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THE TRAGEDY OF FLIGHT: A COMPREHENSIVE CRASH ANALYSIS

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Abstract

This title is expressed on an airplane crash case to analyze and identify the accident contributing factors. The accident occurred on 27th of December 1991 in a few minutes after a Scandinavian Airlines System plane departed from Stockholm on a route to Copenhagen, Denmark. It was found that the cause of this accident is a combination of several factors. Errors can result from ambiguously written procedures, inadequate training, unexpected operational situations or individual judgments. Situational awareness, environmental and crew coordination factors, as well as shortcomings in pilot technical knowledge, skills and experience, also can cause incidents.

1. Introduction

1.1 Over view

On 27th of December 1991, an aircraft of model MD-81 operated by Scandinavian Airlines System (SAS), flight SK 751 departed from Arlanda International Airport in Stockholm, Sweden, on a route to Copenhagen, Denmark. In a couple of minutes afterthe departure both engines failed and the emergency landing had to be made on a field. Unfortunately, it did not succeed and the aircraft was broken in three pieces on impactwith the ground

1.2 Purpose

The aim of this study is to analyze the accident and identify the sequence of events and conditions that contributed or caused the crash.

2. The Problem Definition and Design Thinking

The day before accident SAS MD-81 plane arrived to Stockholm from Zurich in late evening hours and was parked at gate overnight with temperatures of around +1 °C. There were left approximately 2550 kg of fuel in each wing tank. Thenext day aircraft was scheduled to leave Stockholm for Copenhagen at 08.30 h.

After 5 s captain could hear a humming noise. After 25Ss the right engine started to surge. Surging occurs when the compressor is no longer able to compress the incoming air to the pressure obtaining in the engine's combustion section and this result in violent air shots in the opposite flow direction.

The captain throttled back on the surging engine somewhat, but the surges continued until the engine stopped delivering thrust after 76 s of flight. When the flight had lasted 65 s the left engine also started to surge, which the pilots did not notice before this engine also lost thrust. This happened two seconds after the right engine had failed.

When both engines had failed the crew prepared for an emergency landing. When the aircraft wasentirely out of the cloud at a height of 300 to 250 m, a field in the direction of flight waschosen for an emergency landing. During the approach the aircraft collided with trees and a major part of the right wing was torn off.

The tail of the aircraft struck the groundfirst and after the impact the aircraft slid along the ground for 110 m before stopping. The fuselage was broken into three pieces and no fire broke out. All 129 people on boardsurvived and most without physical injury. One passenger suffered a disabling back injury. Figure 1 shows the flight pass of SAS flight 751.

2.1 Empathy Map

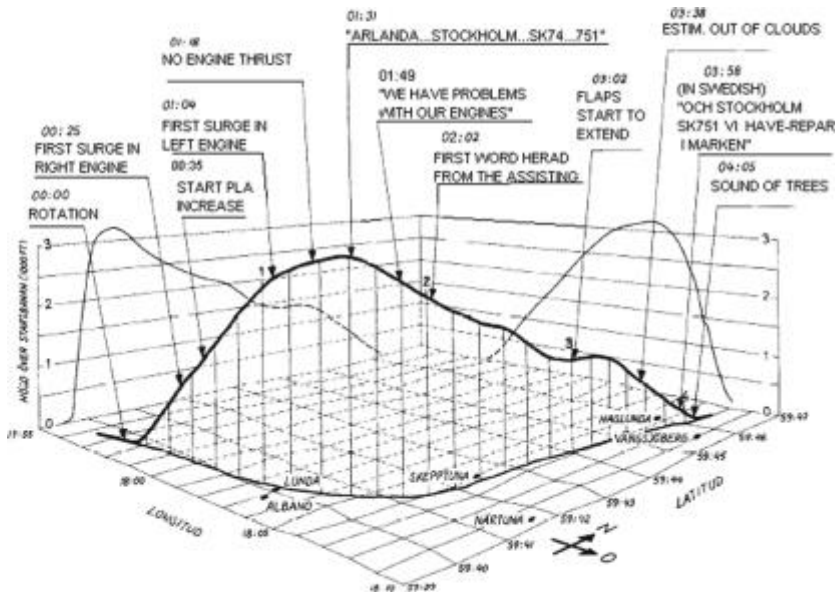

Fig. 1. SAS flight 751 flight pass

2.2 Ideation & Brainstorming Map

Modern business aircraft are technological marvels. Utilizing the big screen multifunction electronic displays that have replaced the dozens of traditional single purpose mechanical instruments in the cockpit, “smart” fuel control systems that protect the engines from exceeding specified temperature or power limits and advanced airfoil designs, that achieve both high-speed cruise and slow-speed stability, commercial jetsand turboprops have attained an unprecedented level of efficiency and safety. Today, mechanical problems account for only a fraction of aircraft-related safety incidents.

These developments are welcome news to all which travel by air; but to focus solely on the machinery of flight is to overlook the most critical safety component. The fact is that even the most technologically sophisticated commercial jet is only as safe as the pilots flying it are. Analysts estimate that 70% to 90% of aviation accidents involve some degree of pilot error.

An airplane is now part of a complex modern technology system, and there are threeaspects combined in safety matters within these systems as shown in Fig. 2. All combined, had an important influence in the occurrence of the accident.

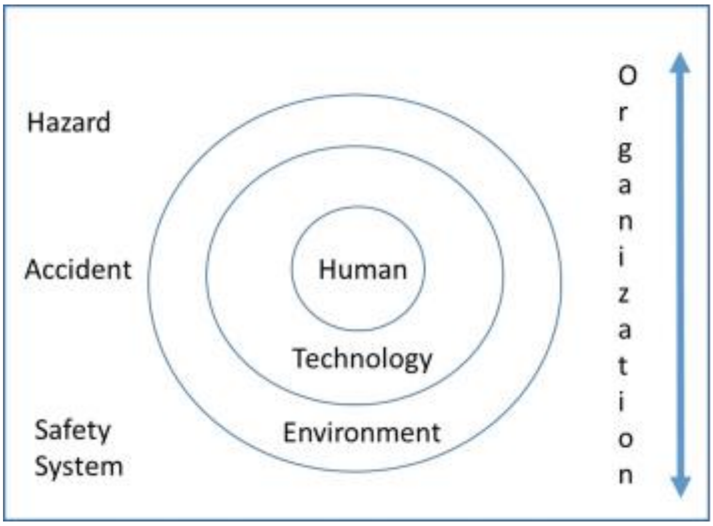

Fig. 2. Safety matter within complex technology system

The aircraft MD-81 crash can be called a system accident with a chain of different causes. Here we provide an identification of initiating events and states as causal factors.

3.Result

The weather conditions on December 27,1991 at the time of departure in Arlanda airport was intermittent light snow, windy winter morning with the temperature approximately –0 °C.

During the rescue operation it was overcast but with no precipitation, with temperatures around 0 °C. The ground was frozen crust with a thin layer of snow.

Icy weather is a matter of life or death for the Federal Aviation Administration. Ten airline accidents during takeoffs between 1978 and 1997 are attributed to ice forming on jets. As a result, the FAA established tougher rules for aircraft de-icing on the ground.

4.Advantages and Disadvantages

4.1 Advantages

Modeling of traffic crashes is a complex undertaking. This short paper, from the Traffic Records Forum, held in Buffalo, NY in 2005, reports on a study of the advantages and disadvantages of different crash modeling techniques.

The authors review the methods that have been used, including regression analysis, artificial neural networks, and pattern recognition methods that include nearest neighbor rule and Bayesian belief network technique.

4.2 Disadvantages

The disadvantages and that the suitability of the method depends upon the desired output and the model inputs. The output of the model could include type of the crash (fatal, injury, and property damage only, number of crashes, crash rate, segment/intersection severity rating); the inputs may include different environmental, traffic, and roadway variables.

5. Applications

5.1 Knowledge of ATR within SAS

At the time of the accident there was no knowledge of ATR (Automatic Thrust Restoration) within SAS. The pilots were therefore not trained on ATR and information about it was not included in their operational documentation. However, all the necessary information was given in the aircraft manufacturer's manuals avail-able within the company. Hence ATR was described in manuals which every operator is obliged to know.

Even though the system was originally developed for usein special procedures not applied by SAS, a sufficiently careful study of the manualsshould have led to SAS noting the system and training its pilots in its function. If the pilots had been informed concerning ATR they would have had more chance of noticing the changeovers.

They would then have been better prepared to take adequate action. It was a serious deficiency in flight safety that the pilots lacked knowledge of ATR and its function. It should be noted that in the event of loss ofthrust from one engine during the takeoff phase, ATR must ensure that the ATS (Auto Throttle System) immediately regulates thrust in the functioning engine.

The ATS always maneuvers the engine throttle levers simultaneously and equally. This means that ATR initiates increase of an engine thrust and affects the engine that caused the system to be activated. Therefore there is strong requirement for instructions on how pilots are to act in the event of engine surging during takeoff.

5.2 The combustion system failure

Nothing has emerged to indicate that the aircraft's engines before the rotation had any technical fault that affected the development of engine surging. However, a manufacturing fault in a weld seam in the aircraft's main fuel duct to the left engine contributed to a fuel leak occurring in connection with the engine failure.

The course of the failure was very similar in both engines. Mentioned before sequence of events will be now stated with more details:

Modern turbofan engines are sensitive to damage to fan blades and outer fan blade seals. Fan blade damage located on the blades outer tips is particularly critical. Such damage can at high engine power cause local fan tip stall.

The fan tip stalls can increase and form "rotating cells" in the fan stage which called as continually rotating fan tip stalls.

The aerodynamic disturbances in the fan stage propagated themselves to the compressors and caused engine surging. As it was indicated before activated ATS through the effect of ATR caused an increase in throttle that contributed to the fact that

the surging continued and intensified until the engine finally broke up. The risk of engine surging as a consequence of damage in the fan stages depends on the extent and character of the damage.

The surges subjected the engines to aerodynamic and mechanical stresses that became greater with the increasing engine power. The engine damage indicates that the stage 1 stators were finally broken up by these stresses and the engine failed.

The increase in engine power also caused the left engine to surge and fail in the same manner. The impact damage found on the fan blade trailing edges was caused largely by broken-off stator pieces. The pieces then accompanied the airflow into the front compressors, causing extensive damage to their front stages. Blades and guide vanes in the rear parts of the compressors were damaged by pieces struck loose further forward in the engines.

When the engine compressors failed there was high air pressure and thereby a copious supply of oxygen. Local high temperatures were generated through friction between rotating, static and broken-off metal pieces. Titanium alloy pieces were thus ignited. Through a combination of high temperatures and mechanical load, holes were made in the engines' rear compressor cases, which serve, as pressure vessels for the rear compressors. The pressure and temperature thereby decreased rapidly, causing the titanium fire to stop spontaneously after the brief break-up phase.

Thanks to the fire alarm system the first officer has recognized the risk and initiated the engine fire extinguishing system.

As the further consequence of the engine failure was electrical power failure that inactivated captain's Electronic Flight Instrument System presentation that caused more difficult to steer the aircraft in emergency landing.

5.3 Negligent Attitude by SAS

The risk of ingestion of clear ice by the engines of the aircraft type has been known for many years. As early as 1985 a DC-9-51 suffered serious engine damage for this reason. On the MD-80 series, the risk is greater due to the configuration of the wing tanks and the larger engine air intake area.

The manufacturer has therefore over the years taken a number of steps to inform operators of the problem and has distributed numerous service bulletins intended to reduce the risks.

The problem has thus long been known within SAS. In 1987 the aircraft were equipped with warning triangles with indication tufts to facilitate the discovery of clear ice. It was stated that it is the captain's responsibility to check the presence of snow and ice which might affect the aircraft's performance.

In the training of MD-80 pilots the clear ice problem has not been specially dealt with; nor were there any special written instructions for the pilots' action if there was a risk of clear ice. If the pilots had more knowledge and unambiguous instructions, they would probably have been more alert to the risk of clear ice formation.

Technical personnel were thus familiar with the clear-ice problem through training and information. In the Board's view, however, the clear-ice problem as dealt with in LMH, which is the formal governing document for direct work, had an obscure position and lacked detail instructions on how the check for clear ice should be carried out; nor was there any follow-up on how the check should be performed in daily practice. There was no routine for reporting on observations regarding clear ice.

Though, the technician who inspected the aircraft during the night noted the presence of clear ice, but there was no instructions obliging him to report this to the mechanic who was to carry out the departure check next morning.

Furthermore, the technical personnel had no access to suitable aids for checking effectively. To reach the critical area on the upper side of the wing without risking an accident, either special tools or specially built ladders would have been required.

It must be considered remarkable that the numerous different warning signals on the risks associated with clear ice that have reached SAS over the years have not led to effective actionbeing taken to ensure that aircraft did not take off with clear ice on their wings.

It is obvious that SAS self-monitoring has been deficient regarding the handling ofthe clear-ice problem. It also emerges that the Scandinavian Civil Aviation Supervisory Agency was not aware of the deficient quality assurance. The Board points out that theidea of self-monitoring presupposes that the supervisory authority ensures that the company possesses a well functioning system of quality assurance.

6. Conclusion

The cause of this accident is the combination of several factors, ambiguously written procedures, inadequate training, unexpected operational situations or individual judgments. Situational awareness, environmental and crew coordination factors, as well asshortcomings in pilot technical knowledge, skills and experience, also can cause accidents. Other mistakes might be the result of improper airspace design or crew coordination.

As an initial event, the clear ice formed on the upper surface of the wings was not detected and de-iced well. The company instruction, procedures and even the equipmentwere not sufficient to remove the clear ice from the wing surface.

Hence during the take-off the clear ice was broken off the wings and ingested by the engines and caused damagethe engine fan stages, which led to engine surges and failure. The pilot had no sufficient knowledge and training to identify the problem and taking the necessary action. Furthermore, there was no knowledge for applying Automatic Thrust Restoration system (ATR) within the company (SAS).

7. Future Scope

This was activated and increased the engine power without the pilot knowledge. Another contributing cause was poor emergency landing responses in terms of speed and flap position for approach and landing.

Finally, it may be concluded that unsafe pre-conditions which had been created by SAS organization in terms of training, instruction, operational procedures etc. were blamed for pilot and technicians errors and mistakes which led to the crash.

8. Appendix

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