ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1213510

AIRCRAFT ENGINES − ANALYSIS OF REPORTED SYSTEMS FAILURES IN POLISH AVIATION DURING YEARS 2008-2015

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Abstract

Aircraft engine failure during different aircraft flight phases can cause accidents or incidents.

ICAO Annex 19 requires from each state establishing the state safety program (SSP) and from the subordinate aviation organizations safety management system (SMS). Point 5.2.1 of Annex 19 instructs to establish safety database, which should be used for effective analysis of actual and potential safety deficiencies. Such analysis should lead to determining necessary measures in order to improve safety.

Polish Civil Aviation Authority among other databases manages an important one called European Coordination Centre for Aviation Incident Reporting Systems (ECCAIRS).

The authors have done a laborious processing of the data contained in that database analysing engine failures based on criteria like phases of flight, ATA chapters concerning powerplant and category of the occurrence. Separately, under consideration were taken engines installed on aircraft with an MTOM <5700 kg (mainly General Aviation) and for aircraft with MTOM > 5700 kg (commercial aviation).

The article presents a proposed method of predicting the number of events, the alert levels for the next years and for ATA chapters' determination, assuming a normal distribution (Gaussian).

It is one of the first attempts to use the actual data contained in the database of events in Poland. The results of this analysis can support the decisions of supervisory authorities in the areas where security threats are most important.

Keywords: *aircraft engine, failure, engine system, ATA chapter, safety system*

1. Introduction

Aircraft engine failure, especially during flight, can cause serious events with dramatic consequences. Despite the fact that aircraft powerplants both jet and piston are "state of the art" products, however, according to Murphy's laws: "If anything can go wrong, it will" and "New system generates new problems" operational disturbances can be expected.

That is why a continuous analysis of the aviation occurrences generated by engines defects and direct their "health monitoring" is so important for the flight safety. The participants in these processes have different roles. Aviation authority staff should observe adverse events from bird's eye view and after an analysis release adequate ordinance. Aviation organizations, apart from engines' performance monitoring, should implement aviation authority instructions in the scope of their specific activities.

The article based on ECCAIRS data for years 2008-2015 presents statistical calculations results of aviation events reported at that time caused by powerplants (SCF-PP) [1] installed on Polish registration aircraft.

They were divided into occurrences which took place on MTOM< 5700 kg aircraft with piston engines installed and those on MTOM > 5700 kg aircraft powered by turboshaft, turboprop and turbofan engines. The method of the analysis can be briefly described as follows: during 2008-2015, the number of aircraft involved in air traffic was changing. In order to objectify the analysis of the data, coefficients relating the number of all the SCF-PP events or in any ATA chapter [4] to the number of the aircraft registered in this category (per 1,000 aircraft) was introduced.

$$ZS_{GA(X)} = \frac{1000*\mathrm{LZ_{GA}}}{\mathrm{LSP_{GA}}} \text{ or } ZS_{K(X)} = \frac{1000*\mathrm{LZ_K}}{\mathrm{LSP_K}}, \quad (1)$$

where:
LZ_{GA}, LZ_K – number of events for aircraft MTOM<5700 and MTOM>5700 kg respectively,
LSP_{GA}, LSP_K – number of registered aircraft MTOM<5700 kg and MTOM>5700 kg respectively,
X – index for any ATA chapter or for SCF-PP aviation occurrence category.

The authors propose forecasting based on observation of the trend of several years and setting alert levels assuming a normal distribution. These forecasts should be verified annually by comparing them with actual numbers of events.

To determine the alert levels the method of Shewhart Control Charts could be used that allows for an observation of process variability, as well as identifying the reasons that cause this increase in volatility [3]. 2σ limits on both sides of the line of mean values were assigned as the maximum predicted levels also denoted in figures as AL (alert levels).

2. Piston engines

At present, there are more than 1,000 piston engines in exploitation in Poland; most of them power single engine aircraft including approx. 70 helicopters. Between 2008 and 2015, 182 aviation events occurred caused by powerplants. Fig. 1 shows an annual distribution of the mentioned occurrences per 1,000 aircraft. In addition, the mean and maximum values (AL) predicted for 2016 and 2017 are presented.

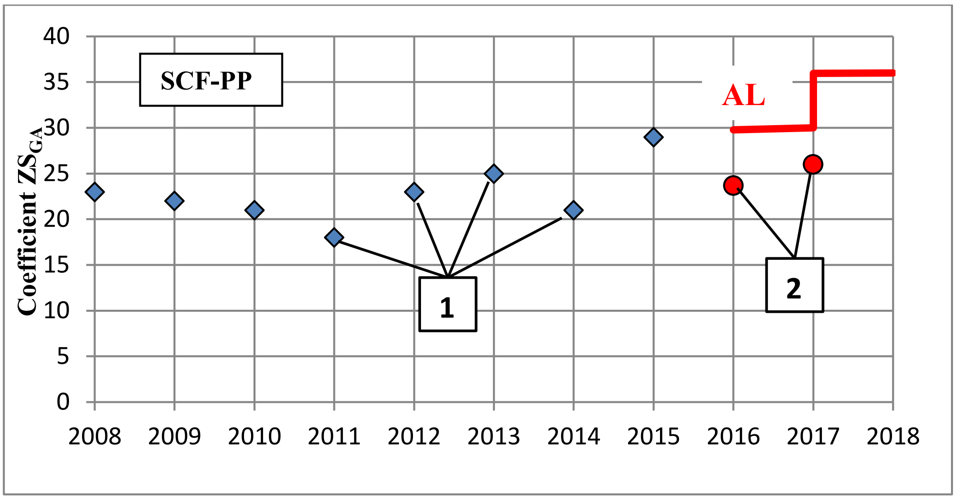

Fig. 1. Annual and forecasted value of $ZS_{GASCF-PP}$ coefficient for powerplant (SCF-PP): 1 – current year coefficient value, 2– forecasted mean, AL –calculated predicted alert level

Figure 2 gives, in the percents, information during which aircraft manoeuvres mentioned above events occurred.

It is not desirable that the vast amount of the powerplants reported failures occurred during aircraft movement. Only 30% of them were detected during routine maintenance tasks.

Figure 3 shows frequency of the systems defects appearance in the years 2008-2015 for powerplants installed on MTOM < 5700 kg aircraft.

Figure 4 presents results of the statistical calculations performed for ATA 72 chapter – engine. It has to be mentioned that similarly other powerplant systems, which caused significant number of failures, were analysed. These systems are engine fuel and control – ATA chapter 73, ignition – ATA chapter 74 and engine controls – ATA chapter 76. Oil system – ATA chapter 79 ZS_{GA79} coefficient calculation results are shown in Fig. 6.

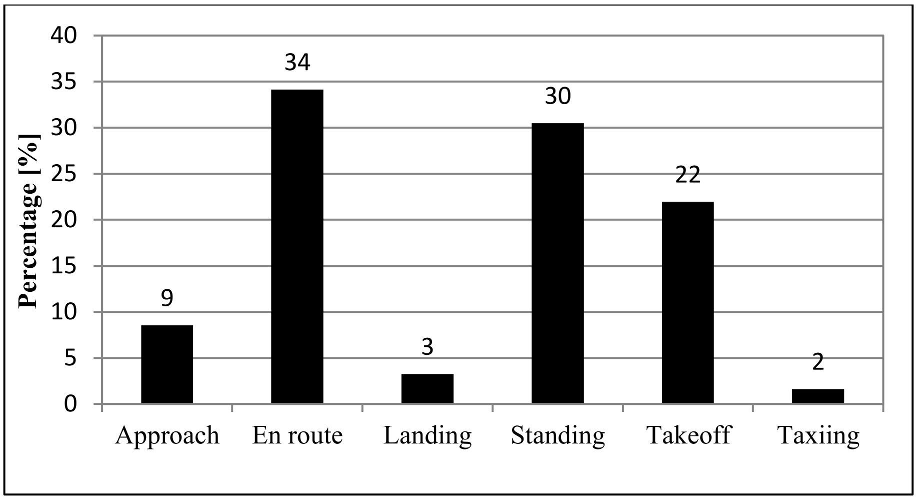

Fig. 2. The share in percents of particular manoeuvre of aircraft when powerplant events have occurred in the 2008-2015 on MTOM <5700 kg

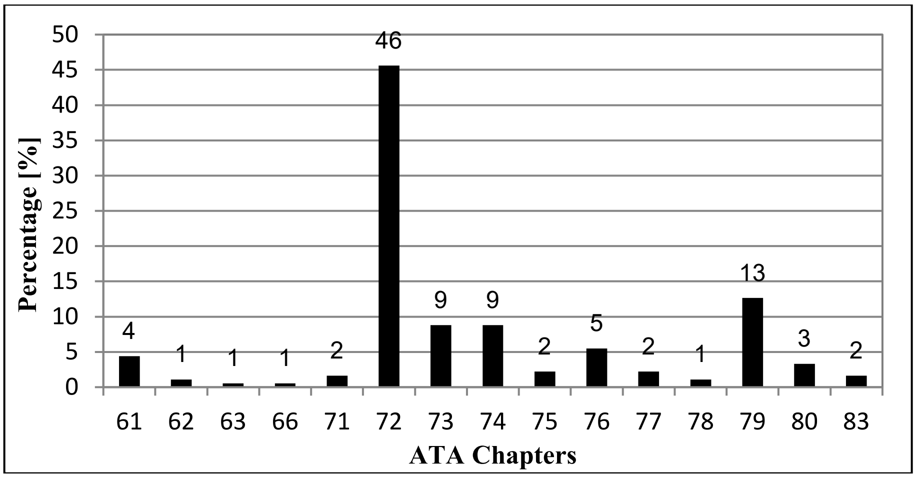

Fig. 3. Share of each powerplant system (ATA-100 chapter) for SCF-PP aviation category event in percents for engines installed on MTOM < 5700 kg aircraft

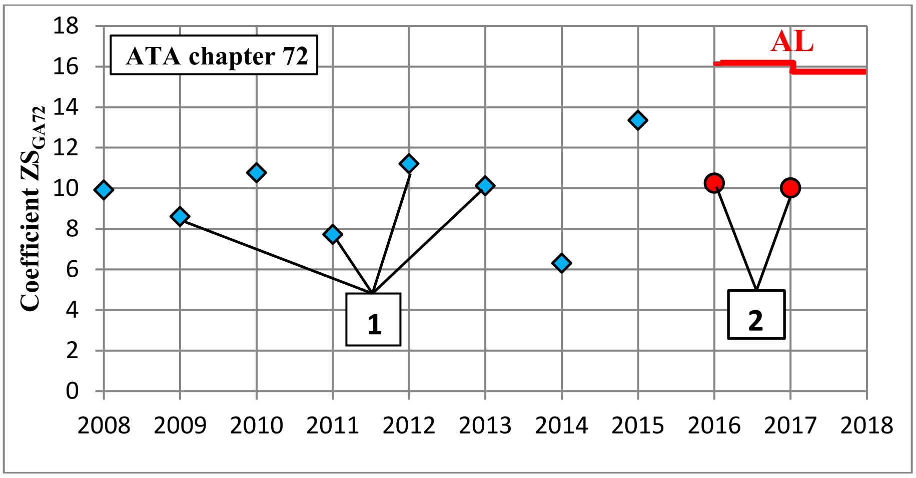

Fig. 4. Annual and forecasted value of ZS_{GA72} coefficient for ATA chapter 72- engine: 1 – current year coefficient value, 2– forecasted mean, AL – calculated predicted alert level

Almost 50% from occurrences caused by powerplants can be assigned to the engine itself.

Most of the events are connected to powertrain and cylinder systems. There were events caused by cracked exhaust valves. In addition, carbon deposit on valves has been observed. Some occurrences were caused by different failures of cylinders. It can be presumed that those damages were due to engines overheating, resulting by improper exploitation. Compared to 2014, the number of reported events increased twice in 2015.

Figure 5 shows the frequency of the reported events occurrences in the ATA – 72 chapter during certain aircraft phases of the flight in 2008-2015.

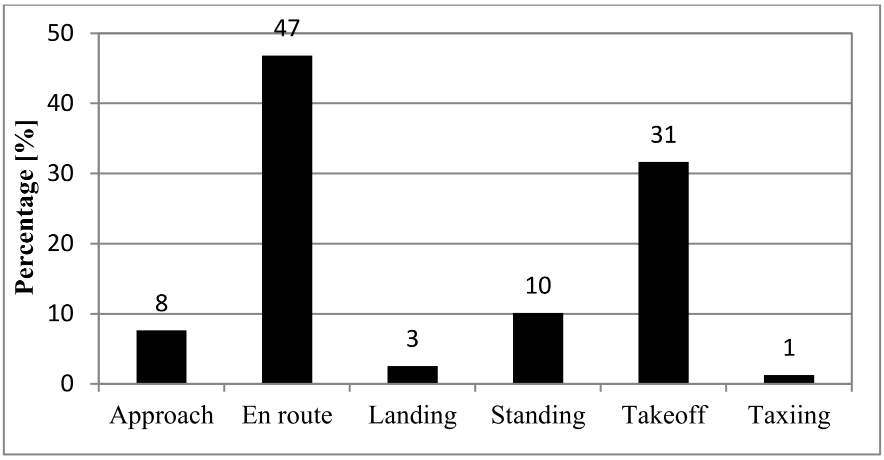

Fig. 5. The share in percents of particular manoeuvre of aircraft when powerplant related events in ATA-100 chapter 72 occurred in 2008–2015

About 80% of the engine reported events during end route and take-off phases of flight require serious consideration of the maintenance quality and operational procedures in the organizations operating in the area of the light aircraft.

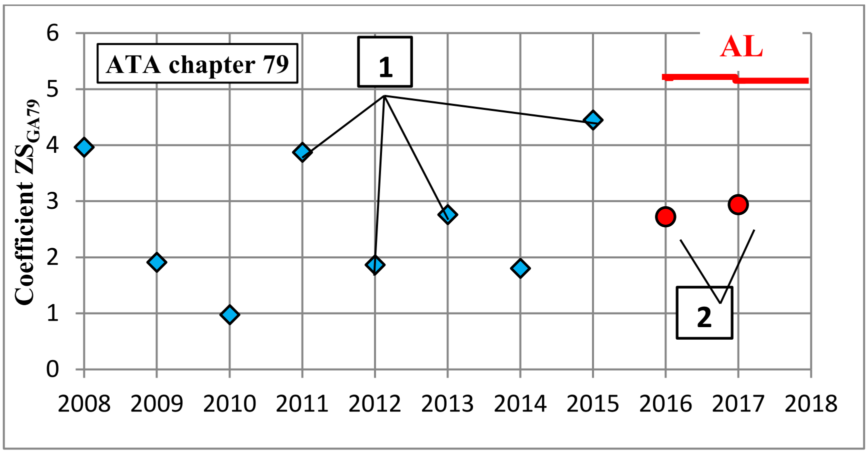

Fig. 6. Annual and forecasted value of ZS_{GA79} coefficient for ATA chapter 79- oil system: 1 – current year coefficient value, 2– forecasted mean, AL –calculated predicted alert level

Improperly installed/connected oil pipes causing leaks are the main but not the only reason for reported events connected with the engine oil system. They occurred due to maintenance imperfections. Oil system faults have a significant impact on flight safety. It needs to be mentioned that in 23 cases in the years 2008–2015 of the oil system malfunctions, 16 of them resulted in aborted flights or emergency landings. Similarly, as for 72 ATA chapter, compared to 2014, the number of reported events increased twice in 2015.

3. Turbine jet engines

In 2015 one hundred seventeen MTOM > 5700 kg aircraft powered by turbofan or turboprop engines were registered in Poland. Additionally 14 helicopters powered by turboshafts were operated with Polish registration. All of the mentioned aircraft are twin-engine type. There were 207 reported events caused by powerplant systems between 2008 and 2015.

Figure 7 shows an annual distribution of the mentioned occurrences per 1,000 registered aircraft. In addition, mean and maximum values (alert levels) predicted for 2016 and 2017 are presented.

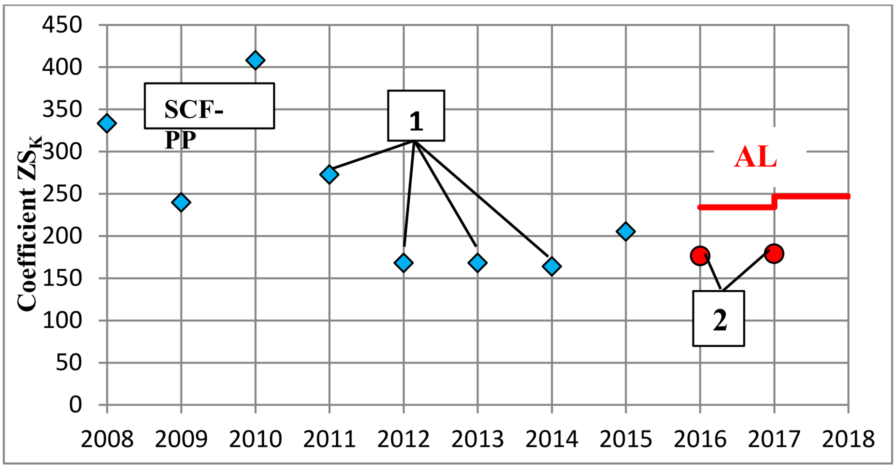

Fig. 7. Annual and forecasted value of ZS_K coefficient for powerplant (SCF-PP): 1 – current year coefficient value, 2– forecasted mean, AL – calculated predicted alert level

Figure 8 gives in the percents information during which aircraft manoeuvres mentioned above events occurred.

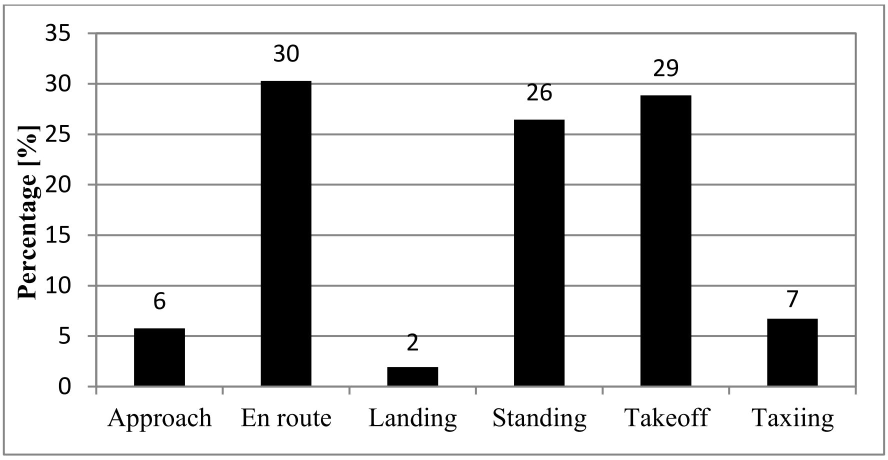

Fig. 8. The share in percents of particular manoeuvre of aircraft when powerplant events have occurred in the 2008-2015

Despite the fact that powerplants installed on commercial aircraft require the engine "health monitoring", only 26% of their defects are found during routine maintenance tasks.

Such a situation is a signal for exploitation processes review by the aviation organizations in order to improve engine failures detection on the ground.

Figure 9 shows frequency of the systems defects appearance in the years 2008-2015 for powerplants installed on MTOM > 5700 kg aircraft.

Figure 10 presents results of the statistical calculations performed for ATA 72 chapter – engine.

Slow but steadily decreasing value of the ZS_{K72} coefficient for events recorded in ATA 72 chapter is observed. It should be emphasized that out of the 73 reported events mentioned in this chapter, 42 of them were caused by turbofan, 27 by turboprop and 4 by turboshaft engines powered helicopters. Unfortunately, only 24% of all of the reported events were detected on ground.

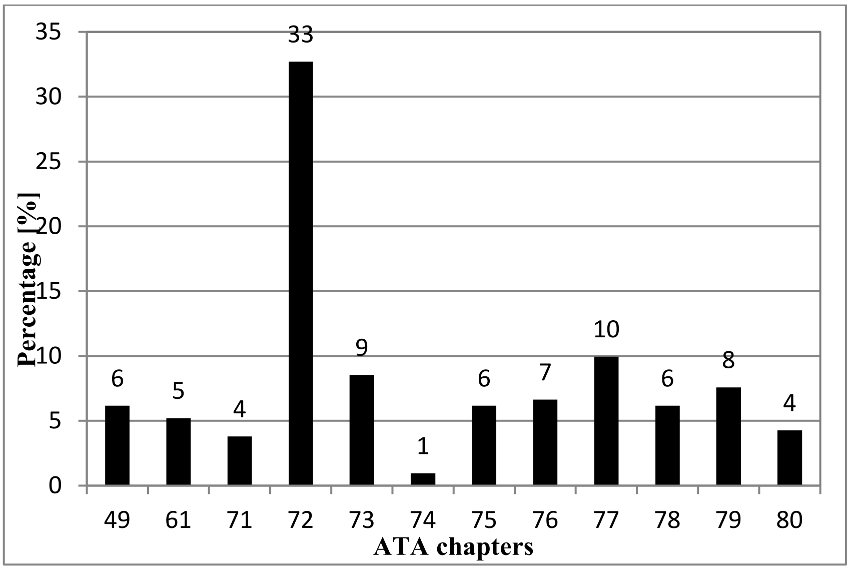

Fig. 9. Share of each powerplant system (ATA-100 chapter) for SCF-PP aviation category event in percents for engines installed on MTOM > 5700 kg aircraft

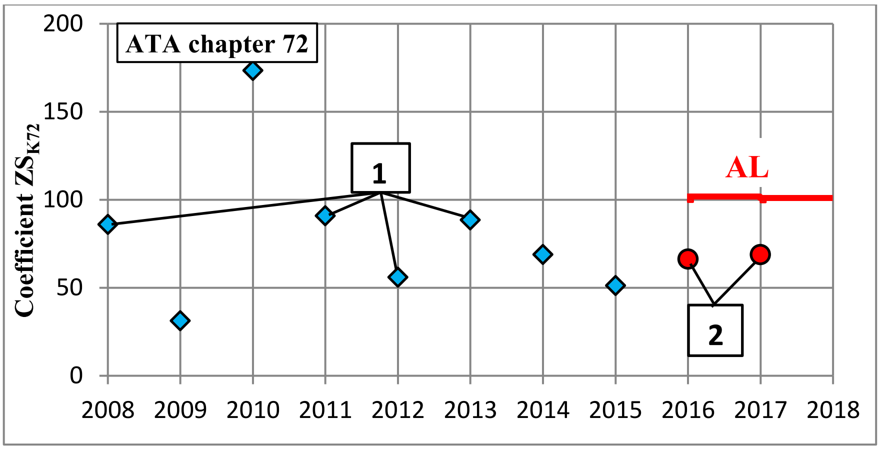

Fig. 10. Annual and forecasted value of ZS_{K72} coefficient for engine: 1 – current year coefficient value, 2– forecasted mean, AL – calculated predicted alert level

Figure 11 shows frequency of reported events occurrences in the ATA – 72 chapter during a certain aircraft phase of the flight in 2008-2015.

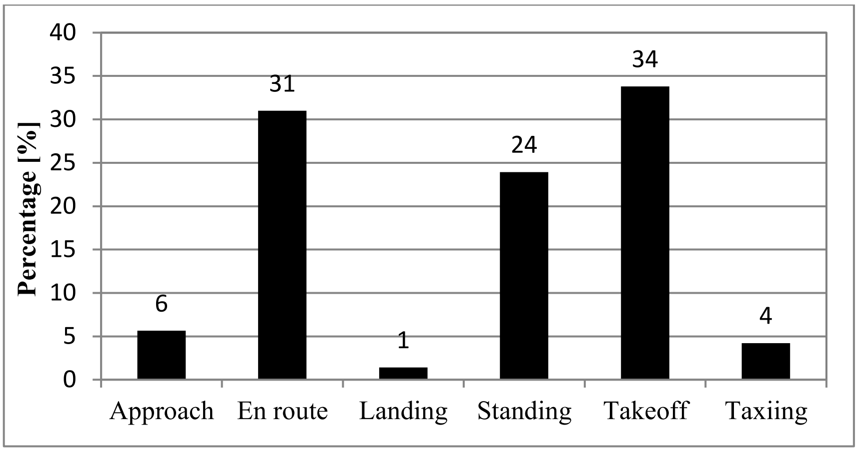

Fig. 11. The share in percents of particular manoeuvre of aircraft when powerplant related events in ATA-100 chapter 72 have occurred in the 2008-2015

There are more powerplant systems, which require special attention when improvement of the flight safety is considered. These are (presented in the order of the number of events) as follow: engine indicating – ATA chapter 77, engine fuel and control – ATA chapter 73, oil – ATA chapter 79 and engine controls – ATA chapter 76.

Separately Auxiliary Power Units (APU) has to be handled (ATA chapter 49) due to their important role, especially in twin-engine aircraft. In the case of the engine in flight, shut down APU has to deliver electricity to the aircraft's various systems.

4. Conclusions

About 30% of the events in both cases have occurred during the flight. It is not a positive situation, because they often happen at the inhabited areas, so each engine fault may consequently cause unimaginable damages. Aviation organizations should review its maintenance procedures so that the number of detected powerplants serious defects on the ground will be as big as possible. For example, the introduction as a rule engine condition monitoring (piston engines) based on the flight parameters or an introduction the engine "on-watch" task as soon as a fault possibility of any engine's installation is suspected.

In 2015, the number of events associated with the powerplant per thousand registered aircraft in both types of engines increased. It seems that the detailed analysis should take place led by national authority. Aviation organizations involved in the aircraft exploitation has to be a part of such an activity.

Similarly, as for the airframes, knowledge of the engines flight hours/cycles is required because the desirable statistical tool is a factor, i.e. number of events per 1,000 hours/cycles. Aviation authority (especially for MTOM < 5700 kg aircraft) should force operators to report flight hours data, e.g. annually.

Miniaturization and regular cost reduction of the flight data recorders probably will lead to their common use on the light aircraft. Registered engine as well as flight management parameters analysis will enable accurate detection causes of the failures and provide immediate information about an exceedance.

Acknowledgement

The work is financed from the Institute of Aviation statutory fund (Project no 21751).

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