircraft

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DOI: 10.13111/2066-8201.2020.12.1.20

Received:11 November 2019/ Accepted: 03 February 2020/ Published: March 2020

The 38th "Caius Iacob" Conference on Fluid Mechanics and its Technical Applications
7 - 8 November, 2019, Bucharest, Romania, (held at INCAS, B-dul Iuliu Maniu 220, sector 6)
Section 5. Technical Applications

Abstract: *Each time an aircraft system fails, a series of steps are required to repair or restore the aircraft to full operational status. The steps include failure detection, fault isolation, disassembly to gain access to the defective element, repair, and so on. The frequency of the maintenance becomes a significant parameter in determining system support requirements. The maintenance frequency for a particular item depends very much on the reliability of that item. In order to exemplify this idea the present paper contains a series of analyzes whose purpose is to identify the critical parts for a medium courier turboprop aircraft operated by the Romanian Air Force.*

Key Words: *aviation, critical parts, turboprop aircraft, maintenance, reliability*

1. INTRODUCTION

Air transport is the organized delivery of material or personnel either with a fixed wing or rotary wing aircraft.

The military transport aircraft is a fixed-wing transport aircraft used in the transport of troops, weapons, or other military equipment by various methods to military operations in progress worldwide.

They usually use non-commercial air routes or fly in uncontrolled air spaces.The first transport aircraft were converted from bombers or civilian aircraft and were used for parachute launching or material transport during World War II.

The actions of air transport allow the effective support of the military effort and deployment capacity. Depending on the flight distance they have to travel, they can be strategic or tactical.

For example, if between two theaters of operations, there is an air movement of personnel, fighting technique and materials, this is called strategic air transport.

The difference between strategic and tactical air transport consists of their amplitude.The theater of operations is the environment of tactical air transport and the strategic air transport operations being the carriage of passengers and cargo between theaters.The main advantage of the air transport over the other means of land transport, is given by the capacity to transport quickly, big loads at appreciable distances.

The main disadvantages of this mode of transport are due to the necessity of having adequate airport infrastructure or prepared runways for takeoffs and landings, providing special means of service, dependence on time, season and weather conditions as well as the high costs of these services.

In order to be successful in specific combat actions, these missions must have a number of characteristics, such as:

a) Flexibility –the ability of the aircraft to be easily adapted, without major changes, to the requirements of the transport mission.

b) Opportunity - involves the realization of the transport or mission in a timely, real time. This characteristic derives from the rapidity and is particularly important in humanitarian actions, which often require a very short time of intervention.

c) Effectiveness - can be deduced from the ratio between the missions executed according to the planning, without delays, cancellations or other negative aspects, and the total of planned air missions within a certain time interval.

d) Accessibility - is the ability of the aircraft, especially helicopters, to reach places that are difficult to access for other transport categories.

The efficiency of the transport is also appreciated depending on the type of aircraft used. Airplanes are much more efficient than helicopters in strategic transport, but helicopters are best suited for the air transport in the theater of operations.

Lately changes in economic trends, rising inflation, rising costs for many systems and products, the continuing decline in purchasing power and budgetary constraints have led to awareness and increased interest for the total cost of a system/product. Besides the rising costs of acquisition of the new systems, the operating and maintenance costs of the systems already in use are rising at alarming rates.

The net result is that less money are available to meet new requirements, as well as to maintain the existing systems. In essence, many of the systems/products that exist today are not really profitable [1].

In terms of expenses, we have to consider the total cost of the life cycle. In the past, the total cost of the system was often not too visible, especially those costs associated with operating and maintaining the system [2].

Performing a needs analysis in a satisfactory manner can be better accomplished by focusing the study on the customer, the end consumer or the user (if different from the customer), the contractor or the major manufacturer and suppliers, as appropriate [3].

The aim is to ensure that there is appropriate communication between the parties involved. The “customer voice” must be heard and the system developer must respond appropriately.

2. IDENTIFICATION OF THE CRITICAL PARTS OF THE AIRCRAFT

The aircraft subject of this paper is a medium courier tourboprop aircraft operated by a squadron of theRomanian Air Force.

We made a situation with all the failures occured on two aircrafts (generically named as Aircraft A and Aircraft B), during two years of operation, between January 2016 and December 2017; a total of 308 defects resulted, of which 170 on plane A and 138 on plane B.

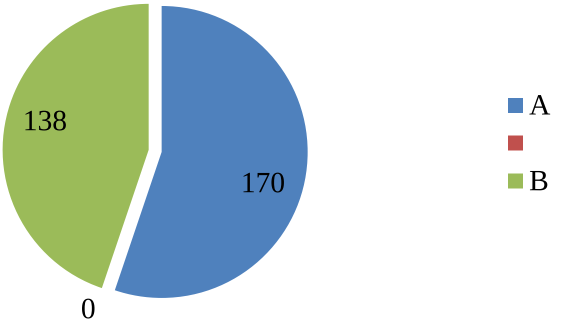

Figure 1. – Total failures on both aircraft

During the study we found out that most of the failures were noticed by the pilots during the flight, a total of 190, of which 94 on aircraft A and 96 on aircraft B, while on the ground, the aircraft maintenanceservice discovered 118, 76 on aircraft A and 42 on aircraft B.

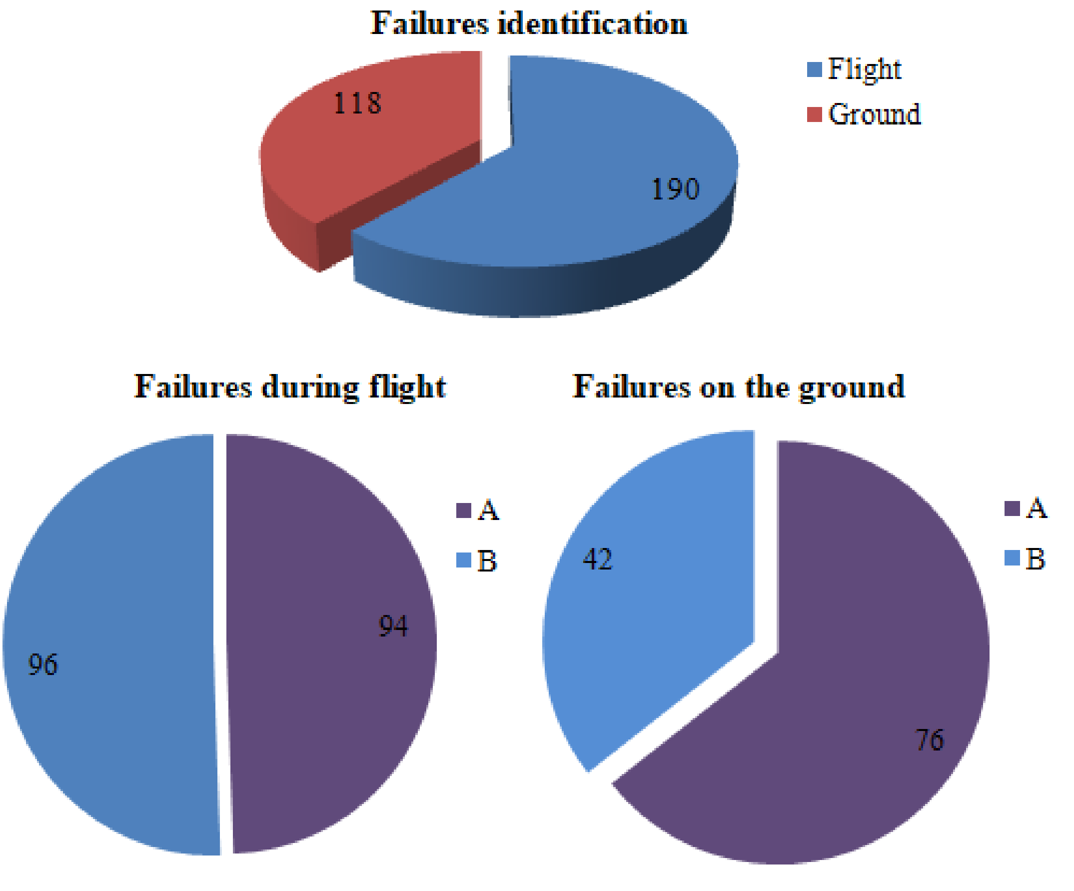

Figure 2. – Total failures during flight or on the ground

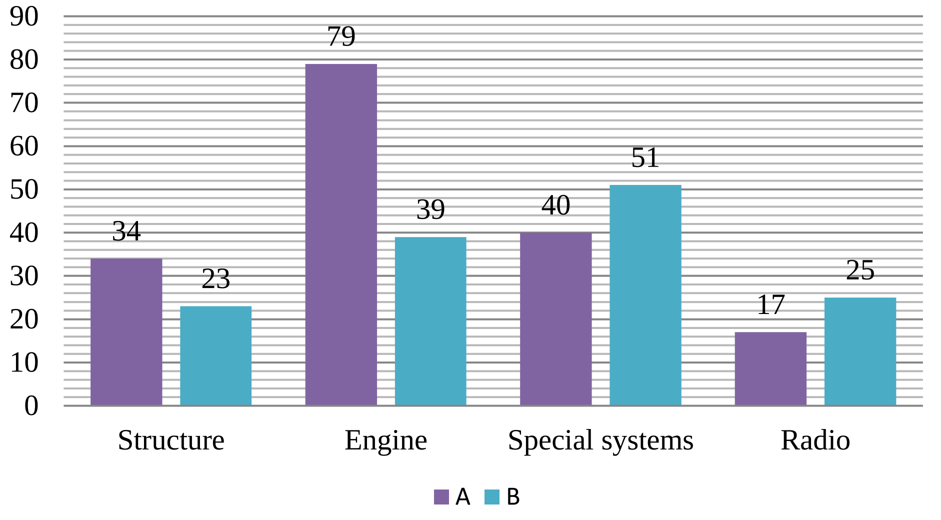

Figure 3. – Failures by categories of components

Regarding the cause of the defects, we identified that the main cause is the failure of material, resulting in 235 defects out of the total of 308.

In the second place, we identified a total of 21 system disturbances, mainly discovered in the fuel correction and control system (TD), in the negative torque detection system (NTS), but also in auxiliary equipment installed on the aircraft (lighting systems, door locks, and so on), 15 failures caused by short circuits/imperfect contacts, on measuring and control systemsof the aircraft, at radio stations and at electronic engine control systems, 15 defects were due to clogging of filters or systems.Weidentified 10 situations of pressure losses in the case of shock absorbers from the landing gear, the parts of the hydraulic system assembly, or the parking brake, 3 decalibration situations caused defects in the fuel indicators and radio stations, 9 situations in which the impurities deposits caused defects in the braking blocks, the air conditioning system and the transmitter of the engine oil quantity.

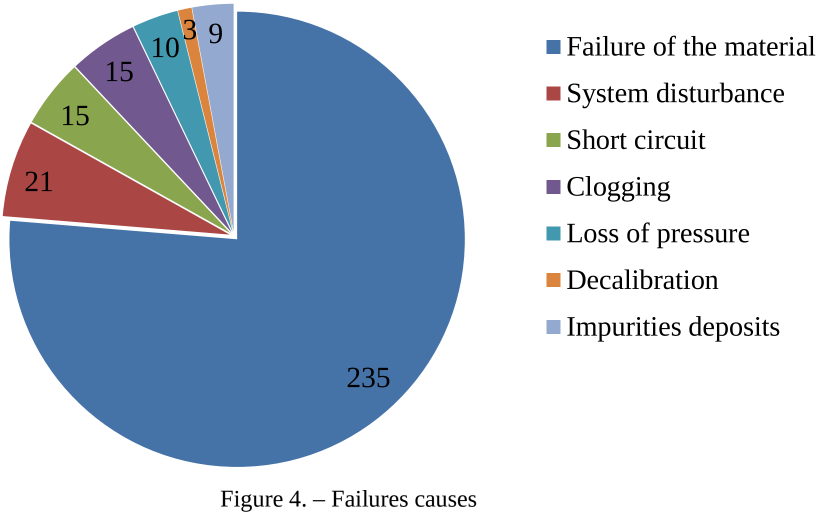

Figure 4. – Failures causes

In order to discover the critical parts of the aircraft, we extracted five of the most common failures and we determined the mean time between their failure, knowing that the aircrafts flew together 2470 hours between January 2016 and December 2017.To determine the mean time between failure we have to determine the failure rate ($\boldsymbol{\lambda}$) for the component, firstly. The failure rate is the rate at which failures occur in a specified time interval and may be expressed interms of failures per hour, percent failures per 1000 hours, or failures per million hours [4].

a) Engine oil cooler flap. During the study, 12 defects in the engine oil cooler flap were identified, due to incorrect operation or malfunction of the flap actuator, 8 of them occured during the flight, and 4 were detected and remedied by the aircraft maintenance service, on the ground.

In the case of defects during the flight, they did not endanger the safety of the mission execution, the crew acted according to the flight manual, selected the operation of the cooler flap on the manual working mode and locked it to the maximum open. Thus, overheating of the engine was avoided.

$$\boldsymbol{\lambda = \frac{number\ of\ failures}{total\ running\ time} = \frac{12}{2470} = 0,0048}$$

As it can be observed, the failure rate, or the corrective maintenance frequency per one thousand of hours running time is 4,8.

Assumingan exponential distribution, the system mean life or the mean time between failure (MTBF) [5] is:

$$\text{MTBF} = \frac{1}{\lambda} = \frac{1}{0{,}0048} = 208{,}33 \text{ hours}$$

b) Radio altimeter. There were detected 11 radio altimeter failures, caused by material failure and solved by replacement, 10 of them occured during the flight, and 1 was detected and remedied by the aircraft maintenance service, on the ground.The flight with the defective radio altimeter is not a dangerous one, nor did it require the emergency landing of the aircraft.It is necessary in case of a precision landing procedure, if the weather conditions are VFR, the flight without a radio altimeter is permited.

$$\boldsymbol{\lambda = \frac{number\ of\ failures}{total\ running\ time} = \frac{11}{2470} = 0,0044}$$

The failure rate is 4,4 failures per one thousand of hours running time.

$$\text{MTBF} = \frac{1}{\lambda} = \frac{1}{0{,}0044} = 227{,}27 \text{ hours}$$

The mean time between failures in case of radio altimeter is 227,27 hours.

c) Brake system. As everybody know, the braking system of an aircraft is one of the most important systems. Although the turboprop engines can reverse, to slow down the aircraft after landing, but the brakes system is essential for controlling it on the ground and to stop it.
10 failures occured at brakes system, due to the material failure and solved by replacement. Although they were either discovered by the technical team or reported by pilots after the flight, all happened on the ground.

None of the situations affected the safety of the flight; in one case it was necessary to use the emergency braking system.

$$\boldsymbol{\lambda = \frac{number\ of\ failures}{total\ running\ time} = \frac{10}{2470} = 0,0040}$$

The failure rate is 4 failures per one thousand of hours running time.

$$\text{MTBF} = \frac{1}{\lambda} = \frac{1}{0{,}0040} = 250\ \text{hours}$$

The mean time between failures in case of radio altimeter is 250 hours.

d) Tachogenerator. The failure of tachogenerator leads to imposibility in reading the engine speed (RPM). The RPM indicator has the role of permanently ensuring the possibility of checking the proper functioning of the engine by the crew. This has no other implications for aircraft piloting, but can reveal a certain propeller failure.

We identified 12 tachogenerator failures, which had different causes and were solved by replacing the system.

$$\boldsymbol{\lambda = \frac{number\ of\ failures}{total\ running\ time} = \frac{12}{2470} = 0,0048}$$

The failure rate is 4,8 failures per one thousand of hours running time.

$$\text{MTBF} = \frac{1}{\lambda} = \frac{1}{0{,}0048} = 208{,}33\ \text{hours}$$

The mean time between failures in case of tachogenerator is 208,33 hours.

e) AC generator. The current generator is an aggregate of the engine gearbox which is meant to provide power supply during operation. We identified 7 generator failures, 3 happened during the flight and 4 were discovered and remedied by the aircraft maintenance service on the ground.All three inflight situations were solved by shutting down the affected engine, according to the flying manual andperforming an emergency landing.

$$\boldsymbol{\lambda = \frac{number\ of\ failures}{total\ running\ time} = \frac{7}{2470} = 0,0028}$$

The failure rate is 4,8 failures per one thousand of hours running time.

$$\text{MTBF} = \frac{1}{\lambda} = \frac{1}{0{,}0028} = 357{,}10\ \text{hours}$$

The mean time between failure in case of AC generator is 357,10 hours.

3. CONCLUSIONS

Based on the data presented and the calculations made, we consider that the critical components for the studied aircraft are the oil cooler flap, the braking system, the tachogenerator and the AC generator.

Flying with a defective oil radiator can lead to a very dangerous flight situation. The oil can overheat and lead to engine failure and in the worst case it may result in engine fire.

Even though the study refers to a turboprop aircraft, which can also brake with the reverse thrust, a defective braking system can lead to unforseen situations, especially in the case of differential braking or hydraulic fluid leakage which can lead to a fire in the landing gear compartment.

A faulty tachogenerator can lead to misinterpretation of the engine control parameters. In this situation, a correctly functioning engine can be treat as a defective one and vice versa.

If anAC generator malfunction is experienced during the flight, even though the consumers are picked up by the backup system, an engine fire can occur, which could lead to the tragic ending of the flight.

AKNOWLEDGEMENT

This work has been funded by the European Social Fund from the Sectorial Operational Programme Human Capital 2014-2020, through the Financial Agreement with the title "*Scholarships for entrepreneurial education among doctoral students and postdoctoral researchers (Be Antreprenor!)*", Contract no. 51680/09.07.2019 - SMIS code: 124539.

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