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Bird strike as a threat to aviation safety

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Abstract

This article discusses air safety and the importance of safety studies as an effective tool for detecting safety risks. It has to provide a brief overview of Aviation Safety Hazards with a detailed look at the danger of collision of aircraft with birds. There is a technical description of course of events in the bird ingestion into the engine flying aircraft in the particular case. The final chapter generally deals with ways to minimize the risk.

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Keywords: aviation safety hazard; bird strike; engine; damage

1. Introduction

Aviation safety is an area that is at the forefront of the interest of both national supervisors and operators themselves. One of the underappreciated tools in pursuit of increase civil aviation safety are the safety studies.

1.1. Safety Studies

The safety studies are an important means of increasing aviation safety and at the same time plays its part in minimizing safety risks. Their content usually ranks among the predictive methods of the security management system because its content addresses a specific security threat, even though it is based on practical knowledge of investigating

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the causes of events, which we classify as a reactive method. Both methods are sometimes referred to as direct methods.

Safety studies are primarily carried out as a follow-up step to identifying the causes of specific air accidents. If we analyses these accidents, we may find that the causes of some accidents recur frequently. This is exactly the space for the implementation of security studies.

1.2. Application of safety studies

In the conditions of the Czech Republic, the application of safety studies in the process of air accident investigation is not yet used, such as in France or Canada.

Air transport has been the safest from all kinds of transport such as road, rail and water for a long time. This trend is retained despite its continuous growth. For example, the total number of movements (arrivals and departures) at the Vaclav Havel Airport Prague (LKPR), the largest domestic airport, in 1990, was 48,745. There were 94,117 movements in 2000. This represents an increase of 93%. In 2010 there were reported 156,052 movements, which is more than triple in 1990 (Report on the noise situation at Prague/Ruzyně Airport in 2010-2011, 2012). The development of air transport is still growing. The increase is about 3-5% per year in general. In 2020 there were reported 53,440 movements. This decrease was caused by the COVID19 pandemic.

In the case of air transport, it is necessary to emphasize that concurrently it is the most financially costly kind of transport. The price of a new mid-size airplane (A320 or B737) is approximately USD 80 million. It is necessary to realize that the safety aspect only for conservation of significant funds is not important but the safety is related also with people´s lives that cannot be quantified financially.

Both of these factors have led to the establishment of Aviation Safety Program to minimize safety risks. This target is pursued by the Safety Management System (SMS), using the following methods:

- Predictive (safety studies),
- Proactive (audits and inspection),
- Reactive (investigation of causes of events).

At the same time there have been created Aviation Safety Hazards in SMS (Safety Management Manual (SMM), Doc 9859, 2006) which are subdivided into groups such as:

- Foreign object debris,
- Misleading information and lack of information,
- Lightning,
- Ice and snow,
- Engine failure,
- Structural failure of the aircraft,
- Fire,
- Ground damage,
- Volcanic ash,
- Human factors,
- Runway safety,
- Bird strike.

The last group will be described in more detail in the following chapters.

1.3. Methodology

Literature in the form of journal-articles, international-committee reports, air accidents investigation institutes reports, statistical analyses and news-media articles were reviewed with the aim of providing solutions to the problem, besides outlining salient recommendations.

2. Bird strike

When we are talking about bird strike we think about collision between a bird (one or more than one) and an airplane. The birds are a serious safety threat for crew and passengers on board as they can cause a great deal of damage to an airplane in a short period of time. Bird strikes most often occur during take-off or landing, or during a low altitude flight, when an airplane is most likely to be sharing the same airspace as a bird. Occasionally, they occur at higher altitudes. Take-off can be particularly dangerous for an airplane (maximum power of engines and the angle of ascent).

The Fig. 1 illustrates parts of an airplane which are most affected in the bird strikes. Three-quarters of bird strikes involve the wing or engines, but they can damage almost any part of an airplane. The impact of a flying bird into flying airplane does not have to be as a result of airplane damage. Most events do not cause any damage of the airplane. More serious situations are usually during spring and fall due to migration of birds flying in groups.

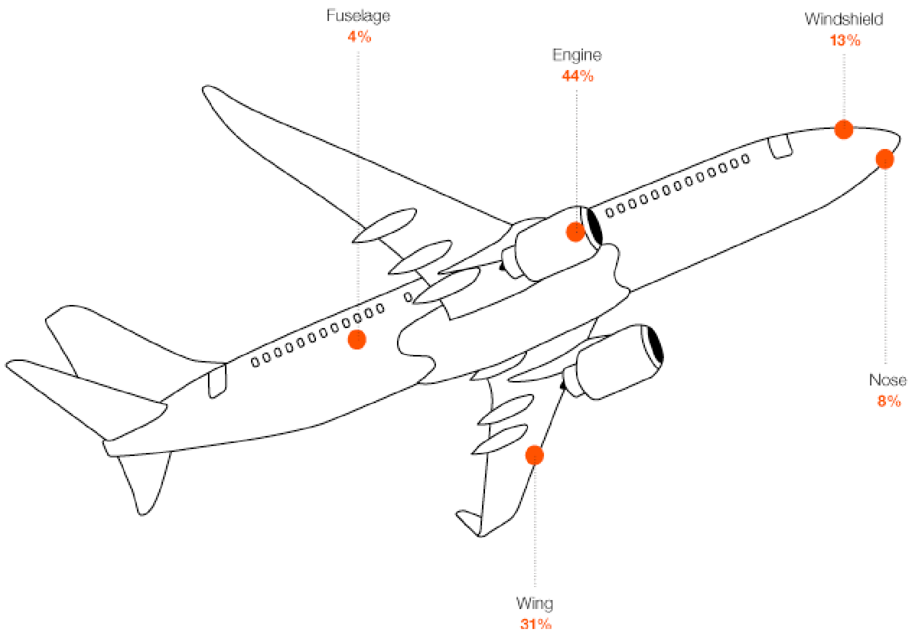

Fig. 1. Locations of Bird strike damage (Boeing).

One of the world's most famous accidents is an Air Asia Flight from Medan, Indonesia to Penang, on 26th September 2017, was forced to return to Medan after a bird was sucked into one of its engines. The airliner was carrying 150 passengers. On January 15th, 2009, a US Airways flight 1549 hit a flock of geese shortly after it took off from LaGuardia Airport in New York and was forced to land in the Hudson River. Reports indicated no deaths, nor serious injuries (Meer, 2019).

According to the statistical data, there were reported 92 bird strikes in the Czech Republic in 2013, of which 5 resulted in damage of airplane. The statistics of reported bird strikes in the last ten years are presented in the following graph Fig. 2. The figures given represent approximately 1% of the total number of reported events in the Czech Republic.

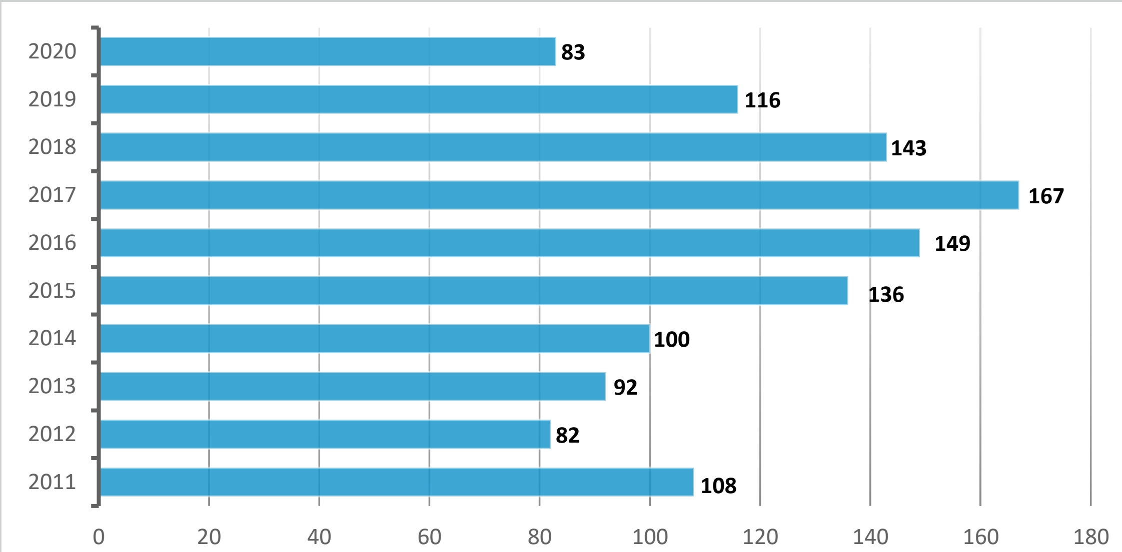

Fig. 2. Graph of Reported bird strikes per year (data AAII of the Czech Republic).

The most serious consequences of a Bird Strikes can affect the operation of propulsion units. The graph on Fig. 3 presents the number of events reported for each type of power unit.

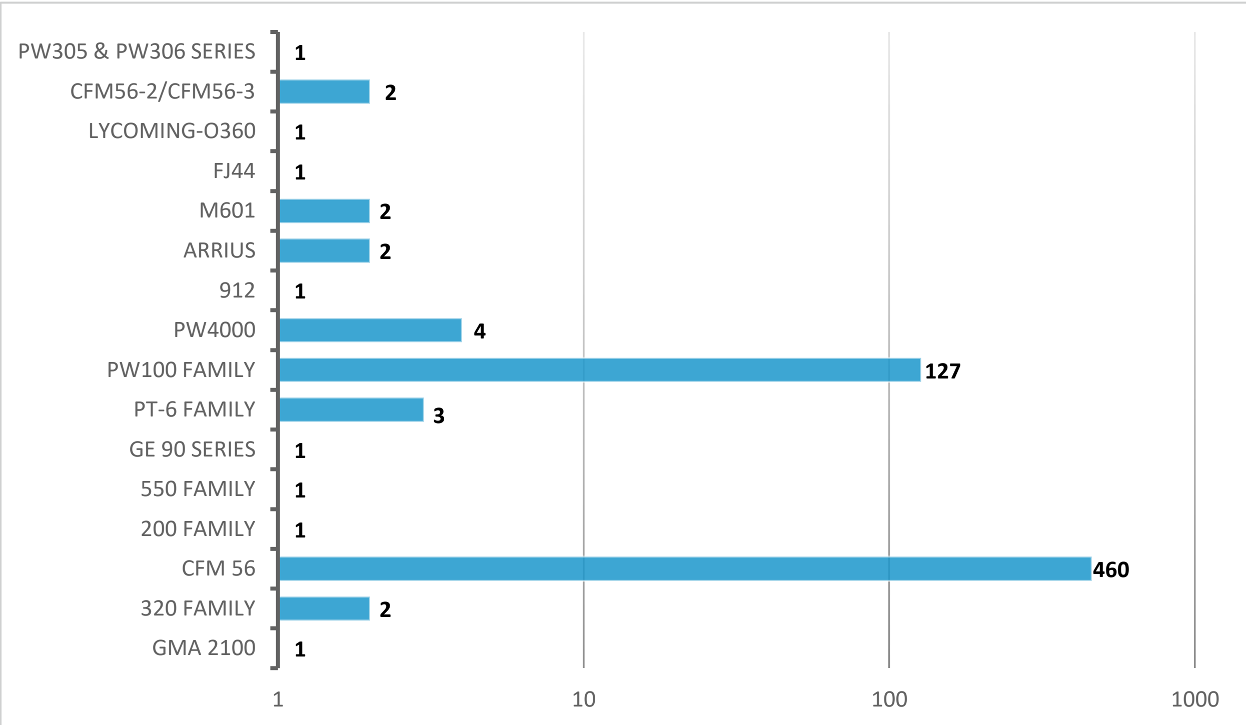

Fig. 3. Graph of Types of Engines impacted by bird strikes 2011-2020 (data AAII of the Czech Republic).

3. Bird strike with a Boeing B737

The actual occurrence which happened in the Czech Republic, at the Ostrava–Mosnov airport (LKMT) will be described in this chapter. This event, which took place at the regional airport (not at the airport with the highest traffic), was chosen due to the most serious consequences registered in the Czech Republic.

3.1. History of flight

On 14 November 2008 the flight crew of Boeing B737 registration mark OK-WGX was due to make a commercial flight from LKMT to Hurgada airport (HEGN). The crew pre-flight preparation and embarkation of passengers went in a standard way. The first officer was the pilot flying on this route. According to the flight recorder, the parameters of both of the engines were alright during the start and taxiing. RWY 22 was used for taking off. At the beginning of the take-off run the crew spotted a bird of quite a big size. At the final stage of the aircraft´s take-off run the bird flew out, headed for the aircraft passing it to the right. A moment later the crew felt something hit the fuselage on the starboard side, thinking the shock took place at the right-hand main landing gear.

At a speed of 176 kt the aircraft left the runway surface and then retracted the landing gear. The TWR controller informed the crew he had spotted flashes coming from the engine. The crew received the information and at the same time noticed that engine 2 vibration got to the limit value.

After the flaps retraction, the autopilot on the co-pilot side was switched on. 40 s later the crew put the landing gear down because they thought the right landing gear tyre had been damaged after collision with the bird.

The crew told the TWR controller they intended to fly back and land at the LKMT as soon as they had finished Non – Normal Checklist according to Quick Reference Handbook (QRH).

The crew solved the problem of exceeding the exhaust gas temperature limit by switching off the engine 2. The captain decided to fly to LKPR.

The aircraft landed on LKPR RWY 24 with a landing mass of 54,594 kg experiencing no more failures. After the aircraft had come to a halt, been inspected and towed to a stand, the passengers got off in a standard way (Final Report No. CZ-08-562, 2009).

3.2. Damage to airplane

On landing at the LKPR and inspection by operator´s technical staff it was confirmed that the engine 2 had been seriously damaged (Fig.4). Other damage, to the skin, airframe, or the supposed damage to the main landing gear wheel tyre, has not been found.

The engine 2 was seriously damaged as a consequence of having sucked a bird. Directly on the stand of the aircraft it was found that the fan blades were damaged, the inlet cowl inner wall had been pierced, and a small amount of fuel had leaked from the engine control system. A closer inspection revealed that assemblies on the engine outer part and their hinges (starter, Main Engine Control, fuel pump) were damaged too.

Based on this findings and after discussion with the engine manufacturer it was decided to remove the engine and send it to a foreign repair shop to know the damage in more detail and the way and scope of repair.

Apart from the damage already mentioned, extensive damage to the compressor was also found. The low pressure and high pressure rotor blades were ground off by the contact with compressor case and seriously damaged. The combustor was without damage only some deposit of brushed dust from the compressor was found. The high pressure turbine had its cooling holes blocked with brushed dust, which caused its overheating (Fig.5, 6). The low pressure turbine moved to the rear due to the nut of bearing 1 coming loose, thus making contact between the rotor and stator of the turbine, resulting in low pressure turbine damage (Final Report No. CZ-08-562, 2009).

Fig. 4. Overall view of engine inlet (AAII of the Czech Republic)

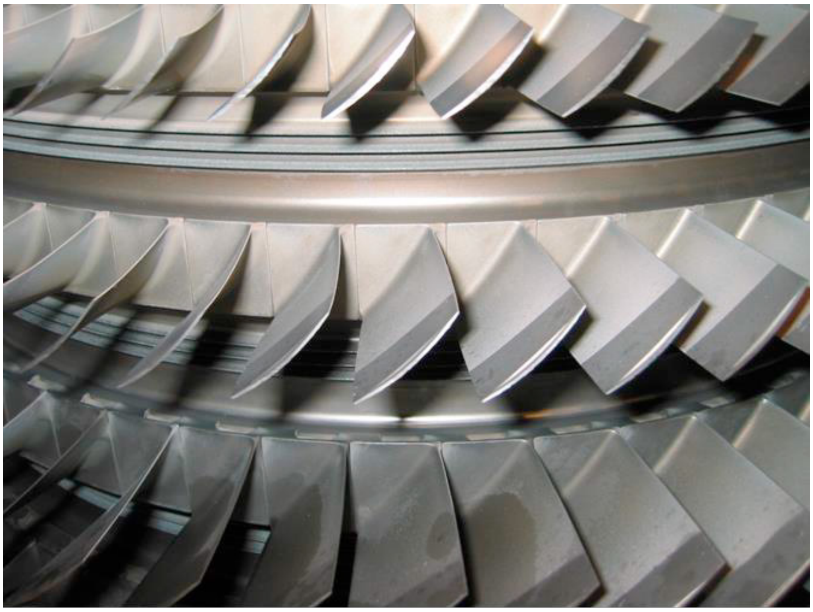

Fig. 5. Abrasion of high-pressure compressor blades (AAII of the Czech Republic)

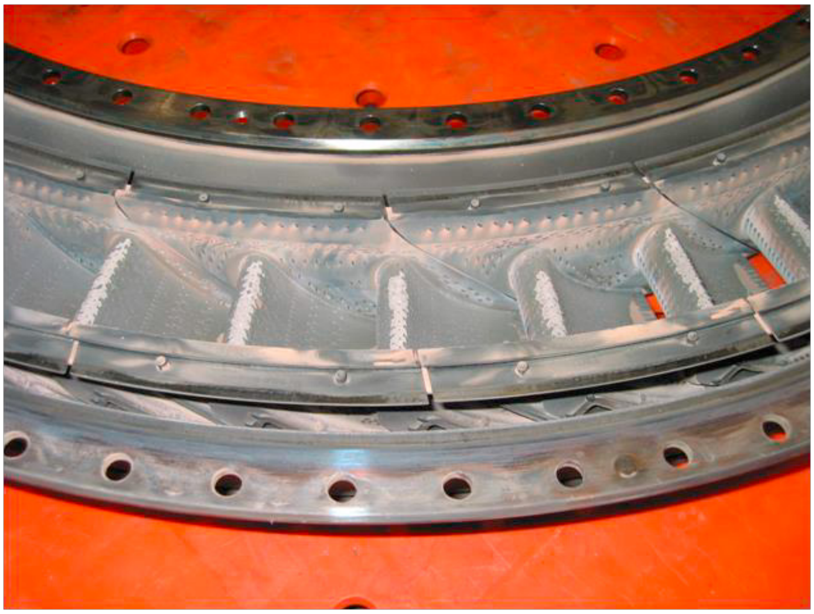

Fig. 6. Deposit of abrasion dust on high-pressure turbine stator blades (AAII of the Czech Republic)

Flight recorders

The course of the flight has been evaluated from the Quick Access Recorder (QAR). The data record was easy to read.

It is evident from the recording that engine´s parameters had not deviated from standard values till the moment the bird was absorbed (Fig.7).

Time sequence of the values of selected parameters (Final Report No. CZ-08-562, 2009):

- 10:54:28 engines 1 and 2 are on idle regime, parameters of either engine are steady and vibrations of fans of either of them are at value 0.20
- 10:56:28 take-off regime set in the course of take-off run, fan vibration of engine 1 at value 0.18, fan vibration of engine 2 at value 0.10
- 10:56:43 at an airspeed of 166.5 kt revolutions shoot of engine 2 low-pressure compressor (take in a bird)
- 10:57:08 ramp change of engine 2 fan vibration from 0.10 to 4.88; engine 1 fan vibration at 0.27 value
- 10:58:07 engine 1 regime reduced to flight idling
- 11:05:27 exhaust gas began to rise from 531.4 degrees Celsius
- 11:06:15 exhaust gas maximum temperature reached 974.8 degrees Celsius (Fig.8).
- 11:06:18 engine 2 shut down

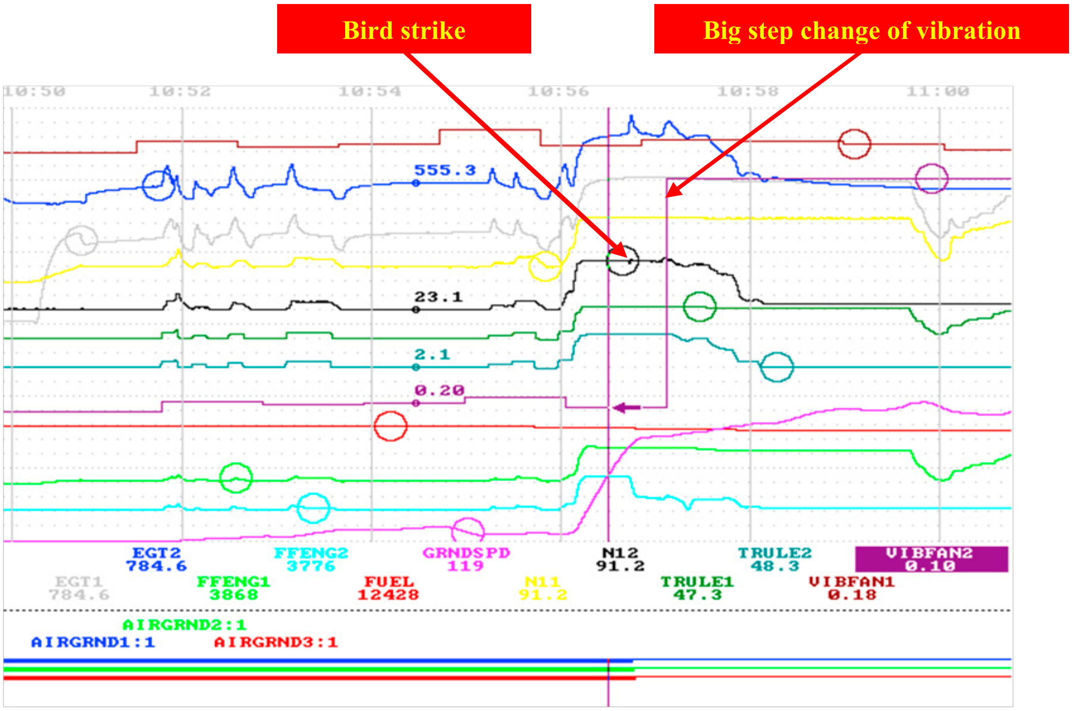

Fig.7. Engine parameters as recorded at the time of collision with bird (AAII of the Czech Republic)

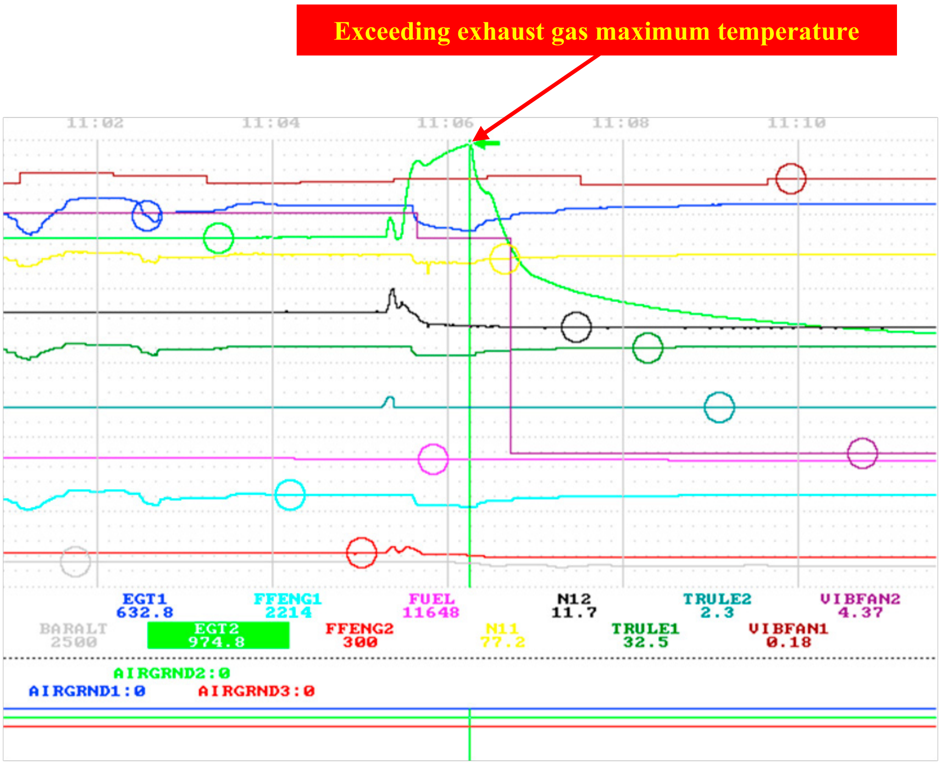

Fig.8. Engine parameters as recorded when exceeding exhaust gas maximum temperature (AAII of the Czech Republic)

3.3. Likely cause of engine failure

A few fan blades broke off after engine 2 took in a bird. Rests of the bird and blades left the engine with by-pass flow, damaging the fan case. Broken blades caused the engine to vibrate strongly. Consequently, parts on the engine external side were damaged. The bearing no.1 nut came loose, causing the Low Pressure Turbine (LPT) shaft to loosen and move back. This made the stator get in contact with the LPT rotor discs. The strong vibration caused mutual oscillation of the high-pressure rotor and the High Pressure Compressor (HPC) box, which in turn caused Low Pressure Compressor (LPC) and HPC rotor blades and box to get in contact. The blade tips were ground off on the case. The created grind dust moved to the rear through the engine where it plugged cooling holes on High Pressure Turbine Nozzle Guide Vanes (HPT NGV) and HPT blades. Consequently, the cooling capability was gradually reduced, causing exceeding of engine maximum allowable temperature even at flight idling regime (Final Report No. CZ-08-562, 2009).

This event demonstrates that the risk of bird trikes can be a serious factor influencing aviation safety even at smaller, regional airports with low density of the traffic, in areas with small and medium-sized bird species. In this case, the fact that only 1 engine was hit played a role. In the event of shutdown of both engines, there would be a real threat of a similar situation as for flight 1549 mentioned in Chapter 3.

4. Discussion

4.1. Tests of engine resistance to bird collisions

Bird strikes, the mass of the bird and the part of the aircraft struck are all random elements (Fig. 9 shows numbers of Bird Strikes per 10000 flights in Czech Republic airspace). In managing risk all that can be controlled are the design and testing of the aircraft driven by certification specifications, the aircraft's flight profile and, to a limited extent, the populations of birds near airports (Bird Strike Damage & Windshield Bird Strike 5078609-rep-03, 2009).

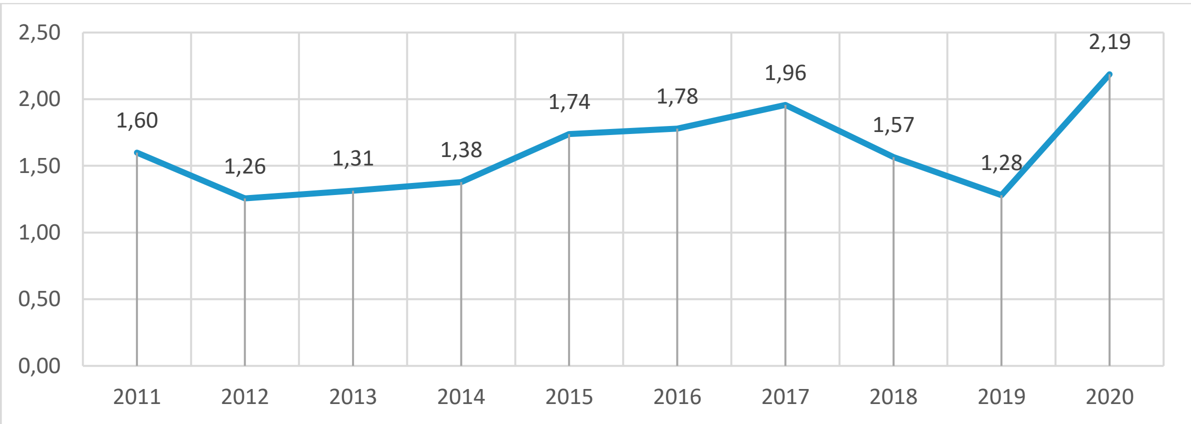

Fig. 9. Number of Bird Strikes per 10 000 flights (data AAII Czech Republic)

CS-25 /FAR Part 25 - Large Turbine Powered/Transport Aeroplanes requirements are worded somewhat differently with FAA requirements but the principal requirements (Continued safe flight and landing after impact with a 4 lb bird at cruise speed (V_C) at sea level or 0.85 V_C at 8000 ft (2438 m), whichever is the most critical.) are effectively the same (CS-25 Large Aeroplanes, 2020; Part 25 Transport Category Airplanes, 2021).

Kinetic Energy Equivalence of Bird Strike Requirements involved a bird mass and an impact velocity related to particular aircraft performance parameters (e.g. V_C or V_{FE}). The energy of the collision between the bird and the aircraft can be used as an indicator of the potential for structural damage to the aircraft. The kinetic energy (KE) of the collision is given by the expression (1) where m is the bird mass and v is the relative velocity.

$$KE = \frac{1}{2} \cdot m \cdot v^2 \quad (1)$$

EASA conclusion is that, CS-23 (excluding commuter) and CS-27 aircraft categories there are currently no specific bird strike requirements and this is reflected in a higher rate of bird strike. Other conclusion specified that 96% of strikes occur during take-off, climb, approach and landing.

The question is whether the requirements are adequate for current types of high-performance engines.

4.2. Bird strikes prevention

Indirect methods and Direct methods (technical solutions) applicate to reduce the risk of a collision between a bird and an airplane:

- pyrotechnics: firecrackers, automatic gas cannon, firearms;
- acoustic means: e.g. 'shout of fear' reproduced around loud-speakers, or voices of hunting predators (high recording quality must be maintained);
- chemicals: spraying repellents, e.g. anthranilic methylate (range up to 500 m);
- use of trained birds of prey and trained dogs (the most effective border collie, which, however, must be accustomed to airplanes, and denied from entering the runway);
- a motorised 'flying crew' to drive away the flock (Balicki et al., 2021).

The problem is that birds are able to adapt to the applied methods and after a certain time they become resistant to them. Therefore, it is necessary to deal with the continuously development of new methods leading to the elimination of possible conflicts.

5. Conclusion

Nowadays there are a number of organizational measures (Indirect methods) and technical solutions (Direct methods) to reduce the risk of a collision between a bird and an airplane.

It is important that all methods of a biological protection at the airport were based on the results of an ornithological research and monitoring. If you know which animal species are dangerous for air traffic, you will choose the right methods to reduce the risk of collisions.

Indirect methods include ornithological research and statistical processing of results, record keeping of bird strikes, determination of animal species, statistical data processing, presentation of ornithological reports and personnel training.

Direct methods include dogs that are used for scaring animals inside the airport, birds of prey (Saker Falcon, Peregrine Falcon, Northern Goshawk and Gold Eagle), weapons (shotgun) and different acoustic means (flare gun, shrapnel).

The whole process of preventing dangerous collisions of aircraft with birds is all the more complicated because the individual specific measures from direct methods are only effective as long as the birds become accustomed to them. Then their efficiency decreases, and therefore it is necessary to replace them, i.e. to introduce new and effective ones. It follows from the above that this is an open process, which needs to be constantly renewed and supplemented with new methods.

Many experts engage in this issue worldwide. The result of their work is to improve current practices and the development of new methods, based on new findings.

New ways of eliminating collisions with birds may focus on the application of bird-repellent visualization elements, which may be the subject of further applied research.

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