

Investigation Report

Identification

| | |
|-----------------------|---------------------------|
| Type of Occurrence: | Accident |
| Date: | 5 March 2013 |
| Location: | Chicago, USA |
| Aircraft: | Transport aircraft |
| Manufacturer / Model: | Airbus / A 330-300 |
| Injuries to Persons: | None |
| Damage: | Aircraft severely damaged |
| Other Damage: | None |
| State File Number: | BFU 2X001-13 |

Factual Information

As the aircraft was rotating during take-off for a flight from Chicago, USA, to Munich, Germany, the aft fuselage section touched the ground. The National Transportation Safety Board (NTSB) delegated the investigation into the occurrence to the BFU.

History of the Flight

At 2119 hrs¹ the airplane left gate B16/17 and taxied to the edge of the apron. On board were 182 passengers and 15 crew members. At the edge of the apron the airplane was de-iced. At 2146 hrs the airplane taxied via taxiways H, U, and B to runway 32R. The Pilot in Command (PIC) stated the runway had been cleared of snow and ice except for a few remaining patches.

At 2151 hrs a Boeing B737-800 took-off from runway 32R ahead of the Airbus A330-300. At 2152 hrs an Embraer 145 took-off from runway 4L which crosses runway 32R at approximately half the runway length.

The co-pilot conducted the take-off. At 2153 hrs as the airplane was rotating during the take-off run, the aft fuselage section touched the surface of the runway (tail strike). During the subsequent initial climb a cabin crew member, sitting in the area of the aft galley, reported an unusual noise. The third pilot in the cockpit received the report. The cockpit crew stated they had not noticed anything unusual during take-off. After a short analysis of the available airplane data and consultation with the operator's maintenance department the crew decided to continue the flight to Munich. The continuing flight and the landing in Munich occurred without further incident.

Personnel Information

The 57-year-old PIC held an Airline Transport Pilot's Licence (ATPL(A)) issued in accordance with to JAR-FCL, German. It was first issued on 24 August 1987 by the Luftfahrt-Bundesamt (German civil aviation authority, LBA). The licence carried the entries for A330 including Instrument Rating (IR) valid until 7 February 2014 and A340 including IR valid until 7 August 2013. In addition, he held the ratings for Single-Engine Piston (SEP) land and Touring Motor Glider (TMG) valid until 31 March 2014. He also held the instructor rating for private pilots and a TMG rating valid until 31 March 2013.

His class 1 medical certificate was valid until 26 September 2013. It included the restriction to wear glasses.

The pilot had a total flying experience of 17,693 hours. His flying experience on the type was 2,729 hours. In the last 90 days he had flown 184 hours. In the last 24 hours prior to the occurrence he had flown 10 hours.

¹ All times local, unless otherwise stated.

The pilot deployed as Senior First Officer (SF) on this flight was 36 years old. He held an Airline Transport Pilot's Licence (ATPL(A)) issued in accordance with to JAR-FCL, German. It was first issued on 17 August 2000 by the Luftfahrt-Bundesamt. The licence carried the entries for A330 including IR valid until 12 April 2014 and A340 including IR valid until 12 October 2013. He held the ratings for co-pilot and Pilot In Command Relief (PICR).

His class 1 medical certificate was valid until 10 February 2014 with the restriction to wear glasses.

He had a total flying experience of 8,697 hours. His flying experience on the type was 4,186 hours. In the last 90 days he had flown 182 hours. In the last 24 hours prior to the occurrence he had flown 10 hours.

The co-pilot was 39 years old. He held an Airline Transport Pilot's Licence (ATPL(A)) issued in accordance with to JAR-FCL, German. It was first issued on 6 August 1999 by the Luftfahrt-Bundesamt. The licence carried the entries for A330 including IR valid until 15 September 2013 and A340 including IR valid until 15 March 2014. He held the ratings for co-pilot and Pilot In Command Relief (PICR).

His class 1 medical certificate without restrictions was valid until 30 March 2013.

He had a total flying experience of 9,332 hours. His flying experience on the type was 5,431 hours. In the last 90 days he had flown 218 hours. In the last 24 hours prior to the occurrence he had flown 10 hours.

Aircraft Information

The aircraft type Airbus A330-300 is a transport aircraft equipped with two Rolls Royce RB211 Trent 772B-60 engines. The airplane was manufactured in 2005 and had the manufacturer's serial number 701. It had a German certificate of registration and was operated by a German operator.

The airplane had a Maximum Take-Off Mass (MTOM) of 233,000 kg. At the time of the accident the aircraft had a take-off mass of 225,405 kg.

The airplane was equipped with a nose landing gear and two main landing gears underneath the wings. Until the occurrence, total operating time had been 36,356:01 hours at 5,241 cycles.

Meteorological Information

During the day there was an onset of winter in Chicago including snow fall which was confirmed by the ATIS report of 2102 hrs. The crew stated the snow fall ceased while the airplane was de-iced. At the time of take-off the recorded ground wind was 350° with 14 kt.

Radio Communications

The radio communications recordings were not available for the investigation.

Aerodrome Information

Chicago-O'Hare International Airport has seven runways. These were: 04L – 22R, 04R – 22L, 14L – 32R, 14R – 32L, 09L – 7R, 09R – 27L and 10 – 28.

Runway 32R was used for take-off. It was an asphalt-covered runway with a length of 3,050 m (10,005 ft) and a width of 46 m (150 ft).

Flight Recorder

The BFU read out the recording of the L-3 COM FA 2100 Flight Data Recorder (FDR).

The L-3 COM FA 2100 Cockpit Voice Recorder (CVR) was available for the investigation. Due to the duration of the flight the time period of the take-off phase relevant for the investigation had already been overwritten.

Wreckage and Impact Information

Since the crew did not perceive the tailstrike or interpret the occurrence as one, there was no report to the aerodrome of departure. Therefore the runway was not inspected for possible ground traces.

The lower surface of the tail section showed damages. Affected were frames 69 to 76 with a length of about 4.5 m. Laterally the damage affected stringer 53 left up to stringer 53 right. The stringer at the lowest part of the fuselage is stringer 57. The area showed rub marks, scratches, paint abrasions, and dents (Appendix). Several rivet heads were either partially or entirely abraded.

On the inside of the fuselage the web plates of stringer 57 between frame 69 and frame 73 were deformed (Appendix). The cross beams of frames 70 to 73, onto which the floor of the aft cargo compartment was mounted, were also deformed. Parts of the mounting elements between the inner structure and the outer skin were either damaged or severed.

The manufacturer stated the ferry flight to the maintenance organisation was conducted after makeshift repair work on the fuselage and with unpressurised cabin and a minimum crew.

Fire

There was no evidence of in-flight fire or fire after the landing.

Organisations and their Procedures

In the Operation Manual B (OM-B FCTM 2-050 Take-Off, Tail Strike Avoidance) the operator describes the following:

ROTATION TECHNIQUE

The recommendation given in the ROTATION TECHNIQUE paragraph should be applied.

A fast rotation rate increases the risk of tailstrike, but a slow rate increases take-off distance. The recommended rate is between 2 and 3 °/s, which reflects the average rates achieved during flight test, and is also the reference rate for performance calculations.

CONFIGURATION

When performance is limiting the takeoff weight, the flight crew uses TOGA thrust and selects the configuration that provides the highest takeoff weight.

When the actual takeoff weight is lower than the permissible one, the flight crew uses FLEX TO thrust. For a given aircraft weight, a variety of flap configurations are possible. Usually, the flight crew selects the configuration that provides the maximum FLEX temperature. This is done to prolong engine life.

A330-300 / A340 (A340-300)

The configuration that provides the maximum FLEX temperature varies with the runway length.

On short runways, CONF 3 usually provides the highest FLEX temperature, and the tail clearance at lift off does not depend on the configuration. So, the flight crew should select CONF 3.

On medium or long runways, the second segment limitation becomes the limiting factor, and CONF 2 or CONF 1+F becomes the optimum configuration, in term of FLEX temperature. In these cases, the tail clearance at lift off depends on the configuration. The highest flap configuration gives the highest tailstrike margin.

There is a difference between twin and quadri, regarding this concern: The A330 has more tail clearance than the A340, that has quite often, takeoff speeds closer to VMU limitation. This is true with one engine inoperative. Since twin aircraft have more thrust margin for takeoff, this is even more the case with all engines operative.

Note:

detailed effect:

- *From CONF 1+F to CONF 2: Tail clearance increased by 0.5 to 1 ft, loss in FLEX temperature generally less than 1 °C.*
- *From CONF 2 to CONF 3: Tail clearance increased by 1 ft, loss in FLEX temperature generally less than 2 °C.*

The first degrees of flexible thrust have an impact on maintenance costs about 5 times higher than the last one.

END A330-300 / A340 (A340-300)

Additional Information

Tailstrike

An occurrence is called a tailstrike when the tail of an airplane has ground contact with the runway surface either during take-off or landing. This can happen with any airplane, but aircraft with long fuselages are more prone to it than shorter ones. According to the Flight Operations Briefing Notes of the manufacturer and the FCOM (Flight Crew Bulletins - Avoiding Tailstrikes) of the operator the following technical and operational factors may influence the risk of a tailstrike:

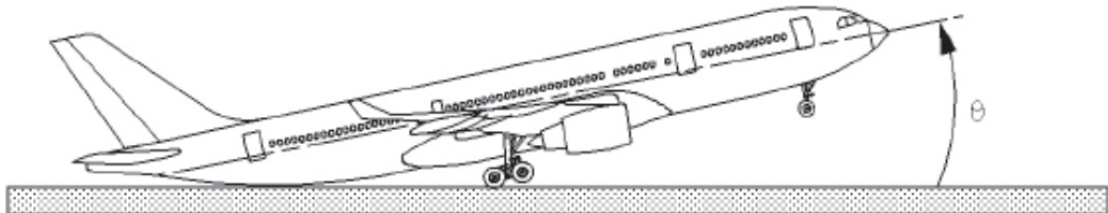
- A/C Geometry Limits
- Rotation Rate
- Early Rotation
- Take-off-/Rotation Technique
- Configuration and Speed
- Thrust/Weight ratio
- Erroneous CG position and trim setting
- Crosswind
- Shock absorber oleo inflation

Other factors which may influence or increase the risk of a tailstrike are de-icing prior to flight and the runway slope.

Each of these factors is considered as follows:

Aircraft Geometry Limits

Prior to take-off the airplane rotates around the main landing gear, see image. There are two limitations between which the tail section has ground contact with the runway. In one case the main landing gear is fully rebound and the pitch angle is 14.4° . In the other case the landing gear shock strut compression is complete and the pitch angle is 10.1° .



Rotation Rate

The rotation rate is the angular rate $^\circ/\text{sec}$ with which the pitch angle increases. A high rotation rate increases the tailstrike risk and a low rotation rate increases the take-off distance. The manufacturer recommends a rotation rate of 2° to $3^\circ/\text{sec}$. These reflect the mean rotation rates which were reached during flight tests. It is also the rotation rate on which the flight performance calculations are based.

According to the FDR data the rotation rate in the time period between lift-off of the nose landing gear until the rebound of the main landing gear was at most $4.2^\circ/\text{sec}$.

Early Rotation

Early rotation is the result of an initiation of the rotation prior to reaching rotation speed VR. (Rotation speed is the speed in kt, which the airplane needs to lift off the nose landing gear (rotation)). Potential reasons are:

Incorrect calculated VR for the aircraft mass or configuration.

The rotation occurs below VR due to gusts, wind shear, or obstacles on the runway. Whatever the reason for early rotation it can result in increased pitch angle during lift-off and a decreased tail clearance.

The rotation speed VR for the take-off in Chicago had been calculated as 150 kt. The FDR data showed that at a computed airspeed of 150 kt the co-pilot began to pull the stick back and therefore initiated the rotation.

Take-off / Rotation Technique

According to the Flight Operations Briefing Notes of the manufacturer take-off under normal conditions should be conducted as follows: Once the thrust levers were set, the airplane begins to taxi, the pilot flying keeps the stick in “half forward”. Between 80 and 100 kt the stick is put into neutral. Once rotation speed VR is reached the stick should be pulled about 2/3 of the way back which initiates rotation; then wait for the reaction of the airplane. A continuous rotation rate with an angular speed of not more than 3°/sec should be reached. Fast and strong corrections should be avoided. Once the airplane is airborne the Speed Reference System (SRS) is used. Starting in 50 ft the pitch angle trim begins to work.

Take-off in Chicago based on FDR Data Read-Out

After the airplane had taxied onto the runway it stopped. The co-pilot pushed the sidestick forward by 6°, and then the airplane accelerated. At a computed airspeed of 86 kt the sidestick was slowly pulled back; at 100 kt the sidestick was in neutral. After the airplane had reached a speed of 150 kt the pilot flying pulled the sidestick back with a rate of 12.5°/sec until about 9° were reached. Approximately one second later the rotation began and the nose landing gear lifted off. The pitch angle increased with a maximum rate of 4.2°/sec. The recording of the vertical acceleration showed a peak of 1.18 g once 11.5° were reached. At that time the pitch angle decreased somewhat and reached a rate of 2.8°/sec. Approximately one second later at a speed of 164 kt and a pitch angle of approximately 13.5° the main landing gears lifted off.

Weight and Centre of Gravity

The loadsheet of 5 March 2013 at 2127 hrs shows a take-off mass of 225,405 kg and 60,000 kg of fuel. The resulting MACTOW was 22.87% and the take-off configuration was 6.07° nose up. For the flight performance calculation a take-off mass of 227 t was used.

The FDR data showed a ground gross weight prior to take-off of 225.435 kg. MACTOW was 23.4% and take-off trim position 6.1° nose up.

The permissible centre of gravity for this take-off mass was between 18 and 39%. According to the Operating Manual Part B (OM-B) of the operator the permissible trim position during take-off was 0° to 7° nose up.

Configuration and Speeds

The software for the flight performance calculation had recommended configuration F2, i.e. the slats are set to 20°, the flaps to 14°, and the ailerons to 10°. Since the crew feared the flaps could be hit by raised snow slush and ice they chose flap position 1+F for take-off. This setting means slats 16°, flaps 8°, and ailerons 5°. In this configuration the flaps do not extend as far down as in configuration F2.

The risk of a tailstrike decreases with a larger flap position because the pitch angle is lower, i.e. the chosen flap position increased the tailstrike risk compared to the configuration recommended by the software. Configuration 1+F means less lift surface than configuration F2. In order to lift the same weight at take-off speed into the air a higher angle of attack and therefore pitch angle is needed.

The choice of configuration also influences the significant speeds for the take-off run the flight performance software calculates. For configuration 1+F the following speeds were calculated: VR 150 kt, V2 155 kt, V1MIN 124 kt, VRMIN 126 kt, and V2MIN 155 kt. For configuration F2 and the same conditions the following speeds were calculated: VR 148 kt, V2 153 kt, V1MIN 124 kt, VRMIN 126 kt, and V2MIN 148 kt. This shows that with configuration F2 rotation speed VR equals minimum climb speed V2MIN. This means with the rotation speed the airplane already has enough lift to begin climb after take-off.

Thrust / Weight Ratio

The configuration resulting in the most flexible temperature for the thrustsetting should be chosen, because it increases the service life of the engines. It has to be kept in mind that not every favourable configuration for high flexibility in temperature always results in a larger tail clearance.

True is also that the probability of a tailstrike increases with a lower thrust / weight ratio.

In this case take-off was not limited by flight performance. With its take-off mass the airplane remained below the maximum take-off mass. Therefore thrust could be reduced this could be read on the flex parameter. A higher flex value equals more thrust reduction and a lower thrust / weight ratio. Reduced thrust preserves the engines and reduces operating costs. The flex value is influenced by the

configuration. The flight performance software had calculated a flex of 40 for the configuration 1+F and the take-off conditions in Chicago. For the investigation the manufacturer's flight performance software was used to calculate the flex for configuration F2 and the same conditions; the flex was 41.

Crosswind

If the crosswind is very intense the aileron control can be used to counteract the effect. Acting with caution is recommended and strong aileron deflection should be avoided, because these result in excessive deflection of the spoilers. This in turn increases the tendency of the airplane turning into the wind, reduces the lift, and increases drag. Extension of the spoilers becomes important when the sidestick is moved sideways by about half the possible way. Once the airplane has lifted off each aileron control input results in roll movement. The reduced lift due to the extended spoilers on one wing reduces the tail clearance during rotation and therefore increases the tailstrike risk.

According to ATIS, at the time of take-off the ground wind was 350° with 14 kt.

Fluid Level of the Hydraulic Fluid in the Main Landing Gear Cylinders

The correct rebound of the main landing gear shock absorbers depends on the correct fluid level of the hydraulic fluid. Thus, the nominal increase of tail clearance during rotation. A shock absorber with low hydraulic fluid level delays the rotation of the landing gear which results in reduced tail clearance.

On 6 March 2013 at 2300 hrs the shock absorbers of the main landing gear were checked. The shock absorber of the left main landing gear extended by 237 mm and had an internal pressure of 85 bar at a temperature of 17°C. The right extended by 240 mm and had a pressure of 85 bar at a temperature of 17°C. According to manufacturer information required were 309 mm with a tolerance of +/- 15 mm. According to the data in the Aircraft Maintenance Manual the difference was compensated by filling the shock absorbers with Nitrogen. After refilling, the left shock absorber extended by 305 mm, had an internal pressure of 86 bar at a temperature of 17°C. The right extended by 307 mm, had a pressure of 37 bar at a temperature of 17°C. Because it is very complex to check the main landing gear fluid level an extra check was scheduled. This check was conducted on 15 June 2013. The left shock absorbing strut showed 67.7 l and the right 66.0 l. The required ideal fluid level for each shock absorber strut is 65.8 l. Therefore the left shock absorber strut was overfilled by 2.9% and the right by 0.2%.

De-Icing of the Airplane prior to Take-Off

The de-icing fluids for aircraft have a certain adhesion so that they are not running off the airplane right after application. The higher speed during the take-off run or shortly afterwards is supposed to drain the de-icing fluid off the airplane. Due to the characteristic of the de-icing fluid the airplane's mass is increased. With an airplane the size of the Airbus A330 this can easily amount to several hundred kilogram.

Another effect of the de-icing fluid is a change in airflow around the wings. This effect is similar to drops of water.

Runway Slope

A strong runway slope may increase the tailstrike risk due to the geometrical ratios in combination with aerodynamic angles.

The runway at Chicago O'Hare Airport has an ascending slope of 0.05%.

Situation prior to Take-off at Chicago O'Hare Airport

At 2151 hrs a Boeing B737-800 took-off from runway 32R ahead of the Airbus A330-300. At 2152 hrs an Embraer 145 took-off from runway 4L which crosses runway 32R at approximately half the runway length. Time of departure (TOD) for the A 330-300 was 2153 hrs.

Comments of the Manufacturer Concerning other/possible Influencing Factors

The aircraft manufacturer was involved in the investigation process. The manufacturer conducted a simulation of the take-off with the Aircraft Engineering Model for the aircraft type. The recorded FDR data was used.

Essentially during the simulation two additional factors were determined which influenced the tailstrike:

- Analysis of the wind data recorded by the FDR showed a downward wind gradient of 6 kt in 2.5 s and a tailwind gradient of 6 kt in 5 s. The manufacturer wrote: *"[...] The upshot of the wind estimation is a lift reduction during rotation.[...]"*
- Assessment of the CG the simulation showed a CG value which was located 4.5% farther aft than the one recorded by the FDR.

Analysis

The damages on the tail section of the airplane could be associated to the tailstrike. The area of the pressurised cabin was damaged but not degraded in its stability. There was no pressure loss during the flight. After the landing the airplane was visually inspected and the extent of the damages determined. The manufacturer confirmed the damages and only agreed to the ferry flight with unpressurised cabin and minimal crew after makeshift repairs of the fuselage. Due to the severity of the damages the occurrence was classified as accident.

A tailstrike during take-off occurs during a very dynamic phase of the take-off run. During this phase several factors, such as technology, environment, and man-machine-interface, influence the course of events (see Chapter Additional Information).

This tailstrike accident occurred about one second prior to the main landing gear lifting off completely from the runway and the air-ground-switch being triggered. The ground impact was very brief and like a strike.

The energy of the strike was transported by struts and cross beams to the cabin floor of the aft galley where the flight attendants were seated.

Due to the airplane's length the cockpit was far away from the place of ground contact. Therefore the cockpit crew could not determine the tailstrike. In this phase, the cockpit crew did perceive the blows coming from the landing gears due to the condition of the runway. In addition, flight crew often expect the tail section to scrape along the runway or cause scraping sounds during tailstrike. The reason is that often during presentations regarding tailstrikes, film sequences or images of flight tests to determine VMU (see Appendix) are used. In these cases the tail section of an airplane often scrapes along the runway spectacularly spraying sparks along the way. In this case there was no scraping along the runway, because the airplane had already reached rotation speed VR which was above minimum take-off speed.

Communications between cockpit and cabin crew were very good. Immediately after the occurrence, one flight attendant sitting in the aft galley reported her observations, about the unusual noise during take-off, to the cockpit. The third pilot had answered the call and given the information to the PIC and the co-pilot. Subsequently the PIC talked with the flight attendant and asked her to describe the situation. Later the PIC explained to the cabin crew the measures taken and the decision to continue the flight.

Due to the report by the flight attendant the crew was alerted but could not detect the source of the noise (tailstrike). For such an occurrence the airplane is not equipped with indications or sensors. Had, for example, pressure drop in the cabin occurred it would have been an indirect indication of a tailstrike. The pressurized cabin functioned properly because the outer skin of the airplane was still intact even though the fuselage had been damaged. All available parameters were within normal ranges and therefore the enquiry with the maintenance centre did not reveal any indication of a tailstrike either. Technicians and pilots pooled their experience and came to the conclusion that no tailstrike had occurred. This resulted in the decision to continue the flight.

The documentations of manufacturer and operator indicate that a possible tailstrike risk is decreased with higher flap configuration. Ergo, lower flap configuration results in a higher risk. This is a very general statement. There is no quantification or assessment, e.g. between the different configuration options. Therefore it is difficult for a pilot to assess the risk.

In configuration 1+F the slats, flaps, and ailerons are used as lift support to a much lower extent than in configuration F2. Ergo, less lift surface was available for take-off. Subsequently the airplane has to have a steeper angle of attack to lift the take-off mass into the air, if less lift surface is available but rotation speed is almost the same. This in turn resulted in less distance between tail section and runway surface and therefore contributed to the tailstrike.

Choice of configuration influences the speeds necessary for the take-off phase. Rotation speed VR for configuration 1+F was 150 kt and minimum speed for subsequent climb V2MIN was 155 kt. For configuration F2 VR was 148 kt and V2MIN was also 148 kt. With the recommended configuration, at the time of rotation the airplane would have had the lifting force required after rotation and a certain acceleration. With configuration 1+F the minimum required speed was adhered to.

The BFU does understand why the flight crew decided to use a lower configuration thus avoiding that the extended lift surfaces were hit by runway contamination. Due to weather and runway conditions it was highly likely that the lift surfaces and engines of the airplane would be hit by snow slush. As a result freezing after retraction and problems during subsequent extension during the landing were a possibility. From the flight crew's point of view entering the alternative configuration 1+F into the flight performance software did not result in changed speeds, and

therefore difficulties during take-off would not have to be expected, hence the decision.

The airplane's geometry is determined by its design and cannot be changed. Past experience has shown that the A330-300 is generally not very prone to tailstrikes.

The rotation rate, which the pilot essentially influences, is a decisive factor in regard to tailstrikes. At the time the airplane had reached 150 kt, the pilot flying pulled the sidestick back. The speed with which the pilot pulls the sidestick back influences the speed with which the elevator moves and subsequently changes the pitch angle and therefore the rotation rate. In this case the pilot pulled the sidestick back with a rate of 12.5°/sec. The airplane rotated with a maximum rotation rate of 4.2°/sec. The manufacturer recommended a rotation rate of 2° to 3° per second. There is no cockpit indication for the rotation rate. The reaction of the airplane shows the pilot which consequences his control inputs have. Essentially a pilot utilizes his flying experience when moving the sidestick and assessing the airplane's reaction.

Analysis of the FDR data showed that early rotation did not occur. Rotation was initiated at a speed of 150 kt. This corresponded with the VR the flight performance software had calculated.

The Appendix shows the FDR diagram of the rotation. Parameters were chosen which show the pilot's control inputs and the airplane's reaction. Zero point is the time of rotation of the main landing gears (air-ground sensors).

At a computed airspeed of 150 kt, as calculated by the flight performance software, rotation was initiated. The pilot pulled the sidestick back with a rate of up to 12.5°/sec. After about half a second the airplane rotated and after 2.5 seconds had a constant rotation rate of a maximum of 4.2°. The rotation rate was determined with the help of three different calculation methods. The results are depicted in the diagram. The results were all very similar. The calculated maximum value was significantly higher than the rotation rate of 2 - 3°/sec the manufacturer had recommended. The rotation rate had been calculated using the FDR data. The on-board systems of the airplane do not determine or provide these values directly. The pitch angle had had a linear trend up until 4 to 1 second prior to rotation. About one second prior to rotation the straight line bends and the rotation rate decreases and stabilises at approximately 2.8°/sec. At this time vertical acceleration shows a significant peak of 1.18 g. According to the data this is the moment the airplane's tail section hit the runway.

The loadsheet values and the values recorded by the FDR are very similar. The resulting values for centre of gravity and trim were within the allowable range. MACTOW was nose up in regard to the allowable range. The trim was therefore strongly nose up. It is possible that the trim added to the dynamic of the rotation behaviour and the tailstrike. In the simulation the manufacturer comes to the conclusion that the CG should have been 4.5% farther aft than indicated in the loadsheet. A take-off mass of 227 t was entered into the flight performance software. The entered value was higher than the calculated mass. This is not unusual and constitutes a higher safety level. Therefore, take-off thrust could be reduced. For configuration 1+F the flex value was 40; for configuration F2 it would have been 41. With the software the flex value reflects the engine thrust. Ergo, for configuration 1+F more thrust was available than for F2.

At the time of take-off the wind velocity was 350° at 14 kt. Thus the wind came from 30°. The measuring points on the ground did not record any unusual wind conditions, such as strong crosswind or wind shear.

Both landing gears had the required amount of hydraulic oil, or the filling level was slightly above requirements. Both shock absorbers lacked gas and gas pressure so that the required rebound was not met. This resulted in decreased tail clearance.

The de-icing fluid adds weight to the take-off mass due to its adhesion characteristics. During the take-off run most of the de-icing fluid runs off the airplane which reduces the mass again. The manufacturer stated it can be neglected.

The outside air temperature at the time of take-off was 1°C. Gelling of the de-icing fluid due to very low temperatures can therefore be ruled out. Therefore the effect of the de-icing fluid on the aerodynamics of the wings is negligible and did not pose an increased tailstrike risk.

The runway slope of 0.05% did not affect the tailstrike risk.

Conclusions

The BFU is of the opinion that the tailstrike was caused by a reduction of tail clearance due to the following factors:

- Flaps configuration
- Rotation rate dynamic
- Position of centre of gravity and pitch trim

- Reduced rebound of the main landing gear shock absorbers

It is to be pointed out that the concurrence of these factors resulted in the tailstrike. The complete system would have tolerated each individual factor by itself.

Safety Recommendations

Safety Recommendation No. 04/2016

The manufacturer should improve the indications of a possible tailstrike risk in the documentation, especially in combination with the configuration of the lift surfaces during take-off. Indication of the flight performance program's design should alert the cockpit crew whenever the provided flap configuration is not one with the highest level of tailstrike tolerance.

Safety Recommendation No 05/2016

The manufacturer should develop a strategy, which allows the crew to unambiguously detect a tailstrike in flight, if it actually did occur.

The BFU decided to not issue a safety recommendation to the operator because in the course of the safety investigation appropriate measures were already taken. The crews were informed that compared to flap configuration 2, flap configuration 1+F poses an increased tailstrike risk.

In the course of the annual line checks the issue of "Avoidance of Tailstrike" was discussed with all crew members of the A330/340 fleet.

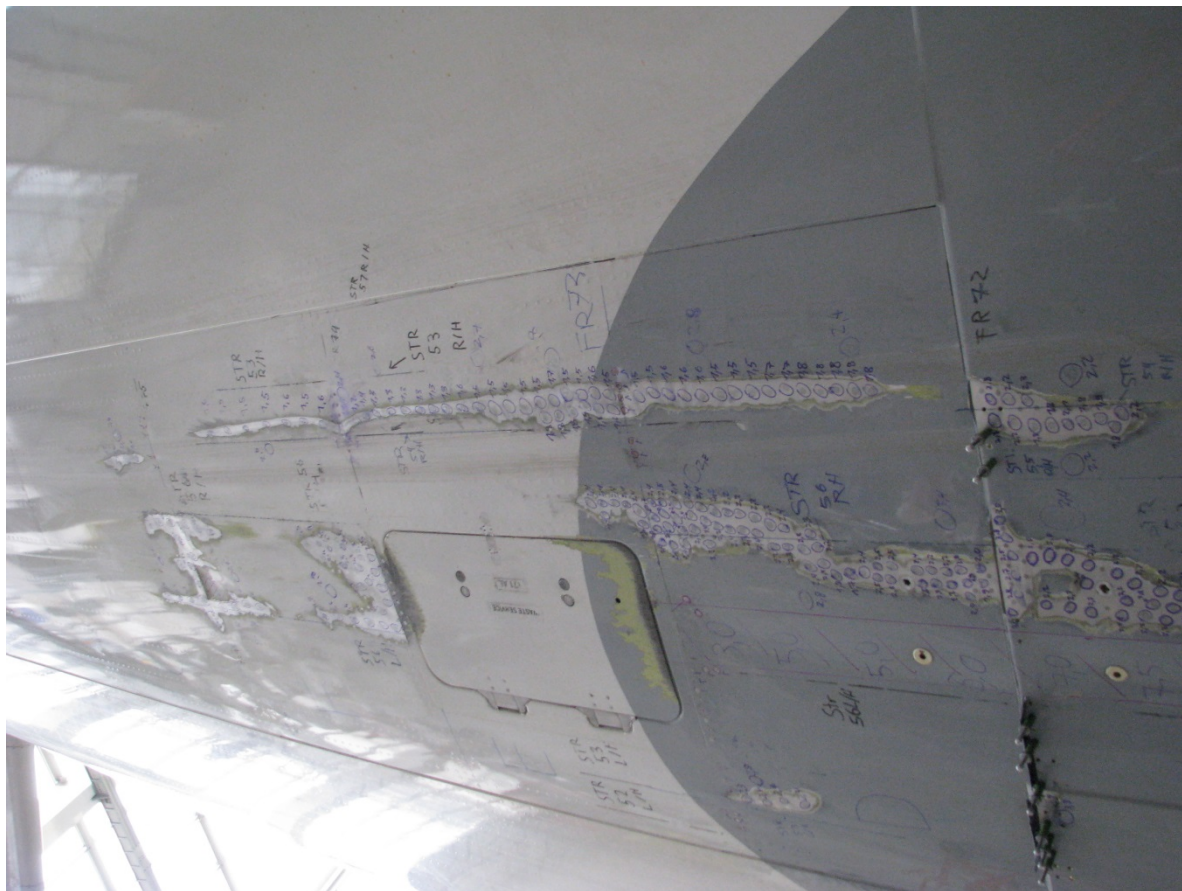
Investigator in charge: D. Nehmsch

Assistance: L. Jäkel

D. Ritschel

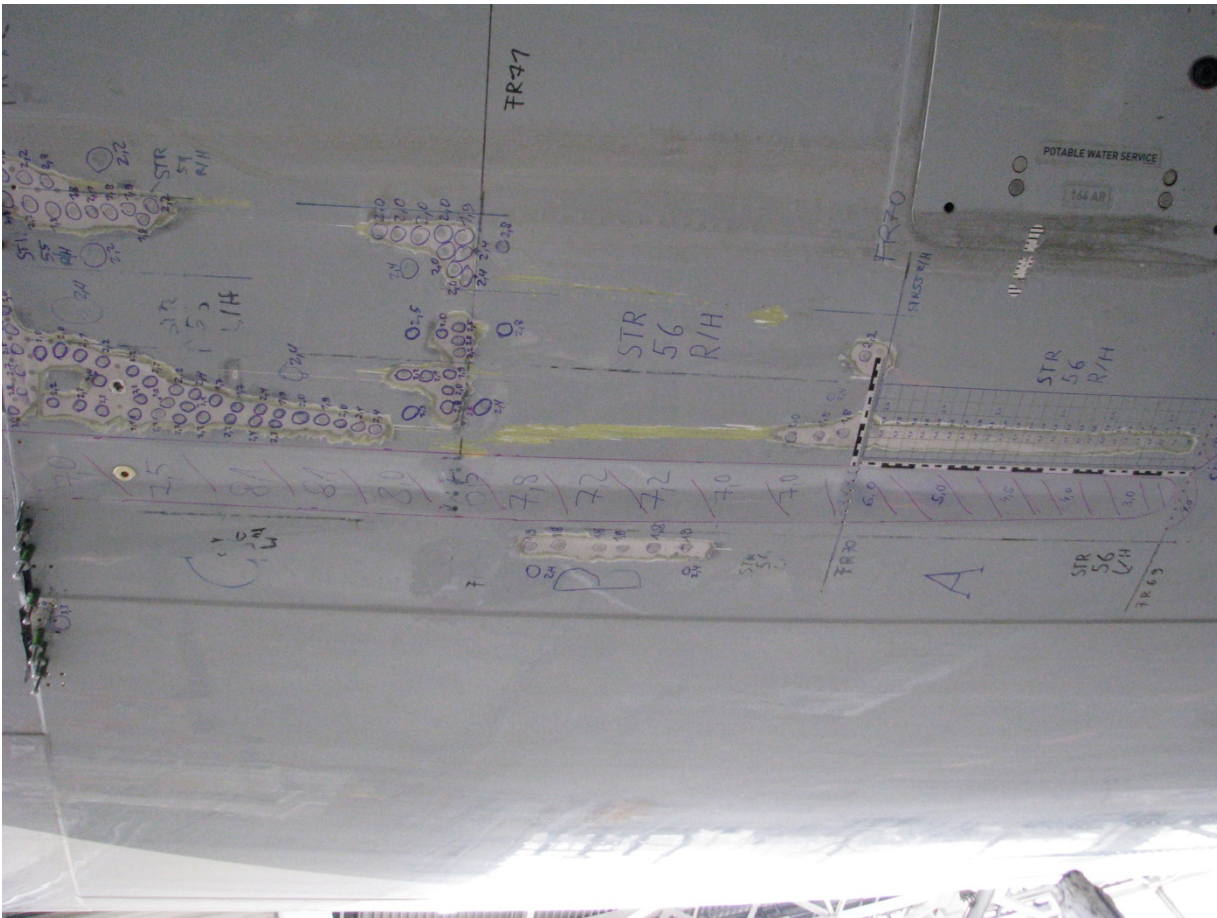
Braunschweig 2016

Appendix



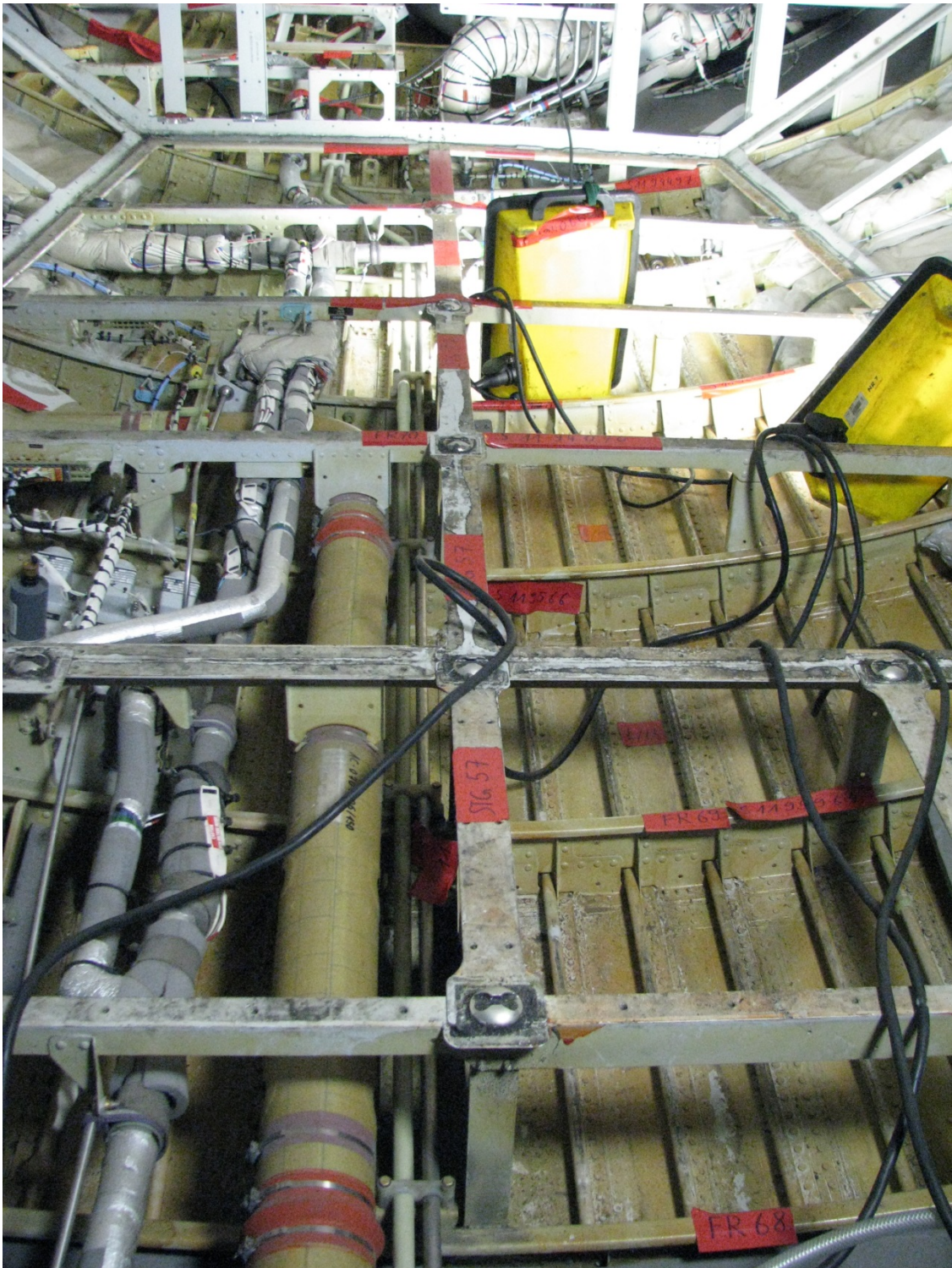
Damages on the lower surface of the tail section (flight direction right)

Photo: BFU



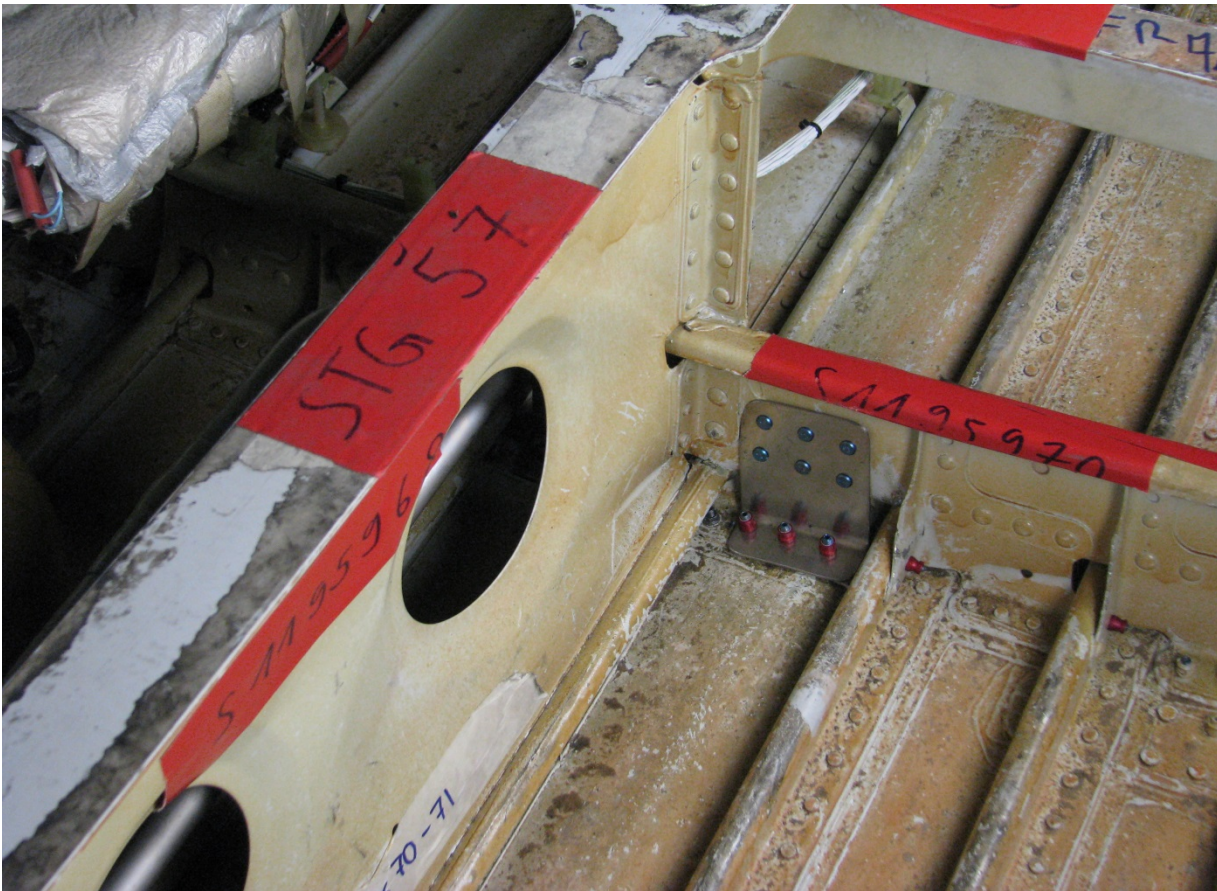
Damages on the lower surface of the tail section (flight direction right)

Photo: BFU



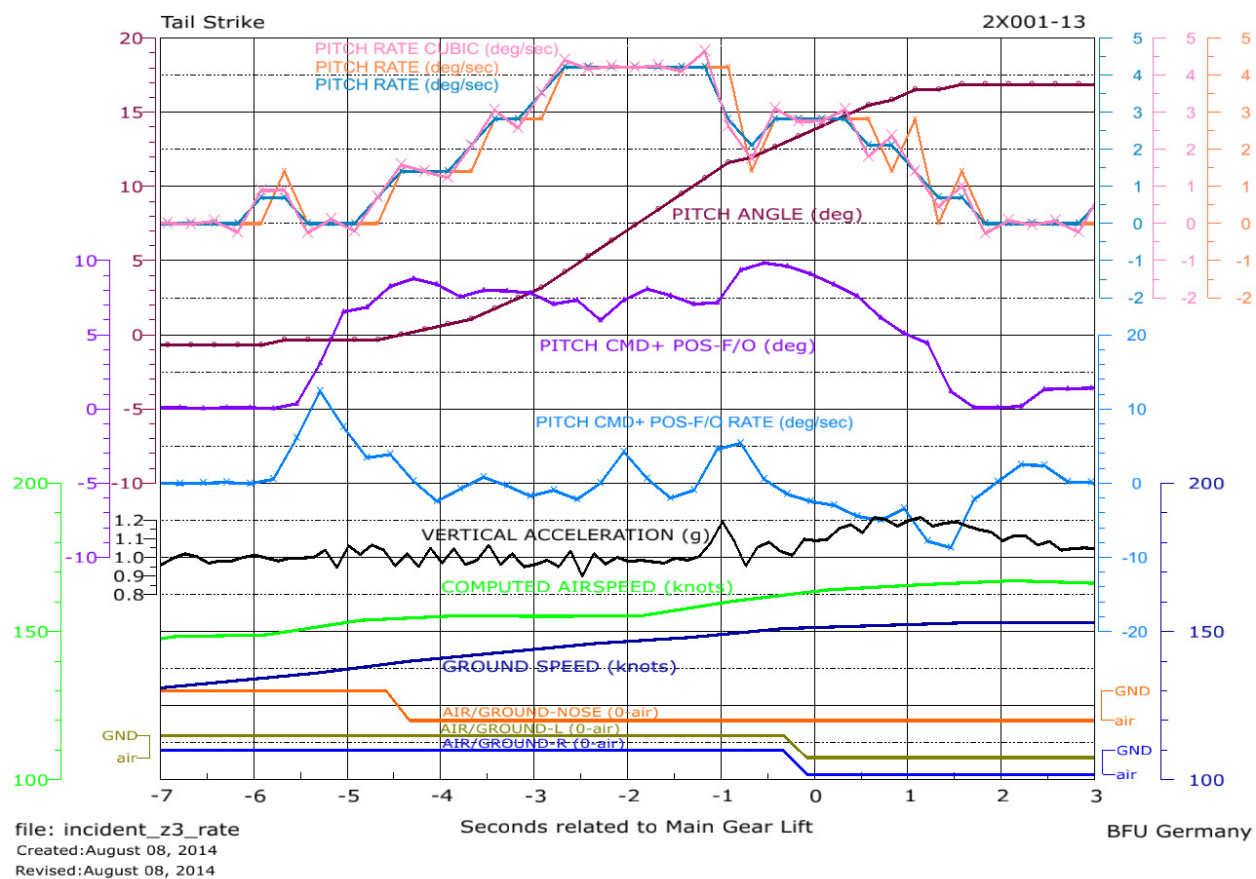
Damaged area inside the fuselage, in the foreground frame 68 (FR 68) stringer 57 is in the centre of the photo

Photo: BFU



Deformed web plate of stringer 57 between frames 70/71, temporary connecting element right of stringer 57

Photo: BFU



FDR Diagram

BFU



VMU-Test Airbus A330

Airbus

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.

According to the law the sole objective of the investigation shall be the prevention of future accidents and incidents. It is not the purpose of this activity to assign blame or liability or to establish claims.

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