

Investigation Report

Identification

Type of Occurrence:	Accident
Date:	25 March 2012
Location:	Near the county Gelsdorf
Aircraft:	Helicopter
Manufacturer / Model:	Aerospatiale / AS 350B2
Injuries to Persons:	Pilot severely injured, three passengers and one ground crew member with minor injuries
Damage:	Aircraft severely damaged
Other Damage:	Crop damage
Information Source:	Investigation by external expert for field investigation and BFU staff members
State File Number:	BFU 3X014-12

Factual Information

History of the Flight

On the day of the accident during a springtime festival, sightseeing flights were to be conducted with an AS 350B2 helicopter. After several sightseeing flights had been conducted an engine failure occurred during turning right into take-off direction in about 5 m shortly after the helicopter had lifted off. The helicopter began to descend.

At about 1148 hrs¹ the helicopter came to rest at the edge of a fire protection pond lying on its fuselage bottom. The pilot and the five passengers left the helicopter unaided.



Overview take-off site, accident site, fire protection pond

Photo: BFU

The pilot stated during an interview by the police that after the engine failure he had tried to cross the fence in front of him and to settle the helicopter in the fire protection pond also in front of him.

Personnel Information

The 62-year-old pilot held a German Commercial Helicopter Pilot's License (CPL(H)) issued according to JAR-FCL 2 valid until 18 September 2014. The license contained the valid type ratings as pilot in command for AS350/350B3, HU369/MD500N/600 and HU269. He also held an aerial spraying and dusting permit. He held a class 1

¹ All times local, unless otherwise stated.

medical certificate issued according to JAR-FCL 3, with restrictions valid until 19 August 2012.

He had a total flying experience of about 24,367 hours; more than 1,000 hours of which were on the type. The pilot was an employee of the helicopter operator.

Aircraft Information

The single engine helicopter AS 350B2 manufactured by the former manufacturer Aerospatiale is a lightweight multi-purpose helicopter for up to seven occupants. It was certified in accordance with FAR/JAR Part 27 in 1989. Generally, it is equipped with one Turbomeca Arriel 1D1 engine, a three-blade main rotor, landing skids and a tail rotor for anti-torque. Maximum take-off mass is 2,250 kg. In accordance with the Supplementary Type Certificate (STC No. SR01647SE) it is possible to equip the helicopter with a Honeywell LTS 101-700D-2 engine.

The helicopter was built in 1990 and had the manufacturer's serial number 2371. The empty weight was about 1,273 kg and the flight mass at the time of the accident was about 2,056 kg. The centre of gravity was within limits. In 2010, the helicopter was equipped with a Honeywell LTS 101-700D-2 engine. The last annual inspection was conducted on 9 May 2011 at about 8,480 operating hours. At the time of the accident, the helicopter had a total of approximately 9,135 operating hours.

The engine in use was built in 1990. In 2009, the manufacturer conducted an overhaul of the engine in the USA. At the time the engine had 6,834 operating hours. On 30 April 2010 the engine was installed in the accident helicopter. Since the overhaul up until the engine failure the engine had been in service for 1,282 hours. On 6 March 2012 the last 150-hours and 600-hours inspections were certified.

In 2004, the helicopter also had an accident (BFU 3X051-0/04). Due to a problem with the controls the helicopter had crashed into a forest and was severely damaged.

The helicopter had a German certificate of registration. The operator of the helicopter was certified by the Luftfahrt-Bundesamt (LBA) in accordance with JAR-OPS 3.

Meteorological Information

According to the Meteorological Aviation Report (METAR) of Cologne-Bonn Airport (EDDK), about 18 Nautical Miles (NM) away, at the time of the accident there was a visibility of more than 10 km, wind from 270° with 7 kt, no clouds below 5,000 ft

AGND (CAVOK), and a temperature of 18°C with a dewpoint of 5°C. Air pressure (QNH) was 1,030 hPa.

Take-off Site

The take-off site for the planned sightseeing flight was located in the rear property area of an agriculture business. The entire estate was fenced in by a wire fence which was about 2 meters high. Stacked merchandise, building material, empty wooden pallets and other objects surrounded the take-off site on all sides. A red and white plastic chain cordoned off the take-off site.



Overview take-off site and surrounding objects



Photos (2): BFU

Flight Recorder

The helicopter was not equipped with a Flight Data Recorder (FDR) or a Cockpit Voice Recorder (CVR). There were no legal requirements for such equipment to be fitted.

A bystander filmed the flight from take-off up until close to the impact. The video was made available to the BFU for evaluation purposes. The video showed a jet of flame in the area of the engine's exhaust approximately three seconds after take-off. During the subsequent descent flames flickered from the engine cowling above the exhaust. A total of nine seconds elapsed between lift-off and impact.

Wreckage and Impact Information

The accident site was located north of the buildings of the local agriculture business in the county Gelsdorf. The helicopter was lying on its belly. The skids were destroyed and the aft part of the tail boom was bent downwards by about 30° and to the side. In the lower area of the vertical fin green paint transfer was found. The tail rotor drive shaft had separated in the area of the splined coupling and had been torn off the tail section. Parts of the drive shaft and of the control tube for the tail rotor were found separate of the wreckage. On the rotor head the Starflex for the "blue" main rotor blade was fractured. The main rotor blades were partially damaged. The main gear box did not show any irregularities.

The engine oil level was reduced to about 15%. In the compressor and the exhaust extinguishing powder from hand fire extinguishers was found. Compressor as well as power turbine could not be turned manually and both were oily. All pitch links to control the engine were connected and adjustable within their control range. The fuel system was filled with fuel up to the injection for the combustion chamber. The tank contained about 360 kg fuel which was removed on site. The Bundeswehr Research Institute for Materials, Explosives, Fuels and Lubricants (WIWEB) examined the fuel sample taken at the accident site. The institute used infrared spectroscopy and gas chromatography to examine the fuel sample. The sample fully complied with the specifications.

Two screws of the fuel divider on the fuel injector ring around the combustion chamber were found loose. The divider could be raised by about 3 mm. The divider has two seals one of which was missing. Fire traces were found in the area of the divider and the engine cowling.

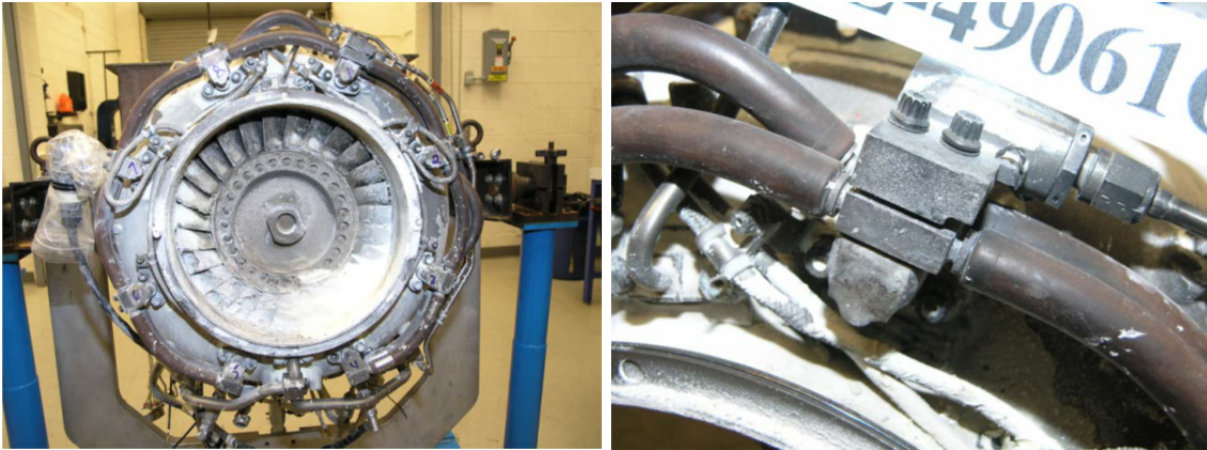
After the helicopter was salvaged, a maintenance organisation removed the engine in preparation for the examination by the manufacturer in the USA.

Engine Examination at the Manufacturer

In the presence of representatives from the operator and the helicopter manufacturer, the engine manufacturer conducted an initial examination. Then the engine was dismantled and individual components were subject to further examination. Some metallurgical expert opinions were commissioned. The manufacturer documented the examination in a 197-page engine examination report.

The initial examination determined that the engine could not be turned manually. The outside and the inside of the engine showed, in parts, massive amounts of

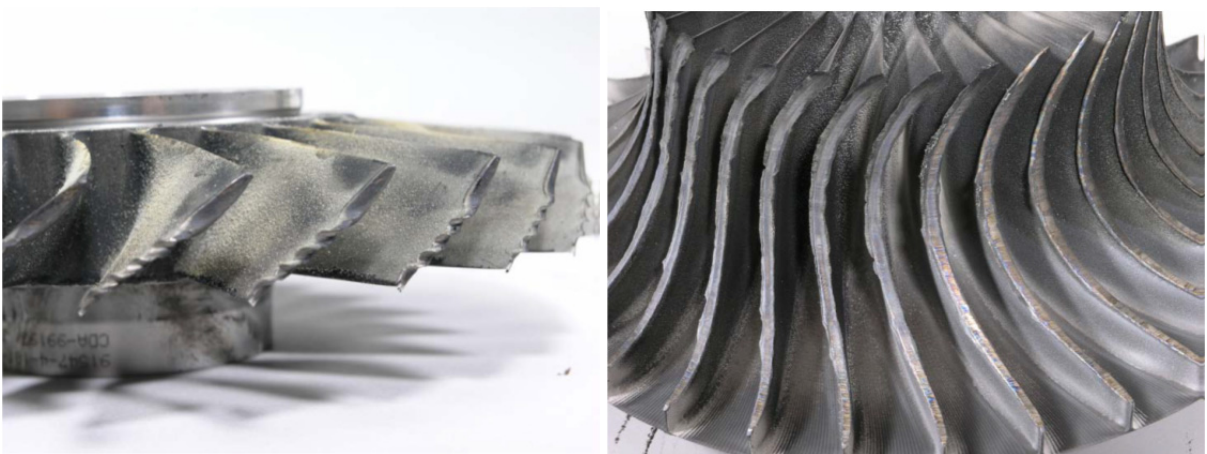
extinguishing agent. Oil and fuel filter and the chip detector in the oil system were free of dirt and chips. The oil pressure sensor mounting was loose. Of the eight fuel nozzles only the one on the fuel divider was loose. A compressed air check was conducted which showed leakages on the T1 compensator, the fuel control housing, the Pg accumulator and the Pr accumulator.



Contamination with extinguishing agent and loose connections on the divider Photos (2): Honeywell

After the initial examination the engine was disassembled into its components. The gear box could be turned manually and there was continuity in N1 (gas producer) and N2 (power turbine) gear trains. The free-wheeling unit functioned properly. The oil pump drive turned.

The compressor showed contact traces of the blades with the outer wall in the axial and the radial area. There were corresponding rub marks on the outer wall of the compressor. All rotor and guide blades were present.



Axial and radial compressor blades with contact traces

Photos (2): Honeywell

The gas producer module (N1) was disassembled and damages to the turbine nozzles were found. One blade of the gas producer turbine rotor was separated at the fir tree connection.



Damage to the nozzle vanes and separated turbine blades

Photos (2): Honeywell

The rear bearing support housing of the turbine was loose and twisted by about 180°. The No. 2 bearing and bearing races were intact but the roller elements were flattened. The power turbine module was comparatively intact but individual blades had damage to the leading edge.



Damages on the rear main bearing and the power turbine

Photos (2): Honeywell

Based on the findings the following additional examinations were conducted: rear bearing support housing material analysis, fuel manifold assembly material analysis, fuel manifold flow test, gas producer turbine blade material analysis, and of the oil supply system.

It was determined that the fuel flow divider bolts of the fuel nozzle No 1 most probably loosened due to the rotor imbalance when the gas producer turbine blade separated. The respective documentation for the engine overhaul showed the check mark for the correct tightness with the correct torque moment of 25 in-lbf according Service Bulletin (SB) LTS101-73-10-0240. During function test of the fuel injection system all measured values were within the prescribed target limits.

The rear main bearing is normally located in a bearing housing which is connected with the outer turbine wall by 18 welding points. The bearing housing was torn off and twisted by 180°; the oil supply pipes were torn off. Three of four welds illustrated features consistent with fatigue. In the view of the laboratory the examination was difficult because the fracture surfaces were "smudged" and damaged, respectively.

The oil supply system did not show any irregularities. The filter housing was filled with oil, the oil filter was clean and the bypass was not open. The oil pump drive could be turned manually. There were no chips on the metal chip detector of the oil system. The oil splash ring of the main bearings 2 and 3 were partially dirty. A flow measurement was conducted and determined a flow rate of 216 pph which is 10% below the minimum target flow rate. After the splash ring was cleaned the flow rate was within the target range (263 pph).

The investigation of the remainder of the torn-off gas producer turbine blade determined a high cycle fatigue fracture as cause. The fatigue fracture began in the area of the inner cooling air flow where the coating was either brittle or missing (Appendix 4). Based on these findings, additional gas producer turbine rotor blades of the same production lot were examined which did not determine any irregularities or deficiencies in coating.

In closing, the engine manufacturer came to the following conclusion:

Teardown and inspection of engine LE-49061C disclosed that the loss of engine power was due to a high cycle fatigue separation of a single gas producer turbine rotor blade. The HCF separation is believed to be due to abnormalities in the blade coating.

When the gas producer turbine blade separated, the resulting rotor imbalance and vibration caused the bolts fastening the flow divider to the #1 fuel nozzle to loosen and fuel to leak from the joint, resulting in a fire in the engine nacelle. The rotor imbalance and vibration also caused the rear bearing support housing stitch welds to fracture and flatten the No. 2 bearing roller elements.

Fire

Above the engine, the inner side of the engine cowling showed traces of fire.

Organisations and their Procedures

The operator of the aircraft was certified by the Luftfahrt-Bundesamt (LBA) in accordance with JAR-OPS 3 and also a flight school with their own maintenance organisation.

The operator offered all forms of helicopter flights including flight training. The operator specialised in so-called aerial work with helicopters. The operator operated several helicopters of various types. There was one other AS 350B2 helicopter equipped with a Honeywell engine in operation.

The operator had commissioned the retrofitting of the helicopter involved to a maintenance organisation working in cooperation with the operator. This maintenance organisation then continued to maintain the engine.

Permission for Take-off and Landing outside an Airfield

For the sightseeing flights the responsible regional civil aviation authority, the Landesbetrieb Mobilität Rheinland-Pfalz (LBM), had issued the permission for take-offs and landings outside an airfield. The permission required a take-off area of 40 m x 40 m or with a diameter of 40 m free of all obstacles and emergency landing areas which are accessible at all times. A field adjacent to an agriculture business was defined as take-off area.

The field stated in the permission was not used due to dust formation and because of the adverse effects on the adjacent sales booths. Instead, the back area of the agriculture business property was used for take-offs.

According to the pilot the take-off area was examined prior to starting the flight operation. Hereby, no loose objects or danger for bystanders were determined. Also during the 13 take-offs and landings on the day before and the three take-offs on the day of the accident no objects were blown away by the downwash of the rotor.

Additional Information

In case of an engine failure during the operation of single-engine helicopters, there are combinations of flight altitude and airspeed which are unsuitable to guarantee a

safe autorotation. The helicopter manufacturers describe areas which should be avoided during flight operations using airspeed-height envelope diagrams (so-called Deathmans Curve) and recommend departure and approach profiles. With the helicopter type AS 350B2 it was recommended to not fly higher than 9 m up until an air speed of 40 kt was reached. Once these parameters were met the climb should be continued with increasing speed (Appendix).

Due to several air accidents caused by engine failure during commercial operation of single-engine helicopters the BFU issued Safety Recommendation No 18/2012:

The Federal Ministry of Transport, Building and Urban Affairs (BMVBS) should together with the Luftfahrt-Bundesamt (LBA) and all Luftfahrtbehörden der Länder (regional regulatory authorities) ensure in the scope of their supervision of helicopter operators that during flight operations where emergency landings due to engine failure cannot be carried out or where third parties are possibly put in danger, only helicopters with the flight performance class 1 under consideration of category A procedures are used.

Analysis

The video illustrating the course of events shows the take-off, the engine failure and the subsequent descent. The turbine failed at a time when the altitude and airspeed were problematic for a controlled and successful autorotation and emergency landing, respectively.

Measured by his total flying experience and experience on the type the pilot was unusually experienced. He held the required licenses and ratings.

The helicopter was maintained in accordance with legal regulations. During the field investigation no indications were found regarding a malfunction of the helicopter's controls or the engine's fuel system. Centre of gravity and take-off mass were within the prescribed limits.

The engine examination at the manufacturer's facilities determined that one blade of the gas producer turbine separated and caused the turbine failure. Further investigation of the engine showed it is highly likely that the short-term unbalance and the subsequent vibrations caused several screw connections to come loose as well as the massive bearing failure. This is supported by the fact that the engine had been operated for more than 1,200 hours after the last overhaul and the experiences of the engine manufacturer during certification tests. The loose screw connections

would have made operation of the engine impossible due to pressure and fuel loss and a progressing bearing failure would have produced chips and metal abrasion. The oil supply was free of chips, however. Further examination of the remaining blade base revealed unambiguous signs of fatigue fracture, so-called high cycle fatigue, probably caused by a faulty coating of the cooling duct within the blade.

The weather was good and did not influence the course of the accident or the performance of the engine. Only take-off and landing direction were influenced by the wind direction.

The chosen take-off and landing site was suitable only to a limited extent. The area behind the agriculture business was surrounded by goods which were partially bulk goods. During take-off and landing there was always the danger of objects being pulled up by the downwash and thrown at bystanders or sucked into the rotor. Take-off and landing paths were not free of obstacles. This resulted in a steep take-off and landing profile. Due to this, the helicopter was for a short period of time in altitude and speed areas which were, according to the flight manual, unfavourable for successful autorotations in case of engine failure. The chosen site did not correspond with the site stipulated in the permission.

In the past, there were accidents with single-engine helicopters. Often the cause was that the helicopters were operated in flight areas which were unsuitable for safe autorotations in case of engine failure. During the planing phase helicopter operators should check if flights can safely be conducted at all times with the chosen helicopter. In regard to safe flight operations pilots also have the responsibility to decide whether a flight can be conducted or not when short-term changes to the original plan occur. Unnecessary risks should not be accepted.

Conclusions

The accident was caused by a hard landing during an emergency landing attempt after a mechanical engine failure occurred shortly after take-off. Contributory factors were the choice of an unsuitable take-off and landing site and the subsequent unfavourable departure profile which contributed to the severity of the damage.

Safety Recommendation

Actions by the engine manufacturer

Based on the determined results, the engine manufacturer has conducted an analysis in regard to the operational safety of the type of engine involved.

The loose screw connection on the fuel divider due to engine vibrations after the turbine blade separated was classified as a safety issue. An engineering change order is in process to implement safety wire on the flow divider bolts.

Low weld penetration and starting fatigue fractures in the rear bearing support housing was classified as a quality issue. Root cause and corrective actions are underway with the vendor of the part.

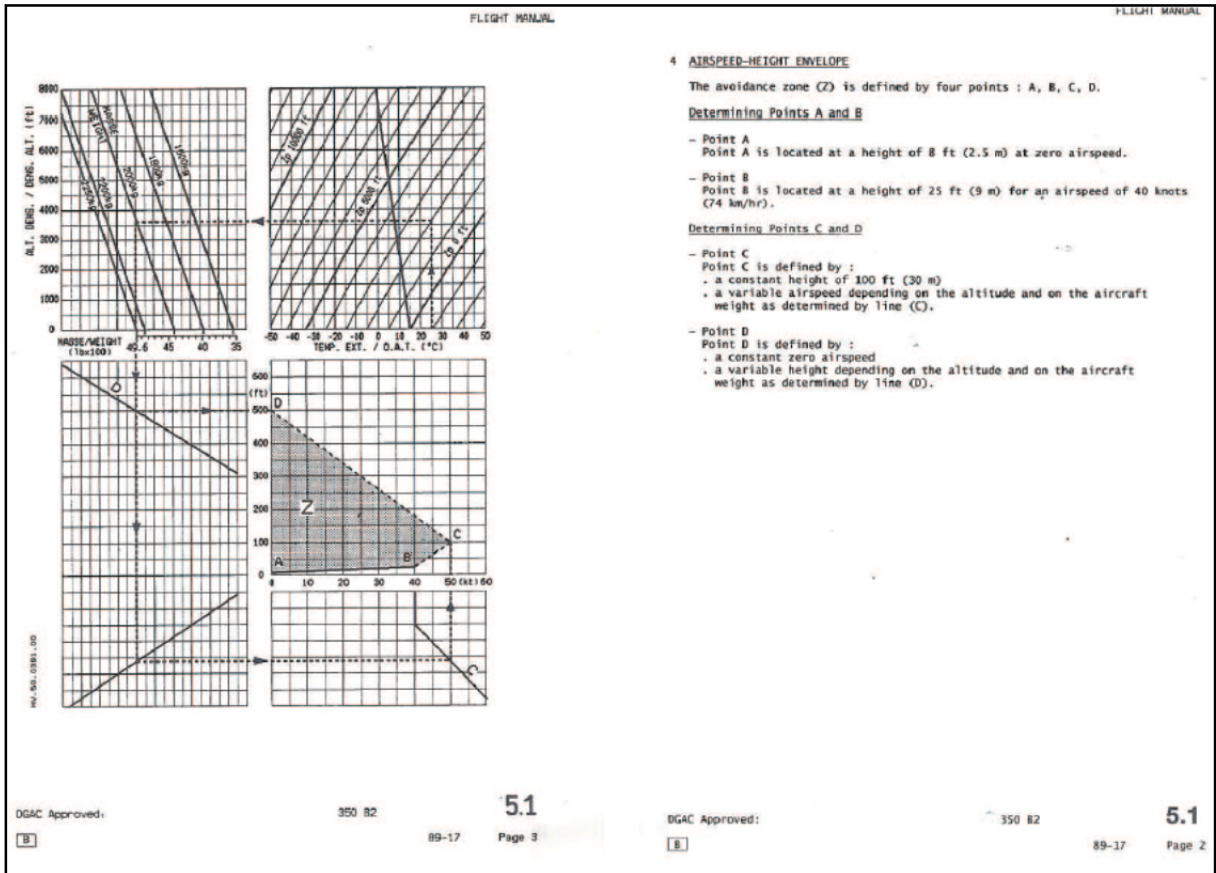
Honeywell aerospace, which applied the coating to the gas producer turbine blades, completed a design of experiments study to investigate the coating process. By packing coating media into the internal blade passages, Honeywell was able to duplicate the characteristics of the separated blade including internal coating thickness and aluminium content. The most likely scenario is that the blade was accidentally dropped into the coating media. Coating media may have remained inside the blade in the cooling passages during the coating process. In 2008 the coating procedure was changed and since then a similar incorrect coating could be eliminated. All other turbine blades from the same production lot were identified and 2013 removed from flight operations.

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Assistance: Thomas Karge
Field Investigation: Klaus-Uwe Fuchs, Christian Baudorff
Braunschweig: 24 May 2013

Appendices

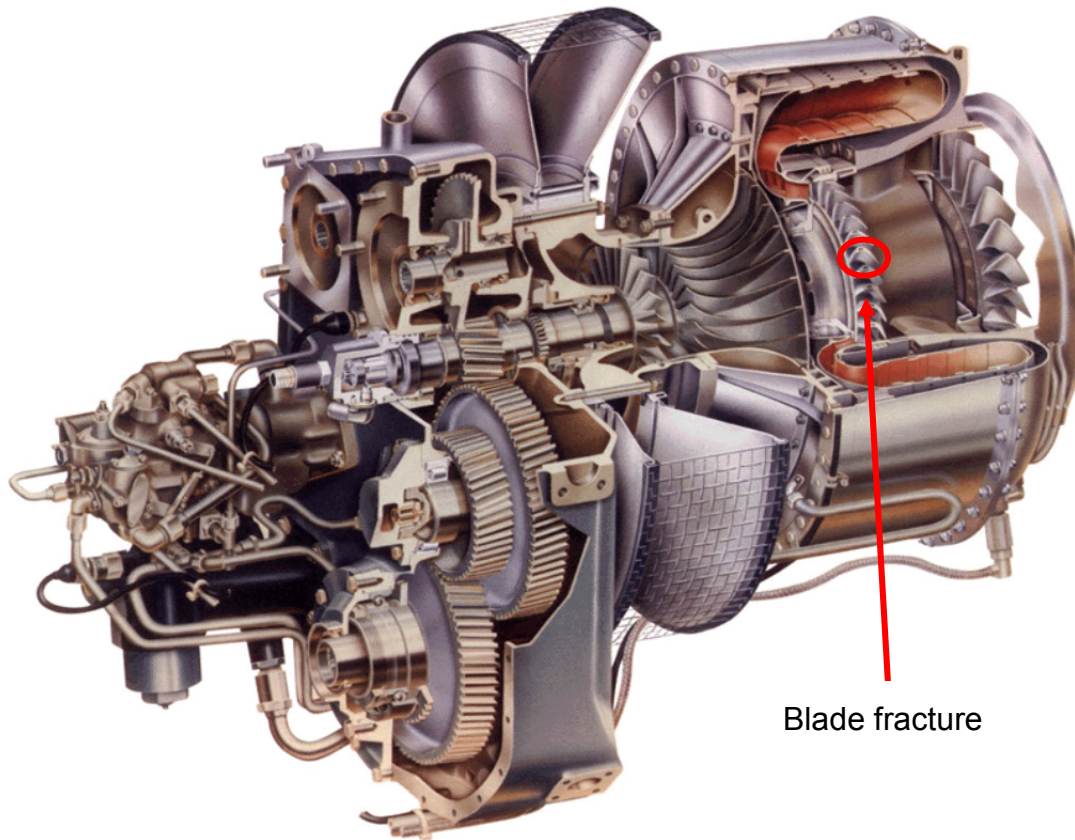
1. Recommended airspeed-height envelope diagram of the manufacturer
2. Cross section LTS 101 turbine
3. Overview of the engine Ng (N1) and Np (N2) systems
4. Photos of the examination of the torn-off turbine blade

Appendix 1: Recommended airspeed-height envelope diagram of the manufacturer

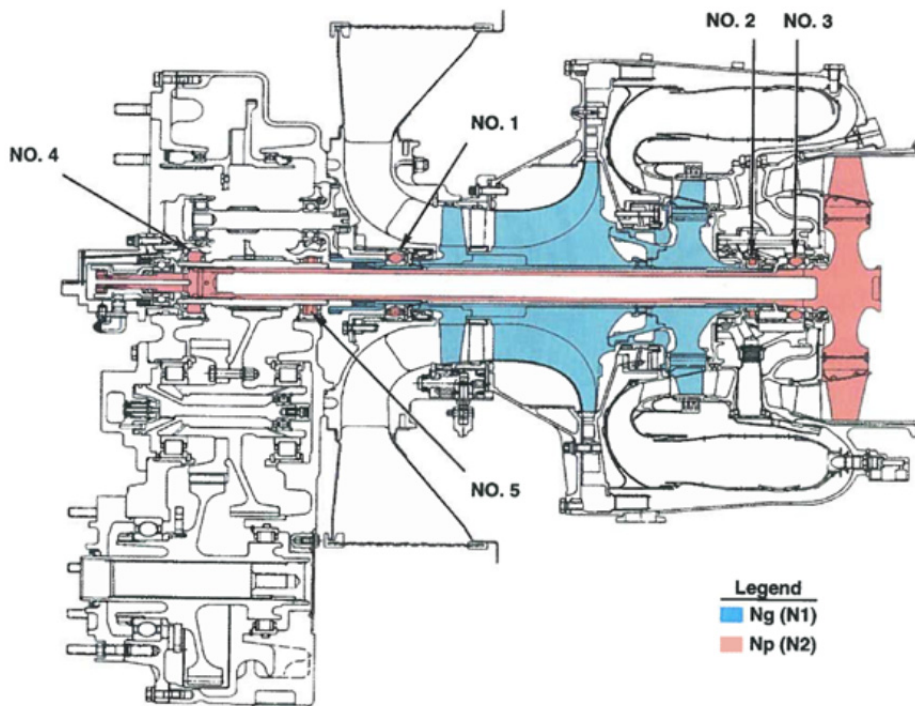


Source: Excerpt from the flight manual

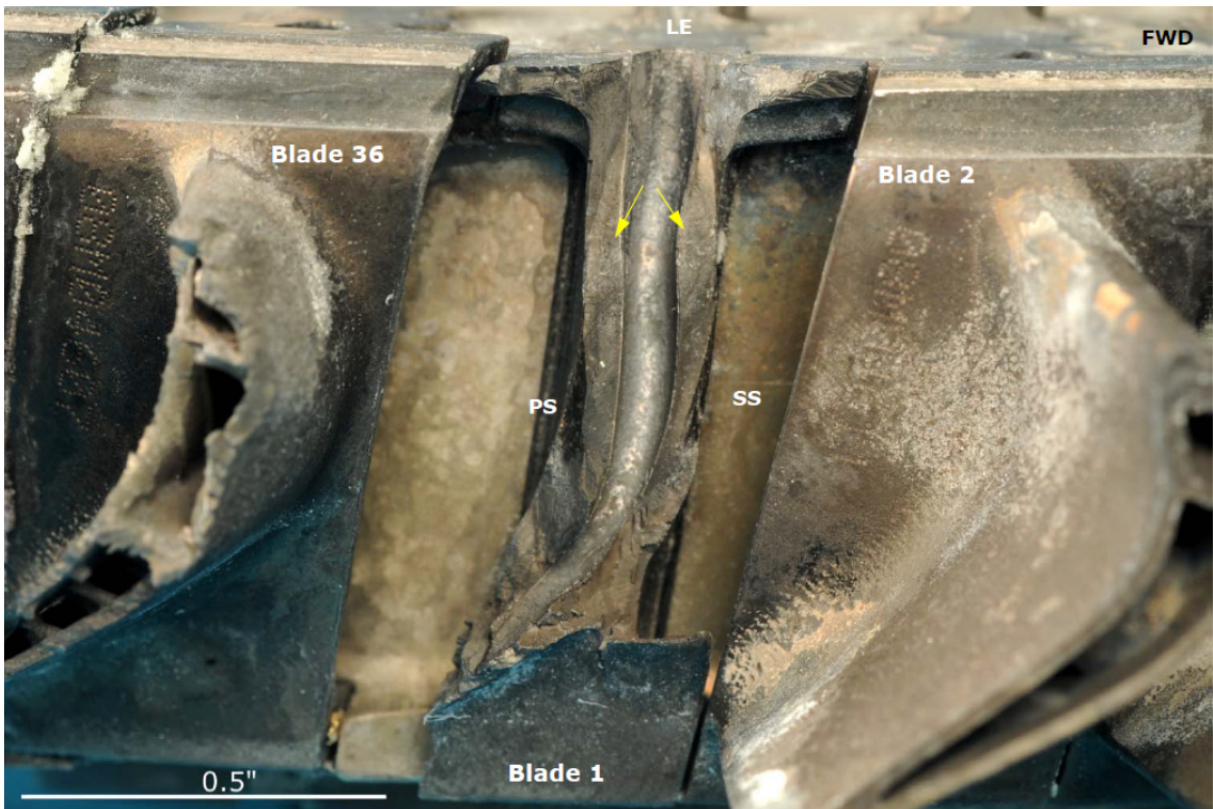
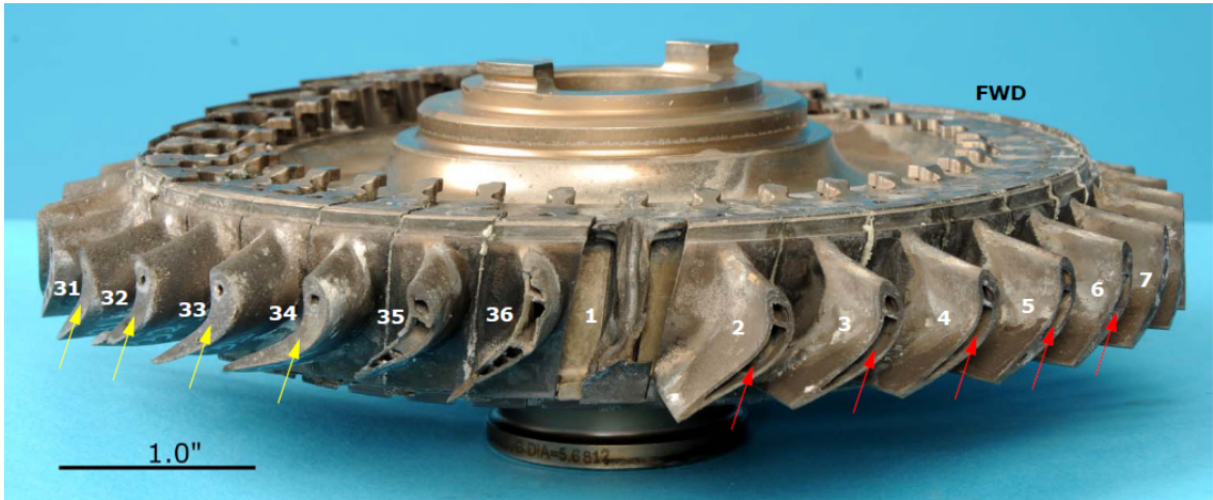
Appendix 2: Cross section LTS 101 turbine

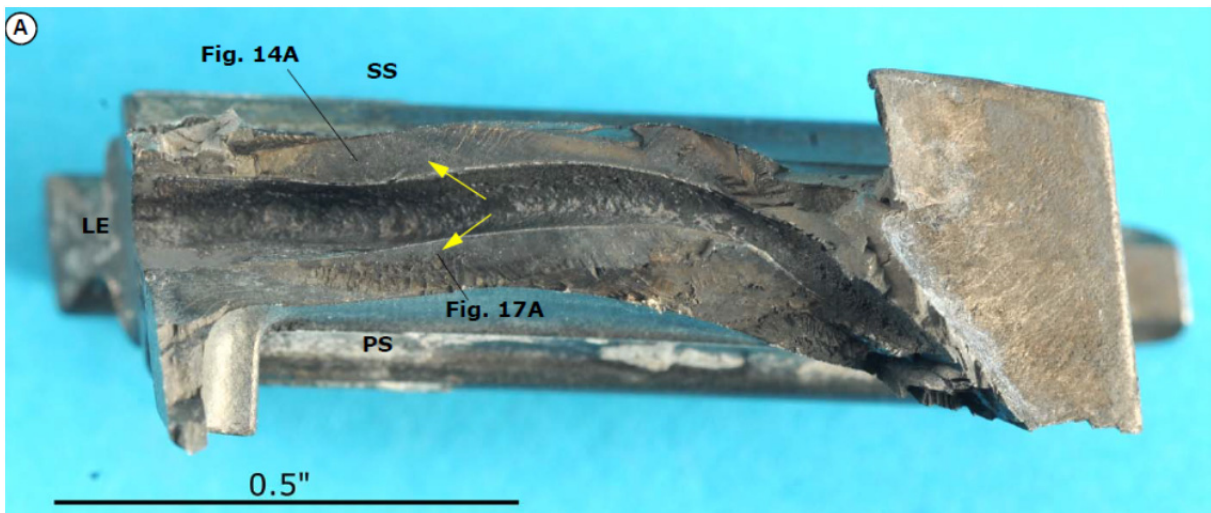
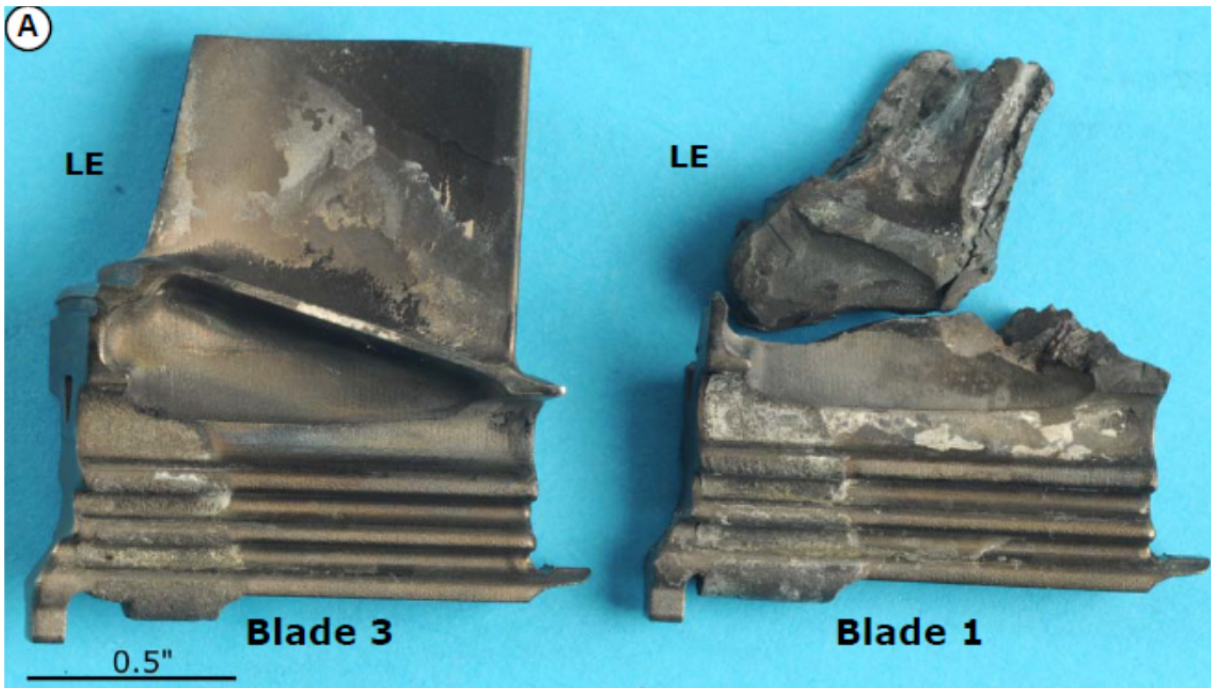


Appendix 3: Overview of the engine Ng (N1) and Np (N2) systems



Appendix 4: Photos of the examination of the torn-off turbine blade (N1)





This investigation was conducted in accordance with the regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and the Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft (*Flugunfall-Untersuchungs-Gesetz - FIUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

This document is a translation of the German Investigation Report. Although every effort was made for the translation to be accurate, in the event of any discrepancies the original German document is the authentic version.

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