Statens haverikommission
Swedish Accident Investigation Board

ISSN 1400-5719

Report RL 2011:03e

Aircraft accident to helicopter SE-JBU, north-north-west of Klutsjön, Dalarna county, on 1 July 2009

Case L-08/09

This report is also available on our web site: www.havkom.se.

In case of discrepancies between the English and the Swedish texts, the Swedish text is to be considered the authoritative version.

29 August 2011 L-08/09

Distribution list

Report RL 2011:03e

The Swedish Accident Investigation Board has investigated an accident that occurred on 1 July 2009 north-north-west of Klutsjön, Idre, W län (Dalarna county), to a helicopter registered SE-JBU.

In accordance with Regulation 996/2010 of the European Parliament and of the Council and SFS (the Swedish Statute Book) Section 14 of the Ordinance concerning the investigation of accidents (1990:717), the Swedish Accident Investigation Board herewith submits a report on the investigation.

The Board will be grateful to receive, by 29 November 2011 at the latest, particulars of how the recommendations included in this report are being followed up.

Carin Hellner Agne Widholm

Distribution list

EASA

NTSB

Rolls Royce

General

The Swedish Accident Investigation Board (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended so far as possible to determine both the sequence of events and the cause of the events, along with the damage and effects in general. An investigation shall provide the basis for decisions which are aimed at preventing similar events from happening again, or to limit the effects of such an event. At the same time the investigation provides a basis for an assessment of the operations performed by the public emergency services in respect of the event and, if there is a need for them, improvements to the emergency services.

SHK accident investigations try to come to conclusions in respect of three questions: *What happened? Why did it happen? How can a similar event be avoided in future?*

SHK does not have any inspection remit, nor is it any part of its task to apportion blame or liability concerning damages. This means that issues concerning liability are neither investigated nor described in association with its investigations. Issues concerning blame, responsibility and damages are dealt with by the judicial system or, for example, by insurance companies.

The task of SHK does not either include as a side issue of the investigation that concerns emergency actions an investigation into how people transported to hospital have been treated there. Nor are included public actions in the form of social care or crisis management after the event.

The investigation of aviation incidents are regulated in the main by the Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation. The investigation is carried out in accordance with the Chicago Convention Annex 13.

The investigation

The Swedish Accident Investigation Board (SHK) was notified on 1 July 2009 that a helicopter with registration SE-JBU had an accident at 10:12 on that day north-north-west of Klutsjön, Idre, Dalarna county.
The accident has been investigated by SHK represented by Carin Hellner, Chairperson, Stefan Christensen, investigator in charge and operations investigator, up to and including 14 September 2009, and thereafter Agne Widholm, Henrik Elinder, technical investigator, until 31 December 2010, and thereafter Staffan Jönsson and Urban Kjellberg, investigator for the rescue services.
SHK was assisted by Liselotte Yregård as a medical expert and Lars-Peter Peltomaa as a technical expert.
The investigation was followed by Ulrika Svensson and Magnus Holmén, Swedish Transport Agency.
The accredited representative from the National Transportation Safety Board, NTSB, was Jennifer S Rodi, USA

Report RL 2011:03e

L-08/09
Report finalised on 29 August 2011

Aircraft; registration and type	SE-JBU, Hughes 369D
Class, airworthiness	Normal, valid ARC
Registered owner/Operator	Dala Helikopter DH AB, Nybrogatan 35, SE-114 39 Stockholm, Sweden
Time of occurrence	1 July 2009, at about 10:12 in daylight Note: All times are given in Swedish daylight saving time (UTC + 2 hours)
Place	North-north-west of Klutsjön, Idre, Dalarna county, (posn. 62°08′ N 012°49′ E; approx. 760 m above sea level)
Type of flight	Aerial work
Weather	According to SMHI's analysis: Wind west to southwest 2-5 knots, visibility >10 km, cloud 1-4/8 with base at 6-8000 feet, temperature/dew point +20/+11 °C, QNH 1021 hPa
Persons on board:	
pilot	1
assistant	1
Injuries to persons	Minor
Damage to the aircraft	Substantially damaged
Other damage	None
The pilot:	
Age, certification	52 years, CPL(H)
Total flying time	9 208 hours
Flying hours previous 90 days	106 hours, all on type
Number of landings previous 90 days	162, all on type

Summary

This particular flight concerned reindeer herding by helicopter. After about an hour and a half of flight without any problems, a loud bang was heard, the helicopter shook and the engine stopped dead. At that moment the helicopter was hovering, at low speed, about 10-12 metres above the ground.

The helicopter immediately lost altitude and struck the ground hard on a boggy surface, so that the rotor blades also hit the ground. Those on board were injured by the impact but were able themselves to leave the helicopter and call the rescue services.

During the investigation it was found that the engine stoppage occurred while the helicopter was being operated within a range of speed and altitude where the loss of engine power normally means that it is not possible to perform a safe emergency landing.

The engine stoppage was caused by a coupling between the engine compressor and the turbine, known as the Splined Adapter, fracturing during flight as the result of a fatigue crack. In the opinion of SHK the Splined Adapter, despite

measures taken by the engine manufacturer and the supervisory authority, remains a weak component in the design of the engine.
Despite a SAR helicopter was engaged by the rescue services, one of the injured was first forced to be transported on a stretcher in a tracked vehicle, and subsequently driven for approximately 200 km in a road ambulance to the nearest hospital. SHK is of the opinion that there is a need to expand the current operational requirements in respect of the operational time and load capacity of SAR helicopters.

The accident was caused by the measures taken to eliminate the risk of Splined Adapter fatigue fracture being inadequate.

Recommendations

It is recommended that the EASA and the Swedish Transport Agency:

- prescribe measures that would lead to phasing out of Splined Adapters of the earlier design sooner than March 2012 *(RL 2011:03 R1),* and to
- ensure that the engine manufacturer investigates the risk that fretting damage and fatigue fractures on Splined Adapters could be caused by non-linearity in the engine drive shaft line as a result of loose studs in the stud and nut coupling between the compressor and the gearbox, and if this is so, to initiate the necessary maintenance measures in order to eliminate such a risk *(RL 2011:03 R2).*

It is recommended that the Swedish Civil Contingencies Agency (MSB):

- in co-operation with Transportstyrelsen (the Swedish Transport Agency), Sjöfartsverket (the Swedish Maritime Administration), Rikspolisstyrelsen (the Swedish National Police Board) and Socialstyrelsen (the Swedish National Board of Health and Welfare) ensures that the search and rescue services and the mountain rescue services are co-ordinated for efficient rescue missions in case of aircraft accidents in mountainous areas where there may be a need for medical transport *(RL 2011:03 R3).*

It is recommended that the Swedish Transport Agency:

- in connection with the preparation of a national set of regulations for requirements and supervision procedures of SAR operations, in accordance with the SHK recommendation *(RS 2008:03 R14)*, in co-operation with Sjöfartsverket (the Swedish Maritime Administration),considers the need to generally expand the requirements concerning the operational capability of SAR operations, *(RL 2011:03 R4).*

1 FACTUAL INFORMATION

1.1 History of the sequence of events

The flight concerned reindeer herding by helicopter. During reindeer herding the helicopter is mostly flown at low speed at a low altitude, often including hovering, so that the reindeer herd and individual reindeer are “driven” in the desired direction.

On the day concerned, the pilot himself performed the daily inspection of the helicopter. The flight was the second of the day and began after those involved had taken a break, during which the helicopter had been refuelled. Accompanying the pilot in the helicopter was a reindeer owner who was regarded as a crew member (assistant).

After about an hour and a half of flight without any problems, a loud bang was heard, the helicopter shook and the engine stopped dead. At that moment the helicopter was hovering, at low speed, about 10-12 metres above the ground.

The pilot maintained the collective control position and concentrated on holding the helicopter stable horizontally by using the cyclic control and the pedals. The helicopter immediately began to lose altitude. Just before it hit the ground, the pilot tried to reduce the sink rate by moving the collective control to its highest position.

He found that this action had no noticeable effect. Instead the helicopter struck the ground hard on a hill bog, with low horizontal speed but at a high sink rate.

The right side landing skid sank deeper into the bog than the left side skid and was partially broken. This caused the helicopter to tip over to the right, whereupon the main rotor blades struck the ground.

After the impact, the helicopter stood partly on its skids, leaning to the right. Those on board could leave the helicopter without assistance and called the emergency services by telephoning the emergency number 112.

The accident occurred at about 10:12 in daylight, at position 62°08′ N 012°49′ E; approximately 760 m above sea level.

1.2 Injuries to persons

	Crew members	*Passengers*	*Others*	*Total*
Fatal	–	–	–	–
Serious	–	–	–	–
Minor	2	–	–	2
None	–	–	–	–
Total	2	–	–	2

Pilot
The pilot suffered minor injuries in the accident, which were limited to back pain without any fractures.

Assistant
The assistant suffered minor injuries in the accident, which were limited to neck and back pain without any fractures.

1.3 Damage to the aircraft

Substantially damaged.

1.4 Other damage

None.

1.5 The crew

1.5.1 Pilot

The pilot was 52 years old at the time and had a valid CPL (H) Licence.

Flying hours			
previous	24 hours	90 days	Total
All types	7	106	9 208
This type	7	106	About 5 700

Number of landings this type previous 90 days: 162.
Flight training on type carried out on 13 October 1989.
Latest OPC[1] carried out on 21 March 2009.
Latest PC[2] carried out on 30 October 2008.

1.5.2 The pilot's duty schedule

Before the accident the pilot had had about seven hours sleep and thereafter been on duty since 03:30 in the morning. During this time he had first flown for about 2,5 hours. After that he took a meal break before starting this particular flight.

[1] OPC - Operational Proficiency Check
[2] PC - Proficiency Check

1.6 The aircraft

1.6.1 General

The aircraft	
Manufacturer	Hughes
Type	369D
Serial number	480294D
Year of manufacture	1978
Gross mass	Max. authorised take-off mass 1 360 kg, actual approx. 970 kg
Centre of mass	Within permitted limits
Total flying time	4 210 hours
Number of cycles	5 719
Flying time since latest inspection	29,3 hours
Fuel loaded before event	Jet A1
Engine	
Manufacture	Rolls-Royce (RR), (previously Allison)
Engine model	250-C20B
Number of engines	1
Engine S/N	CAE-830672
Compressor running time since inspection	1 684 hours
Rotor	
Manufacture	Hughes
running time since basic inspection	
Main rotor blades	3 373 hours
Tail rotor blades	354 hours

The aircraft had a valid Airworthiness Review Certificate (ARC).

Technical maintenance had been performed in accordance with the applicable regulations, apart from the updating of CEB A-1392 Rev. 2. (See Section 1.16.6.)

1.6.2 Engine

The engine is a turbo shaft engine consisting of a gas generator and a free turbine. The engine is divided into four main modules; Compressor Section, Gearbox Section, Turbine Section and Combustion Section, which are in principle connected together by bolted joints.

The turbine module consists of both a gas generator turbine and a free turbine. The main modules have individual running time limitations and can be changed separately.

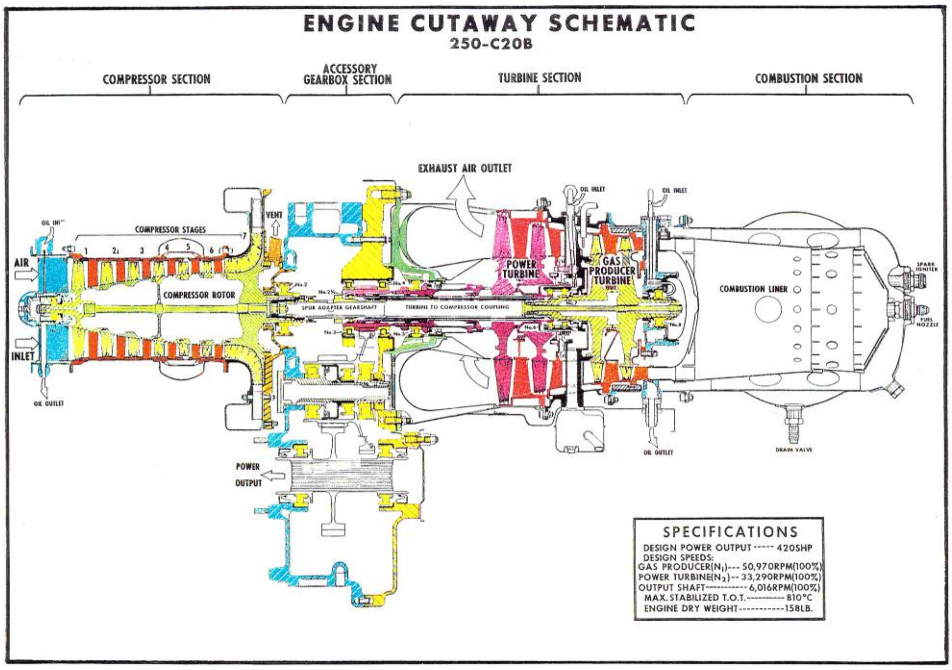

Figure 1. RR 250-C20B

1.6.3 *Drive shaft line*

The gas generator's compressor and turbine are located on each side of the gearbox. They are joined to each other by a drive shaft and two couplings, which together form a drive line which goes through the gearbox. The normal rotation speed of the gas generator during operation is 40 000 rpm.

When fitting the compressor to the gearbox, there is a strict requirement that the drive line is perfectly straight. In order to achieve this, shims are used in the bolted connections. The shim thicknesses must be calculated and the shims selected individually after careful measurement of the affected contact surfaces of the compressor and gearbox.

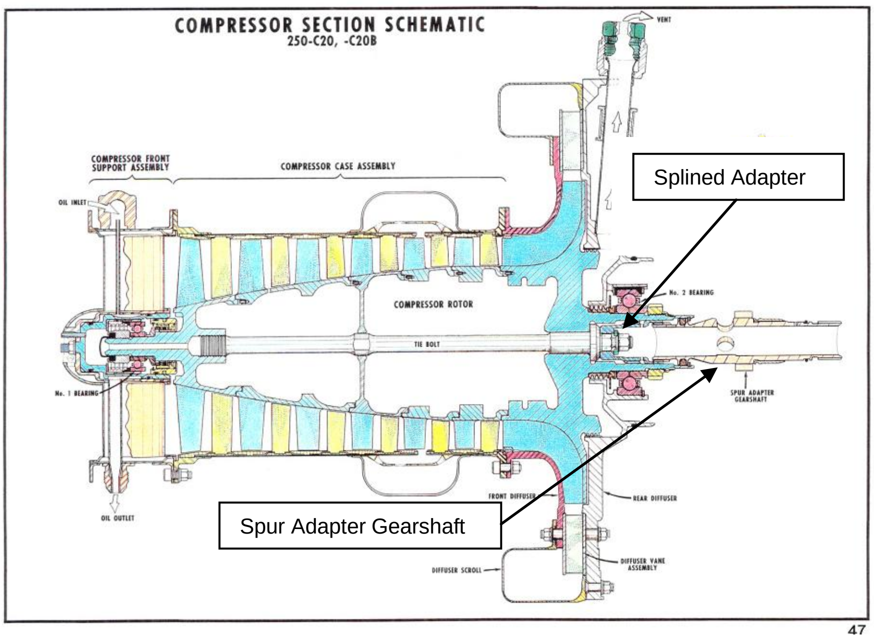

Figure 2. Compressor section with couplings

1.6.4 *Drive shaft couplings*

The coupling between the drive shaft and the compressor is by means of an adapter, called the Splined Adapter (or Compressor Adapter Coupling), which is bolted to the final stage of the compressor (Impeller). The Splined Adapter is coupled by its internal splines to an intermediate adapter called the Spur Adapter Gear Shaft, which among other things has an external drive gear to drive the gearbox. The Splined Adapter is included as a component in the compressor module and follows the module's running time limitations.

Figure 3. Splined Adapter

Figure 4. Spur Adapter Gear Shaft

1.6.5 *Splined Adapter*

According to published reports, there have been at least twelve cases of the Splined Adapter breaking during operation, with the engine stopping immediately as a result. On 15 June 2003 such an engine stoppage occurred on Hawaii, which resulted in the total destruction of a McDonnell Douglas 369D helicopter, and the deaths of four people.

In practically everyone of these cases the adapter had fractured at approximately the centre of its external circular contact surface facing the impeller, as a result of a fatigue fracture. A fatigue fracture had been initiated where there was fretting[3] on the contact surface, which had then grown into the underlying material until the entire thickness of the metal had been penetrated.

Fretting damage is said to be the most common reason to change the Splined Adapter during repairs and inspections of compressors.

In order to tackle the problem, the US Federal Aviation Administration (FAA), published an Airworthiness Directive (AD), and the engine manufacturer Rolls-Royce (RR), published a number of service bulletins, Commercial Engine Bulletins (CEBs), in respect of the Splined Adapter and its installation on the compressor.

The aim of these measures was to successively change the earlier design of Splined Adapters and install new, Rolls-Royce-manufactured type of adapter with the contact surface against the impeller silver-plated, with the intention of offering greater resistance to fretting.

[3] Fretting – Chafing damage that occurs between two adjacent metal surfaces.

The following summarises the directives that were issued.

Date	Directive	Instructions
8 February 2008	AD 2004-26-09	• Adapters which have not been manufactured by RR (PMA parts) must be changed within the specified time period (< 600 hours). • As soon as the compressor is disassembled for any reason, but in any case not later than 1 March 2012, the RR adapter P/N 23039791 -1, -2 or -3 must be replaced by an RR adapter P/N 23076559 -1, -2 or -3.
19 February 2007	CEB-1325 Rev. 4	At the next inspection or repair of the compressor, the work must include: • The RR adapter P/N 23039791 -1, -2 or -3 must be replaced by an RR adapter P/N 23076559 -1, -2 or -3. • The Spur Adapter Gearshaft must be replaced. • The Impeller must be replaced or reworked.
12 January 2009	CEB A-1392 Rev. 3	At the next disassembly of the compressor for any reason, the work must include: • The RR adapter RR P/N 23076559 -1, -2 or -3 must be replaced by an adapter with a higher dash number. • The RR adapter RR P/N 23079637 -1, -2 or -3 must be replaced by an adapter with a higher dash number. • The Impeller must be replaced or reworked.

1.6.6 *Formulations in CEB A-1392 Rev. 3*

The introduction to CEB A-1392 Rev. 3 states:
"If you have complied with the previous issue of this bulletin, no additional work is required."

The requirement to implement CEB A-1392 Rev. 3 the next time the compressor is dismantled for any reason is formulated as follows:
"Compliance Code 4. To be complied with the next time the affected module or component is at an approved repair/overhaul facility and the compressor rotor is disassembled for any reason."

The requirement when carrying out CEB A-1392 Rev. 3 to change the RR Adapter P/N 23076559 for an adapter with a higher dash number is formulated as follows:

"2. ACCOMPLISHMENT INSTRUCTIONS

A. Replace Compressor Adapter Coupling (23076559).

1. *Remove compressor assembly (Ref. OMM).*
2. *Send compressor assembly to an approved maintenance facility.*
3. *Select and measure pilot OD (-B-) of a new larger dash size compressor adapter coupling, ie., if a -1 adapter is removed a -2 adapter must be installed (Ref. chart below). If a -3 adapter is removed, a new impeller is required. Machine ID of impeller to achieve a fit of 0.000-0.0018 in.T (0.000-0.046 mm)T.*

NOTE: This procedure of installing the next dash size compressor adapter coupling is also applicable to compressor rotor assemblies that have adapter (23076559) installed."

Note:
The text of CEB A-1392 Rev. 3 referred to above is the same as that in the earlier issue, CEB A-1392 Rev. 2 (except that the fit dimension was stated as 0,0013 in instead of 0,0018 in).

1.7 Meteorological information

According to the SMHI (Swedish Meteorological and Hydrological Institute) analysis: Wind west to southwest 2-5 knots, visibility >10 km, cloud 1-4/8 with base at 6-8000 feet, temperature/dew point +20/+11 °C, QNH 1021 hPa.

1.8 Aids to navigation

Not applicable.

1.9 Radio communications

Not applicable.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders and voice recorders

None. Not required

1.12 Accident site and aircraft wreckage

1.12.1 Accident site

The helicopter came down on to flat boggy ground about two kilometres north-north-west of Klutsjön. At the time the area was sparsely covered by low deciduous trees and bushes.

1.12.2 Aircraft wreckage

On impact the landing skids broke so that the underside of the helicopter cabin contacted the ground.

Figure 5. SE-JBU

1.13 Medical information

The pilot had undergone the prescribed examination by a doctor and had a valid medical certificate. The pilot had high blood pressure which was well controlled by medicine.

The days before the accident he had, according to his own account, had normal nights´ sleep and felt well.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 General

The Emergency Locator Transmitter (ELT) was activated by the accident and switched off by the pilot of the helicopter which had flown medical personnel to the accident site.

The descent rate of the accident helicopter was high on impact. Despite the soft and energy-absorbing boggy ground surface, which helped to mitigate the ground impact, one landing skid broke and there was compression damage to the pilot's seat.

Impact with firm ground would have resulted in more powerful vertical G forces imposed on those on board, creating the conditions for more serious personal injury.

1.15.2 Search, localisation and rescue

<u>Alarms</u>
An alarm came in to the SOS centre at 10:15 from the pilot of the accident helicopter, who had himself called 112, the emergency number. The call was

switched through to the aeronautical rescue leader at JRCC[4], who took over the interview concerning the events.

The pilot related that there had been two people on board the helicopter when the engine suddenly stopped, and the helicopter had impacted with the ground from a relatively low altitude. They had exited the helicopter by themselves. Both had back pain but were otherwise unhurt. At the end of the telephone call, which lasted about ten minutes, the pilot gave the geographical co-ordinates of the accident site, which was located at a boggy area about four kilometres from a road that could take vehicles in the vicinity of Klutsjön, north of Idre.

At 10:23 the SOS centre in Falun sent the alarm to the fire station at Idre and to two ambulances which at the time happened to be attending a fire in Särna. At the same time, the police authority county communications centre (LKC) in Falun was informed about the accident.

The JRCC rescue leader contacted the SOS centre at Östersund and was told that the ambulance helicopter normally stationed there was not available as it was already engaged on a task. It was then decided to send an alarm to the SAR[5]helicopter at Sundsvall, a Sikorsky 76 type called “Lifeguard 906”.

The commander of the SAR helicopter was called by the rescue leader at 10:27, told of the accident and was given the task of locating the accident site. The helicopter took off from Sundsvall at 10:45 with a crew of four. It has not afterwards been possible to establish whether it was equipped with one or two stretchers.

A helicopter from another aviation company, which was near to the accident site, was contacted via a Lapp village in the area. The pilot of that helicopter then called the SOS centre and offered his services.

The JRCC rescue leader decided to engage this helicopter, as it was in the vicinity of the accident site. This helicopter was given the task of bringing in medical staff from the ambulances to the accident site to wait for the SAR helicopter from Sundsvall to arrive.

The co-opted helicopter arrived at the assigned location on the driveable road at about 11:24 and picked up two medical personnel from one of the ambulances.

Medical and rescue actions
After a flight of only a few minutes, the two medical personnel were left at the accident site. In terms of time, this was about an hour and a quarter after the 112 telephone call reporting the accident had been answered. More medical personnel from the ambulances were transported to the accident site by the rescue services tracked vehicle.

The pilot and the assistant were treated at the accident site by the medical personnel. Three of these were trained nurses, and one of them was appointed as medically responsible at the accident site.

The medical personnel assessed the pilot’s back pain and the assistant’s neck and back pain as minor injuries. Both were immobilised with neck collars and vacuum mattresses.

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[4] JRCC - Joint Rescue Coordination Centre (The National Rescue Centre)
[5] SAR - Search And Rescue

The rescue leader at JRCC called at 10:52 to the Dalarna police authorities to say that the responsibility for the task should be transferred to the mountain rescue services once the accident site had been located and the air rescue services had been completed. This suggestion was not accepted by the police, who questioned the need for mountain rescue since resources had already been alerted, in the form of both helicopters and tracked vehicles. The result of the telephone call was that the police authority did not assume responsibility for calling in mountain rescue.

The SAR helicopter, "Lifeguard 906", arrived at the accident site at 11:43, which was almost an hour and a half after the 112 telephone call concerning the accident had been answered. Due to the nature of the ground, which could not take the weight, the helicopter could not land to unload, and had to "hover with ground contact" close to the accident site.

The winchman, who maintained radio contact with the helicopter commander, then proceeded to the accident site. There the medical personnel, via the winchman, asked the commander if the helicopter would be able to transport two patients on stretchers. It was not possible afterwards to determine exactly how this request was specified.

The commander understood that, in addition to the helicopter's winching stretcher, they wished to use one of the ordinary medical team "ALFA" stretchers for this. Because this type of stretcher could not, without prior preparation, be anchored safely to the helicopter during flight, he stated that this transport would not be possible.

The medical personnel asked then if it would be possible for the helicopter to first transport one patient to a driveable road and then take the other patient to hospital. Taking into account the fact that the fuel consumption during hovering is greater than that during cruising flight, the commander assessed that the amount of fuel available in the helicopter was insufficient to do this, which was reported to the medical personnel.

Taking into account the neck symptoms, the medical personnel thus made it a priority for the assistant to be transported by the SAR helicopter to the hospital in Mora.

The helicopter departed from the accident site at 12:04 with its normal crew, the injured assistant and two of the medical personnel on board. After being transferred to an ambulance at Mora hospital, the patient was delivered to the hospital's emergency intake at 12:56, 2 hours and 41 minutes after the 112 telephone call reporting the accident had been answered.

The injured pilot was first taken about 3-4 kilometres to the meeting point on a vacuum mattress on a stretcher that was suspended from the roof of the rescue services tracked vehicle. This transport was supervised by the medically responsible nurse and rescue service personnel who travelled in the tracked vehicle. During this transport, which the pilot experienced as very uncomfortable, his back pain became more severe.

The tracked vehicle arrived at the meeting point at 13:33, where the pilot was transferred to an ambulance.

The pilot was then taken by the road ambulance about 200 km to Mora hospital, where he was delivered at 15:57, about 3 hours later than the assistant's arrival at the hospital, and 5 hours 42 minutes after the 112 telephone call reporting the accident had been answered.

The JRCC rescue leader called at 12:11 to the police and the on-site rescue services commander to report that the national aeronautical rescue commitment was terminated. The on-site rescue services commander stated during the telephone call that there was no need for further rescue services, as there was no fuel leakage or fire risk, and that both patients had been taken away from the accident site. All that remained at the accident site was the helicopter wreckage.

1.15.3 Applicable regulations for the rescue services and patient transport

National search and rescue services

The Swedish Accident Prevention Act (SFS 2003:778) 4 Chapter 2 § states that it is the responsibility of the national search and rescue services to search for missing aircraft. The Swedish Accident Prevention Regulations (SFS 2003:789) 4 Chapter 2 § states that aeronautical search and rescue services are the responsibility of Sjöfartsverket (the Swedish Maritime Administration). The same legislation, 4 Chapter 3 § states that there shall be a rescue centre for aeronautical search and rescue services.

Since the shift 2008/2009, in connection with the establishment of the Swedish Transport Agency, the Swedish Maritime Administration has taken over responsibility for the aeronautical search and rescue centre. This organisational unit is called the Joint Rescue Coordination Centre (JRCC), and has the task of being responsible for the management and co-ordination of aeronautical search and rescue missions. (JRCC forms the Swedish rescue services centre for aeronautical rescue services that in international terminology is called ARCC.) The inspection authority for aeronautical search and rescue services is Transportstyrelsen (the Swedish Transport Agency).

According to TSFS[6] 2010:111 "The Transport Agency regulations and general recommendations concerning aeronautical rescue services" a known accident site is defined as: "an accident site, the precise location of which has been determined by ATS personnel directly observing the site or by a rescue unit arriving and confirming the location".

The aeronautical rescue services are responsible for the search and localisation until the accident site becomes known.

Local district rescue services

The Swedish Accident Prevention Act (SFS 2003:778) 3 Chapter 7 § states that rescue services are the responsibility of the local district authority if the national search and rescue services are not responsible, in accordance with Chapter 4 of the same legislation. By "rescue services", Chapter 2 § of the Swedish Accident Prevention Act (SFS 2003:778) refers to the rescue services for which the government or district councils are responsible in the event of accidents and considerable danger of accidents, to prevent and limit injury to people or damage to property or the environment. The Swedish Civil Contingencies Agency (MSB) is the central inspection authority.

Within the Älvdalen municipality there is, among other things, a fire station at Idre at 24 hour readiness with firemen, vehicles and rescue equipment.

Mountain rescue services

[6] TSFS – The Transport Agency Statute Book

According to the Swedish Accident Prevention Act (SFS 2003:778) 4 Chapter 1 §, the national mountain rescue services are, among other things, responsible for rescuing those who have had an accident in mountainous areas. Such a rescue mission could in certain cases also involve medical transport. The principal responsibility for medical transport is at the same time clearly that of the local district council, regardless of which type of transport is used.

According to the Swedish Accident Prevention Act (SFS 2003:789) 4 Chapter 1 §, the Dalarna police authority is responsible for mountain rescue services. The police authority has also prepared a programme for mountain rescues in Dalarna. To assist the police there are voluntary mountain rescue teams which are trained and equipped by the police. These mountain rescue teams operate under the leadership of either a rescue leader from the police or a task leader from the official mountain rescue services. The inspection authority for police authorities in Sweden is Rikspolisstyrelsen, the Swedish National Police Board.

Medical transport

According to the Swedish Health and Medical Care Act 6 §, county council health authorities (Landsting) are responsible for ensuring that there exists a suitable organisation for the transport of people to and from hospitals, i.e. provision of ambulances.

All forms of ambulance transport, regardless of whether employed in connection with rescue missions or other cases, including transportation across country to driveable roads, is covered by a joint responsibility by county councils (Landsting) for the entire health care and transport chain. The only exception from this responsibility is ambulance transports from vessels which are engaged in maritime rescue service and are regulated in accordance with the Swedish Accident Prevention Act (SFS 2003:778). The inspection authority for health care is the Socialstyrelsen (the Swedish National Board of Health and Welfare).

County councils are able to engage other authorities or participants in order to provide ambulance services, including over terrain without roads, but is still responsible for any ambulance transport and care during transportation of patients. In the case of aeronautical rescue tasks on land, normally the aeronautical rescue leader co-operates with the operator at the SOS centre that is concerned. In the case of such tasks SOS centres may request in certain cases the use of an SAR helicopter for ambulance transport in accordance with their task of implementing ambulance direction.

Landstinget (the county council) of Dalarna has a current agreement with Räddningstjänsten Älvdalen (the Älvdalen Rescue Services) in respect of the latter’s participation in the transport of patients across rough terrain. The transport of injured persons is carried out using the existing rescue services facilities, such as tracked vehicles. The injured can thus be transported lying down, at the same time allowing ambulance personnel to provide care during the journey.

Supervision of the co-operation of national rescue services
According to the Swedish Accident Prevention Act (SFS 2003:789), the Swedish Civil Contingencies Agency (MSB) exercises the supervision of issues which concern co-operation between the various branches of the national rescue services.

Government written communication 2009/10:124
The Government written communication 2009/10:124 calls attention to the importance of co-operation so that the public rescue services shall function efficiently. The government therefore, on 14 April 2010, tasked the Swedish Civil Contingencies Agency in concert with Kustbevakningen (the Coastguard), Sjöfartsverket (the Swedish Maritime Administration), Rikspolisstyrelsen (the Swedish National Police Board), Länsstyrelserna (the County Administrative Boards), Sveriges Kommuner (Sweden’s District Councils) and Landsting (County Authorities), and after consultation with Försvarsmakten (the Swedish Armed Forces), Socialstyrelsen (the Swedish National Board of Health and Welfare) and other rescue services organisations involved, with proposing how co-operation and collaboration between the various public rescue services could continue to be developed.

This task was not reported on 1 February 2011 in accordance with the time stated by the Swedish Government. The Swedish Civil Contingencies Agency (MSB) has requested and been granted a later date for issuing the report. Among other things, the task included co-ordinating the respective organisations in order to make more efficient rescue efforts and transport of patients in mountainous areas.

1.15.4 The airborne resources of the rescue services

General
Sjöfartsverket (the Swedish Maritime Administration), which is responsible for aeronautical rescue services, has for its part of the task signed an agreement with a private aviation company. This part of the task includes search and location in the case of maritime and aeronautical rescues using helicopters, Search And Rescue (SAR), and in certain cases also rescue itself, for example maritime rescue at sea and aeronautical rescues at sea and the larger inland lakes. Similarly, transport of patients from vessels is included in the tasking.
The area of responsibility of the aeronautical rescue services, SRR (Svensk räddningsregion – Swedish Rescue Region), for the most part coincides with the Swedish Flight Information Region (FIR).

This covers in principle the whole of Swedish territory and the adjacent maritime areas to the equidistant boundaries with other nations.

Requirement specifications for SAR helicopters
The requirement specifications for SAR operations state among other things that SAR helicopters with crews and normal equipment, fully fuelled and with the prescribed fuel reserves, must at least be able to perform the following task profiles:

1. To fly out for one hour at a speed of at least 140 knots, spend one hour searching at a speed of 70 knots at sea level (SL) and then return the distance that has been outflown.
2. To fly out at maximum cruising speed for 55 minutes, hover to winch on board 5 persons in the space of 20 minutes and then return at a speed of not less than 140 knots.

3. To fly out for at least 45 minutes at a speed of at least 140 knots and thereafter during 12 minutes winch down a RITS[7] force (6 persons and 9 bags with a total weight of 820 kg) to a vessel.

It must be possible to perform these tasks in both daylight and darkness, in reduced visibility and in other difficult weather and wind conditions. In the case of tasks performed in IMC[8] the need for larger fuel reserves must be taken into account, in order, among other things, to be able to reach alternative landing sites.

SAR helicopters must also be able to take care of five people at the same time, of which two on stretchers and the other three sitting on board. According to the Swedish Maritime Administration, stretcher places means the helicopter's normal winching stretcher and one other suitable equipment which permits a soft, horizontal lying position, such as a vacuum stretcher.

In addition to the normal winching stretcher there exists for the helicopter type a specially adapted stretcher which can be installed fastened in the cabin for flight with a patient, but can be folded up and stowed away in the helicopter when not in use. There is no defined requirement for including this type of stretcher in the standard equipment of the helicopter. SHK understands that this type is carried on tasks only when it is known that there will be a need for it.

A total of five helicopters, of Sikorsky S-76 type, are employed in this work. These can operate in darkness and Instrument Meteorological Conditions (IMC). They are specially equipped for maritime SAR operations, including advanced search equipment, external winches, etc.

This type of helicopter has two engines and can in normal circumstances carry over two tons of load or up to 12 passengers, depending on configuration and fuel load. The cruising speed is approximately 145 knots (269 km/h).

In SAR configuration, with full tanks and a crew of four, the time of action is about 2,8 or 2,6 flying hours at speeds of 145 knots (269 km/h) or 155 knots (287 km/h) respectively. During the hover, the fuel consumption is about 10% higher than when flying at cruising speed.

Each crew consists of two pilots, a winch operator and a winchman. Their principal task is to quickly locate people in emergencies at sea, take them on board and transport them to hospital for care.

At the time of this particular accident there were SAR helicopters and crews based at Sundsvall, Norrtälje, Visby, Ronneby and Gothenburg, and were at 24 hour readiness. In the case of an alarm they shall begin tasks within 15 minutes. The bases have been selected in order to provide sufficient surface cover for maritime rescue work along the Swedish coastline.

Agreement between Sjöfartsverket (the Swedish Maritime Administration) and Luftfartstyrelsen (the Swedish Civil Aviation Authority)

On 13 February 2006 an agreement (SjöV dnr. 1104-06-01312) was signed between Sjöfartsverket (the Swedish Maritime Administration) and the then Luftfartsstyrelsen (the Swedish Civil Aviation Authority, now the Swedish Transport Agency Aviation Department) concerning helicopter services for rescue missions. The purpose was to meet the needs of the Swedish Civil

[7] RITS – Räddnings Insats Till Sjöss - Maritime Rescue Team
[8] IMC – Instrumental Meteorological Conditions

Aviation Authority for aviation rescue tasks across the whole country and to regulate the finances for this. Training and practicing for these tasks would according to the agreement be implemented to such an extent as the Swedish Civil Aviation Authority found justified.

It was specifically stated in the agreement that such tasking would not however affect the availability, surface cover and operational ability of the SAR helicopters in respect of the maritime rescue needs of the Swedish Maritime Administration.

Airborne ambulance health care
Airborne ambulance services are provided by county council ambulance helicopters, ambulance aircraft, and Svenska nationella ambulansflyget (SNAM – the Swedish National Air Medevac); and the health care that is provided in certain circumstances by SAR helicopters hired by the Swedish Maritime Administration, or helicopters or aircraft from the Swedish Armed Forces.

On behalf of the main health care provider, the county councils, ambulance health care and helicopter ambulance transport are provided by Helicopter Emergency Medical Service (HEMS) which is operated by various private aviation companies. These operations are carried out by smaller twin-engined helicopters that are equipped for operation in darkness and IMC.

The HEMS helicopters are also specially equipped in order to provide various types of advanced health care for one or two recumbent patients while in flight. In addition to one or two pilots, the crew normally includes medical personnel. These helicopters do not have permanently installed equipment to locate the positions of emergency transmitting beacons.

HEMS helicopters are based at Gällivare, Lycksele, Östersund, Uppsala, Stockholm, Gothenburg and Visby.

Government study of the use of helicopter resources
The Swedish government decided on 28 June 2007 to initiate a study of the use by the public sector of national helicopter resources. The results of the study were published on 15 December 2008 in a report “The helicopter in the service of society”, SOU 2008:129.

The task of the helicopter study was to review how the use by the public sector of helicopter services could be made more efficient. The aim was to see if such methods as increased joint utilisation and localisation would enable efficiency and rationalisation effects to be achieved.

The study found that there was a potential to co-ordinate public helicopter services to a greater extent, and determined that:

- Police aviation resources did not have a clearly defined mission and had a somewhat divided operational task.
- SAR helicopters had the potential for use in, among other things, more types of rescue service tasks.
- The whole airborne ambulance health care system, including ambulance helicopters (HEMS), ambulance aircraft and the Swedish National Air Medevac (SNAM) were not closely integrated.
- There was no co-operation in the negotiations for other uses of helicopter services.

The helicopter study proposed increased co-operation, both within and between various aviation systems. Cross-sector co-ordination was proposed in order to increase joint utilisation of different resources, and pooling of such aspects as infrastructure and systems for operational co-ordination. In addition structures were proposed for increased Nordic co-operation within different areas.

The SHK investigation on a SAR mission at a maritime accident

In connection with the investigation on a maritime accident on 1 November 2006 involving the vessel Finnbirch, SHK examined the rescue mission, including the SAR operations that were involved. The results were reported in the SHK final report, RS 2008:03.

In respect of the SAR operations, the report issued the following recommendations:

SHK recommends that the Swedish Maritime Administration:

- clarify, in consultation with the Swedish Civil Aviation Authority, the requirements for weather and other conditions under which off-shore SAR operations should or should not be performed, *(RS 2008:03 R12), and*

- ensure that changes in SAR activity are analysed and that the risks they involve are evaluated and that measures are taken to reduce any such risks identified *(RS 2008:03 R13).*

SHK recommend that the Civil Aviation Authority

- develop a national code of rules for requirements relating to and monitoring SAR activity *(RS 2008:03 R14).*

1.16 Tests and research

1.16.1 Technical examination of the helicopter

The helicopter was retrieved from the accident site and taken to a hangar for detailed examination. There a technical examination of the helicopter was carried out, including the affected systems, by the SHK technical expert, with the participation of representatives of the helicopter manufacturer, engine manufacturer and a maintenance facility.

Apart from the engine problem described below, no other fault or abnormality was discovered that could have had any important effect on the accident. All other damage to the helicopter had occurred in connection with the ground impact.

1.16.2 Preliminary fault tracing in the engine

The engine, which appeared externally to be intact, was removed from the helicopter. During removal it was noted that the compressor and turbine could be rotated freely in relation to each other. After the compressor had been removed from the gearbox it was found that the Splined Adapter had fractured, so that the drive line between the turbine and compressor was broken.

1.16.3 Fault tracing of the engine in a workshop

The engine was taken to an authorised aircraft engine workshop for further examination. While the engine was being dismantled it was noted that two studs for securing the connection between the compressor and the gearbox were loose. They could move some tenths of a millimetre axially, and it was possible to turn them by hand. These studs should normally be anchored permanently in the gearbox housing.

The stud connection consists of a total of five threaded studs and nuts. The loose studs were located beside each other on the same side of the gearbox. (See the illustration below.)

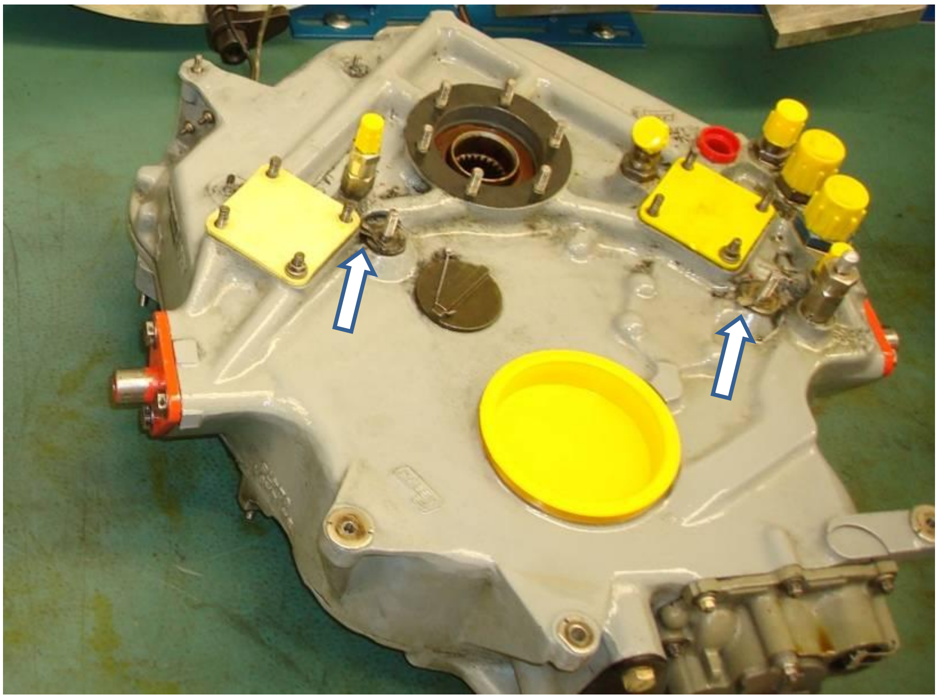

Figure 6. Loose studs in the bolted connection

Otherwise the engine was in a normal condition considering the respective running times of the modules. Apart from the fractured Splined Adapter and the local resultant damage that this had caused to the inner diameter of the impeller, no faults or abnormalities were found.

1.16.4 Metallurgical investigations

On behalf of SHK the Splined Adapter, Impeller and Gearbox Housing, underwent a metallurgical examination. The result of the examination has been presented in a report, Exova TEK09-0318.

Splined Adapter
The adapter has a circumferential fracture at the centre of its cylindrical section. At the point where the fracture occurred the internal splines begin, where the spur adapter gear shaft shall engage. The fracture is partly just inside and partly just outside the ends of the splines. The fracture surfaces has secondary damage that arose when one half rotated on the inside of the impeller. See the photograph below.

Figure 7. Fractured Splined Adapter

The fracture surface has the typical appearance of fatigue. On one half there is an area, which was probably the starting point, which had no secondary damage. The fracture has originated from the outside of the cylindrical part of the adapter. During growth the crack has propagated from the outside and in towards the tops of the splines on the inside, while growing circumferentially.

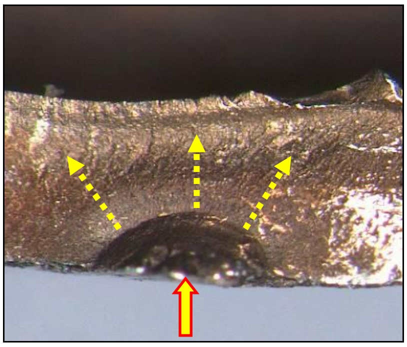

Figure 8. Crack initiation

Figure 9. Crack growth

At the initiation area on the cylindrical part of the adapter there are two areas of fretting damage, and the crack started from one of these.

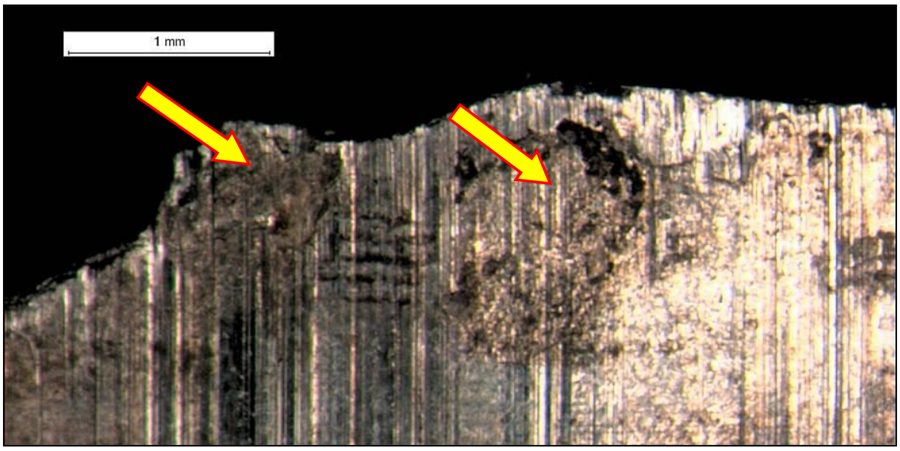

Figure 10. Fretting damage on the cylindrical part

Impeller

On the inner diameter of the impeller secondary damage has occurred as a result of the rotation of one of the broken adapter halves.

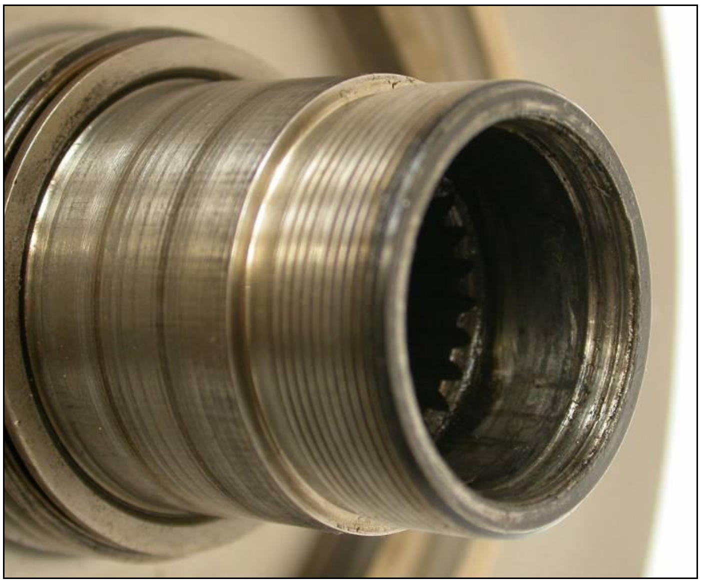

Figure 11. Secondary damage to the impeller

Gearbox Housing

Two of the gearbox housing studs could be unscrewed without using a tool. The damage to the securing threads shows that the studs had moved inside the threaded holes in the gearbox housing.

Figure 12. Loose stud

Figure 13. Worn securing threads

On one of the studs part of the thread had detached from the gearbox housing and become trapped in the stud thread.

A visual check of the stud fastenings in the gearbox housing is performed during the normal 100 hours inspection. It has not been possible to determine when the studs came loose.

1.16.5 Engine maintenance status

As mentioned above, the engine consists of a number of modules with individual running times and running time limits.

The gearbox has no running time limit, i.e. is subjected to “on condition” maintenance.

The compressor inspection interval is 3,500 hours. This particular compressor, S/N CAC-23879, was installed into the engine, S/N CAE-830672, on 30 September 2008. At the time of installation the compressor had accumulated a total of 1,447 hours. Since installation it had run a further 237 hours, so that at the time of the accident it had reached a running time of 1,684 hours.

1.16.6 *The most recent workshop maintenance on the compressor*

Before installation into the engine, the compressor had been repaired by an authorised aircraft engine workshop due to internal damage. During this repair, which was approved on 24 September 2008, the compressor had been dismantled and the damaged parts repaired or exchanged.

According to the compressor module documentation, modification in accordance with CEB A-1392 Rev. 2 had been implemented earlier, and was not ordered by the customer.

The introduction to CEB A-1392 Rev. 2 states: *"If you have complied with the previous issue of this bulletin, no additional work is required."* which was understood by the maintenance facility as meaning that the Splined Adapter P/N 23076559-1 could be refitted after inspection.

During the inspection in accordance with the applicable Overhaul Manual (OM), the Splined Adapter P/N 23076559-1 met the specified requirements and was refitted to the compressor.

In another place in CEB A-1392 Rev. 2 the same requirement is stated for the replacement of the Splined Adapter by an adapter with the next highest dash number as applies in CEB A-1392 Rev. 3 (see Section 1.6.6).

1.17 The company's organisation and management

The aircraft operating company has its headquarters in Stockholm and performs aerial work with three single-engined Hughes 369 and Hughes 329 helicopters. The company has its operating bases at Särna and Borlänge.

The technical responsibility and technical maintenance have been delegated to an approved Part-145 aircraft workshop with authorisation to carry out continuous airworthiness, a Continuous Airworthiness Management Organization (CAMO). The main workshop base is at Borlänge, with detatchments at Västerås and Arvidsjaur.

1.18 Miscellaneous

1.18.1 *Helicopter SE-JKD engine stoppage*

On 8 August 2009, just over a month after this accident, a Bell 206B helicopter registered SE-JKD suffered an engine stoppage during an aerial work in Sweden. The pilot managed to land the helicopter without any damage being caused.

On examination of the helicopter engine, a Rolls-Royce type 250-C20B, it was found that the Splined Adapter had fractured due to metal fatigue. The adapter, P/N 23039791-1-E, was of the silver-plated type and had been installed in the same compressor since 23 June 1998. By that time the compressor had accumulated a total of 2,928 hours since inspection.

The adapter from SE-JKD, with S/N 86008 and manufactured by Rolls-Royce, has on behalf of SHK undergone the same metallurgical examination as the adapter from the accident helicopter, SE-JBU.

1.18.2 Measures carried out by the inspection authority

At a special meeting, SHK informed the Swedish Transport Agency about the two engine failures that had occurred as a result of the same type of adapter fracture within the space of just over a month. SHK has also informed about the results of the metallurgical examinations that had been performed.

The Swedish Transport Agency had thereafter, via several contacts with the European Aviation Safety Agency (EASA) and the engine manufacturer, Rolls-Royce, discussed the need for possible supplementary regulatory measures concerning the Splined Adapter in order to assure the flight safety of the actual types of aircraft.

As a result of these contacts, and with information from this investigation, EASA published on 27 January 2010 a Safety Information Bulletin (SIB) 2010-01, which among other things drew the attention of operators to the need to implement the previously issued AD 2004-26-09 and CEB-A-1392.

In a revised bulletin, SIB 2010-01R, which was published on 5 February 2010, EASA clarified that re-installation of a used Splined Adapter was not permitted in accordance with CEB-A-1392.

The Swedish Transport Agency, in a memorandum to EASA dated 17 February 2011, pointed out the risk that older types of Splined Adapters, or those not correctly replaced, despite taking the above-mentioned measures, could still be in operation.

1.18.3 Correspondence with the engine manufacturer

SHK has been in contact with Rolls-Royce several times in connection with this investigation. Damaged material from both helicopters SE-JBU and SE-JKD had undergone metallurgical examination also by Rolls-Royce.

The results from the Rolls-Royce examinations match very well the results from the examinations carried out on behalf of SHK. Rolls-Royce has also concluded that the fractures in the Splined Adapters had in both cases been caused by fatigue cracks that originated from fretting damage to the external diameters of the adapters.

Below is a summary of the Rolls-Royce comments in respect of this particular issue, and a general description of the problem:

- This particular fracture is the first that had occurred to a silver-plated Splined Adapter.
- Since the two adapter fractures that occurred in Sweden in the summer of 2009, no further adapter fractures have been reported to Rolls-Royce.
- A risk of fretting arises when a Splined Adapter is detached from the compressor and then refitted (“broken joint”). Internal fretting damage may then take place in other positions in the coupling, which can cause accelerated fretting. This is the case despite all the fitting measurements being within the applicable tolerances.
- The latest version of the Splined Adapter, P/N 23079637, has a looser fit to the impeller and more oil channels for better lubrication and cooling. The modification therefore requires a modified impeller.

- No further modification of the Splined Adapter is planned.
- Loose studs in the gearbox are not assessed as increasing the risk of fretting and fatigue fracture in the Splined Adapter.
- Apart from the current running time limitation on Splined Adapters of the earlier design, expiring in March 2012, at present there are no plans for new limitations or other measures.

Apart from the events that are dealt with in this investigation, the manufacturer has stated that they are not aware of any other cases where a silver-plated Splined Adapter of type Rolls-Royce P/N 23076559 or Rolls-Royce P/N 23079637, have fractured during operation. It is not known how many adapters of earlier design are still in use.

On 15 August 2010 Rolls-Royce published a revision of the Overhaul Manual (OM). In this revised edition the manufacturer has removed an instruction for the inspection and refitting of the Splined Adapter and instead prescribed that the refitting of a used Splined Adapter is not permitted, by means of the text: *"Replace the adapter coupling ref. Fig 319"* and in another place with the text: *"ONCE REMOVED, THE SPLINE ADAPTER MUST BE DISCARDED"*.

1.18.4 *The auto-rotation characteristics of the helicopter type*

When flying at a sufficient speed or at a sufficient altitude the pilot, in the case of a sudden loss of engine power, is able to establish a controlled auto-rotation and perform an emergency landing of the helicopter. In the diagram below, taken from the flight manual for the helicopter, the manufacturer has indicated the speed and altitude ranges within which establishment of controlled auto-rotation is difficult or impossible, so that flying within these ranges should be avoided.

A circle has been drawn on the diagram to show the approximate flying situation when the engine stoppage occurred.

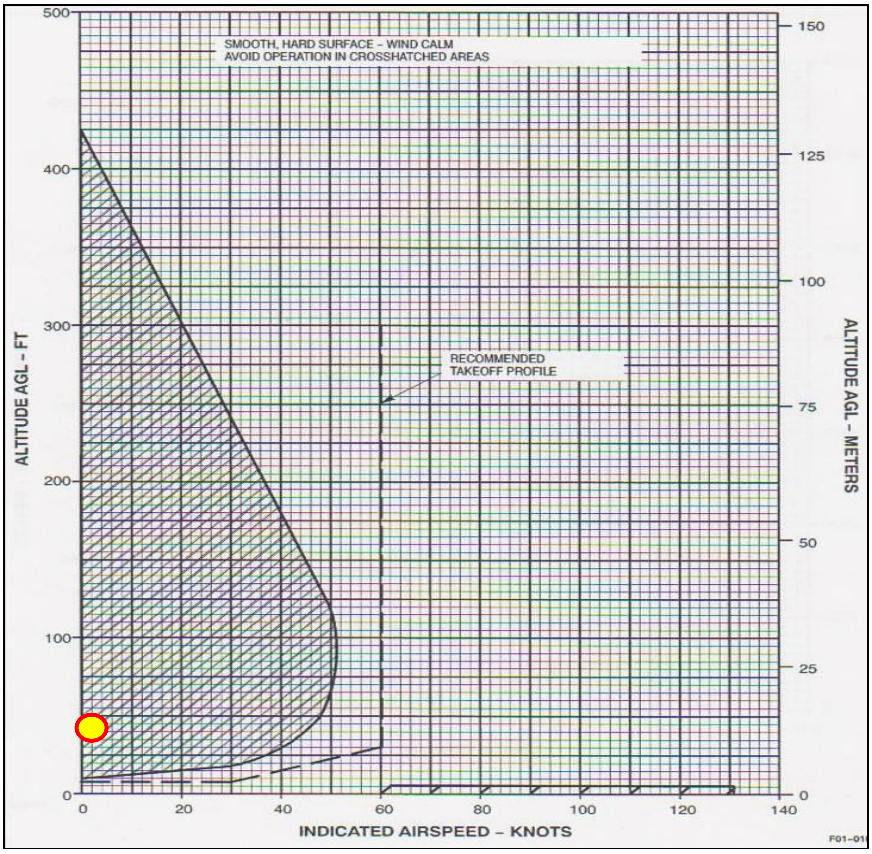

Figure 14. Speed/altitude diagram showing the recommended flight range

1.18.5 *Environmental aspects*

The accident did not have any consequences from the environmental point of view.

1.18.6 *Equal opportunities aspects*

Not applicable.

2 ANALYSIS

2.1 The accident

Reindeer herding with a helicopter is naturally performed to a large extent at low speed and low altitude. This means that the helicopter is often operated within a altitude/speed range where the chances of the pilot, in the case of a sudden loss of engine power, being able to establish auto-rotation and perform a controlled emergency landing are small or impossible, unless there is a certain amount of wind.

In this particular case the wind speed was low and the helicopter was flying at low speed, just over ten metres above the ground. This means that it was being operated deep within the critical altitude/speed range, according to the diagram in Section 1.18.4, where flying should be avoided.

The engine stoppage, which occurred completely without forewarning, therefore placed the pilot in a critical situation where his possibility of carrying out a controlled emergency landing was small.

The pilot concentrated on maintaining the horizontal position of the helicopter, which probably contributed to the fact that it impacted with its landing skids first. The springing of the landing skids and their deformation therefore softened the impact, although it was hard despite this.

There is much evidence that the main rotor speed reduced rapidly when the engine stopped, and the pilot maintained the collective pitch. This can explain why he did not notice any great reduction in the descent rate when he applied full collective just before impacting the ground. There was hardly any chance of the pilot choosing a landing location and it was pure luck that the ground consisted of flat and soft mossy soil without projecting obstacles.

2.2 The engine stoppage

If the Splined Adapter fractures during flight the engine compressor loses its drive. The engine thereby immediately loses all its power and stops. This fault is particularly serious since such an engine stoppage takes place without any forewarning to the pilot in the form of, for example, vibration or unusual noise.

Since the adapter is built into the engine, which is not taken apart during normal inspections, is it not possible for technicians to detect in time any cracks in the Splined Adapter that could grow to cause a fracture.

2.3 Splined Adapter

There is no doubt that the Splined Adapter as a part of the drive line between the turbine and compressor is a weak link in the design of the Rolls-Royce engine type 250-C20B. A large number of engine failures have occurred as a result of the adapter breaking. Some of these have resulted in serious accidents, some of them with fatal consequences.

The background to the problem is that during operation there can occur a small relative movement (chafing) between the outer contact surface of the adapter and the opposing inner diameter of the impeller, which can damage the protective oil film and allow metal-to-metal contact. In this way mechanical abrasion can take place between the surfaces, which can lead to fretting damage.

Fretting damage is the classic initiation point for fatigue cracks in parts that are exposed to oscillating loads in an unfavourable loading spectrum. In this respect the high operating speed of the engine is of great importance.

The inspection authority and the manufacturer have taken notice of this weakness and published several maintenance directives along with modified Splined Adapters and adjacent components in various stages with the intention of solving the problem. An important link in this has been the introduction of a new type of silver-plated adapter that is considered to have greater resistance to fretting.

The fracture of the Splined Adapter mentioned in this investigation shows that the problem remains, even though the situation has probably improved.

Earlier design

The engine stoppage on helicopter SE-JKD was caused by a fracture of the early design of the splined adapter, P/N 2303971, which was not silver-plated. According to the applicable regulations there is nothing to prevent this type of adapter remaining in service until March 2012.

Although it is certainly prescribed that the adapter must be changed if the compressor is dismantled for any reason, that is something that depends on completely different factors than the condition of the adapter itself.

This “liberal” replacement requirement means that a large and unknown number of engines remain in service with Splined Adapters that are not silver-plated and hence more exposed to fretting with thereby an increased risk of fatigue fracture.

Considering the serious flight safety risks posed by such adapter fractures, it is the opinion of SHK that there is a reason for the inspection authorities and manufacturer to prescribe strict measures that will lead to the phasing out of early design Splined Adapters much sooner than March 2012.

Silver-plated design

The engine stoppage on the accident helicopter SE-JBU was caused by a fracture of the silver-plated version of the Splined Adapter, P/N 23076559. Even though this was the first reported fracture of a silver-plated adapter, this event implies that further measures may be necessary before a final solution is achieved.

A possible explanation for the adapter fracture could be that the adapter, in connection with the repair of the compressor on 30 September 2008, was refitted to the impeller. Certainly all the dimensional requirements were met, but according to the manufacturer there is a risk that refitting an already “worn” adapter can increase the risk of fretting damage unless it fits into exactly the same position in the impeller as it was before.

The requirement, in accordance with the directive CEB A-1392 Rev. 2, at each dismantling of the compressor to change the Splined Adapter to a new one with a higher dash number, regardless of whether the applicable measurement tolerances were met, was misunderstood by the maintenance facility and the applicable regulations were therefore not entirely complied with, according to the opinion of SHK.

SHK finds however that this directive is unclear, and considers that it is positive that EASA and the engine manufacturer, after this accident, in a revised SIB-2010-01R1 and by supplementation of the OM in this respect, has reduced the risk that this specific instruction will be misunderstood in future.

Another explanation why fretting damage arose on the Splined Adapter could have been that the compressor and gearbox were not precisely aligned. The slightest misalignment between the centrelines of the impeller and the Splined Adapter means that some, even if small, “chafing” between the contact surfaces takes place at every rotation. The high rotation speed means that even the smallest amount of relative movement can be damaging.

The strict need for drive line alignment is probably one reason for the manufacturer’s requirement to use measured shims when assembling the compressor to the gearbox.

During dismantling of this particular engine it was found that two of the studs on the same side of the gearbox housing were loose and could move axially. This could have meant that the stud and nut joint had some play on one side, so that there could arise a slight angle between the contact surfaces of the compressor and gearbox, and thereby also between their common centrelines for the drive shaft.

Apart from a visual check of the nuts and studs in their installed state, there is no requirement to check the fasteners in the gearbox. How long the engine in this case operated with loose studs is not known. It is the opinion of SHK that this could however have been long enough to create a non-linearity of the drive line that contributed to fretting damage occurring on the Splined Adapter.

It is difficult for SHK to understand the engine manufacturer’s assessment that loose studs do not increase the risk of fretting damage to the Splined Adapter, taking into account the major demands that are set on the linearity of the drive shaft. There is therefore a need to take a closer look at this connection, and the possible need to take measures to eliminate such a risk.

2.4 Search, localisation and rescue

The alarms

The telephone call made by the pilot to the SOS centre and the aeronatical rescue leader at the JRCC, after he had raised the accident alarm via the 112 number, was quite long. It was only at a later stage in the call that the location of the accident site was given. The alarms to the rescue services were thereby somewhat delayed. One possibility that could be used in similar situations, in order to reduce the time period for rescue actions to begin, is to introduce a preliminary alarm, which is used by certain rescue services. In the case of a preliminary alarm, the resources concerned are given the alarm before the exact location of an accident site has been determined. A preliminary alarm is considered in this case not to have been particularly important to the sequence of events, among other things taking into account the distance and transport time.

In accordance with the national rescue services tasking, the aeronautical rescue leader concentrated on his main task, which was to search for and locate the exact accident site. Once it had been found that the ambulance helicopter at Östersund was not available, the SAR helicopter at Sundsvall was engaged for this task.

According to the Swedish Maritime Administration this type of helicopter is normally capable of transporting two recumbent patients. This assumes that only one stretcher is used and that the other recumbent patient is placed on some other type of equipment that permits a soft, horizontal reclining position, such as a vacuum stretcher.

While waiting for the SAR helicopter and the ground-based resources from the municipal rescue services to reach the accident site, the JRCC requisitioned another helicopter that happened to be near to the accident site. Thanks to transportation assistance from this, the medical personnel were relatively quick taken to the accident site and could begin treatment.

The possibility of requisitioning helicopter resources from Norway was not examined. Contributory to this could have been the relatively minor injuries of those who had been on board the accident helicopter.

The operation
When the rescue and medical units reached the accident site a preliminary medical assessment was carried out. Then remained the question of transport of the injured people to hospital.

The mountain rescue services cover all rescue of human life within the defined mountainous area, which means that the police authorities shall take over the responsibility for the rescue services when a crashed aircraft has been located within such an area. A rescue mission of that type can in certain circumstances also include medical transport of injured people, whilst the principal responsibility for medical transport is borne by the county council, regardless of what type of transport is used.

A request was forwarded from the rescue leader at JRCC that the rescue efforts should transition to mountain rescue once the exact accident site had been pinpointed by the first rescue unit to reach the scene. The police authority declined to take over the leadership of the efforts in the form of mountain rescue, in accordance with this JRCC request.

The SHK investigation shows that the involved rescue organisations need more knowledge in order to achieve a joint understanding of the areas of responsibility that apply for rescue services and medical transport in mountainous areas, in accordance with current legislation.

Apart from this need for more knowledge by the involved rescue organisations, there is in this respect also a need to find a formulation for increased co-operation, joint utilisation of resources and co-operation in accordance with the proposals laid out in the report “The helicopter in the service of society”, SOU 2008:129, where increased Nordic co-operation within this area is also recommended.

In this context it should be borne in mind that a possible aircraft accident in a mountainous area could very well involve many more people than in this case.

In this particular case it is however difficult to see how the mountain rescue organisation and resources could have been more appropriate than those which were used to rescue the injured. Once the exact location of the accident site was known, the police authority had at the same time the formal responsibility according to the LSO (the Swedish Accident Prevention Act), but in practice had no influence on the management of the continued efforts.

The need for mountain rescue and management by the police authority can be considered to have been of limited extent in this case. According to SHK it is, however, important that even limited rescue efforts are carried out in accordance with the tasking that follows from the applicable legislation and in accordance with the procedures that are known to the co-operating authorities. This is particularly motivated by the fact that more extensive rescue operations require clear agreement and practised co-operative procedures in accordance with the applicable regulations.

Transportation of the injured

The injured pilot and the assistant were treated at the accident site by qualified medical personnel. Considering the descriptions by the injured of their back and back and neck pains respectively, SHK believes that immobilisation by neck collars and vacuum mattresses was adequate. This immobilisation however meant that the injured had to be transported lying down.

When the medical personnel received the message that the SAR helicopter could not transport two recumbent patients on stretchers, it was relevant to assign priority to the assistant for helicopter transport to hospital, taking into account his neck symptoms.

Because the SAR helicopter did not have the capacity to perform a short additional flight to a driveable road either, the injured pilot was first forced to be transported on a stretcher in a tracked vehicle, and subsequently driven for approximately 200 km in a road ambulance. For him this was a painful journey that lasted about four hours.

Optimal pre-hospital handling of injured people at an accident site involves, as well as adequate medical treatment, transport to a suitable care facility in a safe, comfortable and rapid way so that the condition of the patient is not made worse by the method of transport.

Transport of an injured person in a tracked vehicle does not meet these criteria and is therefore not an optimal transportation alternative. A tracked vehicle can only be considered when any better transport alternative cannot be found.

Considering that the SAR helicopters form a resource to perform medical transport in both air and sea rescue missions, SHK considers that the transport of only one patient in the SAR helicopter as in this case was not an optimal use of the resource from a medical point of view.

The pilot suffered from back pain for several weeks after the accident. This pain began in connection with the accident, but became worse significantly during the transportation in the tracked vehicle. It cannot be excluded that this transport was a contributory factor to the long term pain problem.

It cannot however be confirmed that the transport of the pilot in the tracked vehicle had a long term effect on his health. In a more serious injury scenario, however, this long and painful method of transport could have resulted in serious medical consequences.

The SAR helicopter operational time and load capacity

The accident took place in a relatively impenetrable mountain area. Since the personal injuries had initially not been medically assessed and were therefore undefined, and the usual HEMS helicopter was not available, it was reasonable to call in the SAR helicopter from Sundsvall to locate the accident site and also to transport the injured persons. A comparison can be made with the possibility that exists within the maritime rescue services of using a SAR helicopter for ambulance transport from vessels, which is also established.

The fact that the SAR helicopter base was at the coast meant that its flight to the accident site in the Idre mountains took just under an hour. The planned ambulance flight from the accident site to Mora hospital was calculated as about one hour of flying time and there was no known refuelling capability along the route.

The operational time in normal SAR configuration and with normal fuel reserve is a little more than 2,6 flying hours depending on flying speed. Since the helicopter consumed more fuel during hovering at the accident site than when flying at cruising speed, its available operating time at the site was in this case less than half an hour.

Even if the helicopter is able to meet the applicable Swedish Maritime Administration requirement specification in respect of operating time, SHK establish that in this case the performance was too limited to implement the task. In the judgement of the commander the available fuel amount did not suffice to first perform a brief extra flight to take one of the patients to a driveable road before transporting the second patient away. The consequences of this have been discussed above.

In worse weather conditions than were the case, there would have been a greater requirement for fuel margins, which would probably have meant that this particular rescue task could not have been carried out at all, without supplementary refuelling during the task.

SAR helicopters are expected, from their bases along the coasts of Sweden, to be able to carry out specialised search and rescue missions within more or less the entire Swedish FIR. This means that outward and return flying times in certain cases could together amount to periods of up to two hours. The remaining operational time for the helicopter to perform search and rescue on site thus becomes barely half an hour, which must be considered as a limitation

It addition, it is clear that both the Swedish Maritime Administration and JRCC believe that SAR helicopters should be able and have space to transport two patients on stretchers. When necessary, one of these stretchers could consist of some kind of equipment which permits a soft, horizontal lying position, such as a vacuum stretcher.

When there was an obvious need for two stretcher places, in this particular rescue mission, the possibility of using a vacuum stretcher, for example, for some reason never came into question. The commander understood that one of the patients would lie on an ALFA stretcher that he considered could not be safely secured during flight. The possibility of using the specially adapted and folding additional stretcher was not considered either, which leads to the conclusion that it was not on board.

Even if there was a misunderstanding, that could have occurred in the communication between the medical personnel and the commander, since this took place by radio via the winchman, it was shown that the SAR helicopter in this case was not capable of meeting the requirement specification of being able to transport two recumbent patients on stretchers.

SHK considers that there is good reason for the Swedish Maritime Administration to define more clearly the meaning of the current requirement for two stretcher places, when the specially made folding stretcher must be carried, etc., so that the JRCC understanding of the SAR helicopter capacity in this respect agrees with reality.

Altogether the analysis of these events indicates that the current requirement specification for SAR operations, in respect of operational times and load capacity, are too limited, based on the realistic needs which can arise. Bearing in mind the large land and sea areas over which SAR helicopters are expected to be able to operate, and the different needs for space and load capacity which can arise, there are reasons for the Transport Agency to set national regulations for requirements and supervision of the operators who perform SAR flights in accordance with the previous SHK recommendation, RS 2008:03 R14. In this context, raising the requirements in general for SAR operational capabilities should also be considered.

3 CONCLUSIONS

3.1 Findings

a) The pilot was qualified to perform the flight.
b) The helicopter had a valid Airworthiness Review Certificate (ARC).
c) The engine stoppage occurred while the helicopter was being operated within a range of speed and altitude that should be avoided, and within which the loss of the engine normally means that it is not possible to establish controlled auto-rotation and perform a safe emergency landing.
d) Apart from what is prescribed by CEB A-1392 Rev. 2, the helicopter had been maintained in accordance with the applicable regulations.
e) The Splined Adapter fractured during flight as the result of a fatigue crack.
f) A fatigue crack had been initiated by fretting damage on the outside of the adapter.
g) It is not possible to check the condition of the Splined Adapter in service without dismantling the engine.
h) In the case of the most recent attention to the compressor the Splined Adapter was not replaced by an adapter with the next higher dash number in accordance with the CEB A-1392 Rev. 2 regulations.
i) The regulations in CEB A 1392 is unclear and can be misunderstood
j) It has not been possible to find a definitive explanation for the fracture of the particular Splined Adapter which was of later and silver-plated design.
k) An unknown number of Splined Adapters of earlier design, which are more prone to fatigue fractures than later designs, are still in use.
l) Phasing out of earlier designs of Splined Adapters before March 2012 is taking place based on other random factors than the true condition of the adapters.
m) It is the opinion of SHK that loose studs in the stud and nut coupling between the compressor and the gearbox increases the risk of fretting damage to the Splined Adapter.
n) After this accident, EASA and Rolls-Royce have revised SIB-2010-01R1 and supplemented the OM respectively, in respect of changing the Splined Adapter.
o) The Splined Adapter has caused many engine stoppages and in the opinion of SHK, despite measures taken by the engine manufacturer and the supervisory authorities, remains a weak component in the design of the engine.
p) During the rescue mission the police authority did not act in accordance with the tasking for mountain rescue services.

q) The SAR helicopter had only sufficient capacity to transport one of the injured to hospital.

r) There is a need to expand the current operational requirements in respect of the operational time and load capacity of SAR helicopters.

3.2 Cause of the accident

The accident was caused by the measures taken to eliminate the risk of Splined Adapter fatigue fracture being inadequate.

4 RECOMMENDATIONS

It is recommended that the EASA and the Swedish Transport Agency:

- prescribe measures that would lead to phasing out of Splined Adapters of the earlier design sooner than March 2012 *(RL 2011:03 R1),* and to
- ensure that the engine manufacturer investigates the risk that fretting damage and fatigue fractures on Splined Adapters could be caused by non-linearity in the engine drive shaft line as a result of loose studs in the stud and nut coupling between the compressor and the gearbox, and if this is so, to initiate the necessary maintenance measures in order to eliminate such a risk *(RL 2011:03 R2).*

It is recommended that the Swedish Civil Contingencies Agency (MSB):

- in co-operation with Transportstyrelsen (the Swedish Transport Agency), Sjöfartsverket (the Swedish Maritime Administration), Rikspolisstyrelsen (the Swedish National Police Board) and Socialstyrelsen (the Swedish National Board of Health and Welfare) ensures that the search and rescue services and the mountain rescue services are co-ordinated for efficient rescue missions in case of aircraft accidents in mountainous areas where there may be a need for medical transport *(RL 2011:03 R3).*

It is recommended that the Swedish Transport Agency:

- in connection with the preparation of a national set of regulations for requirements and supervision procedures of SAR operations, in accordance with the SHK recommendation *(RS 2008:03 R14)*, in co-operation with Sjöfartsverket (the Swedish Maritime Administration),considers the need to generally expand the requirements concerning the operational capability of SAR operations *(RL 2011:03 R4).*