# Summary and recommendations

## Summary

Operational

The incident occurred in connection with a commercial air transport with the airline Iran Air. The aircraft in question, an Airbus A300-600 with the registration EP-IBB, was to commence a flight from Stockholm/Arlanda Airport to Tehran in Iran. Following normal preparations, the aircraft was taxied out to runway 19R for take-off.

The runway conditions were reported as good, with some patches of ice along the runway. The investigation has however revealed that the runway was contaminated and likely had coefficients of friction which fell short of the reported values.

After taxiing out, the crew began routine take-off procedures by increasing engine thrust during acceleration on the runway. After just over 10 seconds, one or more of the edges in a repaired section of the engine – the diffuser aft air seal – separated, thereby triggering a sequence which led to a sudden engine failure.

No warning messages were announced in the cockpit at the time of the failure; the pilots only noticed the engine failure through a muffled bang at the same time as the aircraft began to veer to the left. The initial veer, immediately after the engine seizure, was a result of the nose wheel being unable to gain sufficient force against the contaminated surface to counteract the moment which arose when the right engine – for a duration of approximately 1.5 seconds – supplied full thrust at the same time as the left engine rapidly lost thrust. The highest speed registered during the sequence was 59 knots (110 km/h).

Despite the co-pilot's reactions – retarding the thrust levers after just over a second, at the same time as steering and opposite rudder were applied – the veer could not be corrected and the aircraft ran off the runway, mainly caused by the forces from the moment in combination with the slippery surface. The chances of stopping the continued veer were probably reduced by the fact that the pilots did not apply any differential braking in the opposite direction.

The investigation also showed that the pilots' braking was unintentionally asymmetrical, with a higher brake pressure on the "wrong side", i.e., in the direction in which the aircraft ran off the runway. Even if this fact may have affected the aircraft's movement pattern, such an impact has, however, not been possible to determine with any reasonable degree of certainty. It is, nevertheless, noteworthy that analyzed data from the FDR show that the recorded brake angles (asymmetric braking) were not accompanied or followed by any corresponding change in the rate of heading change.

There are no specific certification requirements for aircraft design organization to show that the aircraft is manoeuvrable in the event of a sudden loss of engine thrust during the initial stage of the take-off sequence. There are also no mandatory requirements for training regarding how to handle sudden losses of engine thrust during the initial stage of the take-off sequence for pilots in training or recurrent training for this class of aircraft.

Technical

Following the event, the engine was sent for examination to Lufthansa Technik (LHT) in Hamburg on behalf of SHK. Following a completed damage analysis, LHT provided a report on the examination. In addition to an analysis of the sequence and the damage, the report also contained an
opinion on the probable cause of the engine failure.

According to LHT, it is likely that the diffuser aft air seal had come loose due to micro cracks in the nine attachment lugs that hold the seal against the diffuser.

Neither General Electric Aircraft Engines (GE) nor SHK were in agreement with the LHT's assessment of the recovered hardware for which reason the decision was made for further analysis of the recovered parts of the failed engine at the Volvo Aero Corporation metallurgical labs.

The analysis carried out by Volvo Aero Corporation indicated that the engine failure that occurred – and which was the primary reason for the incident – had probably been caused by fatigue damage in a different part of the diffuser aft air seal.

The engine failure started once the aft air seal separated from the diffuser assembly. Seal fragments began increasing the amount of debris when seal material fractured a six bolt section of the stage 1 HPT[1] blade retainer,
liberating pieces of bolt threads, nuts and retainer material. This debris quickly got into the engine gaspath resulting in downstream damage from the HPT Rotor aft causing an engine stall.

The engine stall is clearly visible in the films taken by onlookers from the station building. As the liberated debris travelled aft down the engine's gaspath, low pressure turbine blades were being broken / separated. With the amount of LPT[2] blade damage, fan speed (N1) began to decrease since the LPT didn't have enough blade airfoils to drive the fan.

The overall assessment of the investigation results suggests that the fatigue had started in the repaired seam at the diffuser aft air seal teeth. All documented cases of CF6-80C2 diffuser aft air seal failures have been seals that had been previously repaired.

The incident that occurred was caused by the following factors:

*Operational*

- Deficiencies in the certification process for large aircraft with wing-mounted engines with regard to requirements for yaw stability in the event of sudden loss of engine power in the speed range below $V_{MCG}$.

- Deficiencies in pilot training with regard to training for sudden losses of engine thrust in the speed range below $V_{MCG}$.

[1] HPT - High Pressure Turbine.
[2] LPT - Low Pressure Turbine.

*Technical*

- Deficiencies in the approval and follow-up of the Dabbler TIG Weld repair on the engine's diffuser aft air seal.

**Recommendations**

ICAO is recommended to:

- Take measures in order for authorities that issue certification directives – the FAA and EASA – to adopt the safety requirements issued by ICAO in Annex 8 concerning safety in large aircraft, so that these are applied during the entire take-off sequence of a flight. *(RL 2012: 21 R1).*

The FAA is recommended to:

- Investigate, in consultation with EASA, the prerequisites for introducing requirements concerning yaw stability in large aircraft in the event of sudden loss of engine thrust below $V_{MCG}$ under the anticipated operating conditions. *(RL 2012: 21 R2).*

- Review and revise processes and permissions issued for the Dabber TIG Weld repair method regarding concerned parts in engines that have FAA type certification. *(RL 2012: 21 R3).*

- Improve processes to expedite safety of flight considerations in granting export licenses and waivers so that political sanctions do not unnecessarily delay civil aviation safety investigations concerning aircraft – or parts thereof – which are manufactured in the USA. *(RL 2012: 21 R4).*

EASA is recommended to:

- Investigate, in consultation with the FAA, the prerequisites for introducing requirements concerning yaw stability in large aircraft in the event of sudden loss of engine thrust below $V_{MCG}$ under the anticipated operating conditions. *(RL 2012: 21 R5).*

- Ensure that initial and recurrent pilot training includes mandatory rejected takeoff exercises that cover events of a sudden loss of engine thrust below $V_{MCG}$. *(RL 2012: 21 R6).*