

# Investigation Report

## Identification

Type of Occurrence:	Accident
Date:	18 February 2012
Location:	Lahr Special Airfield
Aircraft:	Helicopter
Manufacturer / Model:	Amateur-built aircraft / Safari
Injuries to Persons:	Pilot fatally injured
Damage:	Aircraft destroyed
Other Damage:	None
Information Source:	Investigation by BFU external experts for field investigation
State File Number:	BFU 3X006-12

## Factual Information

### History of the Flight

The Flugleiter (A person required by German regulation at uncontrolled aerodromes to provide aerodrome information service to pilots) stated on the day of the accident, the pilot intended to make hover exercises and then fly three traffic circuits with autorotation landings.

After the pilot had flown hover manoeuvres for a few minutes he started his first traffic circuit. He finished it with an autorotation exercise and landed in the grass west of the runway. The Flugleiter then observed the helicopter taking off again and in about 40 - 50 m abeam the tower it suddenly began to spin. During the spinning the nose of the helicopter dipped. At 1248 hrs<sup>1</sup> with the nose first and still yawning the helicopter impacted the runway of Lahr Special Airfield and caught fire immediately.

Two additional witnesses saw the helicopter hover in about tree height in the area of the runway or flying slowly forward in about 20 - 30 m. They saw a part suddenly falling down and then the helicopter began to spin and crashed.

The fire brigade of the special airfield rescued the pilot and extinguished the fire.

The pilot was fatally injured.



Helicopter wreckage

Photo: BFU

## Personnel Information

The 61-year-old pilot held a Private Helicopter Pilot's Licence (PHPL) issued according to JAR-FCL and valid until 16 July 2016. The license carried the entries: Type rating as Pilot in Command (PIC) on R22 and Safari and the night flight

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

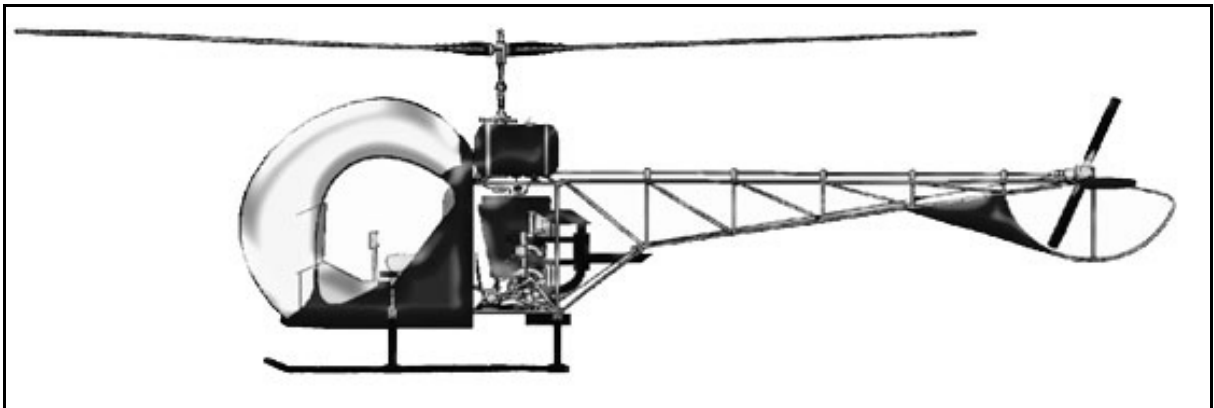
qualification. He held a class 2 medical certificate with the restriction to wear glasses issued according to JAR-FCL 3; it was valid until 21 January 2013.

He had a total flying experience on helicopters of about 220 hours; about 70 hours of which were on the type in question.

He also held a Private Pilot's License (PPL(A)). He had a flying experience on airplanes of about 800 hours.

## Aircraft Information

The helicopter Safari of the current kit producer Safari Helicopter is a two-seat helicopter for self-construction. Visually it is based on the Bell 47. The helicopter has skids, a two-blade main rotor rotating clockwise and a tail rotor for anti-torque. Maximum take-off mass is 700 kg. The helicopter is supposed to be equipped with a Lycoming 360 engine. Components such as main rotor head and tail rotor are delivered to the customer fully assembled.



Side view

Source: Safari Helicopter

The helicopter involved, year of manufacture 2006, had the device number 3003557 which was issued by the Luftfahrt-Bundesamt (German civil aviation authority, LBA). According to the weight report of 13 July 2007 the empty mass was about 465 kg. At the time of the accident the flight mass was about 606 kg and the centre of gravity was within the prescribed limits. On 23 November 2011 the last airworthiness review as experimental was conducted at 73.14 operating hours. At the time of the accident it had a total of about 74 operating hours.

The helicopter had a temporary certificate of registration in accordance with the Regulation on Certification of Aircraft (LuftGerPV) para 3 for flight tests as single piece until 17 June 2012.

The "Report of the function and ground tests" of 10 April 2007 showed that during the first ground tests in August 2006 significant vibrations occurred. After re-alignment of the blades and balancing the main rotor high frequency vibrations still remained. "Only after an extensive balancing of the tail rotor the vibrations were almost corrected." In September 2006 an imbalance in the fan wheel of the engine was determined to also be a cause for the vibrations.

Three written expert opinions had to be prepared for the certificate of registration in the "Restricted Special Class" of the amateur-built helicopter. The first concerning the practicability of the construction project, the second after the helicopter was built and the third after the flight tests. The first two were approved, the third had been submitted to the LBA as draft. The expert opinions did not determine any deficiencies in the construction work or the operational safety. A proof in accordance with JAR 27.571 *Fatigue evaluation of flight structure* was waived. The second expert opinion observed: "The builder cannot conduct fatigue strength testing on his single piece." In regard to proof of airworthiness it was further referred to about 60 helicopters of this type flying worldwide. The oldest of which had been operated for about 1,500 hours.

The preliminary helicopter maintenance manual (of 10 May 2007) stipulated the following checks:

Wartungs-Kontrollliste für Hubschrauber Safari Kennzeichen:		LBA Ger.Nr.: 3003557		1	2	3	4	Kz
1.	25 Std. oder tägliche bzw. Vorflugkontrolle	bei Std.:						
2.	50 Std.	durchgeführt am:						
3.	100 Std.	Unterschrift des Zeichnungsberechtigten:						
4.	250 Std.	Seite 1 von 3						
<b>Heckrotor und Getriebe:</b>								
1.	Kontrolliere die Blattoberflächen und Verbindungsnahte an den Blätterhinterkanten			x	x	x	x	
2.	Prüfe Heckrotorjoch, Schlaggelenklager und Bolzen				x	x	x	
3.	Prüfe Blattlager bei abgenommenen Steuerstangen auf sauberes Arbeiten.					x	x	
4.	Prüfe Lager der Blattverstellungs-Übertragung					x	x	
5.	Prüfe Blattverstellgestänge auf Spiel. Nicht mehr als 0,015".					x	x	
6.	Kontrolliere die gesamte Heckrotorwelle (Kerben nicht tiefer als 0.002")					x	x	
7.	Sämtliche Lagerböcke der Antriebswelle kontrollieren					x	x	
8.	Alle Wellenlager auf ruhigen Lauf und Befestigung auf der Welle kontrollieren					x	x	
9.	Vordere Flex Kupplung auf Zustand, Befestigung, Sicherung				x	x	x	
10.	Hintere Wellenkupplung auf Spiel und Sicherheit kontrollieren				x	x	x	
11.	Prüfe Heckrotorgetriebegehäuse auf Dichtigkeit und Ölstand sowie Befestigung			x	x	x	x	
12.	Heckrotorgetriebe gem. Wartungshandbuch zerlegen und überprüfen						x	
13.	Laufzeitteile (Lager) erneuern						x	
14.	Antriebswelle auseinandernehmen komplett mit Lager prüfen						x	
15.	dto. gem. Wartungshandbuch wieder anbauen, ausrichten						x	
16.	Ölwechsel durchführen, Spänededektor kontrollieren reinigen					x	x	
17.	Einstellung der Steuerung, Ausschläge der Heckrotorblätter mittels Lehre kontrollieren					x	x	
18.	Track and Ballance falls erforderlich durchführen					x	x	

Excerpt from the preliminary helicopter maintenance manual

Source: Operator documentation

## Meteorological Information

According to the Meteorological Aviation Report (METAR) of Lahr Special Airfield, at 1250 hrs visibility was more than 10 km, wind came from 190° with 10 kt, scattered clouds (SCT) in 4,400 ft GND, and temperature was 8°C with a dewpoint of 3°C. Air pressure (QNH) was 1,020 hPa.

## Communication

Radio communications between the helicopter pilot and the Flugleiter were recorded and made available to the BFU as transcript.

## Aerodrome information

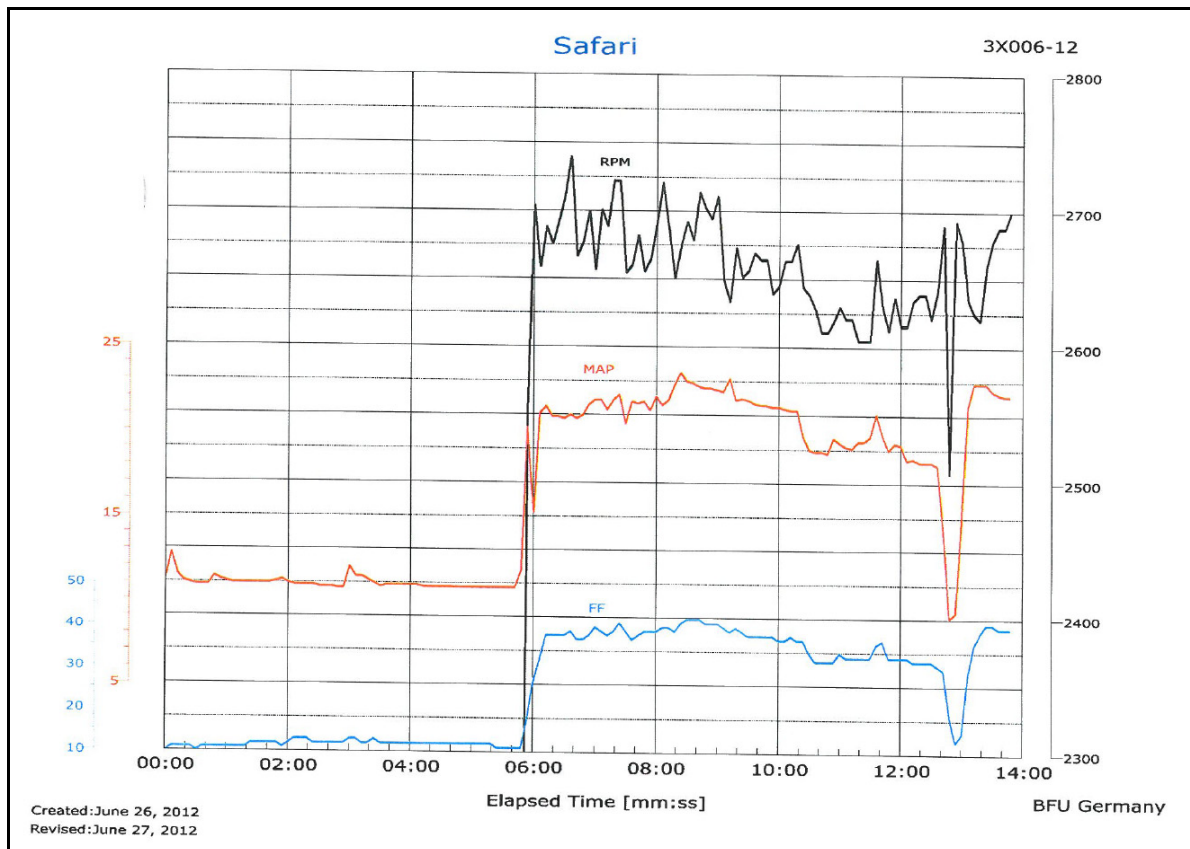
Lahr Special Airfield (EDTL) has one 3,000 m asphalt runway oriented 03/21. North of the runway between the taxiways the grass area for sailplane operation is located. Aerodrome elevation is 511 ft AMSL.

The special airfield is certified for helicopter operation.

## Flight Recorder

The helicopter was not equipped with a Flight Data Recorder (FDR) or a Cockpit Voice Recorder (CVR). These recording devices were not mandatory.

The helicopter was equipped with digital indication devices for engine and flight parameters. The engine indications system J.P. Instruments EDM-930 and the Dynon SV700 were read out. The EDM-930 had stored a total of 119 flights. The data shows that the engine had run about 13:40 minutes from engine start-up until the accident.



Excerpt from the recorded data of the accident flight

Source: BFU



Flight path read-out

Image: BFU/Google Earth™

## Wreckage and Impact Information

The accident site was on the runway of Lahr Special Airfield abreast of the tower.

The helicopter lay on its left fuselage side in the approximate direction of 310°. Initial impact traces were found south of the wreckage. The glass cockpit had burst and lay scattered north of the wreckage on the runway. The left skid had been pushed toward the fuselage; the tip of the right skid including the counterweight had broken off. The instrument panel had been torn out and was only connected with the wreckage by wiring. The control rods to the rotor head were torn off; the rotor blades had been severely damaged. The fuselage structure had been dented in the area of the engine. The elevator was bent upward.

The tail rotor gear box including one tail rotor blade lay about 15 m north-west of the wreckage. The tail rotor blade was bent contrary to the rotational direction. It showed yellow paint traces on the blade side facing the fuselage structure; the tip of the blade showed a semi-circular dent. Corresponding defects in the paint work and impact traces were found on the yellow tail boom.



Tail rotor gear box including tail rotor blade and damages on the tail boom

Photo: BFU

The second tail rotor blade lay about 80 m north-east of the wreckage. On this blade the upper half of the trailing edge was bent toward the blade grip. The leading edge was undamaged. The tail rotor pitch arm of the torn-off tail rotor blade was missing from the blade grip. It was found about 34 m south-east of the wreckage.





Fractured tail rotor spindle and the two tail rotor blades

Photos (2): BFU

The BFU commissioned an expert of the Technische Universität Braunschweig, Institut für Werkstoffe (IfW) to determine the cause for the fracture of the tail rotor spindle.

### 1.13 Medical and Pathological Information

The pilot was autopsied. The cause of death was determined to be injuries to multiple inner organs and a fracture in the area of the cervical spine.

### Fire

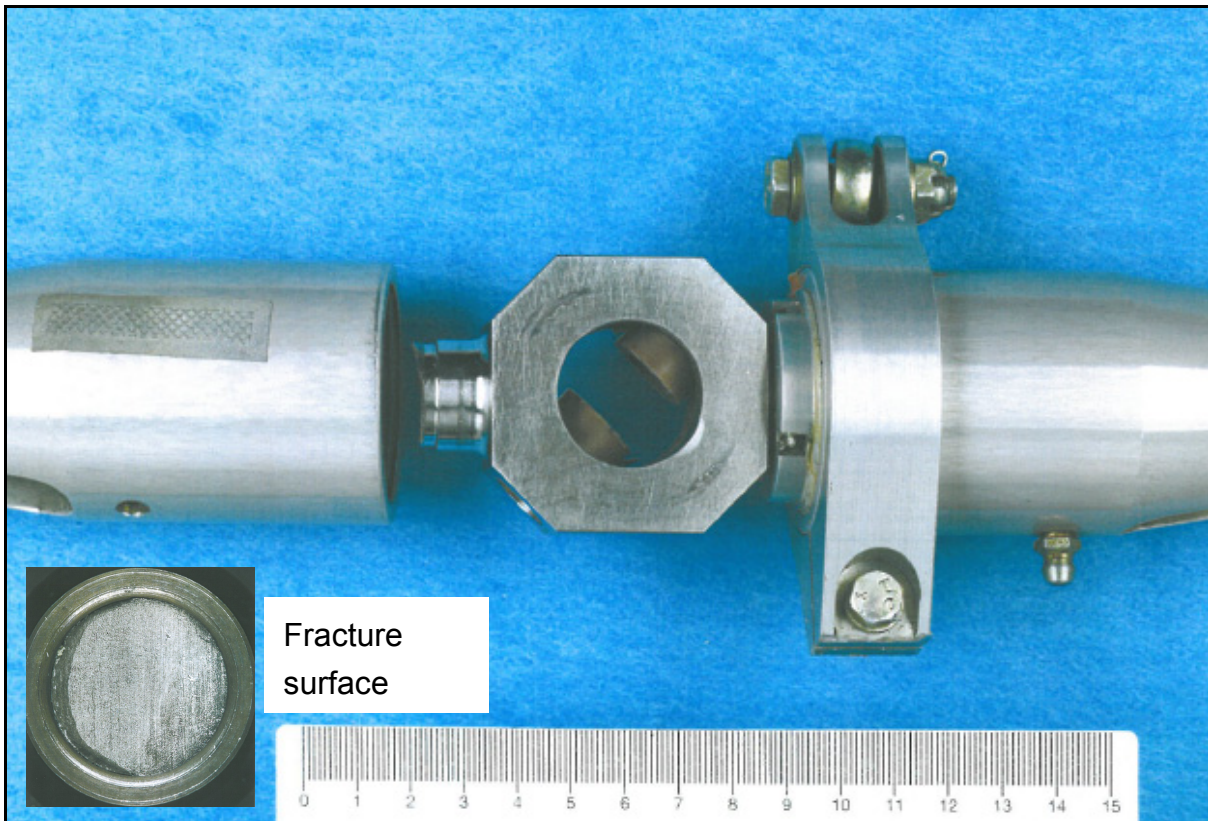
On impact there was a fire in the area of fuel tank and the engine.

### Survival Aspects

Lahr Special Airfield has a fire brigade. At 1248:25 hrs the fire brigade was notified. They extinguished the fire before it reached the cockpit.

## Tests and Research

The expert of the Institut für Werkstoffkunde of the Technischen Universität Braunschweig concluded that the fracture of the tail rotor spindle occurred exactly on the radius of the tail rotor blade bearing seat. Here constructive change in stiffness and maximum bending moment meet. It is absolutely certain that it is a fatigue fracture.



Fractured tail rotor spindle

Photo: IFW

Due to the unusually clearly visible line structure on the fracture surface, a sample for the metallographic cut was prepared from the spindle. A structure unfavourable for fatigue strength in the raw material for the spindle was determined.

The expert opinion concludes *"[...] that the tail rotor spindle was destroyed by a fatigue fracture. The fatigue crack had propagated across half of the cross section area before the residual fracture occurred. The unfavourable structure of the material in regard to the vibration fatigue life has contributed to the development of the fatigue fracture."*

## Organisations and their Procedures

Operation of amateur-built aircraft is allowed in Germany. The LBA has published a leaflet "Testing and registration of amateur-built single pieces in accordance with Regulation on Certification of Aircraft (LuftGerPV) para 3". The leaflet describes the process of the necessary working steps to obtain a registration for flight operations. For amateur-built rotary wing aircraft the design requirements JAR-27 is the basis.

### Kit Producer

Until 2009 the Canadian Home Rotors Inc. produced the kit for the amateur-built helicopter with the type name "Baby Bell". In 2009 the American CHR International Inc. and Safari Helicopters, respectively, acquired the production rights.

On enquiry by the BFU they could not state whether the former producer or a component supplier had produced the tail rotor spindle. At the time, the producer's instructions for the balancing of the tail rotor stated: *The tail rotor should be dynamically balanced within the first four hours of operation, with a Chadwick or equivalent electronic balancer. The blades are matched at the factory, and should provide quick satisfactory balance.*

Nowadays the tail rotors are sent to the customer completely assembled and statically and dynamically balanced. Due to the fracture of a main rotor spindle the producer issued a "Mandatory Inspection" stating: *While the SAFARI is classified as "experimental", and the builder can qualify as the authorized mechanic for his aircraft, we strongly recommend that owners limit their maintenance activities to routine items. Assembly of the main rotor head, main transmission, and tail rotor assembly is an operation requiring considerable experience and skill and should not be undertaken by anyone not trained by the factory. All main components are provided fully assembled and ready to install for this reason. The segments of the main components are assembled in a specific, carefully designed process, with multiple checkpoints and close tolerances. We strongly suggest that you rely on the factory or a dealer for maintenance or repair of these critical systems.*

The kit producer supplied the BFU with a Stress Analysis Report of the tail rotor spindle. For the analysis the assumption was that the raw material specification was Titanium Ti-6Al-4V which should be free of unfavourable structures. Since 2011 lighter titanium tail rotor blades are used instead of the original steel blades to reduce the stress on the spindle, among other things.

## Additional Information

The authorised engineer and inspector for the helicopter type, respectively, stated the tail rotor involved had been dynamically balanced with the Chadwick Vibrex 2000 within the first five operating hours complying with instructions of the former kit producer. The entire tail rotor section had been delivered fully assembled and according to the producer had already been statically balanced. Already during the first test run the tail rotor had shown severe vibrations. Additional test runs had been conducted with mounted balancer. It took some time until feasible results below 1.0 Inch Per Second (IPS) for the balance chart were produced. By using balancing weights permissible values below 0.2 IPS were reached. The owner had filed a complaint with the former kit producer since the balancing weights had been added in straining direction which means the blades had different weights. At the time, the producer had said that this was possible and normal. After balancing the tail rotor had run normally and smooth during the entire operating time which had been checked continuously during flight tests.

During the investigation the tail rotor blade were weighed. The torn-off blade weighed 792 g without the blade grip, with bolts and balancing weights 986 g; the other blade weighed 801 g, with bolts and balancing weights 966 g.

On the basis of photographs the current kit producer analysed the balancing of the tail rotor. Thereby, errors were determined (Appendix). The kit producer assumes that in addition to the weight differences constructional problems during manufacture must have been present which caused vibrations. The needed balancing weights were an unambiguous sign.

## Similar Air Accidents

Already in the past accidents during the operation of a Safari helicopters occurred due to tail rotor and main rotor blade losses.

Aviation Investigation Report of the Transport Safety Board of Canada, Report Number A04C0064:

On 20 March 2004 the elevator bent in flight and the main rotor impacted the tail boom of the helicopter. The helicopter crashed to the ground and the pilot was fatally injured.

Separation of the tail rotor blade during a previous flight had induced an excessive amount of vibration, resulting in bending of the horizontal elevator spar.

Investigation Report of the US National Transportation Safety Board, Report Number CHI05LA243:

On 28 August 2005 a tail rotor blade separated in flight, the helicopter crashed to the ground and the pilot was fatally injured.

The investigation determined that after a hard landing a new tail rotor unit had been installed. Intense vibrations occurred during the subsequently conducted ground tests. The kit producer delivered surrogate tail rotor blades. After about 25 operating hours the tail rotor spindle broke.

Investigation Report of the South African Civil Aviation Authority, Report Number CA18/3/2/8234:

On 12 January 2007 the main rotor blade spindle broke in flight, one rotor blade separated and the helicopter crashed.

During the investigation the history of the accident helicopter showed that in 2002 during vibration balancing testing the tail rotor broke and separated from the tail boom while the helicopter was running at full RPM.

Investigation Report of the US National Transportation Safety Board, Report Number WPR09LA253:

On 22 May 2009 the main rotor head spindle broke in flight due to a fatigue fracture in the area of the main rotor blade bearing. The helicopter crashed to the ground and both occupants were fatally injured. The area of the fracture was obscured by the blade grip nut.

Investigation Report of the US National Transportation Safety Board, Report Number CEN09CA584:

On 13 September 2009 the helicopter lost one tail rotor blade during landing. The helicopter was landed by use of autorotation and was severely damaged. The cause of the tail rotor blade loss was not determined.

On enquiry the current kit producer pointed out that only in one of the listed cases the tail rotor spindle failed which caused a tail rotor blade loss. According to the producer, the owner of the helicopter had installed the spindle mirror-inverted after repair work which then caused the fracture. The former kit producer had issued a Service Bulletin on 12 May 2006 demanding the inspection of the tail rotor spindle's correct installation. In addition, newly produced tail rotor spindles received a marking for the correct installation.

The present kit producer tried to discover the origin of the fractured tail rotor spindle and, if necessary, to find components manufactured of the same raw material. It was determined that the former component supplier was now out of business. The owner of the component supplier was found and he tried to find information about the used raw material in their business documents. He stated that back than production lots consisted of about 14 to 20 pieces.

## Analysis

The accident flight was conducted as private flight to obtain the final certificate of registration as single piece amateur-built helicopter. The engine data shows that about 13:40 minutes passed between start up and accident. The recorded parameters of this time period were inconspicuous. After the first traffic circuit the helicopter was on the ground for a few seconds before the next take-off. During the climb the tail rotor spindle broke. The remaining tail rotor blade impacted the fuselage structure and was torn off the tail boom including the tail rotor gear box. Due to the high engine thrust and the low forward speed the helicopter began to spin. The only possible reaction would have been to conduct an autorotation, but due to the low forward speed and the low altitude it is likely that it would not have been successful. The recorded engine data shows no reduction of manifold pressure or the initiation of an autorotation.

The pilot held the required license and type rating. The BFU is of the opinion that his total flying experience on helicopters was low with regard to his task - testing a new helicopter type.

Except for the starting direction, the weather had no influence on the accident. Due to the low outside air temperature and density altitude performance problems were not to be expected.

In the scope of certification as single piece the amateur-built helicopter had almost finished the test phase. A valid preliminary registration existed for the flights. According to three expert opinions and the last inspection of an examiner there were no visible technical defects on the helicopter. The centre of gravity and the flight mass were within prescribed limits.

The expert determined fatigue fracture as cause for the tail rotor spindle failure. Causal vibrations on the tail rotor can have different reasons. The helicopter in question had been balanced by an experienced examiner for helicopters with

aviation-approved technical equipment. He described the running of the tail rotor and the vibration behaviour as inauspicious after the balancing and up until the accident. The current kit producer determined balancing mistakes: From their point of view the necessary balancing weights and their positions should have raised concern as to the operational safety of the tail rotor and should have led to an inspection of the whole tail rotor unit. It could not be determined whether the tail rotor spindle was pre-damaged within the first operating hours due to heavy vibrations, or if during flight operations a slight ground contact occurred which caused no visible damages on the tail rotor blade but then was the point of origin of the fatigue fracture. Both is possible, however.

The design of the tail rotor made apparent how massive and heavy the individual steel tail rotor blades were compared to tail rotor blades of other producers. It seems possible that with such massive tail rotor blades a slight ground contact may not lead to visible blade damages but it is possible that energy is transferred which then may cause tail rotor spindle damage. It is highly unlikely that the builder made construction errors since the tail rotor was delivered fully assembled by the former kit producer.

In the past amateur-built helicopters of this type suffered tail rotor blade losses, tail rotor spindle fractures and fractures of the similarly constructed main rotor spindle. The fracture occurred in the radius of the tail and main rotor blade bearing seat in an area where constructive change in stiffness and operational bending moment meet. In all known accidents the kit producer referred to operational or maintenance deficiencies of the owners as cause for the structural failure of the components.

The present kit producer acts on the assumption that since 2009 when they took over, the used raw material and manufacture meet the stress analysis criteria and that sufficient strength exists. The kit producer is also of the opinion that the use of lighter, titanium tail rotor blades further reduces working loads.

The investigation of this particular fractured tail rotor spindle determined that the source material had structural characteristics which favour fatigue fractures. The BFU is of the opinion that this is serious because the starting point of a possible tail rotor spindle fracture lies in the blade grip and is, therefore, not visible. A periodic crack inspection is not possible without disassembly of the tail rotor blades.

Due to the determined possible problems with the heavy steel tail rotor blades, the balancing of the tail rotor and the possible structural characteristics of the tail rotor

spindle, old tail rotor units should, together with the current kit producer, be examined and exchanged, respectively.

## Conclusions

The accident occurred because of a tail rotor spindle fracture accompanied by loss of a tail rotor blade which led to loss of control of the helicopter.

## Safety Recommendation

### Actions by the Luftfahrt-Bundesamt

This accident and other occurrences which happened in the past caused the Luftfahrt-Bundesamt to ground all helicopters of this type in Germany which had a temporary certification as experimental or had already received their certificate of registration until safe operations of the tail rotor spindles was proven.

### Actions by Safari Helicopter

On 29 February 2012 the kit producer published a Critical Notice - Tail Rotor Balancing (Appendix).

In addition, Safari Helicopter offers all German Safari helicopter operators replacement of the entire tail rotor spindle free of charge. Each replacement spindle will include material certifications and quality assessment of the raw material used and will be dynamically balanced and free of irregularities.

All removed spindles will be tested by a qualified laboratory to determine the presence of any damages.

The kit producer is also planning to recommend the helicopter operators the use of lighter tail rotor blades.

In the future, the kits will be delivered not only with fully balanced tail rotors but also with documentation of the manufacture of the tail and main rotor spindles.

Due to these actions the BFU abstained from issuing safety recommendations.

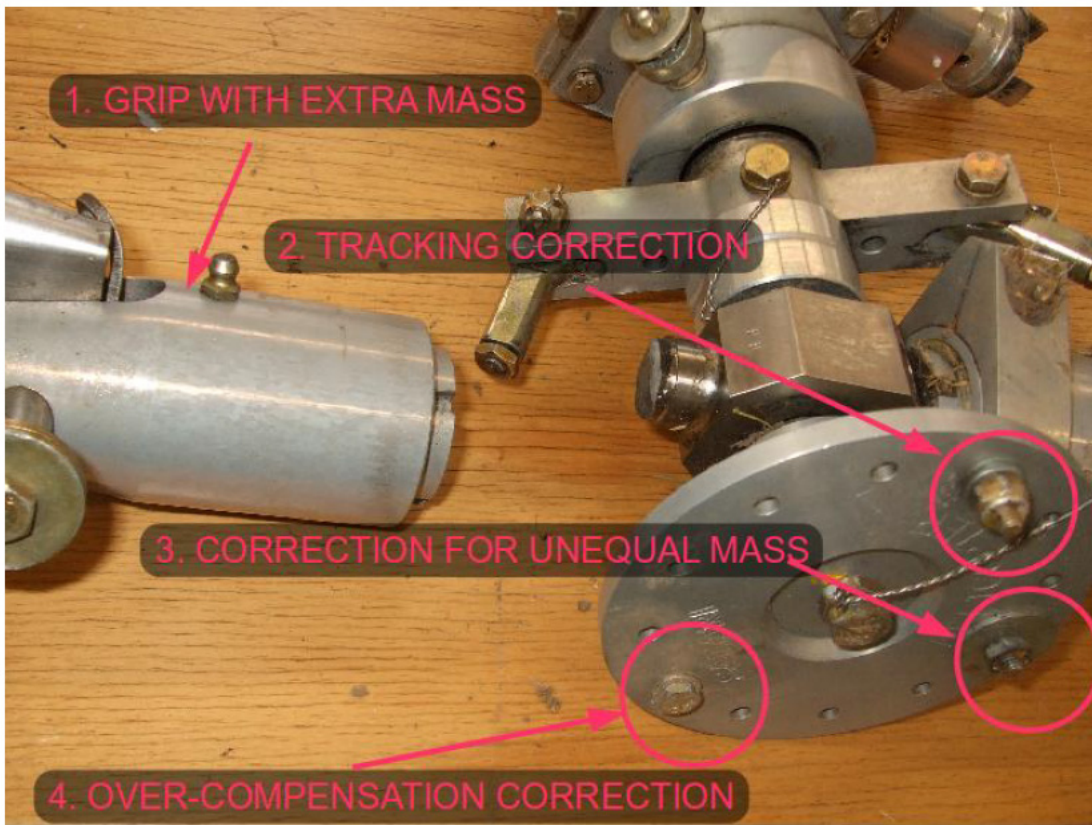
Investigator in charge: Axel Rokohl

Assistance: Philipp Lampert, Dietmar Nehmsch

Field Investigation: Uwe Reibel, Kurt Frieß  
Braunschweig, 16 January 2013

## Appendices

1. Analysis of the conducted balancing by the kit producer
2. Critical Notice published by the kit producer



Picture 2

The balance ring of the incident aircraft displays several elements which are contrary to accepted practice and standards.

1. One grip has extra mass (30g) added to it. This increases the spindle load by roughly 360 N at 2750 RPM.
2. The balance ring has weight at 90° to the blades. This indicates a tracking error or severe lead / lag error which should be corrected by blade adjustment. While the output shaft may be balanced, the rotor head is not.
3. There is weight opposite the grip with extra mass on it. Rather than add mass to the balance ring, mass should have been removed from the grip instead to relieve spindle load.
4. A third balance weight is added opposite the other two, larger masses on the balance ring. This indicates that too much mass has been placed in the wrong position. Further correction is required.

Ideally, as little weight as possible is used to balance. This is not the case on this rotor. Weight has been added and then more weight has been added on the opposite side to counter it. Added weight should have been removed to obtain the proper correction.

Analysis of the conducted balancing of the kit producer



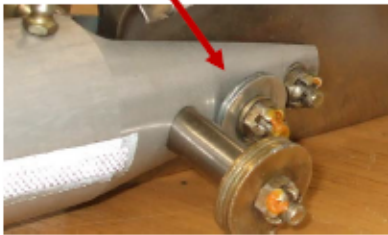
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## CRITICAL NOTICE – TAIL ROTOR BALANCING

February 29, 2012

### IMPROPERLY PLACED WASHERS ON GRIP



TAIL ROTOR  
 BUMP BALANCE

The photo above left shows a tail rotor grip with additional weight added to the tail rotor grip using the tail rotor grip bolts. Under no circumstances should the tail rotor be balanced in this way. Addition of weight to the tail rotor grip increases the centrifugal load on the tail rotor head bearings and increases the amount of stress on the tail rotor spindle.

The bump balance (shown on the right) installed on the tail rotor provides a safe and effective location for weight needed to properly balance the tail rotor of the SAFARI. If the tail rotor cannot be balanced using weight installed on the bump balance, there is a serious underlying issue causing a dynamic out-of-balance condition which must be addressed. The photo above right shows the correct use of the bump balance to add weight.

If you have been operating your SAFARI with weight improperly installed on the tail rotor grips as shown above, please contact the factory before flying your helicopter again.

Balancing of the tail rotor assembly on a helicopter is a complex task that should only be undertaken by experienced aircraft maintenance technicians. If you have any doubt or concerns regarding the condition of your tail rotor assembly, please contact the factory for assistance.

Balancing services for existing tail rotor assemblies are offered free of charge to any SAFARI owner who chooses to return the entire tail rotor assembly, including the tail rotor gearbox, to the factory. Please contact us at [gm@safarihelicopter.com](mailto:gm@safarihelicopter.com) or at 1-850-482-4141 or on Skype at Sales-Safari-Helicopter.

Critical Notice published by the kit producer

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.

## Published by:

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