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Schweizerische Unfalluntersuchungsstelle SUST
Service d'enquête suisse sur les accidents SESA
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Swiss Accident Investigation Board SAIB

Aviation Division

Final Report No. 2153 by the Swiss Accident Investigation Board SAIB

concerning the accident involving the
Agusta helicopter A109K2,
registration HB-XWM

on 24 November 2009

at the former Airport
Interlaken / BE

Ursachen

Der Unfall wurde durch den Bruch zweier Bolzen für die Befestigung des *swash plate driving scissor fitting* am *hub* des Hauptrotors verursacht, was dazu führte, dass der Helikopter annähernd unsteuerbar wurde.

Kausal für den Bruch der Bolzen war der Umstand, dass die vom Hersteller publizierte und vom Unterhaltsbetrieb verwendete Unterhaltsdokumentation fehlerhaft war.

General comments on this report

This report contains the conclusions of the Swiss Accident Investigation Board (SAIB) on the circumstances and causes of the accident under investigation.

In accordance with Article 3.1 of the 10th edition of Annexe 13, effective from 18 November 2010, to the Agreement on International Civil Aviation of 7 December 1944, as well as to Article 24 of the Federal Law on Aviation, the sole purpose of the investigation of an air accident or a serious incident is the prevention of accidents or serious incidents. Legal assessment of the circumstances and causes of air accidents and serious incidents is expressly excluded from the air accident investigation. It is therefore not the purpose of this report to establish blame or to determine liability.

Should this report be used for purposes other than those of accident prevention, this statement should be given due consideration.

The German version of this report constitutes the original and is definitive.

All times in this report, unless otherwise indicated, are stated in local time (LT). At the time of the accident, Central European Time (CET) applied as local time in Switzerland. The relation between LT, CET and Universal Time Coordinated (UTC) is:

LT = CET = UTC + 1 h.

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Final Report

Summary

Owner	Swiss Air Ambulance AG (REGA), Post Box 1414, 8058 Zürich Airport
Operator	Swiss Air Ambulance AG (REGA), Post Box 1414, 8058 Zürich Airport
Manufacturer	Agusta S.p.A., Cascina Costa (VA) Italy
Aircraft type	Agusta A109K2
State of registration	Switzerland
Registration	HB-XWM
Location	Former Airport Interlaken Municipality of Matten near Interlaken / BE
Date and time	24 November 2009, 14:21

Investigation

The accident took place on 24 November 2009 at 14:21. The Aircraft Accident Investigation Bureau (AAIB) received the notification at 15:21. The investigation was opened at about 14:00 on 25 November 2009 by the AAIB. The AAIB informed the Italian Flight Safety Agency about the accident, which appointed an accredited representative who participated in the investigation.

The final report is published by the SAIB, (formerly AAIB).

Synopsis

During a training flight with underslung load, vertical oscillation quickly developed during approach and the helicopter began to lose height. Despite jettisoning the underslung load, the sink rate could not be reduced. The helicopter was difficult to control.

The helicopter touched down in a rolling landing on soft terrain and suffered no further damage. The crew was not injured.

Fractures of two bolts fixing the swash plate driving scissor fitting to the hub of the main rotor head were established.

There was no damage to the field or to any airport installations.

Causes

The accident was caused by the fracture of two bolts that fix the swash plate driving scissor fitting to the hub of the main rotor, which led to the helicopter becoming nearly uncontrollable.

The cause of the bolt fracture was due to incorrect maintenance documentation published by the manufacturer and used by the maintenance organisation.

1 Factual information

1.1 Previous events and history of the flight

1.1.1 General

Following the training on the Agusta A109K2 helicopter completed on 19 November 2009, two pilots were trained on rescue winch and underslung load operations. On 23 November 2009, flights in open terrain with the rescue winch were carried out.

The underslung load training was scheduled for 24 November 2009. The intention was to carry out this training at the former Interlaken airport. In Gsteigwiler, on the premises of the helicopter company BOHAG, a barrel filled with concrete was prepared as an underslung load.

The flight took place under visual flight rules, and was designated a training flight.

1.1.2 Previous events

During flight preparation, there was a detailed briefing on normal and emergency procedures for all participants, including coverage of the position and function of the various switches and control levers in the helicopter for the cargo hook. It was planned to carry out flights with loads of 475 kg on longlines of 10, 30, 40 and 50 metres length. Flights would be carried out using the mirror on the one hand and vertical reference on the other. The intention was that the flight should take place at the maximum take-off weight for the helicopter with underslung load. The helicopter was fuelled accordingly.

The underslung load training would take place at the former Interlaken airport. The second training pilot and the helicopter emergency medical services crew member (HCM) who was designated as flight assistant were present on the ground.

1.1.3 History of the flight

On 24 November 2009 at 14:11, the helicopter, registered as HB-XWM, took off with the pilot and the flight instructor from the REGA base at Wilderswil for the flight to Gsteigwiler. The 10 meter line had already been attached at Wilderswil. At Gsteigwiler, the prepared load was attached by a local flight assistant while the helicopter was hovering. Afterwards, it flew to the area of the former Interlaken airport. When it reached the destination, the pilot asked the HCM on the ground about wind direction. The HCM replied that the wind was from the direction of Bönigen. The traffic pattern for depositing the underslung load at the practice area was planned accordingly. After flying over the practice area, the helicopter performed a shallow left hand circuit to its final approach in an easterly direction.

When turning to the final approach, the helicopter began to vibrate and the sink rate increased. To correct this, the pilot raised the collective slightly. The vibrations intensified and were perceived by the crew as a pitching motion. When the pilot asked if they were in a vortex¹ the instructor replied that they were not. The pilot requested the instructor to release the load. However, the instructor determined that attitude, approach angle, and airspeed were acceptable and did not release.

¹ Vortex: The Vortex Ring State is regarded as a dangerous aerodynamic condition for a helicopter, in which it descends rapidly through the downwash from its own main rotor. This occurs under the condition that the main rotor is under power, the horizontal velocity of the helicopter is low and the sink rate exceeds a critical value. Such a flight condition is also known as settling with power.

The instructor momentarily took control and realised that the helicopter was not responding, whereupon he released the load.

Contrary to expectations, the flight-path of the helicopter did not change, and the vibrations continued. The instructor then raised the collective with the objective of reducing sink rate, but the vibrations increased severely. An increase in rotor speed up to about 104% rotor revolutions per minute (RRPM) was perceived both acoustically and visually.

As the helicopter neared the ground, it began to pitch up somewhat. It then made an uncontrolled landing with a forward speed of about 40 kt on the grass in an approximately horizontal attitude. The tail rotor protection bracket contacted the ground.

The helicopter was not damaged further and the crew were not injured.



Fig 1: Final position of the helicopter and traces on the ground

1.1.4	Accident location	
	Accident location	Open terrain at the former Interlaken airport Municipality of Matten near Interlaken / BE approx. 45 km south-east of Berne
	Date and time	24 November 2009, 14:21
	Lighting conditions	Daytime
	Coordinates	634 005 / 169 500 (Swiss grid 1903) N 46° 40' 33" / E 007° 52' 59" (WGS 84)
	Elevation	580 AMSL 1903 ft AMSL
	Final position of wreckage	Meadow within airport boundaries
	Map of Switzerland	Sheet no. 1228, Lauterbrunnen, Scale 1:25 000

1.2 Injuries to persons

1.2.1 Injured persons

Injuries	Crew	Passengers	Total number of occupants	Others
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	2	0	2	Not applicable
Total	2	0	2	0

1.3 Damage to aircraft

No additional damage occurred to the helicopter due to the landing.

1.4 Other damage

There was no damage to the ground or to airport installations.

1.5 Personnel information

1.5.1 Flight crew

1.5.1.1 Pilot

Person	Swiss citizen, born 1968
Licence	Commercial pilot helicopter licence US CPL(H) ICAO, initially issued by the Federal Aviation Administration (FAA) on 21 March 1998, replaced by CH CPL(H) initially issued by the Federal Office for Civil Aviation (FOCA) on 3 Mai 1999.
Ratings (H)	AS350, SA316/319/315, EC120

		The pilot passed the test for the Agusta A109 rating on 19 November 2009. The new licence was issued by FOCA on 26 November 2009.
		English language proficiency level 4, valid until 14 February 2012.
		Night flying NIT(H)
		Mountain landing MOU(H)
	Medical certificate	Class 1, valid from 10 August 2009 until 14 August 2010. Restriction: VDL (shall wear corrective lenses).
1.5.1.1.1	Flying experience	
	Total	2605:13 h
	of which on the accident type	27:51 h
	during the last 90 days	144:31 h
	of which on the accident type	21:45 h
	during the last 24 h	1:23 h
	of which on the accident type	1:23 h
	Total number of landings	15 553
1.5.1.2	Flight instructor	
	Person	Swiss citizen, born 1970
	Licence	Airline transport pilot licence helicopter – ATPL(H) under joint aviation requirements (JAR), initially issued by FOCA on 16 October 2008. Commercial pilot airplane licence CPL(A) ICAO, initially issued by FOCA on 5 March 1996.
	Ratings (H)	A109 valid until 9 April 2010 and valid ratings for AS332/EC225MP PIC, AS350, BK117, SA316/319/315 Flight instructor FI(H), valid until 7 January 2012. English language proficiency level 4, valid until 8 November 2010. Night flying NIT(H) Mountain landings MOU(H) Take-off in ground and high fog HDF(H)
	Medical certificate	Class 1, valid from 25 June 2009 until 3 July 2010, without restrictions.

1.5.1.2.1	Flying experience	
	Total	6 896:19 h
	of which on the accident type	804:47 h
	during the last 90 days	128:30 h
	of which on the accident type	53:01 h
	during the last 24 h	2:31 h
	of which on the accident type	2:31 h
	Total no. of landings	47 618

1.6 Aircraft information

1.6.1	General information	
	Registration	HB-XWM
	Aircraft type	Agusta A109K2
	Characteristics	Twin-engine general purpose helicopter with fixed tricycle undercarriage in nose-wheel configuration. Fully articulated 4-blade main rotor, conventional torque balancing with exposed tail rotor.
	Manufacturer	Agusta S.p.A., Cascina Costa (VA), Italy
	Year of manufacture	1994
	Serial number	10013
	Owner	Swiss Air Ambulance AG Post Box 1414, 8058 Zürich Airport
	Operator	Swiss Air Ambulance AG Post Box 1414, 8058 Zürich Airport
	Engine	Manufacturer: Turbomeca, 64511 Bordes, France Type: Arriel 1K1 Power: ISA sea level One engine inoperative (OEI) 2.5 min. 575 kW / 771 shp All engines operative (AEO) Take-off 550 kW / 738 shp
	Main rotor / tail rotor	Main rotor with 4 blades, anticlockwise - tail rotor with 2 blades
	Landing gear	Wheels, nose-wheel configuration, non-retractable with protection from sinking in. Hydraulic wheel brakes.
	Equipment	Hydro-mechanical flight control. Digital autopilot Sextant AFCS 95, rescue winch, GPS, health and usage monitoring system (HUMS), moving terrain display system, Floice Flarm collision warning system.

Operating hours, airframe	Total since manufacture: 4148:04 h Since last 300 h inspection: 241:00 h Since last 100 h inspection: 39:07 h
Operating hours, engine 1 (left) No. 16039	Total hours since manufacture: 4153:00 h Since last installed: 39:07 h Since last service: 39:07 h Since last scheduled inspection: 39:07 h Total cycles: 26 944
Operating hours, engine 2 (right) No. 16040	Total hours since manufacture: 4205:00 h Since last installed: 39:07 h Since last service: 39:07 h Since last periodic inspection: 39:07 h Total cycles: 27 341
Max. permissible mass	Maximum take-off mass (MTOM): 2850 kg Max. permissible mass with external load: 3000 kg
Mass and centre of gravity	The take-off mass of the helicopter with the load was approx. 3000 kg on departure, and approx. 2950 kg at the time of the accident. The centre of gravity at the time of the accident was at an arm of 3395 mm. The permissible range at this mass is about 3365 - 3480 mm. Both weight and centre of gravity were within the permissible limits of the rotorcraft flight manual – RFM.
Fuel quality	JET A1 kerosene
Fuel content	The tank content at the time of the accident was about 270 kg
Certificate of registration	Issued by FOCA on 17 April 2007 / no. 2, valid until deletion from the aircraft register.
Certificate of airworthiness	Issued by FOCA on 17 April 2007 / no. 1, valid until revoked.
Last airworthiness review by FOCA	8 July 2009
Airworthiness review certificate	Date of issue: 9 July 2009 Date of expiry: 4 August 2010
Scope of utilization	Commercial
Category	VFR by day VFR by night (restricted according to FOM) Helicopter departures in ground and high fog.

1.6.2 Control of the helicopter

This helicopter is operated with three controls:

The cyclic enables the helicopter to be moved to the right, to the left, forwards, or rearwards by periodic alteration of the blade angle of each main rotor blade during a revolution of the rotor.

The collective changes the blade angle of all main rotor blades simultaneously thereby altering the lift and raising or lowering the aircraft.

The pedals alter the blade angle of the tail rotor blades. With the tail rotor, the torque of the main rotor is balanced and keeps the helicopter in the desired direction. A change of the direction or a rotation of the helicopter around its vertical axis is therefore controlled by the tail rotor, i.e. by the pedals.

The control movements of the cyclic and the collective are transmitted by control rods and servo-actuators to the fixed swash-plate and hence to the turning rotor and the rotor blades through the rotating swash-plate. The swash plates are fixed to the main rotor mast below the rotor.

The swash plate consists essentially of two parts. The fixed lower part is connected to the fixed scissor to the main rotor or servos. This lower part cannot rotate, but can slide along the mast and tilt in all directions depending on movements of the control rods and main rotor servos. The moving upper part is linked to the individual rotor blades. This upper part rotates and is connected to the lower part by a bearing so that it can transfer the control movements of the lower part in a one-to-one ratio.

The rotating part of the swash plate is also connected to the hub of the rotor head with a scissor (swash plate driving scissor) over the fitting (swash plate driving scissor fitting) and therefore rotates with the rotor head.

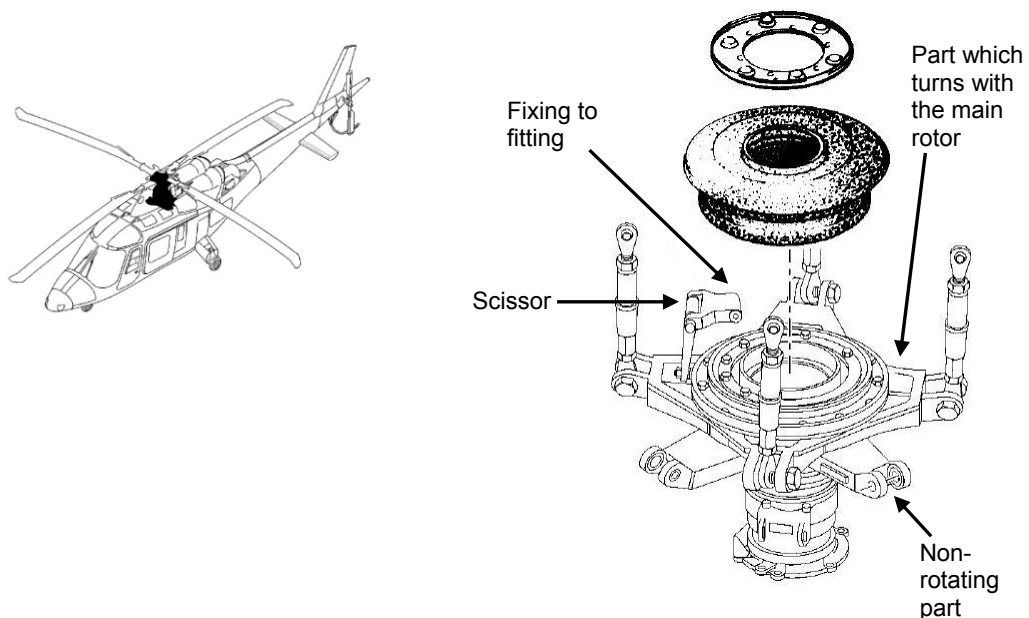


Fig 2: Swash plate

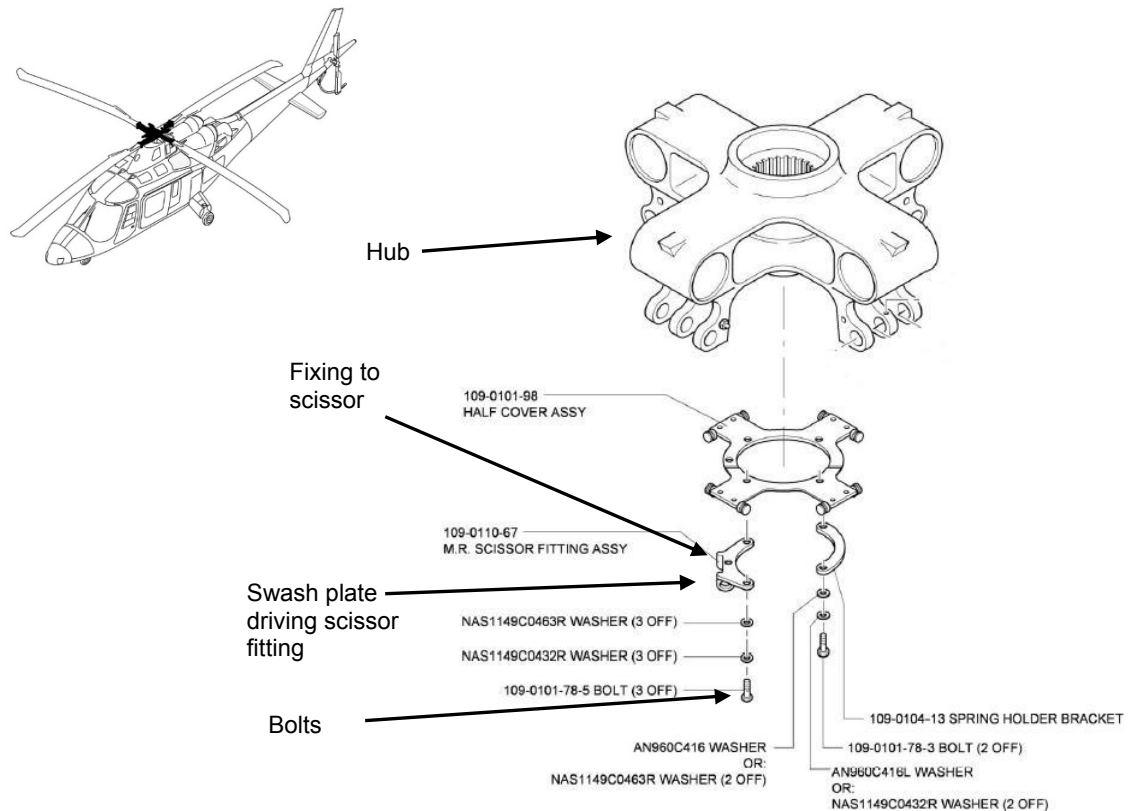


Fig 3: Rotor hub

1.6.3 Maintenance

Maintenance was carried out by the maintenance organisation of Swiss Air Ambulance Ltd.

The last scheduled maintenance on airframe and engines was the 100 h inspection, which was carried out on 3 November 2009 at 4108:57 h.

1.6.4 Rotor head replacement

At 3647 operating hours, on 22 July 2008, the rotor head of helicopter HB-XWM was replaced because it had reached the operating time limitation. A rotor head which had been overhauled by the Belgian company Agusta Aerospace Services SA (AAS) was installed. This rotor head had been released to service with an *EASA FORM 1* on 12 June 2008.

1.7 Meteorological conditions

1.7.1 General

The data in sections 1.7.2 to 1.7.4 were provided by MeteoSwiss.

1.7.2 General weather conditions

A weakening warm front was moving across northern Switzerland in an easterly direction. The wind veering from west to north-west brought drier air into the Alpine region during the course of the day.

1.7.3 Weather at the time and place of the accident

The following data on the weather at the time and place of the accident are based on a spatial and chronological interpolation of observations from various weather stations.

<i>Clouds</i>	<i>1-2/8 at 4000 ft AMSL, 4-6/8 at 7000 ft AMSL, high cirrus</i>	
<i>Weather</i>	<i>-</i>	
<i>Visibility</i>	<i>Approx. 20 km</i>	
<i>Wind</i>	<i>North-easterly, 5 kt, gusting to 9 kt</i>	
<i>Temperature / dew point</i>	<i>09 °C / 08 °C</i>	
<i>Atmospheric pressure</i>	<i>QNH LSGG 1024 hPa, QNH LSZH 1021 hPa, QNH LSZA 1019 hPa</i>	
<i>Hazards</i>	<i>None detectable</i>	

1.7.4 Astronomical data

Position of the sun	<i>Azimuth: 211°</i>	<i>Elevation: 17°</i>
Lighting conditions	<i>Daytime</i>	

1.8 Aids to navigation

Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

Aflight data recorder was not required and was not installed. However, there was a health and usage monitoring system (HUMS) available. The analysed data confirmed a brief increase in RRPM to approx. 104%. Further data was not used in the investigation.

1.12 Wreckage and impact information

1.12.1 Accident location

The accident location was in open terrain at the former military airfield of Interlaken, which had ceased operation at the end of 2003. REGA had rented a hangar at this facility. Underslung load training was planned to be carried out on a aircraft parking area and the taxiways.

1.12.2 Impact

The impact occurred at a forward speed of about 40 kt in an almost horizontal position on grassland. The tail rotor protection bracket touched the ground.

1.12.3 Wreckage

The following facts could be established from the wreckage:

Two of the three bolts fixing the swash plate driving scissor fitting to the hub of the main rotor head were fractured. The third bolt was bent.

No other damage to the helicopter was discovered.

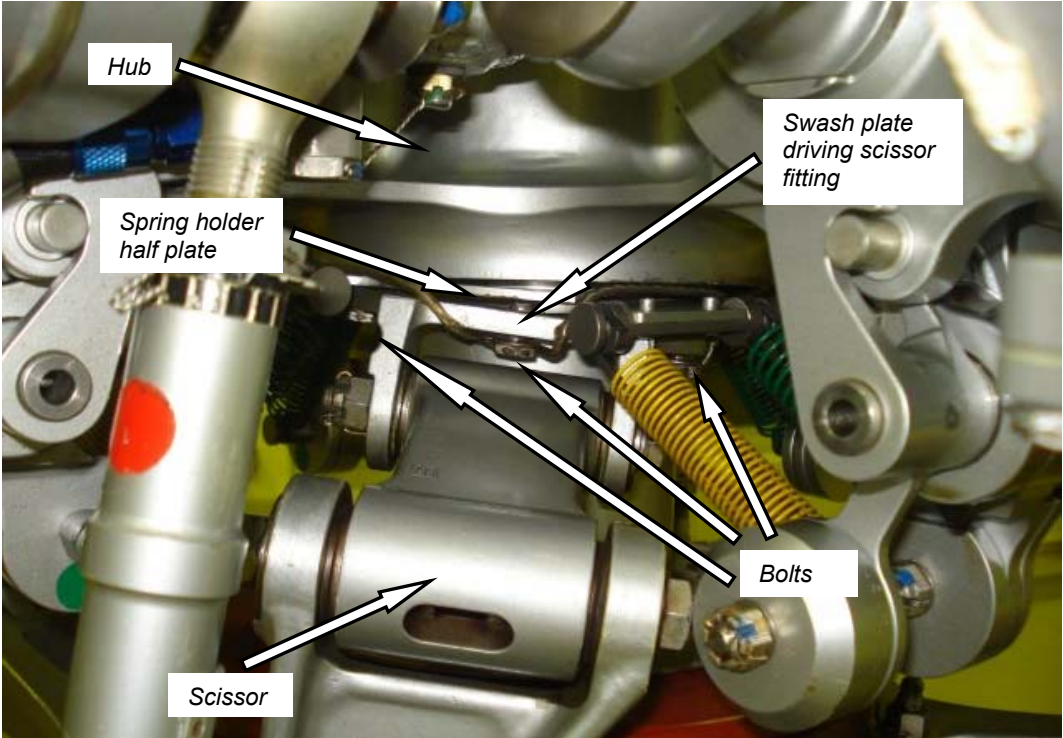


Fig 4: View of main rotor head with fractured bolts

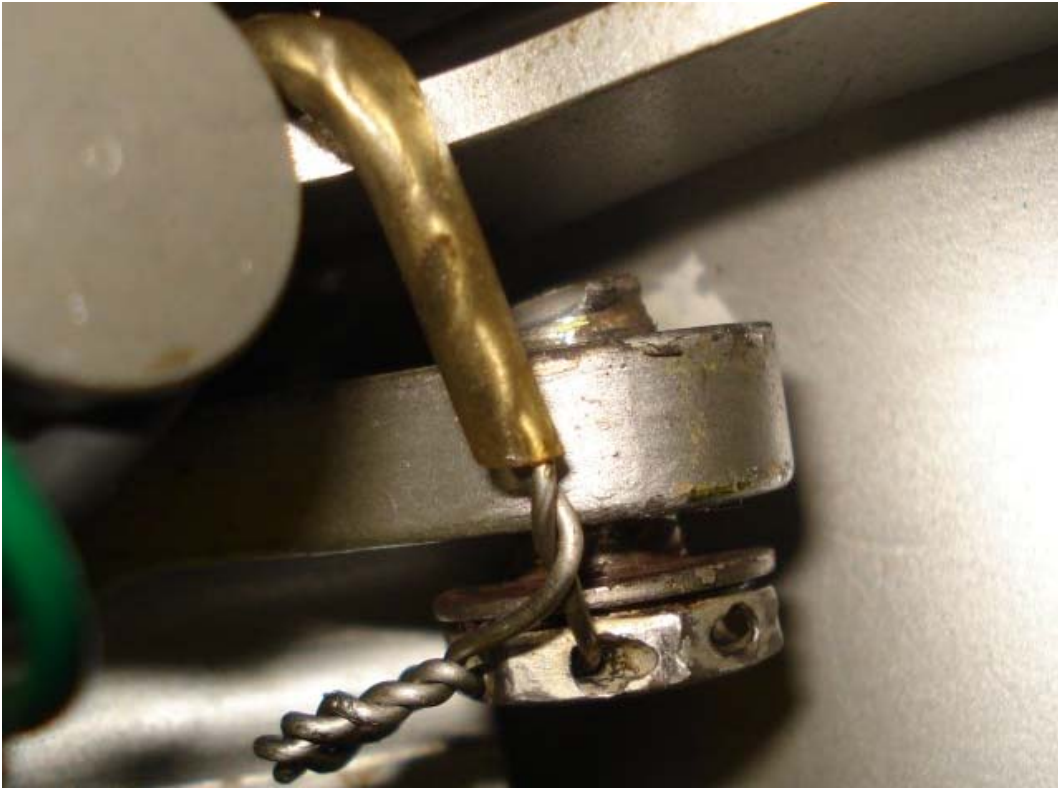


Fig 5: View of fractured bolt in situ

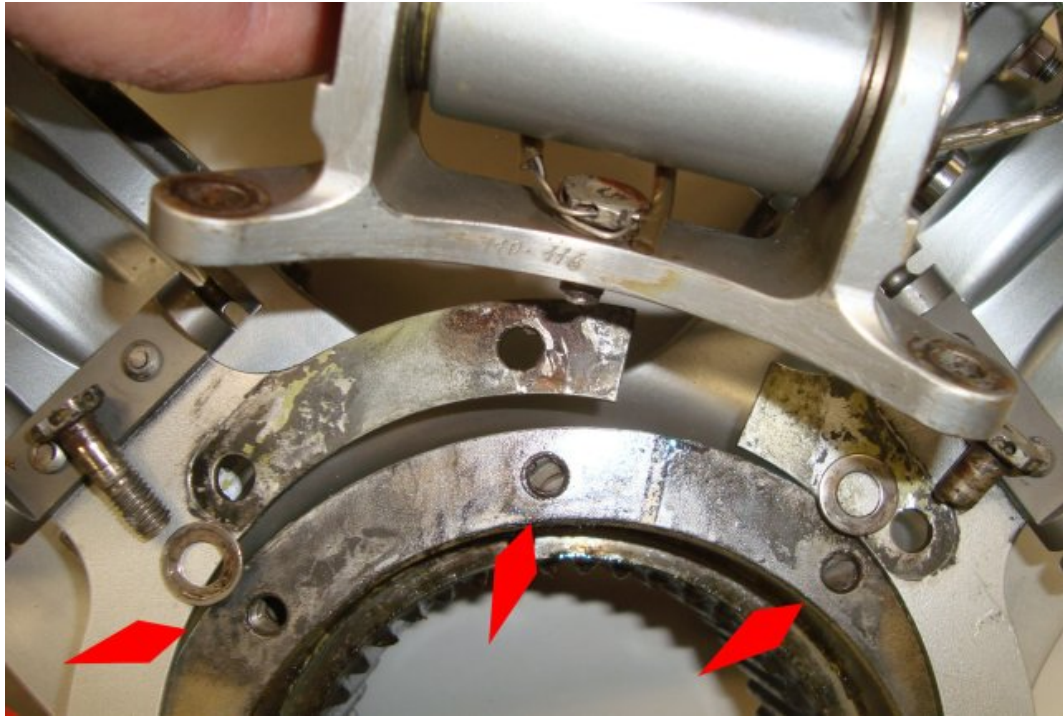


Fig 6: View of the hub assembly with spring holder half plate fitting and bolts

1.13 Medical and pathological information

There is no indication of the crew suffering from any health problems, which might have been a factor in the accident.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 General

The crew were wearing helmets.

Lap and shoulder belts were worn and withstood the loads.

The helicopter was equipped with crashworthy seats.

The accident was survivable.

1.15.2 Emergency location beacon

The helicopter was equipped with an emergency location beacon aircraft – ELBA). The device was installed and operational.

No signals were transmitted.

1.16 Tests and research

1.16.1 Initial findings from the investigation of the main rotor head

Already on the day of the accident, 24 November 2009, it was established that two of the three bolts that fixed the swash plate driving scissor fitting P/N 109-0110-67-111 to the hub of the main rotor head had fractured. All three bolts (P/N 109-0101-78-5) had been installed with **one** AN960 C416L 0.8 mm thick washer each.

A subsequent investigation by REGA indicated that in contrast to the affected helicopter HB-XWM in three other helicopters of the A109K2 fleet the same bolts were each fitted with **two** different washers AN960 C416L and AN960 C416 with a total thickness of 2.3 mm.

On three further helicopters of the A109K2 fleet, it appeared that, like the aircraft involved in the accident, the bolts had been fitted with only **one** washer.

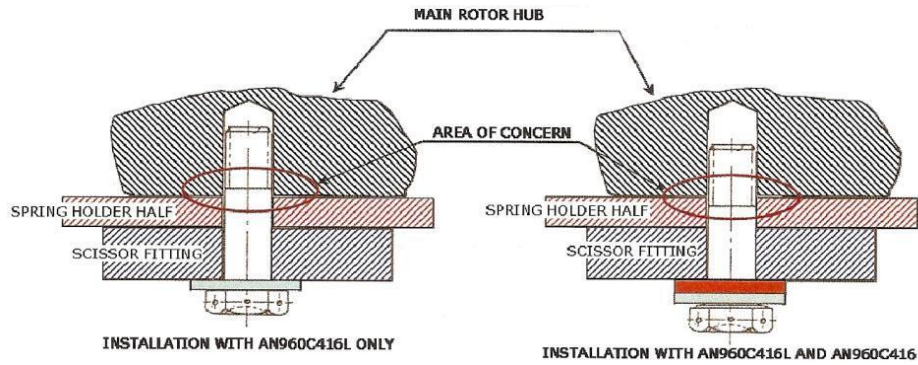


Fig 7: Comparison of installation with one or two washers.

1.16.2 Investigation of the fractured bolts

Investigation of the fracture surfaces showed a fatigue fracture of both bolts due to two way cyclic bending stresses.

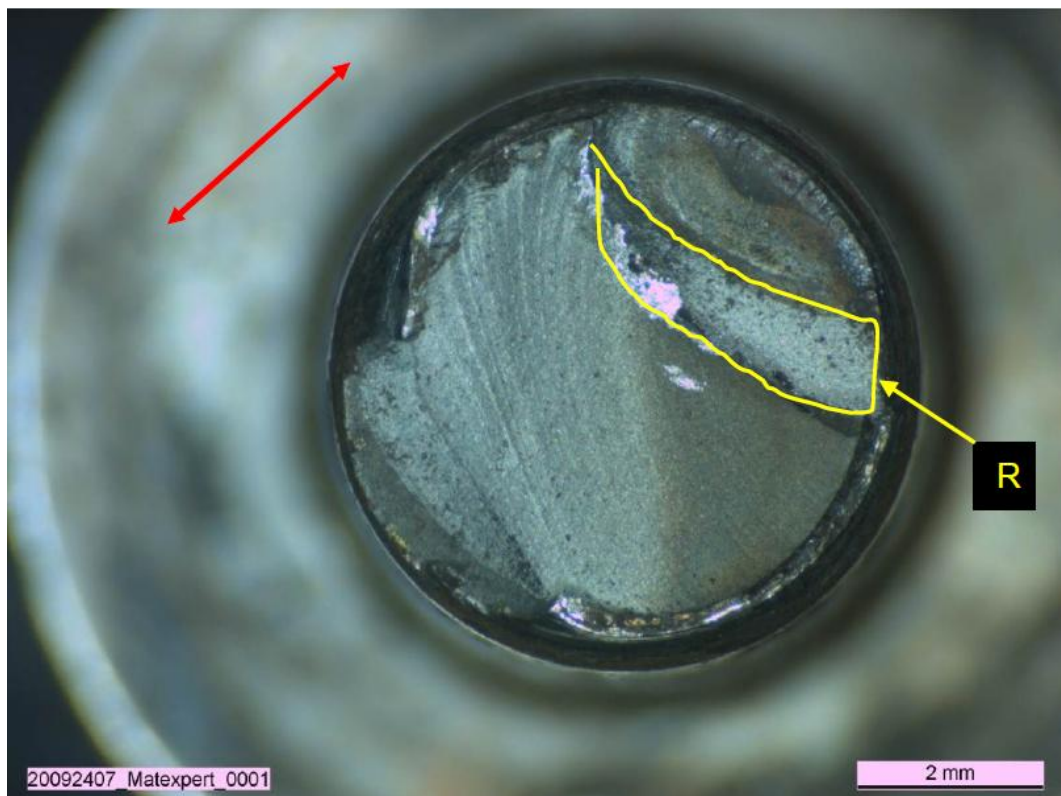


Fig 8: Micrograph of the fracture surface of bolt no. 1

R: Final fracture surface, the remaining fracture surface indicates fracture by cyclic two way bending

Double arrow: direction of bending

1.16.3 Examination of the hub of the main rotor head

Examination of the design drawings of the hub and bolts showed that when fitting the bolts with only one washer either the shanks of the bolts – i.e. the unthreaded section – contacted the thread of the hub, or the bolt bottomed out in the bore in the hub.

Therefore it must be concluded that fatigue damage had also occurred on the internal thread.

1.16.4 Maintenance documentation

The main rotor head P/N 109-0101-01-117 had an operational time limitation of 3600 hours. Repair or overhaul of the complete main rotor head was performed either by the manufacturer or by a suitably qualified maintenance organization.

The organisation AgustaWestland overhauled assemblies of their products, including the main rotor head. This was carried out in accordance with the design documents of the corresponding assembly. According to the original issue of the rotor head drawing no. 109-0101-01 three bolts were to be fitted with one P/N AN960 C416L washer each to attach the swash plate driving scissor fitting to the hub of the main rotor head.

Various revisions had been made to these drawings. They included among other things that – because of a change to the dimension of the swash plate driving scissor fitting – the assembly with an AN960 C416L washer required an additional AN960 C416 washer. This was specified accordingly. This change was first designated as “Note 16”. Later, Note 16 was cancelled and marked in the drawing as *Modifrice L*, with a reference to the modification report *Segnalazione di Modifica* SM 109-4192 dated 16 April 1976.

The published maintenance documentation of the manufacturer was based on the drawings for manufacture and assembly of the main rotor head. The generation of the necessary maintenance manuals and parts lists was started prior to initial type certification. For this, the original drawing which specified only one washer was used as a basis. The change to two washers did not appear in the documentation which had already been published. It was therefore incorrect.

The organisation Agusta Aerospace Services SA (AAS) overhauls components in accordance with capability list AAS-IMP-1031, including the main rotor hub P/N 109-0101-01-XXX of the helicopter type A109K2. This work is carried out in accordance with the manufacturer’s maintenance documentation (Maintenance Manual – MM, Overhaul Manual – OHM, and Illustrated Parts Catalogue – IPC).

At the time of the overhaul of the main rotor head S/N 438, the following revisions were applicable:

- *A109K2 – Maintenance Manual Revision 18, dated 09 March 2007*
- *A109K2 – Overhaul Manual Revision 8, dated 10 October 2006*
- *A109K2 – Illustrated Parts Catalogue, dated 30 October 2007*

The corresponding maintenance documents for fixing the swash plate driving scissor fitting to the hub P/N 109-0101-02-01 specified that the three bolts P/N 109-0101-78-5 are fitted with **one** washer P/N AN960 C416L each.

1.17 Organisational and management information

1.17.1 Manufacturer AgustaWestland

Agusta was the short term for Societa Costruzioni Aeronautiche Giovanni Agusta founded in Cascina Costa (VA) Italy in 1907 by aviation pioneer Giovanni Agusta.

In July 2000, Agusta was merged with the British company Westland helicopters to form AgustaWestland.

1.17.2 Maintenance organisation Agusta Aerospace Services SA (AAS)

Agusta Aerospace Services SA (AAS) with its head office in Liege and Zaventem / Belgium was approved on 11 October 2006 by the Belgian authorities under EASA part 145 to carry out maintenance work on helicopter components with the rating C10 (dynamic components) Main Rotor Hub for Agusta type A109 series with the number EASA part 145 BE.145.22.

The Maintenance Organisation Exposition – MOE was approved by the Belgian Civil Aviation Authority BCAA. At the time of the overhaul of the main rotor head in question, Issue 6, Revision 3 was in force, approved by BCAA on 7 November 2006. Supervision of documentation is maintained by a procedure within MOE and an internal maintenance process.

1.18 Additional information

On the basis of the initial results of the visual assessment of the crashed helicopter, REGA arranged to carry out checks on all their helicopters of type A109K2.

The rotor heads were checked visually, with special focus on the bolts that had fractured in the crashed helicopter. It was established that there were two distinct variants of fixing the swash plate driving scissor fitting to the hub.

On three rotor heads, **two** washers were fitted under the swash plate driving scissor fitting fixing bolts. This corresponds to the illustration and listing in the manufacturer's drawings with reference to the modification report (cf. section 1.16.4). See Annexe 1.

On three rotor heads, **one** washer was fitted under the swash plate driving scissor fitting fixing bolts. This corresponds to the illustration and listing in the IPC (Illustrated Parts Catalogue). See Annexe 2.

Another Swiss-registered helicopter of the same type was also checked. In this case, **two** washers were fitted under the swash plate driving scissor fitting fixing bolts.

In collaboration with the manufacturer, immediate measures were taken to ensure that the swash plate driving scissor fitting fixing bolts were replaced on all rotor heads and reinstalled with **two** washers. This was to permit immediate continued operation of the fleet before the corresponding alert service bulletin and the urgent emergency airworthiness directive were issued by EASA. See Annexe 4.

In the more recent maintenance documents, the new designation in accordance with NAS (National Aeronautical Standard) is used as equivalent parts for the washers, as follows:

- AN960 C416L new designation NAS1149C0432R
- AN960 C416 new designation NAS1149C0463R

For intelligibility only the old designation according to AN (Aeronautical Standard) is used in the report.

1.19 Useful or effective investigation techniques

None

2 Analysis

2.1 Technical aspects

Because of the fracture of the swash plate driving scissor fitting fixing bolts, the upper part of the swash plate was no longer firmly connected to the rotor. As a consequence, control input was no longer correctly transmitted to the rotor blades. Control was therefore severely impaired if not impossible.

The investigation of the remaining helicopters of the same model that took place immediately after the incident showed that there were two different types of assembly for fixing the swash plate driving scissor fitting to the hub. In one type of assembly, each of the bolts had **one** washer, while in the other there were **two** different washers. This discrepancy was described by REGA in its first report to Agusta on the day after the accident.

Agusta analysed the consequences of these two types of assembly taking into consideration the fabrication tolerances of the applicable components (Annexe 3). This analysis showed clearly that in the case of an assembly with only one P/N AN960 C416L washer and the use of components that were manufactured within the specified tolerance, under certain combinations of components it can occur that the shank of the bolts – i.e., the unthreaded section – contacts the thread in the hub, or the bolt bottoms out in the bore in the hub. The pretension of a bolt mounted in this way is either too low or even non-existent despite having the correct tightening torque. This is because when the tightening torque is applied, the thread is jamming in the mating part and thus neither the shank of the bolt is subject to sufficient elastic elongation nor the parts to be clamped are sufficiently elastically compressed.

The fatigue strength of a dynamically loaded connection depends on pretension, i.e. on the elasticity of the bolt, the clamped parts, on the tightening torque as well as the type and magnitude of the stress. Bolts that are not sufficiently pretensioned exhibit inadequate fatigue strength under dynamic loading which can lead to fracture of the bolt due to fatigue.

The results of the material investigation have confirmed that the fracture of both fixing bolts could be attributed to fatigue caused by alternating bending stress.

The reason for the fracture of the bolts was that, during the overhaul of the main rotor hub, the bolts that fixed the swash plate driving scissor fitting to the hub had been installed with only **one** washer.

As a result, despite correct tightening torque, the swash plate driving scissor fitting was connected with inadequate clamping force to the main rotor hub assembly, and, as a result, that the operating forces between the helicopter control system and the swash plate driving scissor fitting were transferred to the hub by the bolts and not by clamping friction as designed.

Maintenance on the main rotor head was carried out by the organisation AAS in Zaventem / Belgium. This organization was approved in accordance with the applicable regulations and supervised by the competent authority. The documentation used (OM, MM, IPC) was published by the manufacturer of the helicopter and was in accordance with the revisions current at the time the work was carried out.

However, the published maintenance documentation contained an error, because at the time of its publication the installation of the P/N 109-0101-78-5 bolt with only one P/N AN960 C416L washer was taken from the original engineering drawing. The change to the assembly drawing made by the manufacturer in

1976, which required the use of two washers, was not transferred to the maintenance documents.

Since nobody noticed during disassembly that two washers were fitted under the bolts, the maintenance organisation had no further possibility of detecting this error and therefore a certificate for release to service / FORM-1 had been issued.

Neither at Agusta nor at AAS was it noticed during maintenance work that the configuration (one or two washers) of an incoming main rotor head did not conform to the available maintenance documents.

2.2 Human and operational aspects

2.2.1 Crew

When the helicopter suddenly began to oscillate vertically and began to sink, the crew tried to assess and analyse the situation. They could not understand the reaction of the helicopter and the almost ineffective control input. Because the helicopter continued to sink and had virtually no reaction to control input even when the load had been jettisoned, the flight instructor took over control of the helicopter. This reaction of the flight instructor was appropriate for the situation. He tried to control the flight path and to set the helicopter down in a level attitude. However, his control input had little effect. The helicopter landed uncontrolled and by chance in such manner that no serious consequences ensued.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The helicopter was approved for VFR-operations.
- Both mass and centre of gravity of the helicopter were found to be within the RFM permitted limits at the time of the accident.
- The last 100-hour inspection was carried out at 4108:57 operating hours.
- The last airworthiness review by FOCA took place on 8 July 2009.
- The aircraft had been equipped with an emergency ELBA transmitter. It did not transmit any signals.
- After the accident, two of the three bolts fixing the swash plate driving scissor fitting to the hub of the main rotor head were found to be fractured.
- The third bolt was bent.
- The metallographic investigation showed that two bolts were fractured as a result of fatigue.
- The fatigue has been attributed to inadequate pretensioning at assembly.
- The inadequate pretension was the result of the assembly with only one washer.

3.1.2 Crew

- The pilots held the necessary licences for the flight.
- There are no indications for any health problems of the pilots during the accident flight.
- The pilot had passed his test for the Agusta A109 rating on 19 November 2009.

3.1.3 History of the flight

- While turning to final approach to the underslung load drop point, the helicopter began to vibrate and sink.
- The control inputs had little effect.
- The underslung load was jettisoned.
- The helicopter made an uncontrolled landing on grassland at a low forward speed.

3.1.4 General conditions

- The main rotor head had been overhauled by an approved maintenance organisation.
- The maintenance documentation used was of the appropriate revision version at the time the work was carried out.
- The maintenance documentation published by the manufacturer and used by the maintenance organisation was incorrect in that an amendment to the design drawings had not been included.

3.2 Causes

The accident was caused by the fracture of two bolts that fix the swash plate driving scissor fitting to the hub of the main rotor, which led to the helicopter becoming nearly uncontrollable.

The cause of the bolt fracture was due to the maintenance documentation published by the manufacturer and used by the maintenance organisation being incorrect.

4 Safety recommendations and measures taken since the accident

4.1 Safety recommendations

None.

4.2 Measures taken since the accident

4.2.1 Immediate actions on all helicopters of the same model in Switzerland

After the accident, all bolts for fixing the swash plate driving scissor fitting to the hub on the remaining helicopters of the same model were immediately checked. After consultation with the manufacturer, all bolts were removed, checked, and installed with **two** different washers P/N AN960 C416L and P/N AN960 C416 on reassembly. All P/N 109-0101-78-5 bolts were replaced within a few days, as possible fatigue due to previous assembly with inadequate pretension could not be excluded.

4.2.2 Publication of an emergency airworthiness directive

The manufacturer of the helicopter published in the context of its Design Organisation Approval (DOA EASA.21J.005) the alert mandatory *Bolletino Tecnico* 109K-53 on 18 December 2009. In this, inspection and if necessary replacement of the bolts and the assembly of both different washers P/N AN960 C416L and P/N AN960 C416 was mandated.

On the same date, the EASA issued emergency airworthiness directive 2009-0274-E, which made the implementation of the mandatory *Bolletino Tecnico* 109K-53 obligatory. The date of effectivity was 20 December 2009.

4.2.3 Possible damage to internal threading in the hub

An evaluation of the internal threads for possible damage on main rotor heads, which had been mistakenly fitted with only one washer, was not required by the manufacturer.

Payerne, 26 September 2012

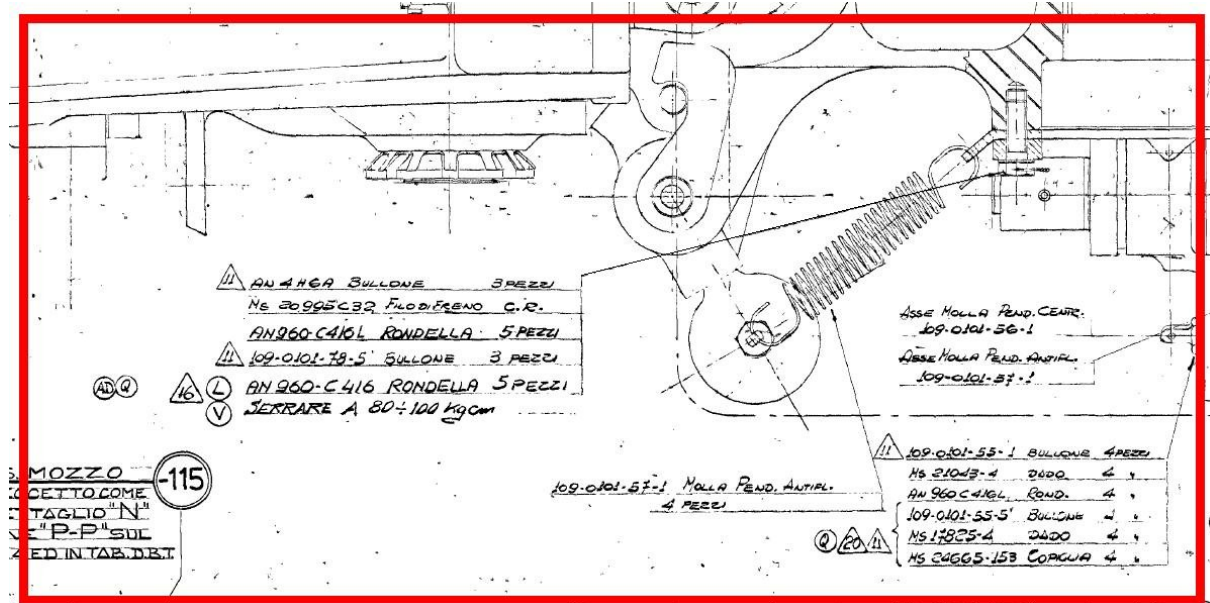
Swiss Accident Investigation Board

This final report was approved by the management of the Swiss Accident Investigation Board SAIB (Art. 3 para. 4g of the Ordinance on the Organisation of the Swiss Accident Investigation Board of 23 March 2011).

Berne, 23 October 2012

Annexes

Annexe 1: Extract from the design drawing of the rotor hub 109-0101-01 and corresponding revision notes



Detail of the connection between swash plate driving scissor fitting and hub

Ⓛ 16 PER NUOVE COSTRUZIONI E PARTI DI RICAMBIO, IL PART. 109-0101-32-3 SOSTITUISCE IL PART. 109-0101-32-1 INOLTRE AGGIUNTE N° 5 RONDELLE AN. 960 C 416

Note 16, later replaced by Modifice L

SIGLA	OGGETTO	DISEGNATORE	DATA
E	VEDERE S.M. 109-2582	Costella	8-7-74
F	VEDERE S.M. 109-2749	Costella	
G	VEDERE S.M. 109-3374	Costella	16-6-75
H	VEDERE FOGLIO 5		
I	VEDERE S.M. 109-3946	Costella	8-1-76
L	VEDERE SM 109-4192	Costella	16-4-76
M	VEDERE SM 109-4402	Costella	30-6-76
N	VEDERE SM 109-4567	Costella	22-9-76
P	VEDI FOGLIO 1 DI 2		14-4-77
Q	VEDI FOGLIO 1 DI 2		28-4-77
R	VEDI FOGLIO 1 DI 2		4-6-78
S	VEDI FOGLIO 1 DI 2		
T	VEDI FOGLIO 1 DI 2		

Revision list: Modifice L referring to SM 109-4192

ISTRUZIONI: Copie per UFF. PIZZAGLIA (1), UFF. OFFICINA (1), UFF. CONTROLLO (1) - 4 UFF. SPEDIZIONE (1)
NOTA: Gli uffici interessati dovranno elaborare all'archivio C.T. le copie in più eventualmente necessarie di questo Segnalazione.

AGGIUNTO IL SEGUENTE PARTICOLARE

AN 960 C416 5 pezzi

AGGIUNTA INFINE LA SEGUENTE NOTA

 - PER NUOVE COSTRUZIONI E PARTI DI RICAMBIO IL PART. -109-0101-32-3 SOSTITUISCE IL PART. -109-0101-32-1 INOLTRE AGGIUNTE N° 5 RONDELLE AN 960 C416

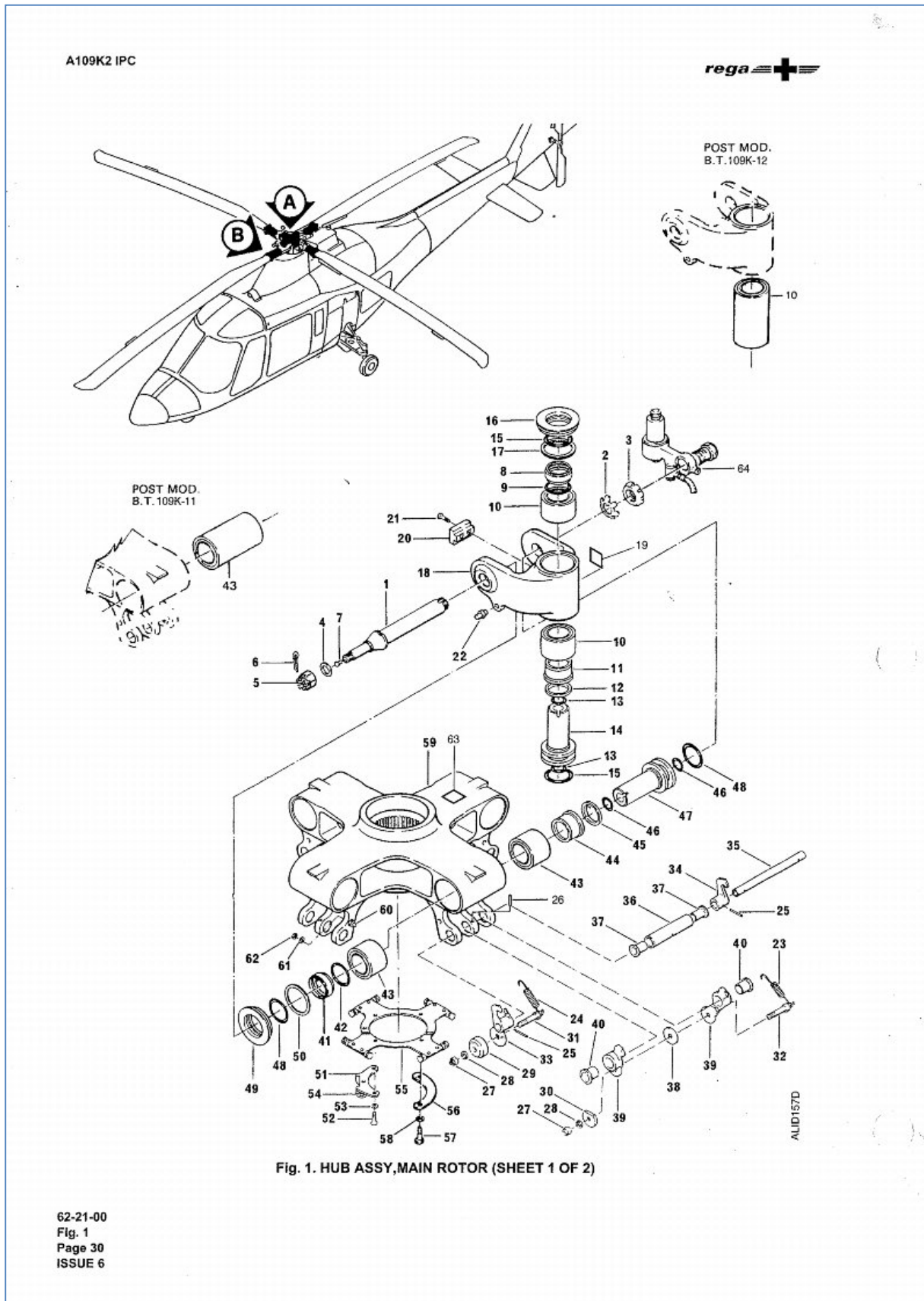
ESR INC. 

Extract from SM 109-4192 (page 2 of 5)

With reference to the additional washers AN960 C416 to be fitted

Annexe 2: Extract from the manufacturer's documentation

Illustrated Parts Catalogue (IPC)



A109K2 IPC

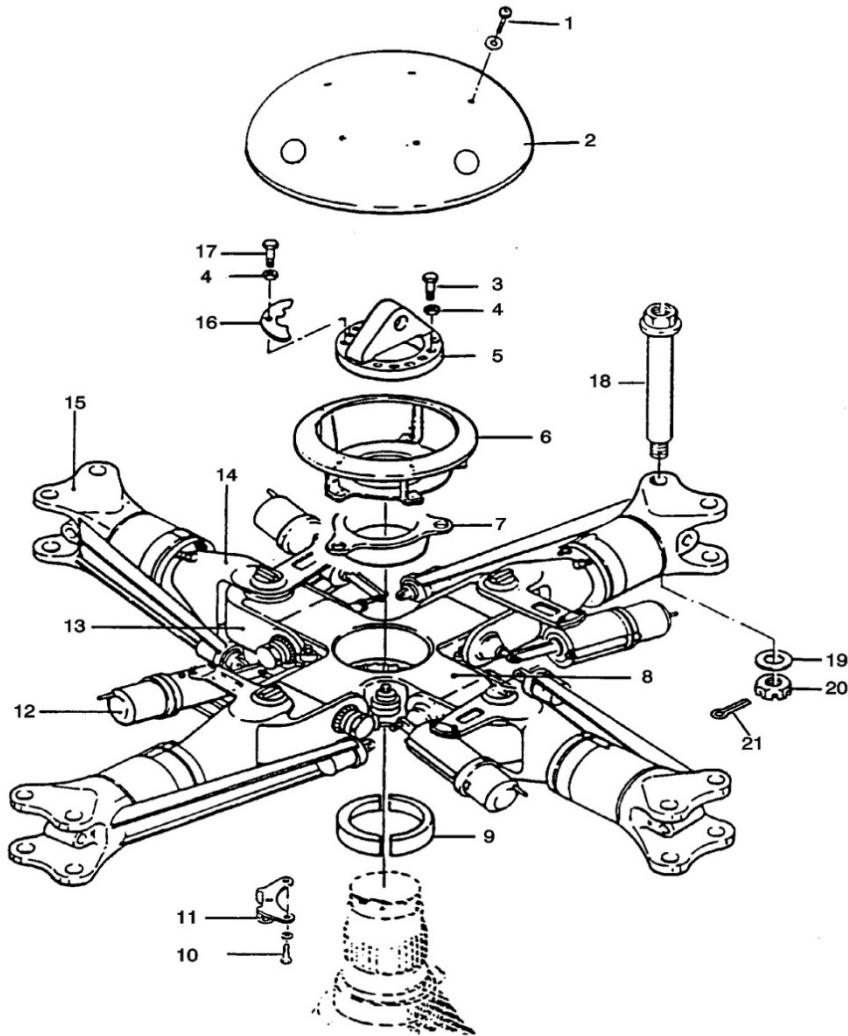


Fig.	Item	Part Number	Description	UOCA MV/Effect	Icy	QNHA UI	SMR
		123456789					
33	109-0101-29-1		• PENDULUM,ANTIFLAPPING				4 PAOZZ
34	109-0101-29-3		• CAM,STOP DROP,ANTIFLAPPING				4 PAOZZ
35	109-0101-31-1		• PIN,HOLLOW				4 PAOZZ
36	109-0101-30-5		• PIN ASSY,HOLLOW				4 PAOFF
37	109-0101-47-1		•• BUSHING		-4		2 PAFZZ
37	109-0102-17-101		•• BUSHING		44		2 PAFZZ
37	109-0102-17-103		•• BUSHING		4-		2 PAFZZ
38	109-0101-11-9		• SHIM,CAM				4 PAOZZ
39	109-0101-28-7		• CAM ASSY,ANTIFLAPPING,CENTER				4 PAOFF
40	NHLF14-211A		•• BEARING,PLAIN,SELF ALIGNING				2 PAOZZ
41	109-0101-16-3		• SEAL,CARRIER,INNER				4 PCFZZ
42	MS29561-131		• PACKING,PREFORMED				4 PAOZZ
43	109-0101-82-1		• BEARING,ROLLER (CONTROL SPECIFICATION FOR PNR NB42637B/IM42637B V.F0270 PRE MOD. B.T.109K-12/DO NOT MIX P/N 109-0101-82-1 WITH P/N 109-0102-16-103)				8 PAOZZ
43	109-0102-16-103		• BEARING,ROLLER,AIRFRAME (CONTROL SPECIFICATION FOR PNR F221319 VENDOR D8984/ POST MOD. B.T.109K-11 DO NOT MIX P/N 109-0102-16-3 WITH P/N 109-0101-82-1)				4 PAOZZ
44	109-0101-89-1		• SEAL,RUNNER				4 PAFZZ
45	109-0101-88-1		• RING,TRUST				4 PAFZZ
46	MS29561-025		• O-RING				8 PAOZZ
47	109-0101-90-1		• SLEEVE,BEARING				4 PAFZZ
48	JF4-32		• PACKING,PREFORMED				8 PAFZZ
49	109-0101-17-1		• SEAL,CARRIER,OUTER				4 PAFZZ
50	109-0101-11-3		• SHIM,PEELING				4 PAFZZ
51	109-0110-67-111		• FITTING ASSY				1 PAFFF
52	109-0101-78-5		* BOLT,SHEAR				3 PAFZZ
53	AN960C416L		* WASHER,FLAT		-1		3 PAOZZ
53	NAS1149C0432R		* WASHER,FLAT		2-		3 PAOZZ
54	109-0110-70-1		•• BUSHING (Rework from 109-0110-70-1A1)				REF PAFZZ
54	109-0110-70-1A1		•• BUSHING ()				2 PAFZZ
55	109-0101-98-101		• COVER ASSY,HALF				2 PAODD
56	109-0104-13-101		• BRACKET,SPRING HOLDER				1 PAOZZ
57	109-0101-78-3		* BOLT,SHEAR				2 PAFZZ
58	AN960C416L		* WASHER,FLAT		-1		2 PAOZZ
58	NAS1149C0432R		* WASHER,FLAT		2-		2 PAOZZ
59	109-0101-02-1		• HUB ASSY,MAIN ROTOR				1 PAFFF
60	109-0101-45-1		•• PIN,STRAIGHT,THREADED				4 PAFZZ
61	AN960C10L		•• WASHER,FLAT		-1		4 PAOZZ
61	NAS1149C0332R		•• WASHER,FLAT		2-		4 PAOZZ
62	MS21043-3		•• NUT,SELF-LOCKING,HEXAGON				4 PAOZZ
63	999-3900-22-101		•• PLATE,IDENTIFICATION		-1		1 PAFZZ
63	A016A001A1		•• PLATE,IDENTIFICATION		2-		1 PAFZZ
64	109-0102-01-105		• LUBRICATION SYSTEM, MAIN ROTOR (Refer to 62-21-01 fig. 01 item 000 for BKDN)				REF XC

62-21-00
Fig. 1
Page 34
ISSUE 6

Extract from the Maintenance Manual (MM)

A109K2-MM



- | | | | |
|------------------|----------------|---------------|--------------------------|
| 1. Screw | 7. Conic ring | 13. Coupling | 18. Blade retention bolt |
| 2. Cover | 8. Hub | 14. Spindle | 19. Washer |
| 3. Bolt | 9. Split cones | 15. Grip | 20. Nut |
| 4. Nut | 10. Bolt | 16. Lockplate | 21. Cotter pin |
| 5. Ring nut | 11. Fitting | 17. Bolt | |
| 6. Cover support | 12. Damper | | |

A6ED432A

Figure 62-17. Main rotor hub

62-21-00

62-38

A109K2-MM



C. Installation procedure

NOTE: Before installation, apply a film of corrosion preventive compound (LCM NO 48) on the splines of the mast and hub.

- (1) Install sling (LSE NO 33) on the main rotor hub and connect the sling to a suitable hoist.

CAUTION: WHEN POSITIONING THE SLING, TAKE CARE NOT TO DAMAGE THE RESTRAINER SPRINGS AND THE OIL RESERVOIRS.

- (2) Carefully lower the main rotor hub assembly on the mast aligning the splines.
- (3) Position split cones (9, fig 62-17) on the mast conic section and carefully lower the main rotor hub into position against the upper surface of the split cones.
- (4) Apply a light film of corrosion preventive compound (LCM NO 46) to threads on mast and ring nut (5).
- (5) Install conic ring (7), support (6), ring nut (5), lock plate (16), bolt (3 and 17) complete with nuts (4). Remove the sling.

CAUTION: CHECK THE BOLTS TORQUE AFTER THE FIRST FIVE TO TEN HOURS OF MAIN ROTOR OPERATION.

NOTE 1: To ensure a correct installation of lockplate (16) position upper surface of ringnut (5) at least 0,2 mm above plane A (bottom of mast tooth) shown in figure 62-20A.

NOTE 2: Bolts (17 and 3) must be torqued diametrically following the sequence indicated in figure 62-21. The bolts must be torqued with increments of 5,9 Nm to 18,1 - 21,5 Nm. Nuts (4) must be torqued to 10,1-12,4 Nm using wrench (LSE NO 37). Lock bolts (17 and 3) and nuts (4) in pairs, as shown in figure 62-21, with safety wire (LCM NO 93).

- (6) Install the support cover (2, fig 62-17) using attaching hardware (1).
- (7) Install rotating scissors (41, fig 62-34) to the fitting (11, fig 62-17) as indicated in para 62-31-14.
- (8) Connect the pitch change links to the swashplate (para 62-31-11).
- (9) Install the main rotor blades (para 62-11-6).

D. Follow-on maintenance required:

- Track main rotor blades (para 62-00-9), if required.
- Install access panel 24 and 25.

62-21-10. Inspection

NOTE: At the 2400 hour inspection, inspect main rotor hub installation as written in A109K2-OM including non-destructive inspections (only if nicks, damage and heavy corrosion are found).

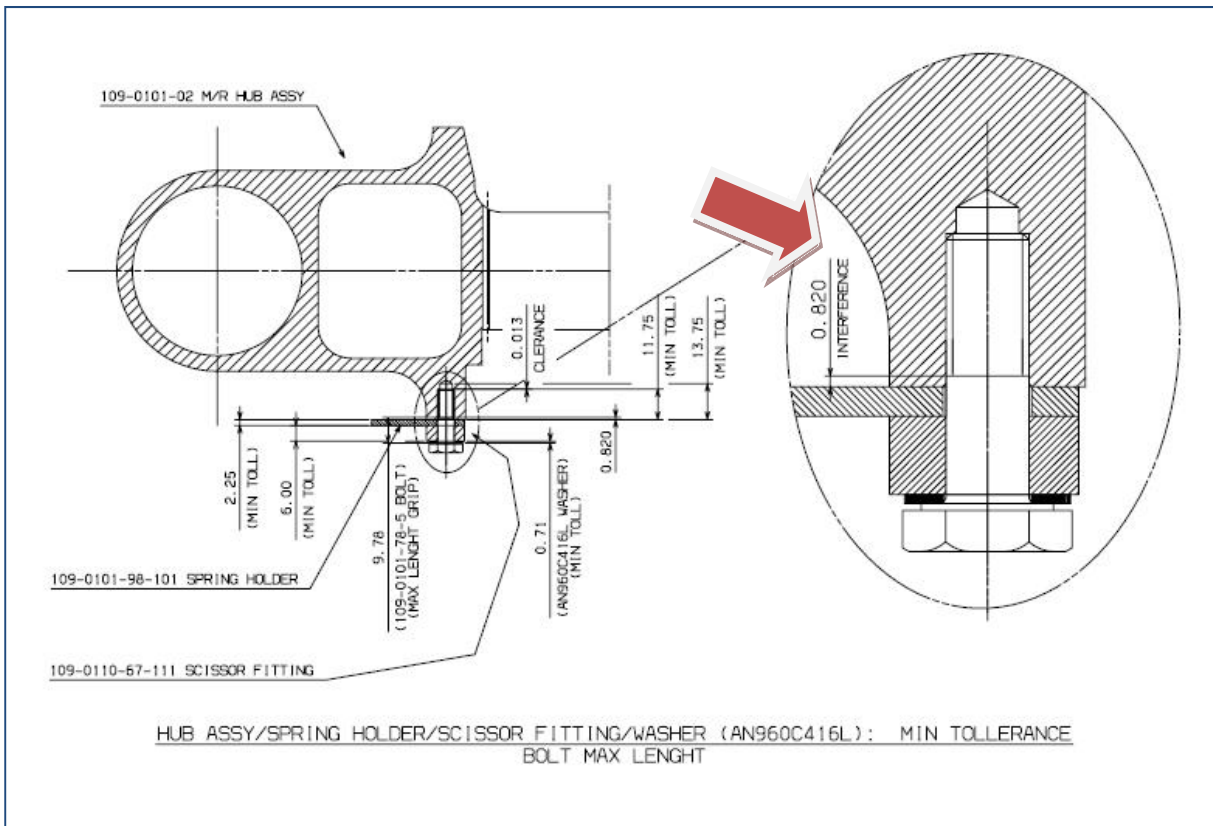
- A. Visually inspect the hub assembly components for security of attachment, traces of corrosion and apparent damage. Inspect the flapping stops and the dampers supporting tabs for condition.
- B. Inspect threads of bolts (18 and 3, fig 62-17), ring nut (5) and bolt (18) using a three-power magnification glass or stronger for presence of corrosion, cuts and distortion. Discard parts with damaged or corroded threads.

62-21-01

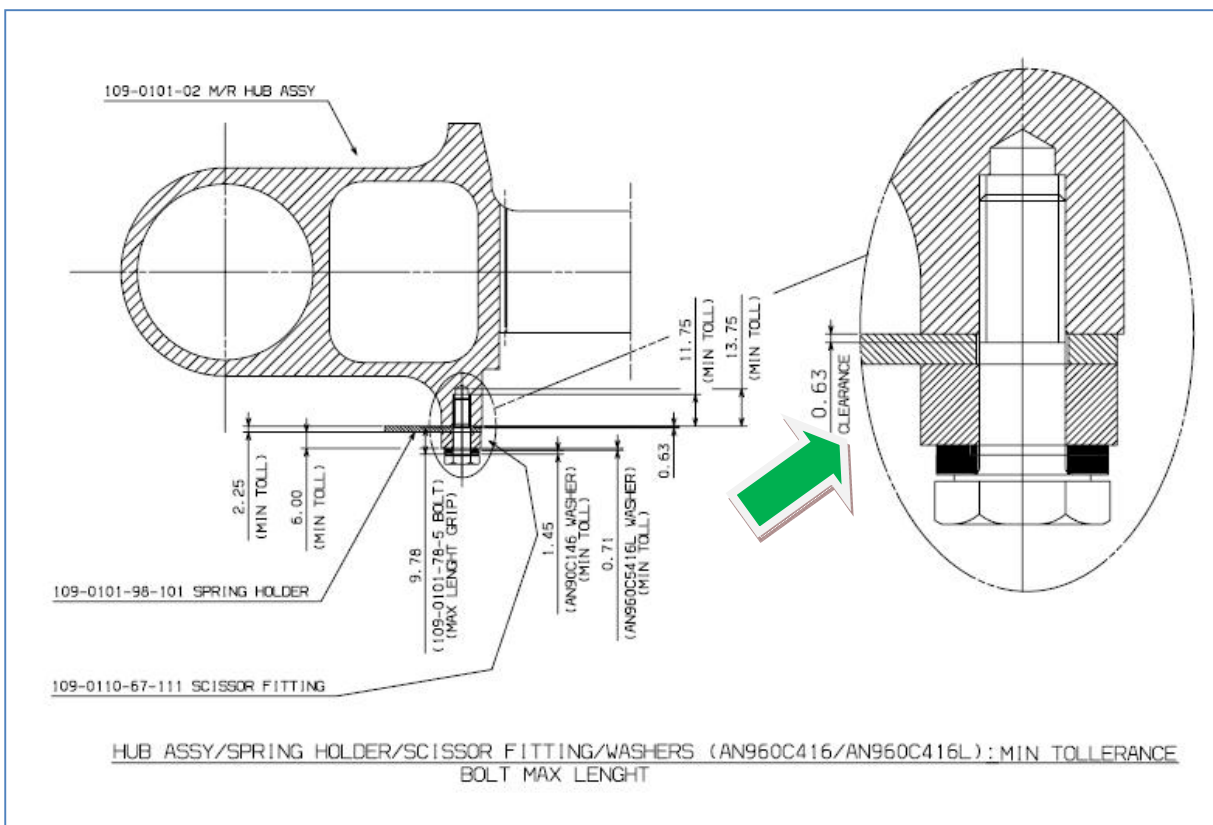
62-44

Rev. 13

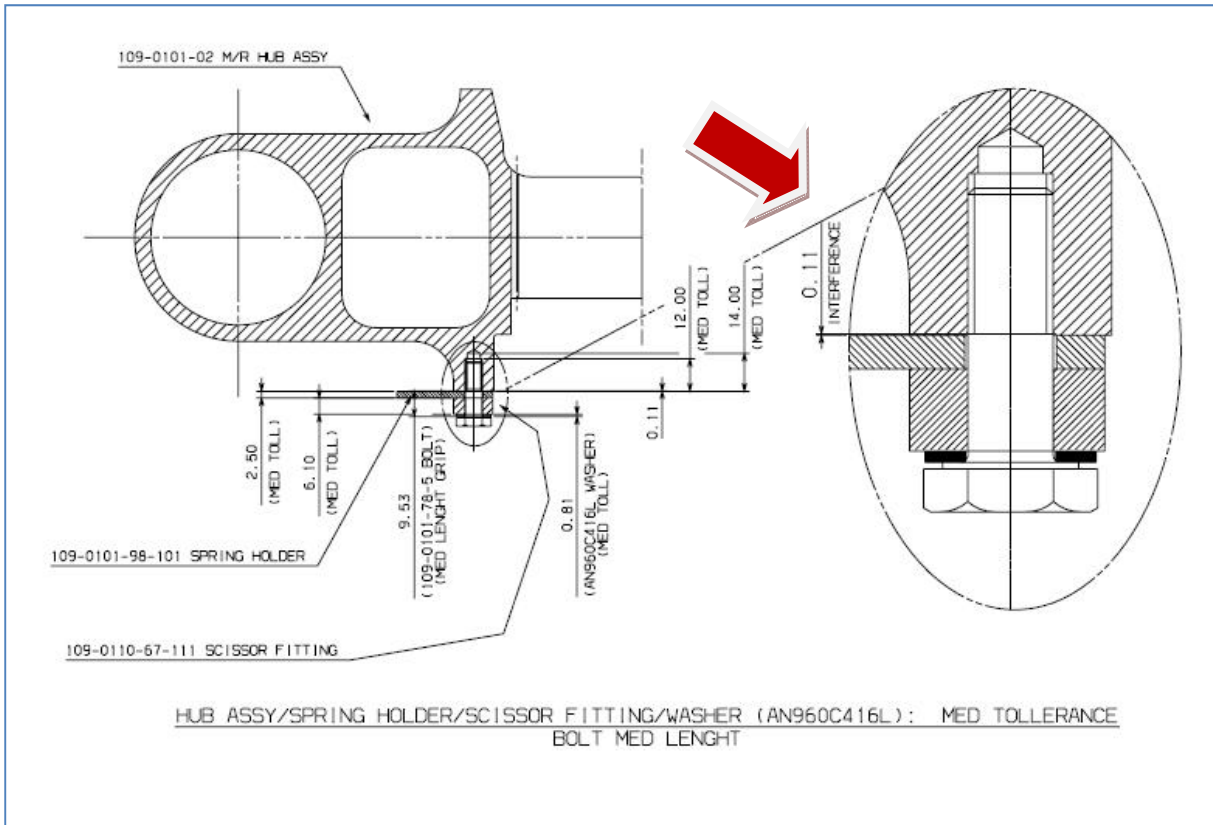
Annexe 3: Comparison of the assembly with one or two washers



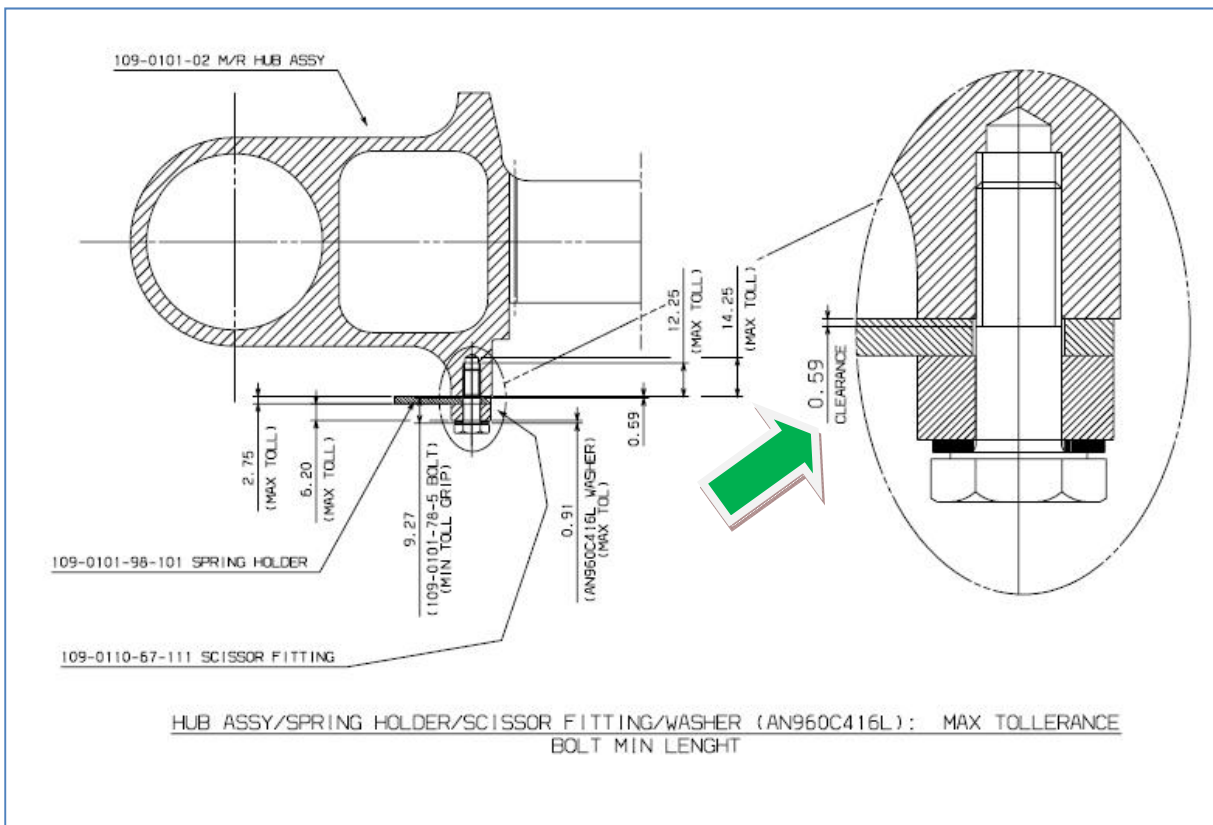
Assembly with only one washer at minimum tolerance of the components = NOT OK



Assembly with two washers at minimum tolerance of the components = OK




Assembly with only one washer at medium tolerance of the components = NOT OK




Assembly with only one washer at maximum tolerance of the components = OK

Annexe 4: Service bulletin and EASA emergency airworthiness directive (title page only)

AGUSTA	ALERT	Via Giovanni Agusta, 520 21017 Cascina Costa di Samarate (VA) Italy Tel.: +39 0331-229111 - Fax: +39 0331-229605/222595
		AN AGUSTAWESTLAND COMPANY 
TRANSLATION OF		
BOLLETTINO TECNICO		№ 109K-53
The technical content of this document is approved under the authority of DOA nr EASA.21J.005.		DATE December 18, 2009
		REV.
Compliance with this bulletin is:	MANDATORY	
SUBJECT: INSPECTION OF THE MAIN ROTOR SCISSOR FITTING ASSY P/N 109-0110-67 FIXING BOLTS P/N 109-0101-78-5.		
REASON: Perform a "one-time" inspection of the subject bolts to verify the presence of two washers under the head of each bolt and provide the instructions to restore the correct installation.		
HELICOPTERS AFFECTED: All the main rotor hub assy P/N 109-0101-01 installed on the Agusta A109K2 helicopters or eventually in stock.		
COMPLIANCE:		
<u>PART I[^]:</u> Within the next 5 flight hours after the receipt of this Bollettino.		
<u>PART II[^]:</u> Within 25 flight hours after the compliance with PART I [^] and however within and not later than April 30, 2010.		
DESCRIPTION: A case of fracture of two of the three bolts P/N 109-0101-78-5 fixing the main rotor scissor fitting assy P/N 109-0110-67 has been reported in flight on an A109K2 helicopter. The occurrence did not cause harm to the occupants nor damage to the helicopter. The investigations revealed that the malfunction was caused by incorrect information contained in the technical publications. This Bollettino is issued in order to provide the necessary instructions to perform a "one-time" inspection to verify the correct installation of the main rotor scissor fitting assy P/N 109-0110-67, that includes the installation of two washers under the head of each bolt P/N 109-0101-78-5 (PART I [^]) and, if necessary, to restore the design		
<small>An appropriate entry should be made in the aircraft log book upon accomplishment. If ownership of aircraft has changed, please, forward to new owner.</small>		
ALERT		Page 1 of 7

EASA AD No: 2009-0274-E

EASA	EMERGENCY AIRWORTHINESS DIRECTIVE
	<p>AD No.: 2009-0274-E</p> <p>Date: 18 December 2009</p> <p>Note: This emergency Airworthiness Directive (AD) is issued by EASA, acting in accordance with Regulation (EC) No 216/2008 on behalf of the European Community, its Member States and of the European third countries that participate in the activities of EASA under Article 66 of that Regulation.</p>
<p>This AD is issued in accordance with EC 1702/2003, Part 21A.3B. In accordance with EC 2042/2003 Annex I, Part M.A.301, the continuing airworthiness of an aircraft shall be ensured by accomplishing any applicable ADs. Consequently, no person may operate an aircraft to which an AD applies, except in accordance with the requirements of that AD unless otherwise specified by the Agency [EC 2042/2003 Annex I, Part M.A.303] or agreed with the Authority of the State of Registry [EC 216/2008, Article 14(4) exemption].</p>	
Type Approval Holder's Name :	Type/Model designation(s) :
Agusta S.p.A	A109A, A109All, A109C, A109K2 Helicopters
TCDS Number:	EASA R.005
Foreign AD:	Not applicable
Supersedure:	None
ATA 62	Main Rotor - Fixing Bolts of the Scissor Fitting Assembly - Inspection/Replacement
Manufacturer(s):	Agusta S.p.A
Applicability:	A109A, A109All, A109C, A109K2 helicopters all serial numbers
Reason:	<p>A failure of a two bolts p/n 109-0101-78-5 on one A109K2 helicopter has been reported to Agusta S.p.A.. The investigation carried out by Agusta S.p.A. has identified that the failure has been originated by the inadequate information reported in the technical publications related to the configuration of the main rotor scissor fitting installation. Failure of these bolts might lead to the loss of control of the helicopter.</p> <p>To prevent this unsafe condition, Agusta S.p.A. has issued two Alert Technical Bulletins (as applicable for the different models) with the proper installation procedure of the main rotor scissor fitting.</p> <p>This Emergency AD requires the inspection of the main rotor scissor fitting for checking its proper installation and if found not to be properly installed, mandates the replacement of the bolts p/n 109-0101-78-5 in accordance with Mandatory Alert Bolletino Tecnico (BT) Agusta. N° 109K-53 or Mandatory Alert BT Agusta N° 109-131.</p>
Effective Date:	20 December 2009