Statens haverikommission
Swedish Accident Investigation Board

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Report RL 2005:13e

Helicopter accident to SE-HSI at Linetjåkke, NV Ammarnäs, AC County, Sweden, on 4 August 2004

Case L-28/04

SHK investigates accidents and incidents with regard to safety. The objective of the investigations is the prevention of similar occurrences in the future. It is not the purpose of this activity to apportion blame or liability.

The report is also available on our website: www.havkom.se.

Translated by Tim Crosfield, M.A., from the original Swedish at the request of the Swedish Accident Investigation Board.

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

Statens haverikommission (SHK) Swedish Accident Investigation Board

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2005-04-14 L-28/04

Swedish Civil Aviation Authority

SE-601 73 NORRKÖPING

Sweden

Report RL 2005:13e

The Swedish Accident Investigation Board (Statens haverikommission, SHK) has investigated an accident that occurred on 4 July 2004 at Linetjåkke, NV Ammarnäs, AC County, Sweden, involving a helicopter with registration SE-HSI.

In accordance with section 14 of the Ordinance on the Investigation of Accidents (1990:717) the Board herewith submits a report on its investigation.

The Board will be grateful to receive, by 14 October 2005 at the latest, particulars of how the recommendations included in this report are being followed up.

Carin Hellner

Sakari Havbrandt Henrik Elinder

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Case L-28/04
Report finalised 14-04-2005

Aircraft: registration, type	SE-HSI, Hughes 369 D
Class, airworthiness	Normal, regarding certificate of airworthiness
Owner/operator	Fjällflygarna i Arjeplog AB
Time of event	04-08-2004 14.00 hrs in daylight. *Note.:* All times are given in Swedish daylight saving time (UTC + 2 hours)
Place	Linetjåkke, NV Ammarnäs, AC County, Sweden (pos. 6610N 01533E; approx 800 m above sea level)
Type of flight	Commercial air transport
Weather	According to SMHI analysis: wind SW/5-10 knots, CAVOK[1], temp./dew point +18/+10°C, QNH 1020hPa
Persons on board:	
crew members	1
passengers	4
Injuries to persons	Slight
Damage to helicopter	Extensive
Other damage	No
Pilot: Sex, age, licence	Man, 41 years, CPL(H)
Total flying time	3 540 hours, of which 8 on type
Flying hours, latest 90 days	50, of which 8 on type
Number of landings, previous 90 days	124, of which 60 on type

The Swedish Accident Investigation Board (SHK) was informed on 4 August 2004 that an accident involving a helicopter with registration SE-HSI had occurred at Linetjåkke, NV Ammarnäs, AC county, on that day at 14.00 hrs.

The accident has been investigated by SHK represented by Olle Lundström, chairman until 15 August 2004, subsequently Carin Hellner; Mats Öfverstedt, chief operational investigator until 14 February 2005, subsequently Sakari Havbrandt; and Henrik Elinder, chief technical investigator.

SHK was assisted by Sven Holmberg as operational expert.

The investigation was followed by the Civil Aviation Authority in the person of Magnus Axelsson.

Summary

The pilot took off with his helicopter with four passengers on board. Approximately half a minute after takeoff he thought that increasing force was needed to keep the helicopter neutral in the roll plane. He attempted to deal with the problem by, among other things, operating the trim control on the cyclic stick, but the force grew greater and greater.

After a minute or so the force to the left had become so great that the pilot was obliged to support with his left hand and left knee to keep the heli-

[1] CAVOK –Visibility > 10 km, no clouds below 5000 feet

copter in normal flying attitude, and he determined to land at the first possible site. The difficulty in manoeuvring the helicopter became so great that he had to abort the first attempt to land. On the second attempt the helicopter struck the ground hard and turned over.

The technical investigation after the accident showed that the lateral trim system was trimmed to its left stop position. Filings of a material resembling silver were found in the trim switch and the trim actuator gearbox in the lateral system was heavily worn.

SHK notes in the investigation that, among other things, design regulations in force for light and heavy helicopters lack limit values for maximum permitted cyclic stick- and pedal forces.

The accident was caused by a technical fault in the helicopter's lateral trim system that resulted in its becoming uncontrollable, successively working to its left stop position. Contributing to this was the fact that the trim system is designed to give cyclic stick forces of almost 14 kp.

Recommendations

The Civil Aviation Authority is recommended:

- to prescribe where necessary for the helicopter type in question and for other types where the trim system can create a flight safety risk, restrictions on operating time for constituent components, and to prescribe that functional checks of the trim system shall be carried out under load *(RL 2005:13e R1)* and

- in cooperation with international civil aviation authorities to seek to ensure that maximum permitted cyclic stick and pedal forces are also introduced into the design regulations for small and large helicopters. *(RL 2005:13e R2)*.

1 FACTUAL INFORMATION

1.1 History of the flight

The pilot was to transport four passengers and their luggage by helicopter from Ältsvattnet to Ammarnäs. The flight to Ältsvattnet and the landing there were without problem and the helicopter took off as soon as the passengers had been taken on board.
Approximately half a minute after takeoff as the helicopter was climbing to operating height, the pilot thought that increasing force was needed to keep the helicopter neutral in the roll plane. It felt to him as if the cyclic stick started to "pull to the left". He attempted to deal with the problem by, among other things, using the four-way trim switch on the cyclic stick, but the force in the cyclic stick became greater and greater.

After a minute or so the force to the left had become so great that the pilot was obliged to use his left hand and knee to keep the helicopter in its normal flight attitude. He informed his passengers that he was having problems controlling the helicopter and intended to land at the first possible site.

Using both hands he approached a flat and open area of fell and planned to land there. While hovering, when he had to release the cyclic stick with his left hand to take hold of the collective stick the helicopter rolled to the left so violently that he aborted the landing.

He thought the cyclic force to the left was very strong and that it was clearly difficult to manoeuvre the helicopter. He then made a second attempt to land a few hundred metres from the place he had first intended to land. Even though he supported the cyclic stick with his left knee he was unable to have the helicopter hover before touchdown: it struck the ground hard with its left landing skid. It then turned over onto its left side.

Those on board were only slightly injured and were able to leave the helicopter unaided.

The accident occurred at position 6610N 01533E, approximately 800 m above sea level.

1.2 Injuries to persons

	Crew	*Passengers*	*Others*	*Total*
Fatal	–	–	–	–
Serious	–	–	–	–
Minor	1	2	–	3
None	–	2	–	2
Total	1	4	–	5

1.3 Damage to the helicopter

Extensive.

1.4 Other damage

No other damage arose. The accident had no impact on the environment.

1.5 Personnel information

1.5.1 The pilot

The pilot, a man, was 41 years and had a valid CPL-H certificate.

Flying time (hours)			
Latest	*24 hours*	*90 days*	*Total*
All types	-	50	3 540
This type	-	8	8

Number of landings this type the latest 90 days: 124, of which 60 on this type.

Type training carried out 16-07-2004.
Latest periodic flight training (PC) July 2004 on Hughes 369.
Latest operative periodic flight training (OPC) July 2004 on Hughes 369.

1.5.2 The pilot's duty schedule

Prior to the accident the pilot had been on duty for 3 hours.

1.6 Helicopter information

1.6.1 General

THE HELICOPTER	
Manufacturer	Hughes Helicopters Inc.
Type	369 D
Serial number	811041 D
Year of manufacture	1981
Gross mass	Max permitted takeoff weight 1 360 kg, present 1 285 kg
Centre of mass	Within permitted limits
Total flying time	8 099 hours
Number of cycles	2 946
Flying time since latest inspection	90 hours
Fuel loaded before event	Jet A1, 150 litres

ENGINES	
Engine manufacturer	Allison
Model	250 C20B
Number of engines	1
Total operating time	
Operating time since overhaul	9791
Cycles since overhaul	9915

ROTOR	
Rotor manufacturer	Hughes
Rotor operating time after overhaul:	
Main rotor	119 hrs
Tail rotor	119 hrs

The control system is mechanical and without servos.

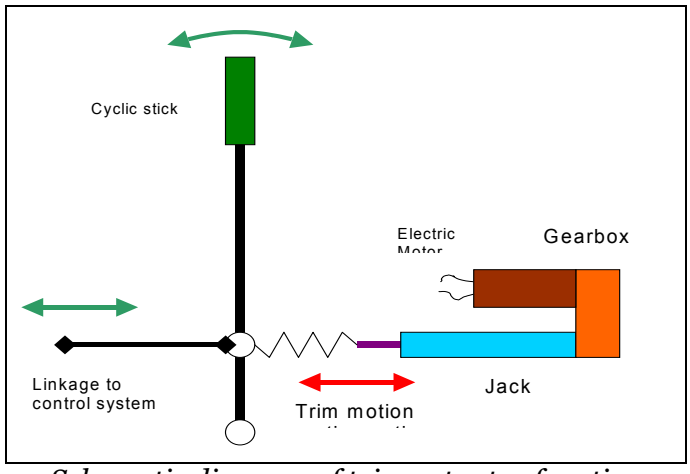
The helicopter had a valid certificate of airworthiness.

1.6.2 The trim system

The helicopter's control system is equipped with an electromechanical trim system. Using the trim system the pilot can, through an electrically controlled spring mechanism, compensate for aerodynamic forces arising during various phases of flying in the cyclical control system, thereby reducing the control forces. The system is operated with a spring-loaded four-way trim switch, often called the "Chinese hat", placed on top of the cyclic stick grip. If, for example, the cyclic stick pulls to the left the pilot can move the control to the right a few times until the force in the cyclic stick becomes balanced.

The cyclic forces are balanced with two trim actuators coupled to the control system in the roll and tip dimensions, respectively. Each actuator has an electric motor which drives a helical jack via a gear. The jack is coupled mechanically to links on each control system via a spring, which at the same time provides an artificial inertia to the control system. The trim actuators have no end stops, i.e. can be supplied with current even if the system is trimmed to its mechanical end stop.

When the rotor system is unloaded (rotor stationary) the cyclic stick is kept in a balanced position by the actuator springs. If the cyclic stick is trimmed in any direction, its position moves in the same direction, i.e. the cyclic stick moves in that direction. (See sketch below.)



Schematic diagram of trim actuator function

According to the manufacturer's Maintenance Manual the four-way trim switch operating life is limited to 1 000 flying hours. For other components in the trim system no operating time restrictions are given. A functional check must be carried out during ordinary inspections and is normally done unloaded.

1.7 Meteorological information

According to SMHI analysis: Wind SO/5-10 knots, CAVOK, temp./dew point +18/+10 °C, QNH 1020hPa.

1.8 Aids to navigation

Not applicable.

1.9 Radio communications

Not applicable.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

None on board. Not required.

1.12 Accident site

1.12.1 The accident site

The helicopter struck the ground in open and relatively level fell terrain. The ground was covered with grass, moss and low bushes.

1.12.2 Helicopter wreckage

The helicopter ended up lying on its left side. The structure was damaged, the left undercarriage was broken and the tail boom broken off. All the rotor blades had been broken off near the rotor hub.

Accident site

1.13 Medical information

Nothing has emerged to indicate that the pilot's physical or mental condition was impaired prior to or during the flight.

1.14 Fire

There was no fire.

1.15 Survival aspects

The emergency transmitter, type CIR-11-2, was activated on impact and turned off by the pilot. Speed on impact was low. The cabin remained relatively intact and those on board were buckled in four-point safety belts and diagonal belts, which probably contributed to the fact that personal injuries were only slight.

1.16 Tests and research

1.16.1 Technical investigation

A technical investigation of the helicopter was carried out by the Board assisted by a qualified flight technician and a licensed helicopter workshop. A first investigation and documentation of the helicopter was undertaken at the accident site. At the site it was established, among other things, that the lateral trim system was trimmed to its maximum left trim position. In an unloaded functional test of the trim system the system functioned normally. The helicopter was then transported to a hangar for further investigation.

1.16.2 Investigation of the helicopter's rotor- and control systems

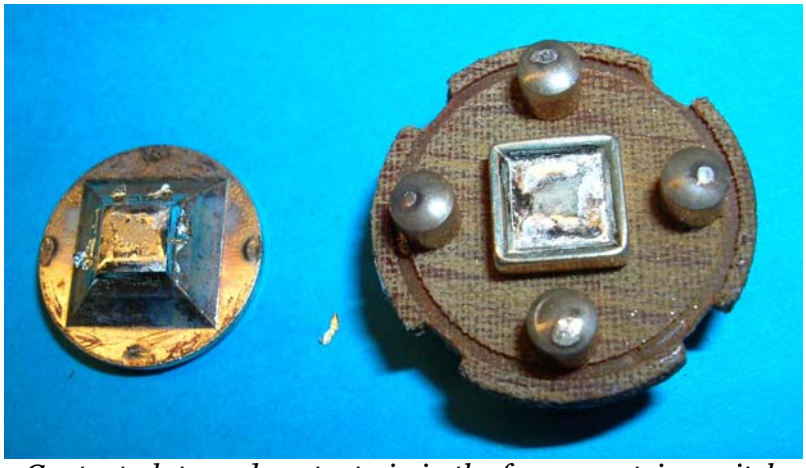
All the helicopter's rotor and control systems and associated components were checked and function-tested as far as practically possible. Apart from the trim system (see below) no fault or abnormality was found that is judged capable of affecting the course of events.

1.16.3 Investigation of the trim system

After recovery of the helicopter, the lateral trim system was function-tested again in an unloaded state in the helicopter. After it had been run several times in both directions, it stopped in the right position. The actual trim motor functioned in both directions but its output push rod did not move normally. Apart from the noise of the motor, a rasping sound could be heard from the actuator gearbox. The cyclic stick and both trim actuators were dismounted from the helicopter for further investigation. Before and after the removal of these items, all cables and switches included in the helicopter's trim system were checked for loose contacts or damage. No fault or abnormality was found.

1.16.4 Four-way Trim Switch

The four-way trim switch, which was of the latest version (see 1.18.2), was bench-tested for function without remark and without any tendency to binding or loose contacts. When the switch was disassembled a number of small metal chips of a material resembling silver were found in the space between the contact pins and the contact plate. On the plate, "smeared-out" filings of the same material were found. No clear sign of short-circuiting between the centre plate and any of the contact dubs was found (see photograph below).



Contact plate and contact pin in the four-way trim switch

The time the switch had been in operation was checked, and according to the helicopter's technical documentation it had accumulated 863 flying hours time before the accident.

1.16.5 Trim Actuator in the lateral system

The trim actuator, which on the outside was physically undamaged, was function-tested unloaded before removal and initially functioned normally in both directions. After being shaken several times in both directions, it "stuck" sporadically in both directions even though the motor was running. When the actuator gearbox was disassembled, extensive damage to the gearwheels was found together with metal chips of different sizes. (See photo below.)

Gearwheels in the trim actuator gearbox

The teeth of the input pinion (the smallest gearwheel) were all largely worn down. The teeth of the intermediate gearwheel were partly worn down in certain sectors. The teeth of the output gearwheel (the largest) were worn but intact. The intermediate gearwheel is seated in the gearbox and its lid. Its axial position can be adjusted with spacers on the gearwheel axles. The damage to the input pinion teeth indicates that it had been axially displaced so that the teeth did not mesh along their full lengths.

The operating time of the trim actuator has not been followed up: it has been impossible to establish how many flying hours it had accumulated before the accident. Nothing in the aircraft's documentation indicates that the actuator had been replaced since delivery of the helicopter as new.

1.16.6 Trim actuator in the longitudinal system

The trim actuator in the longitudinal system was replaced twice in connection with repair of the helicopter before the present accident in consequence of an earlier accident (se 1.18.1). This was done once during the repair because of external damage and once after a transport flight to the owner because of malfunction. The latest actuator had accumulated approximately 115 flying hours after the repair. Inspection and function-testing of the actuator revealed no fault or abnormality.

1.16.7 Measurement of existing stick forces

To get some idea of what force may have been required to neutralise the cyclic stick on maximal trimming in a helicopter of the same type, the Board conducted practical measurements on such a helicopter.

The measurements were taken on the ground with the rotor running at operating speed (100 % RPM) and using a dynamometer applied to the cy-

clic stick grip. The method used was somewhat primitive and fairly small measurement errors may have arisen.

The measurement showed that the trim system can under these circumstances affect the helicopter control system with stick forces between 7.5 kp and 11.5 kp, depending on which limit the stick was trimmed to and where on the stick grip the measurement was taken.

1.16.8 Practical tests of manoeuvring in roll attitude with large trim forces

The board had different people ("pilots") test operating a “dummy cyclic stick” set-up in the roll attitude with various simulated applied trim forces. The tests showed unequivocally that forces over 4-6 kp entailed considerable difficulties for a pilot - even a muscular one - to manoeuvre with precision for longer than a few seconds. This was particularly so if the undesirable force was acting from the natural “hand grip", i.e. to the left if the cyclic stick was held in the right hand.

1.17 Organisational and management information

The company has its main base in Adolfsström and runs various types of taxi flying in the fells area. At the time of the accident there were four full-time employees and two Hughes 369B helicopters in operation.

1.18 Additional information

1.18.1 Earlier accident with this helicopter

This helicopter was involved in an accident in 2003. In that accident the helicopter suffered damage which required extensive repairs. These were carried out by a licensed helicopter workshop. During the repairs the trim system was function-tested unloaded and found to function without remark. After the repairs the helicopter operated for 119 flying hours without any remark concerning the lateral trim system.

1.18.2 MD Helicopters Service Bulletin DN-184

MD Helicopters, which in 1994 carried manufacturing responsibility, published on 10 Mars 1994 its Service Bulletin DN-184 prescribing that the four-way trim switch in question, P/N A218-100646-02, should before 100 flying hours, or within a year of the publication date of the bulletin whichever should be earlier, be replaced with a later version of the switch. The reason given was that switches of the earlier model can bind and cause undesirable trimming, According to the manufacturer, trimming to the end position can give rise to stick forces of up to 30 lbs (13.6 kp), which can ”increase the pilot’s workload”.

The information material regarding the DN-184 also states that internal shorting can occur in the switch if loose silver flakes get into such a position that an electrical bridge arises between the contact plate and a contact pin, which can also result in undesirable trimming.

According to the Board’s technical investigation the four-way switch in question was of the later version.

1.18.3 Regulations and documentation concerning stick forces

The American Federal Aviation Regulations (FAR) 23.143 (small aircraft) and FAR 25.143 (large aircraft) prescribes maximum permitted stick forces in the roll plane as follows:

Momentary: max 30 lbs (14 kp)
Continual: max 5 lbs (2.3 kp)

The Board has not found in the corresponding regulations for small and large helicopters, FAR 27 and FAR 29, or in the European Certification Specifications (design regulations) CS 27 and CS 29 any regulation covering maximum permitted cyclic stick force. These regulations state in general that cyclic stick forces must not be so large that they can impede precise manoeuvre of the helicopter.

The helicopter manufacturer's Flight Manual states the following concerning undesirable trimming:

"Runaway cyclic trim failures can produce cyclic stick forces of approximately 30 pounds in the direction of the runaway. Although the forces required to move the cyclic will be higher than normal, the helicopter will respond normally to all cyclic inputs by the pilot."

The gist of this is that a fault in the trim system can generate an undesirable force in the cyclic stick in a certain direction, of maximum 30 lbs (14 kp). Even though the force then required to manoeuvre the stick becomes higher than normal, the helicopter will react normally to all cyclic stick movements.

2 ANALYSIS

2.1 The accident

The flight to Ältsvattnet and the landing were, according to the pilot, unremarkable. The problem arose shortly after takeoff when the helicopter was accelerating forwards and gaining altitude. In that phase of the flight the pilot probably made small adjustments by working the four-way trim switch on the cyclic stick. This is normal on helicopter types such as the present one, which lack servo systems, to neutralise the aerodynamic forces that can affect the cyclic stick.

The pilot thus thought that increasing force was needed to maintain the helicopter neutral in the roll plane. He felt that the stick was being subjected to a force to the left even though he attempted in different ways to trim to the right.

He perceived the disturbance as a springy resistance in the cyclic stick, rather than a mechanical stop or binding. After the accident, the lateral trim system was found to be trimmed in its left end-position

All the evidence shows, therefore, that a fault arose in the trim system after takeoff, so that it no longer reacted normally to the pilot's application of the four-way trim switch. The fault grew successively more serious and the system finally stuck in its left end-position.

The Board's tests show that the trim system, if trimmed to an end position, can generate cyclic stick forces of more than 10 kp. In addition, there is no doubt that stick forces in the lateral control system exceeding 4-6 kp, for longer periods than a few seconds, make it very difficult for a pilot to manoeuvre a helicopter. This is particularly so if the force is acting towards the left and the pilot has to fly with his right hand.

Since a pilot during landing must manoeuvre the helicopter with great precision with the cyclic stick, the collective stick and the pedals if he is to land safely, a malfunction in the trim system as described above is very serious in terms of flight safety. This is clearly shown in the present accident where the pilot, despite great flying experience, was unable to land the helicopter with this fault.

2.2 The malfunction

In the technical examination of the helicopter, two independent faults were found, each of which could have caused undesirable trimming.

In the four-way trim switch on the cyclic stick, loose metal chips were found which according to Service Bulletin DN-184 can cause electrical arcing between the contact plate and any of the contact dubs. If this happens, there can be undesirable trimming in one direction or another. However there was no burn mark or similar in the switch that could suggest that there had been arcing. Further, it appears unlikely that such arcing between contacts could have persisted so long in this case, particularly in view of the pilot's frequent use of the switch.

It is therefore more probable that the faulty operation was caused by a malfunction in the trim actuator of the lateral trim system. When the actuator was examined it was found that two of the gearwheels in the gearbox were seriously worn. All the teeth of the drive pinion and certain teeth on the intermediate wheel were practically worn down.

On impact there were large forces and abnormal movements in the rotor and control systems that may have damaged the trim actuator. Since the actuator showed no external physical damage, such forces would have been transmitted via the actuator spring which would most likely have acted to take up the shock. The fact that the largest gearwheel in the box, which is connected with the output push-rod, was practically undamaged on impact strongly suggests that the gearbox was not damaged on impact but had already undergone serious damage even before the accident.

The likelihood is therefore that at least the input drive pinion was already severely worn. This may have been because the intermediate gearwheel was not correctly adjusted axially, resulting in incorrect meshing and hence increased wear.

When the wear had grown sufficiently, the gears probably started to unmesh at first sporadically and the more often, which resulted in rapidly increasing wear.

It should be noted here that part of the gearwheel damage found during the investigation may have arisen in connection with the troubleshooting after the accident when the trim motor was run forwards and backwards many times.

A cyclic stick is trimmed frequently during a flight to balance the stick forces. The aerodynamic forces arising in the control system vary during different phases of a flight, so that a pilot does not immediately notice sporadic faults in the trim system.

There may therefore have been serious damage to the trim actuator in the system for some time before the accident without anyone observing this. Damage may even have been present during functional checks in connection with inspections but did not cause any malfunction then because these checks are normally done with the system unloaded.

The most probable scenario is therefore that the fault was already present before the flight and became more serious on takeoff. When the pilot adjusted the trim to neutralize the lateral stick force he did not get the reaction he expected. He probably worked the four-way switch several times to handle the problem. He may unconsciously have moved the switch in various directions to get the system to respond normally.

The gearbox damage probably grew rapidly worse during this phase. The actuator may have been entirely stuck in some positions, while in other positions perhaps moving in one direction only. The pilot's manoeuvring of the cyclic stick may also have transmitted forces to the gearbox, affecting the motion of the gearwheels and causing them to unmesh.

Everything thus suggests that a rapid deterioration in the function of the trim actuator in combination with the pilot's manoeuvring of the four-way switch and cyclic stick, in an unfortunate sequence, caused the actuator successively to work its way to the left until maximum trim position had been achieved. In this position the trim system seized up entirely, perhaps partly because the pilot was then obliged to counteract the position of the trim system with considerable force to be able to fly the helicopter.

When the trim system was tested after the accident and found to work apparently normally, this may be because the system was then unloaded, releasing the previous jam. Less force was then required to achieve movement in the trim system.

2.3 The trim system

The trim system is mechanically linked directly to the lateral and longitudinal control system. The investigation has shown that a possible fault in the trim system, causing an undesirable trim to one of the end positions, can make the helicopter very hard to manoeuvre. This applies in particular to takeoff and landing, when the cyclic stick must be operated with one hand only.

Apart from the fixed cable harness in the helicopter the trim system consists essentially of the four-way switch on the cyclic stick and the two trim actuators. In view of the great flight safety risk a technical fault in any of these components can entail, the Board finds it unsatisfactory that the trim actuator, as opposed to the four-way switch, lacks any restriction on flying time but can be installed in the helicopter for "as long as it works" (on condition. The actuator in question can theoretically have been installed in the helicopter since the latter was manufactured and would in that case have been in operation for just over 8000 flying hours.

This is all the more so since sporadic faults are not always detected by pilots. Certain malfunctions consequent upon internal wear in a gearbox do not, either, manifest themselves during the regular function-checks since the system is unloaded at that time.

There is therefore reason for the Civil Aviation Authority to promulgate, for the helicopter type in question and other types in which the trim system can cause a risk to flight safety, suitable restrictions on operating hours for constituent components, together with the requirement that functional controls be carried out with the system loaded.

2.4 Cyclic stick forces

As stated under 1.18.3 the relevant design regulations in FAR specify maximum permitted stick and pedal forces, momentary and continual, for small and large aircraft. These prescribe among other things that the maximum permitted cyclic stick force in the roll plane may not exceed 5 lbs (2.3 kp) continually.

This limit value and the Board's practical tests signify that the manufacturer's information in the flight manual is misleading when it states that, while flying with undesirable stick forces up to 30 lbs (14 kp) requires greater strength to manoeuvre the stick, the helicopter still reacts normally to all stick movements. In actual fact it is practically impossible to land a helicopter safely with such large lateral stick forces.

It may be wondered why in the first place the trim system in this helicopter type was designed to be able to give such large cyclic stick forces.

The Board also finds it strange that the regulations embodied in the FAR and the CS and pertaining to light and heavy helicopters do not specify limit values for maximum permitted cyclic stick and pedal forces. This is particularly so since helicopter flying often places higher demands on precise manoeuvring than fixed-wing flying does. There are therefore grounds for the Civil Aviation Authority, in international cooperation with other civil aviation authorities, to seek the inclusion of maximum cyclic stick and pedal forces in the design regulations also for light and heavy helicopters.

3 CONCLUSIONS

3.1 Findings

a) The pilot possessed formal certification to carry out the flight.
b) The helicopter had a valid certificate of airworthiness.
c) The lateral trim system was trimmed to its left end-position.
d) Filings of a material resembling silver were found in the four-way trim switch of the collective stick.
e) The trim actuator gearbox of the lateral trim system was greatly worn.
f) Trim actuators have no limitation on operating time.
g) Design regulations in force for light and heavy helicopters lack limit values for maximum permitted cyclic stick and rudder forces.
h) The trim system can give stick forces up to 14 kp.
i) Undesirable cyclic stick forces greater than 4-6 kp, for protracted periods, make it very difficult for a pilot to manoeuvre with precision.

3.2 Causes of the accident

The accident was caused by a technical fault in the helicopter's lateral trim system which rendered it uncontrollable so that it successively worked its way into its left end position. A contributory cause was that the trim system is designed to be able to give cyclic stick forces of almost 14 kp.

4 RECOMMENDATIONS

The Swedish Civil Aviation Authority is recommended:

- to specify – where necessary for the helicopter type in question and for other types in which the trim system can create a flight safety risk – operating time restrictions on constituent components; and to prescribe that functional checks of the trim system be carried out with the control system under load. *(RL 2005:13e R1)* and,

- in collaboration with international civil aviation authorities, to seek the inclusion of maximum permitted cyclic stick and pedal craft forces in the design regulations also for small and large helicopters *(RL 2005:13e R2)*.