

# Investigation Report

## Identification

|                       |                                       |
|-----------------------|---------------------------------------|
| Type of Occurrence:   | Accident                              |
| Date:                 | 6 September 2010                      |
| Location:             | Berlin - Marzahn                      |
| Aircraft:             | Helicopter                            |
| Manufacturer / Model: | Bell Helicopter Textron / Bell 412 HP |
| Injuries to Persons:  | None                                  |
| Damage:               | Aircraft severely damaged             |
| Other Damage:         | None                                  |
| Information Source:   | Investigation by BFU                  |
| State File Number:    | BFU 3X155-10                          |

## Factual Information

### History of the Flight

The rescue helicopter was prepared for an ambulance flight from the hospital in Berlin-Marzahn to a hospital in Berlin-Friedrichshain. The pilot stated that the helicopter stood with its nose pointing west on the landing platform in front of the hangar on the roof of the hospital. At 2000 hrs<sup>1</sup> the patient was in the cabin and the stretcher secured. Afterwards the crew boarded the helicopter, and the pilot started

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<sup>1</sup> All times local, unless otherwise stated.

take-off procedures. At that moment a loud bang was heard. The aft cross tube of the skids fractured. The pilot stated that the helicopter tilted about 15° to the right, and toppled slightly to the rear. The fuselage pointed upward by about 10°.

The four crew members and the patient remained uninjured.

## Personnel Information

The 45-year-old Pilot in Command (PIC) held an Airline Transport Pilot License (ATPL (H)) issued according to JAR-FCL 2, German. The license was initially issued on 30 November 1993 by the Luftfahrt-Bundesamt (LBA) and was valid until 4 July 2014. The class 1 medical certificate was valid until 6 April 2011. The PIC had a total flying experience of 5,953 hours and 18,000 landings; of which 4,600 hours and 15,000 landings were on the type in question. His type rating was valid until 4 July 2011.

## Aircraft Information

The helicopter was a Bell 412 HP Textron in all-metal construction. The helicopter had rigid, raised skids. It was equipped with two Pratt & Whitney PT6T-3BE engines. It had the manufacturer's serial number 36066, and was manufactured in 1993. The aircraft was registered in Germany.

It was operated by a German air rescue operator and was equipped for ambulance flights. It had a full intensive care unit on board. It had an empty weight of 3,681.67 kg (8,116.73 lbs). The maximum take-off mass was 5,398 kg (11,900 lbs).

At the time of the accident the helicopter had 9,199 total operating hours with 26,518 flight cycles.

The fractured skid was a raised version which allowed for more ground clearance.

The Aircraft Maintenance Manual BHT-412-MM-2 of the manufacturer described a procedure in which the standard and the high skids should be pulled together with a tensioning rope in the area of the aft cross tube if the gross weight exceeds a certain limit. The rope was supposed to produce a predetermined tension in the aft cross tube.

The high landing gear consisted of two skids which were connected by a curved cross tube in the aft and forward part of the fuselage. The high cross tube also raised the landing gear. The high aft cross tube was made of aluminium alloy, and had an

outer diameter of 89 mm, and a wall thickness of 15.8 mm. The surface was shot-blasted.

By the Bell 205 and 212, the aft and the forward cross tubes are mounted to the right and left fuselage underside. The high aft cross tube of the Bell 412 is mounted to the centre of the fuselage underside. The manufacturer stated the reason was the reduction of possible ground resonance in connection with the four-blade main rotor. The cross tube was mounted to the structure by way of two half shells. The upper and lower half shells embrace the cross tube and are clamped to it with two U-bolts. In order to avoid contact or friction, the upper half shell is glued to the cross tube; the inside of the lower half shell is lined with a separating agent / insulating agent. The upper half shell has an extension with a drilled hole where a bolt connects the cross tube with the helicopter fuselage (Drawing 1).

The fractured high aft cross tube had the serial number 710. In 2000 it had been installed in another helicopter. On 21 August 2002 after 1,127:01 hours and 3,092 flight cycles it was removed during maintenance action and installed in the helicopter in question. In May 2008, the aft cross tube was inspected and maintained after 4,834:34 hours and 13,570 flight cycles in accordance with the Alert Service Bulletin (ASB) No. AA-07109 of Aeronautical Accessories Inc. which corresponds with ASB 412-08-129 of Bell Helicopter. The inspection revealed no irregularities and the cross tube remained in service on the helicopter in question. Chapter Additional Information contains further details of the service bulletin.

On the day of the accident the cross tube had 6,245:08 hours and 17,690 flight cycles. After the last inspection 1,410;34 hours and 4,120 flight cycles were flown.

## Meteorological Information

Visual meteorological conditions prevailed. The wind came from east-north-east with 7 kt.

## Aerodrome Information

The helicopter landing area is located on the roof of the hospital in Berlin-Marzahn. It consisted of the landing area itself, a moveable platform, and a hangar. The moveable platform was used to move the helicopter into and out of the hangar along a predetermined path. Between the path and the landing area the filling station was located.

## Flight Recorders

The helicopter was not equipped with a Cockpit Voice Recorder (CVR) or Flight Data Recorder (FDR).

## Wreckage and Impact Information

The helicopter was on the landing platform on the roof of the hospital in Berlin-Marzahn. The nose pointed west.

The high aft cross tube was fractured on the right edge of the half shell (Image 1). This half shell connected the aft fuselage with the cross tube. The fractured cross tube damaged the right fuselage bottom side. The damaged tail boom rested on the filling station and the wall of the landing platform behind the helicopter.

The fractured high aft cross tube was transported to the BFU for further examination.

The cross tube was macroscopically examined at the BFU and then the two fracture surfaces were severed from the fracture pieces and sent to the Technische Universität Braunschweig, Institut für Werkstoffe (IfW) for microscope and scanning microscope examinations.

The examination at the Technische Universität resulted in the following findings:

The cross tube fractured directly next to the U-bolt without much deformation (Image 2). On the outer tube underside, i.e. in the area of the largest tensile stress, a distinct thumbnail initial crack had formed. Further cracks had developed on both sides and slightly higher. The cracks were fatigue fractures. The various individual cracks and the big thumbnail crack, which consist of many small cracks, rule out a local defect on the pipe surface.

The area containing the fatigue fracture was cut out of the pipe and examined under the scanning electron microscope (Image 3). The characteristic striation microtopography confirmed the fatigue crack (Image 4). It was clearly different from the combs of the rest of the fracture with the micro-ductile structure of a forced rupture (Image 5). Especially well preserved were the striations in the two medium-sized fractures left of the central crack (Scanning Electron Microscope, Image 6). Further left in approximately the 7 o'clock position a 100 to 200  $\mu\text{m}$  wide border of various individual cracks was visible in Image 3 (Scanning Electron Microscope Images 7 to 8). The same was true for the right side where adjacent individual cracks had formed up to approximately the 5 o'clock position (Images 9 to 10).

In summary, it was determined that the high aft cross tube was destroyed by a distinct fatigue crack. It had formed on the highly stressed area on the outlet of the half shell in the area of the clamp of the right U-bolt on the bottom side of the cross tube (change in stiffness, maximum bending moment, tensile side). The large number of individual cracks indicated an overstressed area and eliminated a kerf as cause for the failure.

## Fire

There was no fire.

## Organisations and their Procedures

### Production Organisation

Aeronautical Accessories Inc. (AAI), a subsidiary of Bell Helicopter Textron, manufactured the fractured cross tube. The cross tubes of AAI are certified for Bell helicopters and these can be equipped with them.

### Maintenance Organisation

The helicopter operator operates a maintenance organisation certified in accordance with Part 145 by the Luftfahrt-Bundesamt as DE 145.0248. This maintenance organisation maintained the helicopter.

## Additional Information

In 2007 at the same operator a fracture of an aft cross tube occurred with an identical landing skid. The fracture surface was almost identical with the one of 2010. The cross tube of 2007 had 10,732 cycles and 3,820 flight hours.

In April 2008 Aeronautical Accessories published the Alert Service Bulletin (ASB) No. AA-07109 because of the incidents with the high aft cross tube. The Bulletin stipulated the operating limitations for the cross tube to be 20,000 cycles. Various inspections for crack detection on the surface of the cross tube and detection of permanent deformations were described which had to be performed in appropriate intervals.

The described initial inspection, ASB Part B, stipulated that an approximately 50 mm wide area on the bottom of the high aft cross tube about 457 to 762 mm from the

central axis is to be stripped off paint. This area is to be inspected for signs of cracking using 10x magnification and strong light source. Afterwards the area is to be painted with a primer and then a clear coat. Part C stipulates recurring visual inspections of the painted and clear coated areas using magnification. Part D stipulates recurring dimensional inspections to identify permanent deformation of the cross tube. For this purpose the helicopter has either to be hoisted or jacked until no weight is on the landing skid. Then the lateral distance between the centre axis (centre of the drill hole for the U-bolt) and the outer side of the skid is measured on both sides. Specified high landing gear deflection limits identify an intact cross tube.

Part E describes the inspection and maintenance actions on the high aft cross tube. The pipe is to be stripped off paint in an area of 63.5 mm left and right of the centre axis; this is the area where the half shells for the landing skid are located. It is especially noted that the upper part of the half shells is not to be removed, and that the area of the half shells is to be protected against the paint remover.

Part F of the ASB provides clarification on helicopter towing instructions to prevent cross tube damage or failure. It stipulates that the high aft cross tube is to be tied down if the helicopter is moved with ground handling wheels installed or is resting on movable platforms (see above).

## Analysis

The in-depth examination of the fracture surfaces has determined that the fracture of the high aft cross tube of the helicopter landing skid occurred due to an extended fatigue fracture. The fracture occurred in a critical area of the component. The weight of the helicopter is distributed across three points to the landing skid. Two of the force transmission points are located on the front cross tube. The third force transmission point is located in the centre of the aft cross tube. A large bending moment is the result of the force transmission. The tension is on the bottom side of the pipe. The force transmission from the fuselage to the cross tube occurs via the two half shells which are clamped to the pipe by two U-bolts. Therefore the area of the two half shells is more rigid than the rest of the pipe resulting in change of stiffness at the ends. Furthermore, on the two places where the U-bolts clamp the half shells to the cross tube a rigid clamping situation exists. Therefore, the area of the half shells is to be viewed as a highly stressed area in the context of the entire assembly of the aft cross tube.

This area is always subject to bending vibrations either in normal operations during each landing, during loading and unloading, during embarkation and disembarkation, or just while standing, e.g. gusty weather conditions, and the empty weight weighs down the landing skid. This is confirmed by the large number of individual cracks in the area of the 5 to 7 o'clock position on the upper side of the cross tube which indicates an overstressed area. Signs of local damages as cause for the failure were not found.

Since the cross tube is subject to high stress the manufacturer designed the manufacturing process as follows: During the manufacturing process the pipe which is made of a high-strength aluminium alloy is shot blasted. The fatigue life of material shall be increased by shot blasting inserting residual compressive stress.

The mounting of the half shells on the cross tube is also well designed. The additional glued on upper half shell for the actual clamp and the use of separating agent between the lower half shell and the pipe surface prevents sliding and grating. The sealing of the entire half shell construction prevents corrosion. These actions have made an impact in so far that the area of the half shells and the fracture on the pipe surface did not show grinding marks or corrosion.

Is the helicopter moved on the ground by either fixing wheels to it or by transporting it on a moveable platform, the aft cross tube has to be tied down with a rope device. This action relieves the bottom side of the pipe which is subject to tensile stress, e.g. in the area of the half shells.

The Bell 205, 212 and 412 were equipped with high landing gears. Over the years the empty weight and the maximum take-off mass of the type series increased. This design was intended for the use in rough terrain, among others. Compared to other types the Bell 412 had a central half shell on the aft cross tube. This caused the locally increased stress. The deployment in rough terrain presupposes a not quite common use range. From time to time this can result in higher stress of the landing skids. The examination of the fracture surface did not reveal a singular occurrence such as a hard landing. The crack and the crack propagation occurred through a fatigue fracture; only the final rupture through the remaining cross section occurred by force. It was triggered by the loading of the helicopter.

The manufacturer published an ASB due to the experiences derived from the operation of the raised landing skid on the Bell 412. The fracture of the cross tube at the beginning of 2007 occurred with a Bell 412 of the same operator. The ASB

stipulated the operating limitations for the high aft cross tube to be 20,000 cycles. The cross tube in question failed after 17,690 cycles. Commensurate cyclic inspections are described for the remainder of the prescribed service life. Essentially these are to check the pipe surface for crack development. During these checks the areas of the central half shells, which have failed verifiably at least twice, were omitted. That means the entire cross tube needs to be inspected for possible cracks.

The BFU is of the opinion that the areas defined in the ASB are better suited for the Bell 205 and 212. Here the paint is removed, the area inspected, and then painted with primer and clear varnish, and then they serve for further scheduled visual crack inspections. These two types have two mounting points between the aft cross tube and the fuselage. The underside of the cross tube is subject to tension and may develop cracks in this area.

The accident has shown that the actions described in the ASB were not successful. The service life limit was not reached in spite of the mandatory inspections, and inspections of the area where the fracture occurred were not stipulated.

## Conclusions

The fracture of the high aft cross tube of the landing skid was caused by a fatigue fracture. Contributing factors were:

- Marginal design of the landing skids in regard to the increased mass of the helicopter compared to its original design.
- The former two mountings were exchange for only one
- Insufficient control and service life limitation according to the Alert Service Bulletin.

## Safety Recommendation

The BFU refrains from publishing a Safety Recommendation because the manufacturer has issued Revision A of the Alert Service Bulletin (ASB) 412-08-129 which now instructs to check the entire lower surface of the aft cross tube for cracks. Therefore the area where the crack of the examined fracture originated from is now covered.

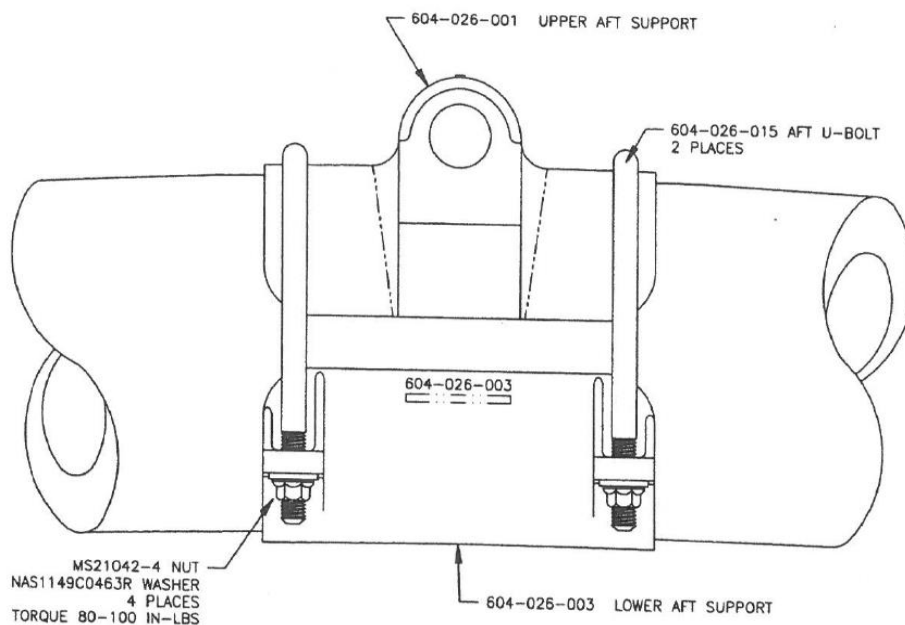
Investigator in charge: Dietmar Nehmsch

Assistance: Axel Rokohl

Braunschweig

19 January 2016

## Appendices



Drawing 1: Aft half shells at the skids

Source: AAI



Image 1: View below the fuselage in flight direction

Photo: BFU



Image 2: View from below onto the fracture

Photo: BFU

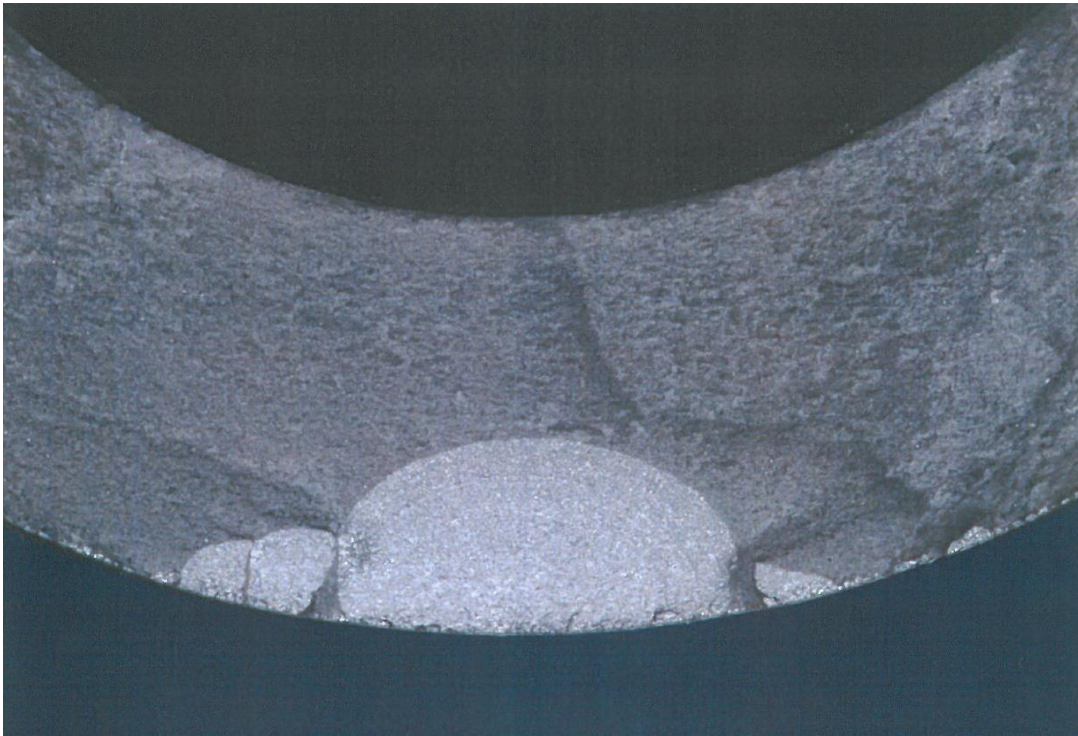


Image 3: Detail view of the fatigue fractures (fracture surface of the half shell)

Photo: IfW

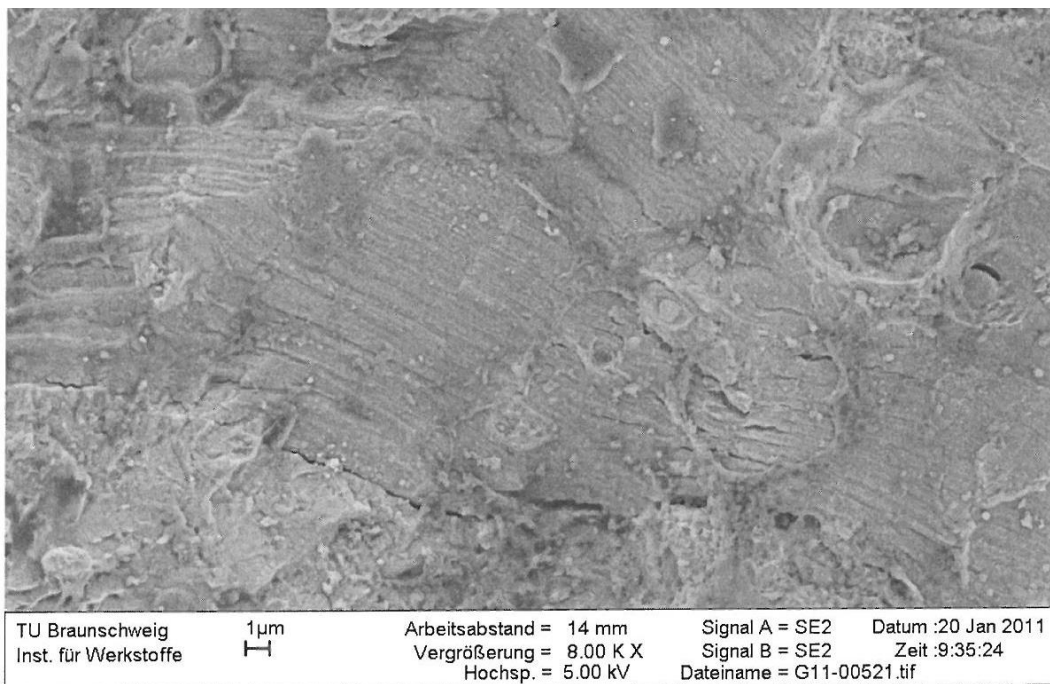


Image 4: Striations at the end of the big thumbnail

Photo: IfW

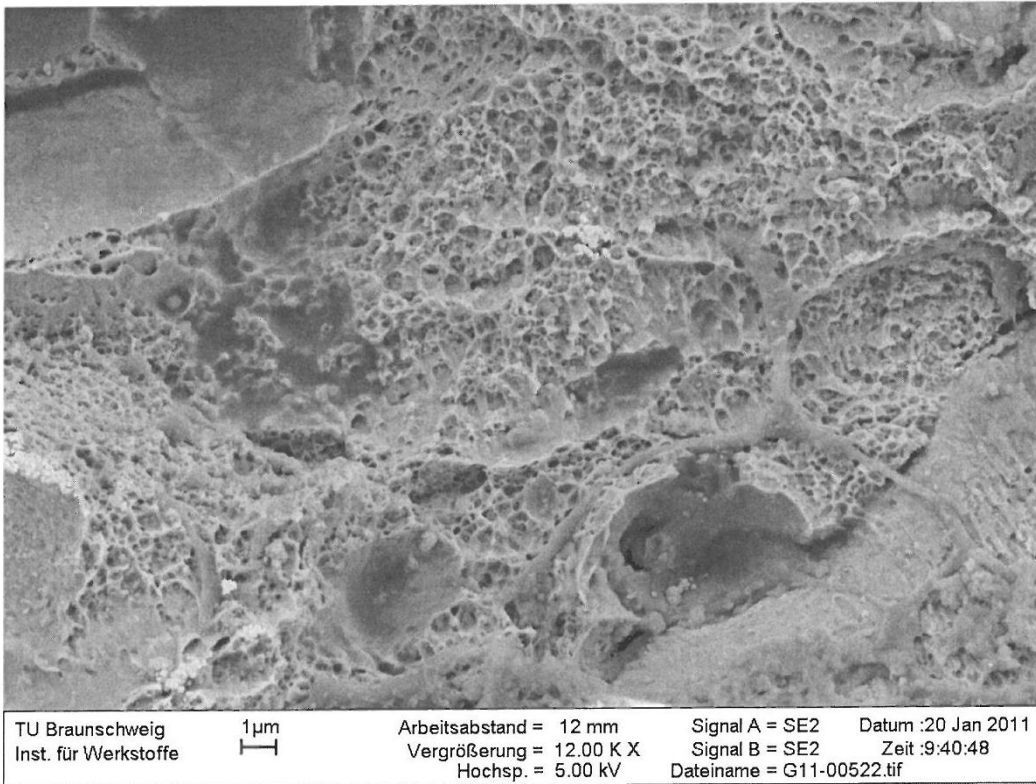


Image 5: Honey-comb structure of the microscopic ductile remaining forced rupture

Photo: IfW

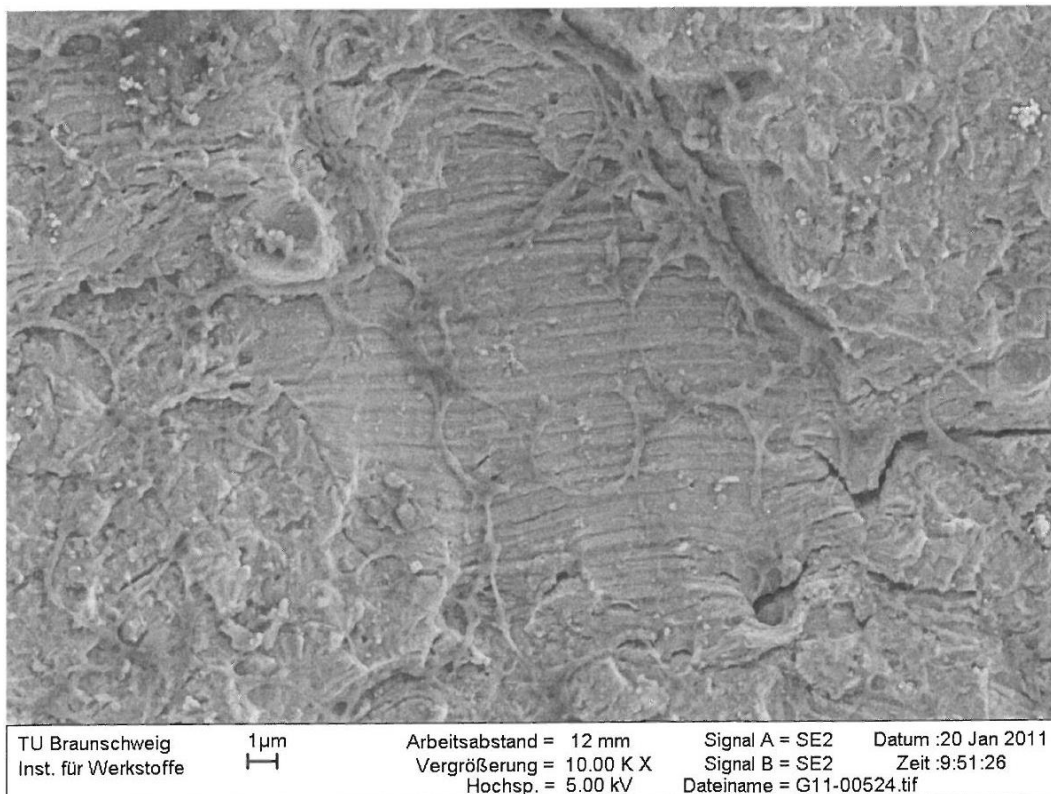


Image 6: Striations in the second crack to left of the central thumbnail

Photo: IfW

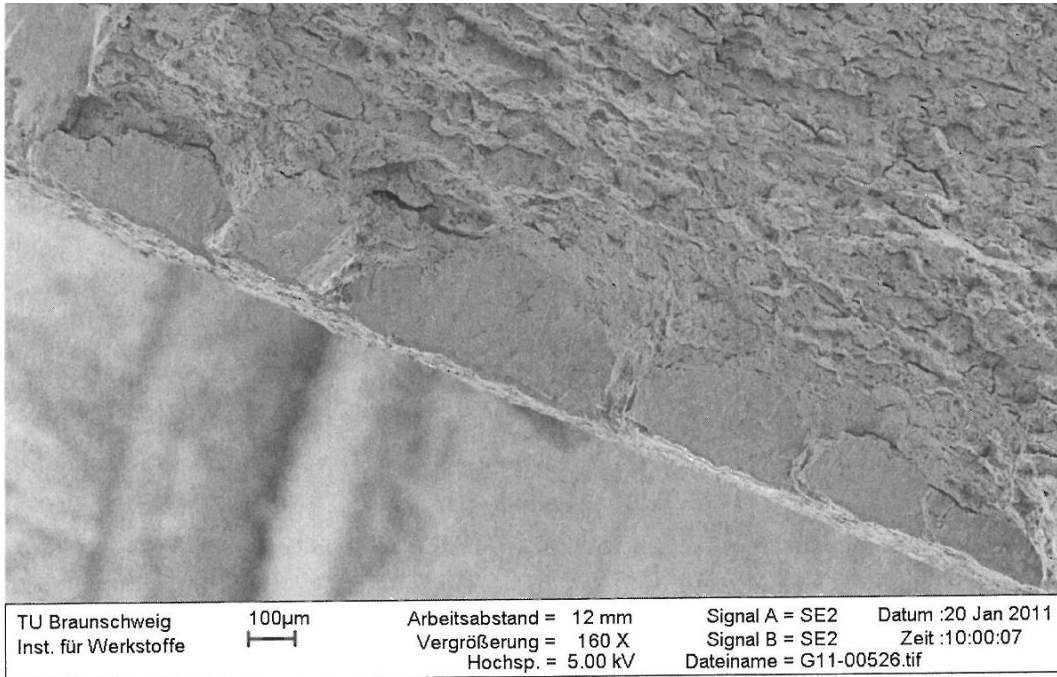


Image 7: Further fatigue fracture cracking in the 7 o'clock position

Photo: IfW

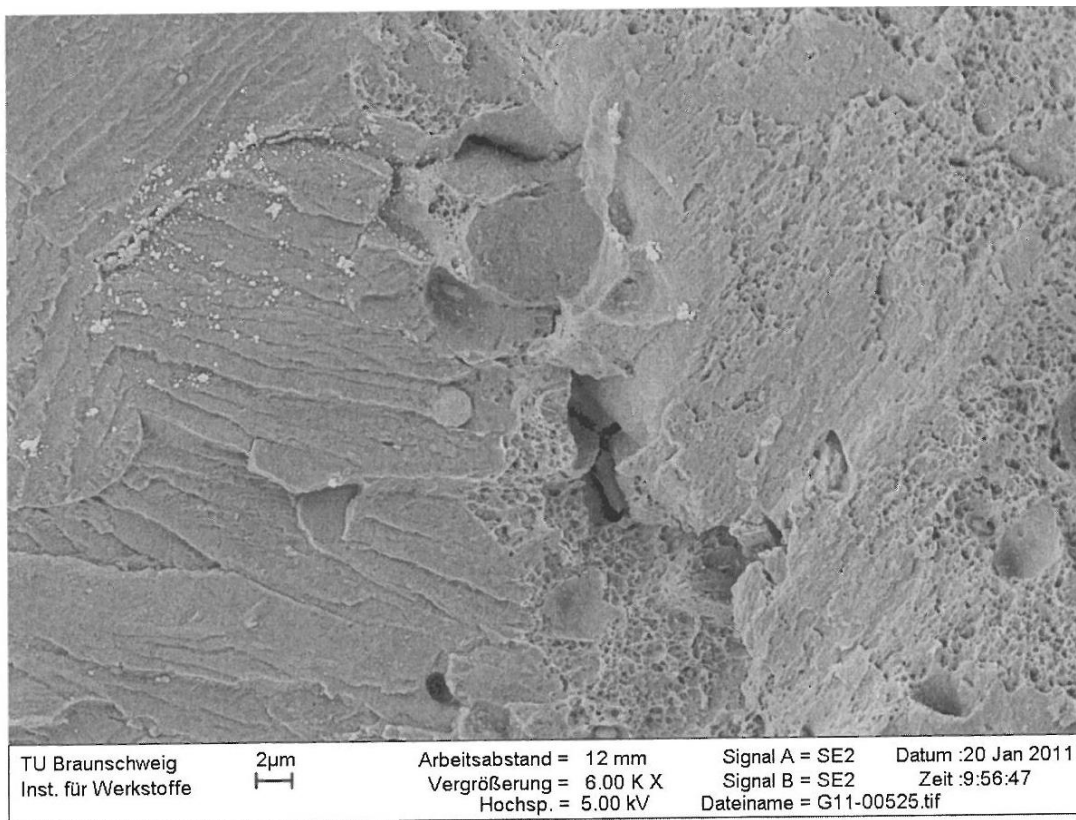


Image 8: Transition area of fatigue fracture to remaining forced rupture

Photo: IfW

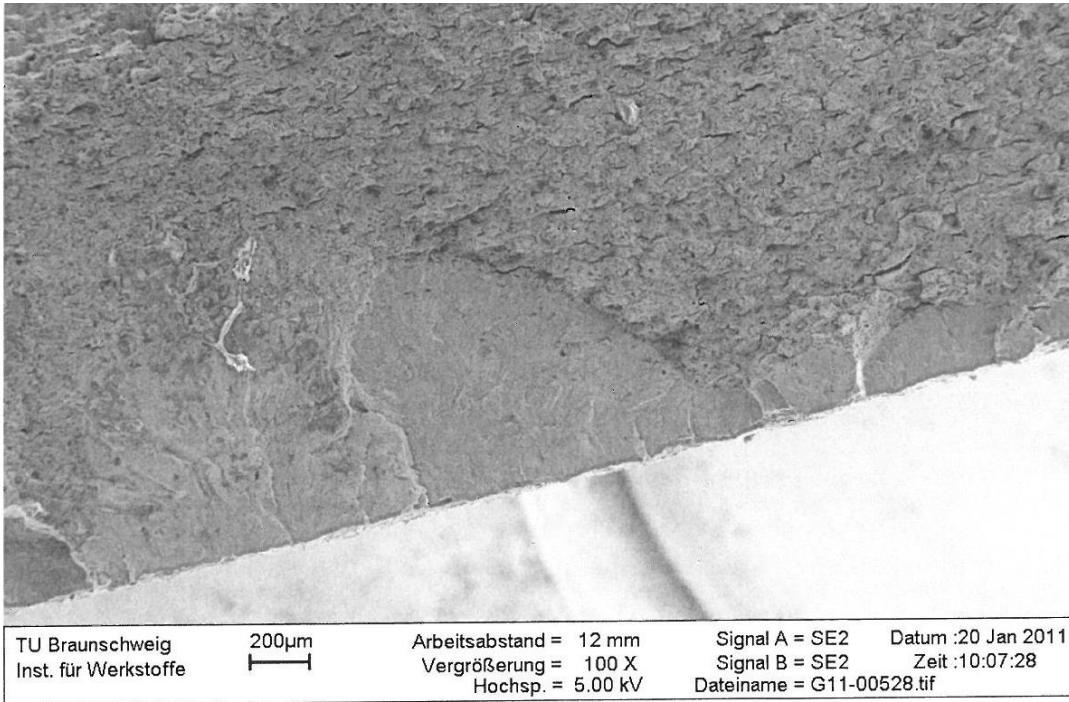


Image 9: Further fatigue fracture cracking in the 5 o'clock position

Photo: IfW

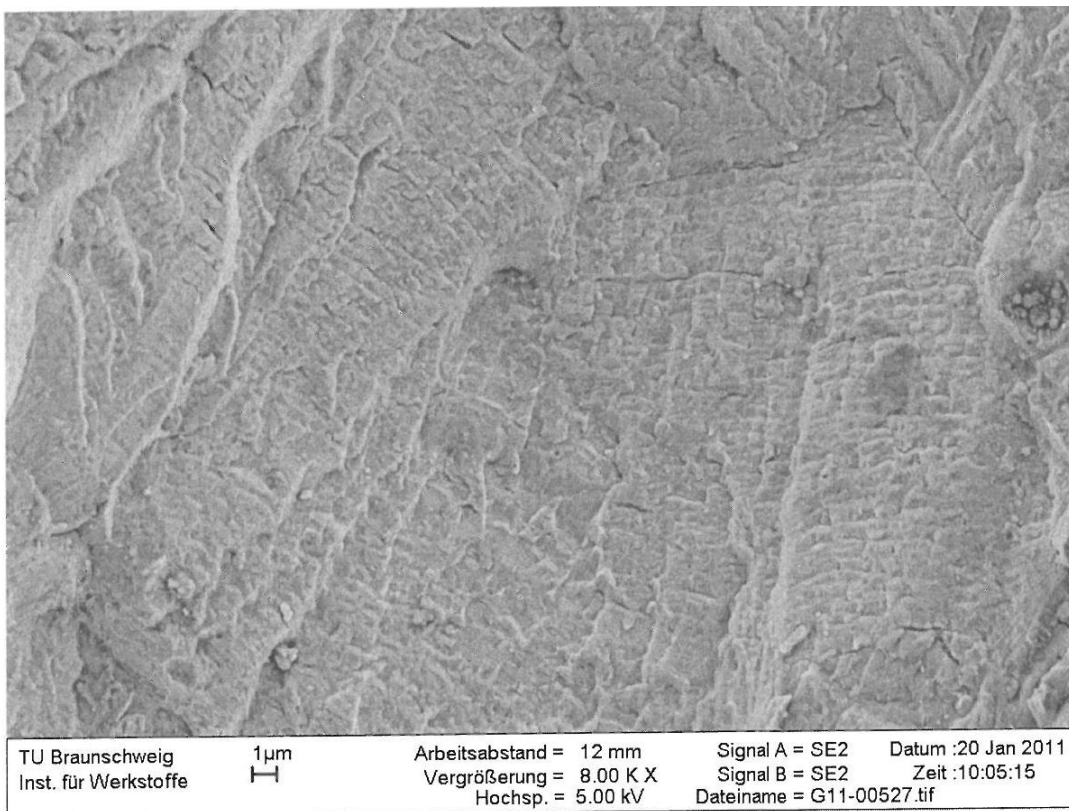


Image 10: Striations in the middle crack of Image 9

Photo: IfW

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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