ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/01.3001.0010.2791

USEFULNESS OF THE ADOPTED METHOD FOR THE NUMBER OF AVIATION OCCURRENCES PREDICTION

Włodzimierz Balicki, Paweł Glowacki

Institute of Aviation
Department of Space Technologies
Krakowska Av. 110/114, 02-256 Warsaw, Poland
tel.: +48 22 8460011 ext. 618
e-mail: wlodzimierz.balicki@ilot.edu.pl, pawel.glowacki@ilot.edu.pl

Abstract

Poland – according to ICAO requirements, is obliged to conduct analyses of the coefficients adopted to assess the level of safety in civil aviation. They are carried out on the basis of the data contained in the ECCAIRS database.

The authors have processed the data contained in this database by analysing them using various criteria (ICAO aviation occurrence categories, flight phases, different airports) to test the methodology of the safety indicators values forecasting and setting their "warning levels". Exceedance of these levels could be a signal for taking preventive action by the relevant competent aviation authorities.

The proposed method is based on the assumption that the determined parameters are governed by normal distribution rules (Gaussian). Parameter values calculated based on real data from 2016 were compared with those predicted a year earlier.

It was found that the factors for different events have increased significantly - above the calculated warning levels, particularly for general aviation.

The results of this analysis may support competent aviation authorities' decisions in areas where safety risks are most critical.

Keywords: *air transport, air traffic safety, safety management, aviation occurrence*

1. Introduction

As an ICAO member state Poland has introduced an aviation safety management system, including reporting of the aviation events collected in the ECCAIRS (European Coordination Centre for Accident and Incident Reporting Systems) database [14, 15].

Reported aviation events are coded for specific categories as defined by ICAO in the periodically issued document (see [1]). It currently provides 37 categories for incidents related to airport traffic, flight, weather, cabin cockpits, and aircraft or engine failure.

However, there is a problem identifying the obvious crew faults, which due to the lack of a relevant category are encoded (OTHER). The process of qualifying events is quite complex, as it sometimes requires identifying the substance of the occurrence from the description provided by the crew or ground services.

Errors made at this stage of the database completion may cause in the results falsification of further processing and conclusions. It seems that we should endeavour to "objectify" this process.

The authorities responsible for aviation safety use a variety of activities: inspections are carried out in aviation organizations; accident investigation committees are issuing appropriate recommendations. Analyses are performed using, for example Bowtie method [10] (e.g., defining cause-effect relationships that generate safety threats, experts are needed, brainstorming, etc.).

Authors who cooperated for several years with the Polish Civil Aviation Authority had access to ECCAIRS and Aircraft Continuing Airworthiness Monitoring (ACAM) databases and could perform analyses, which resulted (among others) in the publications [5-7, 9, 11].

The aim of this work was to identify trends of the factors related to aviation events in certain categories, for example concerning aircraft MTOM> 5700 kg (practically Commercial Air Transport – CAT) and MTOM <5700 kg (General Aviation). Calculations for various phases of flight, ATA-100 chapters, etc. were performed. Level of warning for each event category was established as a prediction for the coming years. Fig. 1 shows the changes in the number of reported aviation events in the years 2008 and 2016.

a) aircraft MTOM<5700 kg b) aircraft MTOM>5700 kg

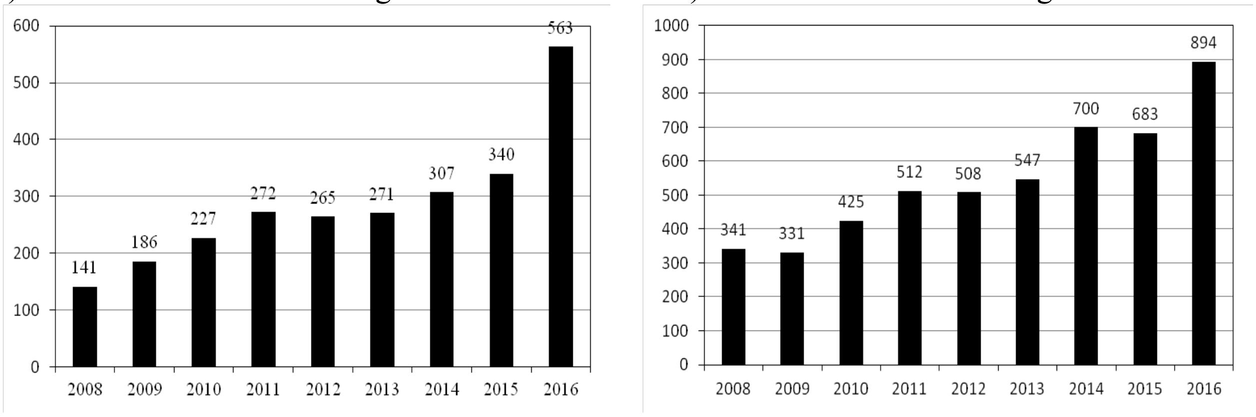


Fig. 1. Number of reported events: a) for MTOM<5700 kg aircraft; b) for MTOM>5700 kg aircraft

2. Research method

The ECCAIRS database contains approximately 7,000 aviation events reported between 2008 and 2016. In order to objectify the analysis, coefficient ZS was introduced. It is referenced to the number of events per number of registered aircraft (per 1000 aircraft), as the number of aircraft involved in air traffic has been changing:

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

where:

X – index for any ATA chapter or for ICAO aviation occurrence category,
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.

The authors used forecasting method based on trend observations from several years and setting the warning levels assuming their normal distribution. This method, which uses the so-called Shewhard's Diagrams of Control, was presented in the paper [7].

3. Data analysis for the year 2016

The method of determining the mean **m** of four years, the standard deviation **σ** and the warning level **m + 2σ**, has allowed verification that the processed data are corresponding to the normal distribution. This was the case for 2014 and 2015. In 2016, there was a “sharp jump” of the coefficients values, as shown in Fig. 2.

For the large aircraft (mainly CAT), the ZS_{K} value slightly exceeded the warning level (6526 against 6442). However, in 2016, an unprecedented jump in the value of the ZS_{GA} was noted, which exceeded the warning level 154 and reached 231. Such a significant difference stems from the increase in the number of reported events in ICAO occurrence categories SCF-NP and SCF-PP (airframe and powerplant systems).

a) aircraft MTOM< 5700 kg b) aircraft MTOM>5700 kg

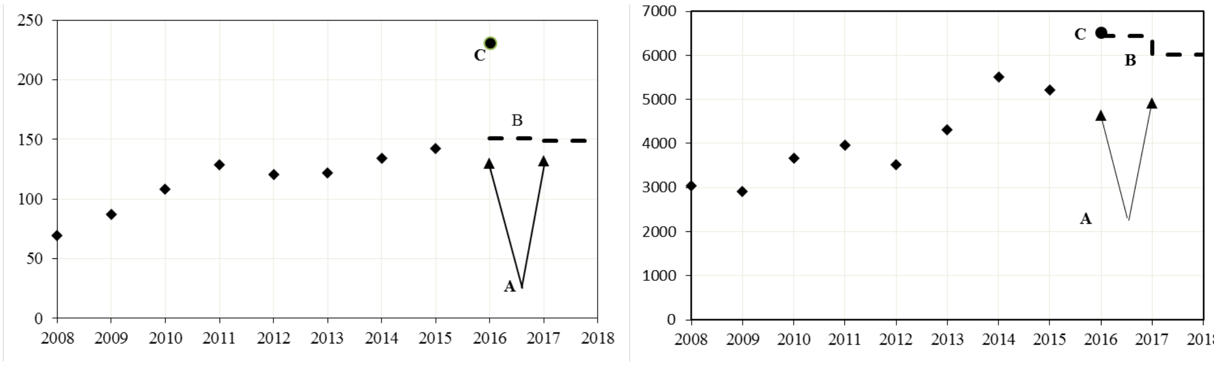


Fig. 2. Changes of the coefficients value related to number of events per number of registered aircraft: a) ZS_{GA}; b) ZS_K; Assumptions: A – Forecasts done in 2015 of mean values for the years 2016 and 2017, B – warning level for 2016 and 2017; C – the actual value of the coefficient in 2016

3.1. General Aviation aircraft

For the SCF-NP ICAO occurrence category, the predicted alert level for 2016 was 44, as shown in Fig. 3a. The actual value of this ZS_{GANP} coefficient in 2016 equals 62. This is due to a significant increase in the airframe systems events, such as landing gear (ATA 32), electrical power (ATA 24) and navigation (ATA 34). For the SCF-PP events category, a warning level of 26 was forecasted for 2016. The actual calculated value of the ZS_{GAPP} was significantly higher and in 2016 reached 38. This is shown in Fig. 3b.

Although it is not the subject of the article, it should be noted that almost 50% out of the total occurrences caused by powerplants could be assigned to the engine itself – ATA chapter 72. Most of the events are connected with powertrain and cylinder systems. The events were caused by cracked exhaust valves. In addition, carbon deposit was observed on them. Other occurrences were caused by different failures of the cylinders. It can be presumed that those damages were mainly due to engines overheating that resulted from an improper exploitation [5].

a) SCF-NP b) SCF-PP

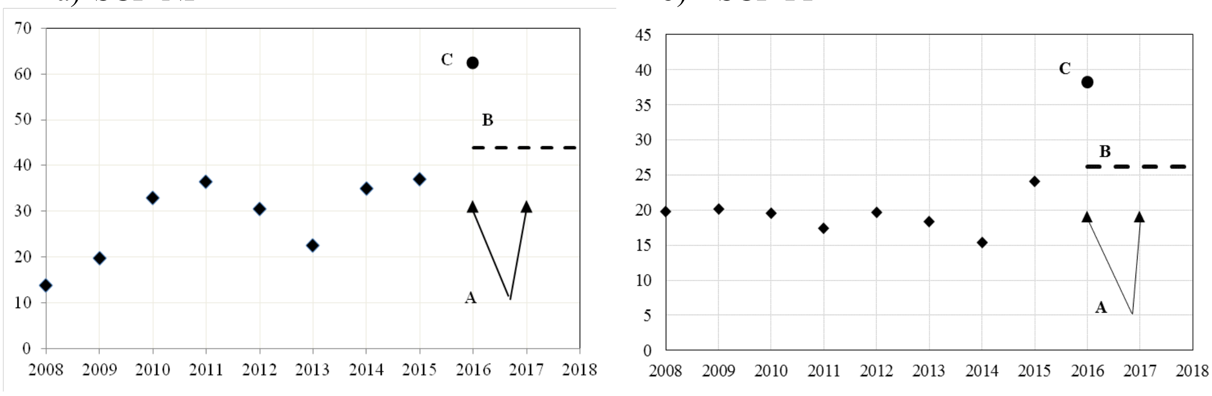


Fig. 3. Coefficients change: a) ZS_{GANP}; b) ZS_{GAPP}; (symbols as on Fig. 2)

There were 97 reported aviation events in the ATA 72 chapter between 2008 and 2016. 14 of them ended with emergency landings, 51 aborted flights and 3-aborted take-offs. It seems that the aviation authority's preventive measures are needed to reverse the dangerous trend of piston engines failures.

As an illustration of the occurring event's trends the changes of the ZS_{GA32}, (landing gear) coefficient between 2008 and 2015 is shown in Fig. 4a. The forecasted warning level for 2016 was 17 and its actual value for 2016 is 21.4.

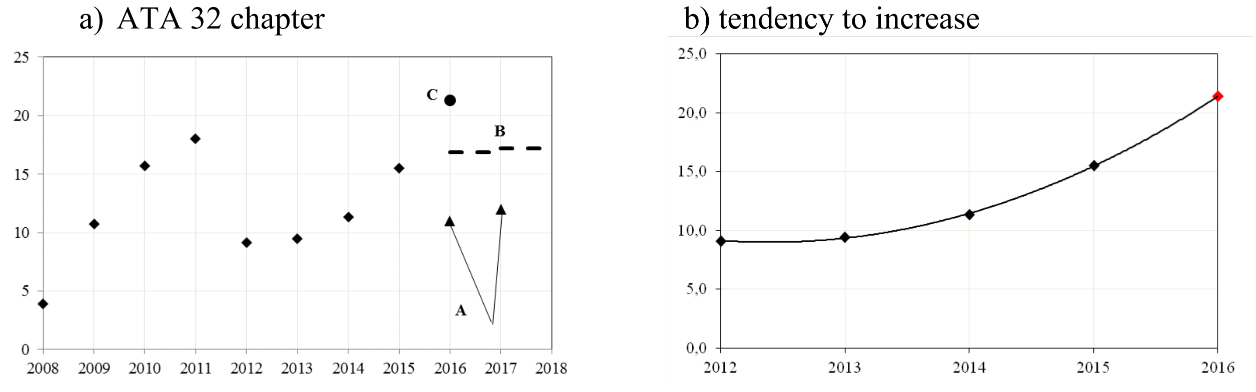


Fig. 4. Coefficient ZS_{GA32} changes: a), b) tendency to increase the value of this factor in the recent period (symbols as on Fig. 2)

As a result of a small number of events in previous years, the calculated average value of the ZS_{GA32} coefficient for 2016 was relatively low. There is a significant increase in its value after 2012 and the trend line is exponential (2-stage parabola). The mean value of the ZS_{GA32} coefficient calculated for 2016 lies on this line. For safety management matters, such situation should not be acceptable. Steady increase in safety or reliability factors must be stopped. Increasing level of the event rate shown in Fig. 4 should not take place. Already in 2014, preventive measures should be introduced in order to abate such upward trend of the events connected to the landing gear system.

3.2. CAT aircraft

As for the general aviation aircraft, the same ICAO categories were considered. For SCF-NP category, this is shown in Fig. 5a. The value of the warning level coefficient for the 2016 was estimated at 1608. The actual value of this coefficient in 2016 is less and equals 1540.

For the SCF-PP category, the forecasted warning level value for 2016 was 215 and a mean coefficient value was 176. The actual value of the 2016 coefficient is 179 as shown in Fig. 5b.

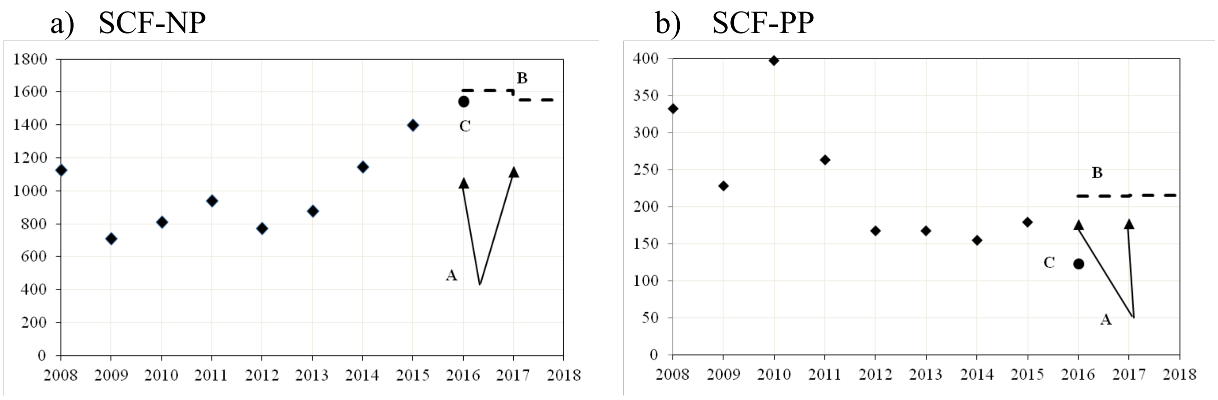


Fig. 5. Coefficients change ZS_{KNP} :a) and ZS_{KPP} :b), (Symbols as on Fig. 2)

Similarly as for general aviation aircraft, the ZS_{K32} event rate (the ATA-32 chapter) has significantly increased in 2016. It crossed the warning level (value 310) reaching 358, as shown in Fig. 6a.

Predictions did not just concern aviation incidents caused by technical failures. Below pictures comparison is showing of forecasts with actual 2016 calculations results for MAC events (Loss of Separation / Near Midair Collisions / Midair Collisions) and cockpit crews blinding by laser light. For the MAC category of a light aircraft, the predicted for 2016 warning level of the ZS_{GAMAC} was 13 and a mean of 8. The actual value of this factor in 2016 is 12 (see Fig. 7a).

For commercial aircraft, the warning level for 2016 was 429 when the actual value of the ZS$_{KMAC}$ in 2016 is 195 (see Fig. 7b). The value of this factor decreased for CAT aircraft but increased for general aviation.

a) ATA 32 chapter b) Tendency to increase

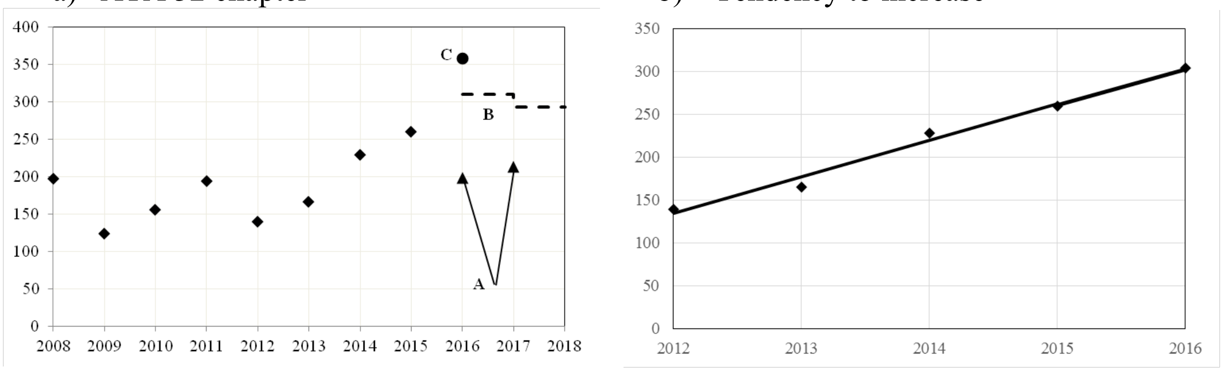


Fig. 6. Coefficient ZSGA32 changes: a), b) tendency to increase the value of this factor in the recent period (symbols as on Fig. 2)

a) aircraft MTOM< 5700 kg b) aircraft MTOM>5700 kg

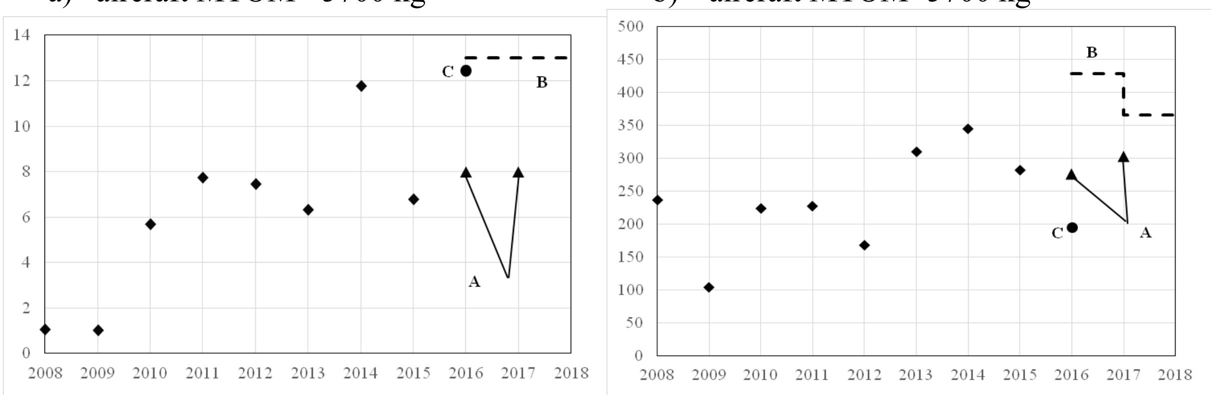


Fig. 7. Changes in the MAC coefficients value related to number of events per number of registered aircraft: a) coefficient ZSGAMAC; b) coefficient ZSKMAC; (Symbols as on Fig. 2)

It also seems that the cockpit crews blinding by laser light tends to decrease. In 2016, the number of events is lower as compared to the previous year, for both commercial aviation and general aviation.

a) aircraft MTOM< 5700 kg b) aircraft MTOM>5700 kg

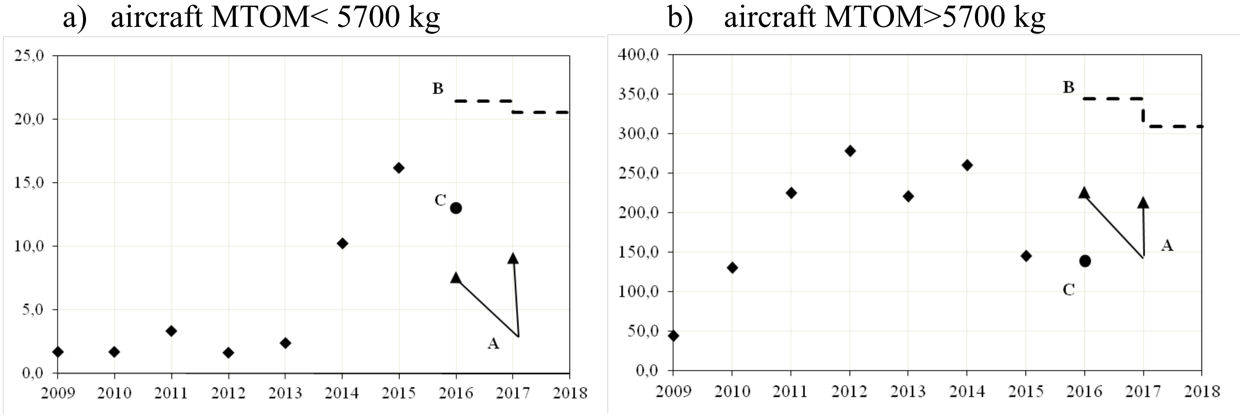


Fig. 8. Changes in the LASER coefficients value related to number of events per number of registered aircraft: a) coefficient ZSGALASER; b) coefficient ZSKLASER; (Symbols as on Fig. 2)

4. Conclusions

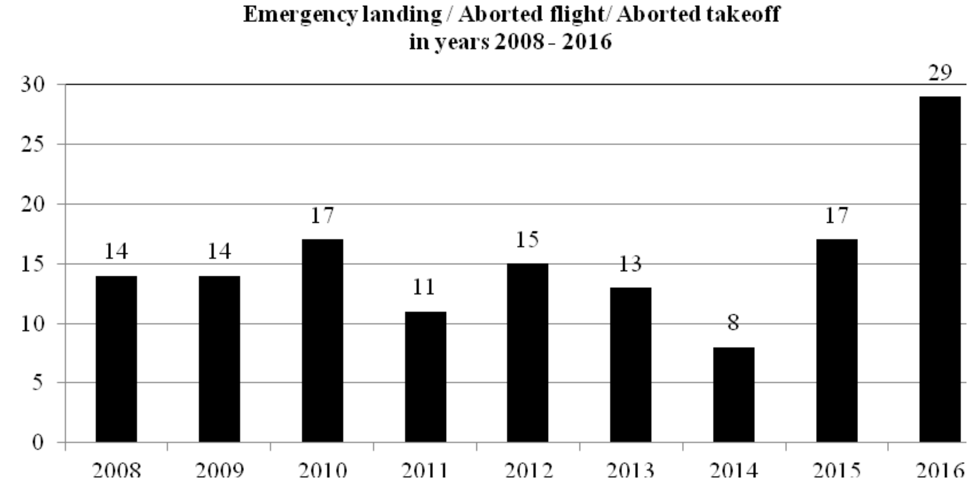
Results of calculations in the adopted methodology for determining warning levels and forecasting values of the $ZS_{GA(X)}$ and $ZS_{K(X)}$ coefficients for another two years are helpful for estimating safety risks at national level. They allow identification of the important aviation safety indicators and evaluate trends in their changes.

A sharp change (increase or decrease) in the value of any aviation safety indicator adopted for the assessment of aviation safety requires an immediate in-depth analysis of the causes of this phenomenon by the team of experts.

The observed overall tendency to increase the number of reported events cannot be justified only by the progressive increase in awareness of reporting those events.

Opposite, there are observed cases of declining number of reports in the following year despite the fact that nothing justifies the sudden reduction of awareness among the aviation staff.

As for example, below picture shows number of reported events caused by powerplant failures.



It is important to classify correctly events as early as entering to the ECCAIRS. This is a task for experts. Many of the events classified as OTHER really belong to other categories. Wrongly, classified events distort later analyses.

References

[1] *Aviation Occurrence Categories, Definitions and Usage Notes,* International Civil Aviation Organization, Common Taxonomy Team, (4.6), 2013.

[2] *Annual Safety Review 2014*, European Aviation Safety Agency, Safety Intelligence & Performance Department, Cologne, Germany 2015.

[3] *Aviation technician advanced training program Continental engine theory*, Teledyne Continental Motors, Inc., 2005.

[4] *ATA Specification 100 – Specification for Manufacturers*, Technical Data, Publications Department Air Transport Association (ATA) of America, Inc. Washington, DC 20004-1707 USA.

[5] Balicki, W., Głowacki, P., *Aircraft engines – analysis of reported systems failures in Polish Aviation during years 2008-2015*, Journal of KONES Powertrain and Transport, ISSN 1231-4005, Vol. 23, No. 1, pp. 31-37, Warsaw 2016.

[6] Balicki, W., Głowacki. P., Kawalec, M., *Assessment of the airframe systems affecting safety risks caused by large aircraft*, Journal of KONES Powertrain and Transport, ISSN 1231-4005, Vol. 23, No. 1, pp. 39-46, Warsaw 2016.

[7] Balicki, W., Głowacki, P., Loroch, L., *Safety performance indicators assessment for small*

aircraft airframe systems, Journal of KONES Powertrain and Transport, ISSN 1231-4005, Vol. 23, No. 2, pp. 31-38, Warsaw 2016.

[8] Coppola, A., *Practical Statistical Tools for the Reliability Engineer*, Reliability Analysis Centre, 201 Mill Street, 13440-6916, Rome – NY 1999.

[9] Głowacki, P., Balicki, W., *ICAO aviation occurrence categories significantly affecting aviation safety in Poland from 2008 to 2015*, Scientific Journal of Silesian University of Technology, Series Transport, No. 94, pp. 47-56, 2017.

[10] Krzyżanowski, Z., Wieczorek, A., Chróściewicz, A., *Wykorzystanie metody Bowtie oraz techniki GSN do analiz bezpieczeństwa ruchu lotniczego*, Prace Naukowe Politechniki Warszawskiej, Transport, Z. 103, Warszawa 2014.

[11] Loroch, L., *Bezpieczeństwo lotnictwa krajowego w działalności Instytutu Lotnictwa*, Oprac. „Bezpieczeństwo i niezawodność w lotnictwie, Rozwój lotnictwa w regionach", Wyd. NOT, Radom 2015.

[12] *Safety Management Manual (SMM),* Doc 9859, AN/474, Third edition ICAO, 2012.

[13] Pettit, D., Turnbull, A., *General Aviation Aircraft reliability Study*, NASA Langley Research Centre, 23681-2199, Hampton, Virginia 2001.

[14] Wiśniowski, W., *XX lat programu samolotów lekkich i bezpieczeństwa (PSLiB),* Transactions of the Institute of Aviation, No. 3(236), 2014.

[15] *Rozporządzenie Parlamentu Europejskiego i Rady (UE) nr 376/2014 z dnia 3 kwietnia 2014 r. w sprawie zgłaszania i analizy zdarzeń w lotnictwie cywilnym oraz podejmowanych w związku z nimi działań następczych,* Dziennik Urzędowy Unii Europejskiej, druk nr L 122/18 z dn. 24.04.2014.

[16] *www.ULC.gov/pl/regulacja-rynku/3724-statystyki-wg-portow-lotniczych.*