Norwegian Safety Investigation Authority

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REPORT AVIATION 2025/01

Aviation accident at Songesand, Sandnes municipality, Rogaland on 16 November 2020 involving Airbus Helicopters AS 350 B3, LN-OAX, operated by Heli-Team AS

Norwegian Safety Investigation Authority • P.O. Box 213, NO-2001 Lillestrøm • Phone: 63 89 63 00 • nsia.no • post@nsia.no

The Norwegian Safety Investigation Authority (NSIA) has compiled this report for the sole purpose of improving flight safety.

The purpose of the NSIA's investigations is to clarify the sequence of events and causal factors, elucidate matters deemed to be important to the prevention of accidents and serious incidents, and to make possible safety recommendations. It is not NSIA's task to apportion blame or liability.

Use of this report for any other purpose than for flight safety should be avoided.

Photo: NSIA

This report has been translated into English and published by the NSIA to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

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Air accident report

Table 1: Data

Type of aircraft:	Airbus Helicopters, AS 350 B3
Nationality and registration:	Norwegian, LN-OAX
Owner:	Heli-Team AS Norge
Operator:	Same as owner
Crew/pilot:	1
Passengers:	None
Accident site:	Songesand, Sandnes municipality, Rogaland County, Norway
Time of accident:	16 November 2020 at 1435 hours

All times given in this report are local times (UTC + 2 hours) unless otherwise stated.

Notification

On Monday 16 November 2020 at 1507 hours, the NSIA's duty officer received notification from the Joint Rescue Coordination Centre (JRCC) that there had been an accident involving a helicopter at Songesand in Sandnes municipality in Rogaland county. LN-OAX, a helicopter of the type Airbus Helicopters AS 350 B3, had an accident in connection with a sling load operation, delivering concrete for a pylon foundation for a new power transmission line. The pilot, who was alone on board, managed to evacuate the helicopter unassisted. Representatives of the NSIA travelled to Stavanger the same evening and began work at the accident site the next day.

In accordance with ICAO Annex 13 Aircraft Accident and Incident Investigation, the NSIA notified Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation civile (BEA) in France (State of Manufacture). The European Union Aviation Safety Agency (EASA) and the Civil Aviation Authority (CAA) Norway were also notified.

Summary

The helicopter LN-OAX crashed on Monday 16 November 2020 as it was delivering concrete for the foundation of a power line pylon.

The NSIA believes the pilot lost control of the helicopter when a phenomenon known as rotorcraft-pilot coupling (RPC) occurred, causing strong vertical oscillations. The phenomenon arose very quickly, and the pilot had neither the time nor the altitude to regain control before the helicopter crashed.

At the pylon foundation, the pilot had to make an altitude correction. The pilot's altitude correction may have been due to a gust of wind, the fact that the concrete bucket came into contact with the mast foundation, or a combination of the two. Immediately after the correction, the pilot felt powerful vertical oscillations whereupon he disconnected the suspended load and attempted to manoeuvre the helicopter out of the situation.

The helicopter sustained significant damage. The NSIA has reviewed the helicopter's technical systems without finding any significant defects. LN-OAX was manufactured in 2002. The investigation has revealed that AS 350 helicopters delivered before 2006 may have servo configurations that make them more sensitive to RPC. In that connection, Airbus Helicopters has published information on the subject as well as recommended replacing the banjo screws to a smaller internal diameter in order to reduce sensitivity to oscillations.

No one was injured in the accident.

About the investigation

Purpose and method

The purpose of the NSIA's investigation into this accident with LN-OAX in Songesand on 16 November 2020 is to clarify the course of events and causal factors and investigate conditions that are believed to be important for the prevention of accidents and serious incidents.

The accident and the circumstances surrounding it have been investigated and analysed in line with the NSIA's framework and analysis process for systematic safety investigations (the NSIA method[1]).

Sources of information

- Pilot's report and statement.
- Witnesses at the accident site.
- Technical examinations together with the French accident investigation authority (BEA), Airbus Helicopters and Safran Helicopter Engines.
- Own investigations at the accident site.
- ARISTOTEL Grant agreement ID: 266073.
- Airbus Safety Notice 3890-S-00 and 3899-S-97.

The investigation report

The first part of the report, 'Factual information', describes the sequence of events, related data and information gathered in connection with the accident, what the NSIA has investigated and related findings.

The second part, 'Analysis', contains the NSIA's assessment of the sequence of events and contributing causes based on factual information and completed investigations and examinations. Circumstances and factors found to be of little relevance to explaining and understanding the accident will not be discussed in detail.

The NSIA's conclusions are described at the end of the report.

Despite the fact that the investigation started at a time when the Covid-19 pandemic made physical cooperation between the NSIA and the helicopter manufacturer challenging, cooperation with the helicopter manufacturer has been close throughout the investigation phase. The helicopter manufacturer has thus been given an opportunity to take several measures to improve the safety of the helicopter type during the investigation.

[1] *See https://www.nsia.no/About-us/Methodology*

1. Factual information

1. Factual information

1.1 History of the flight

A 420 kV power transmission line was to be constructed from Forsand to Fagrafjell, on the border between Time and Sandnes municipalities in Rogaland county. Statnett SF had signed into a contract with Dalekovod as the power line contractor. Dalekovod, in turn, had entered into a contract with Heli-Team AS for helicopter services for the power line in question.

On Monday 16 November 2020, flights took place in the area around Romaheia and Songesand. The operation consisted of transporting cargo, personnel and concrete for pylon foundations for the new power line; see Figure 1.

After the crew arrived from Tau in Strand municipality, Rogaland county to the helicopter parked in Songesand, the pilot conducted a pre-flight inspection (PFI) of the helicopter without identifying any faults or defects. He assessed the weather and observed that there was slightly more wind than expected compared with the weather report obtained in advance via the website yr.no.

The day started with transporting cargo and personnel, and at about 1230 hours, work started on transporting concrete. The concrete bucket was suspended from a 15-metre-long steel wire below the helicopter. The bucket was emptied manually through a hatch operated by personnel on the ground. Due to the short flight route and the altitude difference between the pick-up and delivery sites, the pilot had reduced the load to 700 kg (normally 1,100 kg).

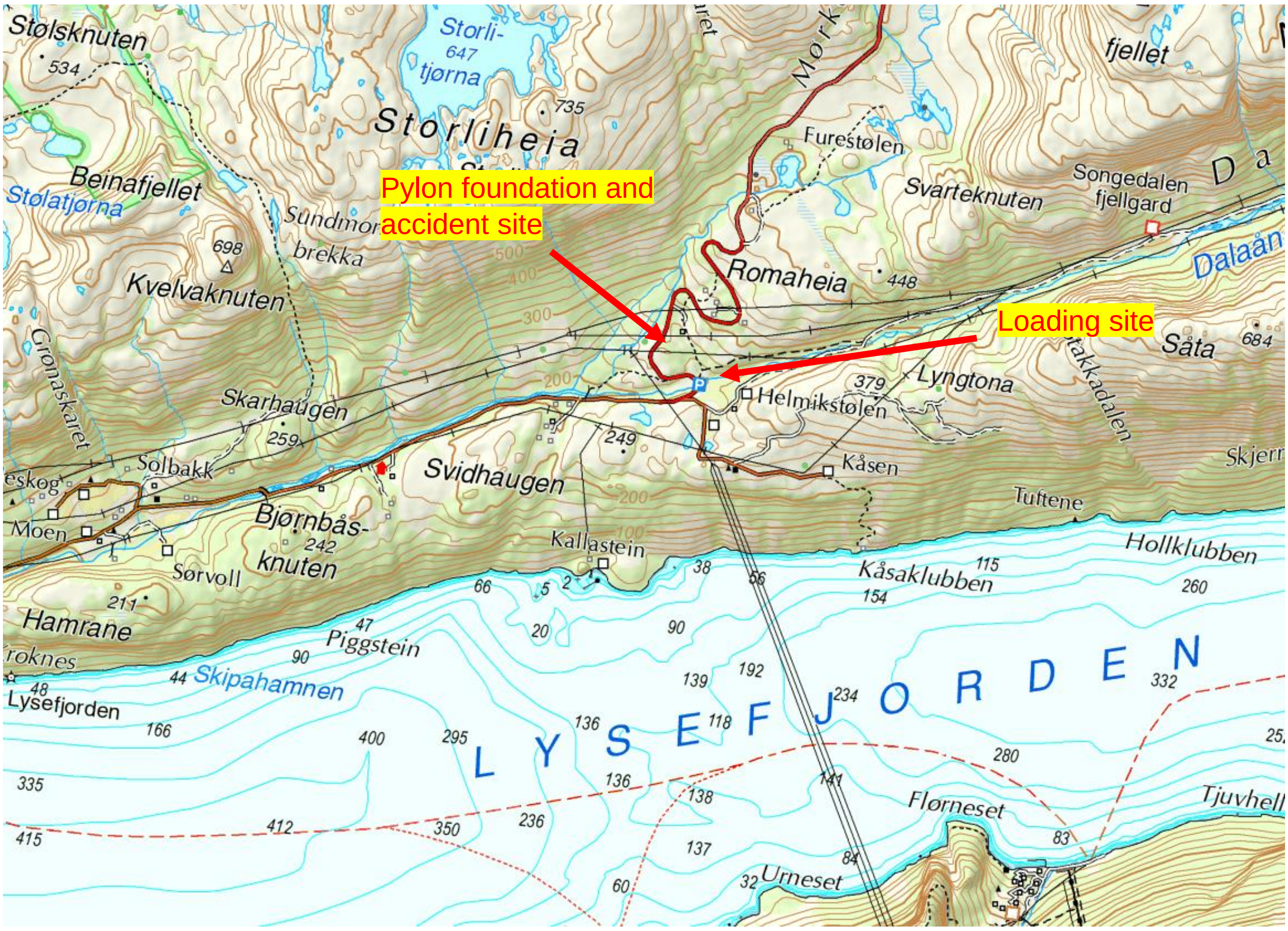

Figure 1: Map of the area showing the loading site and pylon foundation 49. Map: The Norwegian Mapping Authority. Markings: NSIA

After twelve flights delivering concrete to the pylon foundation at mast point, 49; see Figure 1, a work team needed to be picked up a little further west. On the way to the pick-up point, the pilot saw that the weather was deteriorating, with increasing fog. He therefore chose to discontinue the flight and return to the area for flying concrete to the mast foundation. On his return, he landed at the company's fuel station in Songesand and filled the helicopter's fuel tank to 1/3 of full tank, which corresponds to about 180 litres. On the return flight, the pilot felt strong gusts of wind, which was also indicated by the blasts he observed on the surface of the Lysefjord.

After the pilot had resumed the flying with concrete, he noted a deterioration in the weather situation, with low clouds and risk for incoming fog. He considered the visibility conditions at pylon foundation 49 to be acceptable and continued flying. The first flight went without problems, but the pilot saw that the helicopter's windscreen had started to get fog on the inside. He therefore chose to land at the loading site to wipe the moist of the windscreen.

After the front window was cleared, he continued the flight. The pilot has explained to the NSIA that he flew the helicopter over pylon foundation 49 in an easterly direction. The wind was variable and probably struck the helicopter from behind with a slight angle on the right-hand side, at the same time as the bucket was positioned over the formwork. On the ground, two persons from Dalekovod assisted in emptying the bucket. One held the bucket while the other started emptying it by manually opening the hatch. Shortly after the hatch was opened, the pilot noticed strong vertical movements (oscillations). The pilot has explained that he did not feel any contact between the bucket and the pylon foundation. He had not experienced similar vertical movements previously and immediately remotely released the bucket and wire from the helicopter's cargo hook. The fitters have explained to the NSIA that the bucket was in contact with the foundation formwork at the time when the oscillations occurred, se figure 2. The fitters also explained that the half-full bucket was left standing on the foundation's formwork.

Figure 2: Pylon foundation 49, the day after the accident. Casting of the foundation had then been completed. Photo: NSIA

After the load had been released, the pilot concentrated on manoeuvring the helicopter. First, he lowered the helicopter's nose to move eastward, away from the people on the ground. The pilot has explained that he then pulled the helicopter's collective to get more vertical climb, but that the helicopter did not respond as expected. The pilot perceived this to mean that rotor rpm was dropping, and he tried to keep the collective in the same position to retain the remaining energy in the rotor system until the actual landing. The pilot has explained to the NSIA that he had a feeling that the helicopter was ‘going down’, with constantly decreasing rotor rpm.

The helicopter’s main rotor cut through some trees before the helicopter hit the ground and was left lying on its right side about 50 meters from pylon foundation 49. The direction of rotation of the main rotor caused the helicopter at the end get a twist to the left; see Figure 3.

The engine kept running even after the helicopter came to rest on the ground. The pilot attempted to stop the engine by manually closing the fuel valve. The valve closed, but when the engine did not stop immediately, he also shut off the engine in the normal manner by turning the starting selector to the OFF position. The pilot observed white smoke coming from the engine when it stopped.

Figure 3: The helicopter’s final position about 50 metres east of pylon foundation 49. The tail rotor with the vertical stabiliser on the right. Photo looking east, with pylon foundation 49 behind the photographer. Photo: NSIA

After the pilot had turned the engine off, he removed his helmet and evacuated the helicopter. The helicopter’s main power switch was turned off shortly afterwards by another pilot who arrived at the scene of the accident.

The pilot has explained to the NSIA that he normally flew with high friction on the flight controls and that the vertical movement that occurred could correspond to the main rotor rpm. Furthermore, he estimated that the vertical oscillations could have been in the range of 5 cm.

1.2 Injuries

Table 2: Personal injuries

Injuries	Crew	Passengers	Other
Fatal			
Serious			
Minor/none	1		

1.3 Damage to aircraft

The helicopter sustained considerable damage. See section 1.12.1.2 for further information.

1.4 Other damage

Some trees were cut during the crash, and one tree had to be cut down to salvage the helicopter. There was no fuel leak, only a limited fluid leak from the helicopter's main gearbox.

1.5 Personnel information

The pilot had a valid certificate with privileges for helicopter type AS 350/EC 130. His flying privileges were last renewed on 25 November 2019 and were valid until 30 November 2020. The pilot held a valid Class 1 medical certificate, without restrictions. He had successfully completed an Operator Proficiency Check (OPC) in the company on 17 August 2020.

The pilot worked a rotation schedule system for Heli-Team, and the accident occurred on the first working day of the rotation schedule. The pilot has explained to the NSIA that he felt rested when he arrived at the company's accommodation in Tau the night before the accident.

The pilot had experience from his previous employers in flying with suspended loads, and had been checked out for specialised sling load operations in accordance with HESLO 3.[2]

Table 3: Flying experience, pilot

Flying experience	All types	On type
Last 24 hours	4	4
Last 3 days	0	0
Last 30 days	31	31
Last 90 days	85	85
Total	1,803	1,667

[2] See section 1.18.5

1.6 Aircraft information

1.6.1 GENERAL INFORMATION:

The AS 350 B3 is a light, single-engine helicopter with three main rotor blades and a conventional tail rotor. The main rotor speed is 390 RPM, and it rotates clockwise seen from above. Significant parts of the helicopter are built in composite materials, including most of the rotor blades.

The AS 350 can accommodate six people, two in the cockpit and four in the cabin. The minimum crew is one pilot.

LN-OAX was configured for sling load operations. This entailed removal of the load basket, removal of unnecessary cargo from the cargo compartment and removal of flight controls on the left-hand side of the cockpit.

1.6.2 HELICOPTER DATA

Serial number:	3555
Build year:	2002
Total cumulative flight time:	10,621.7 hours
Main rotor:	Diameter 10.69 m, 3 blades
Engine:	Safran Helicopter Engines, Arriel 2B
Type certificate:	EASA.R.008
Engine serial number:	22129
Fuel type:	Jet A-1
Airworthiness Review Certificate:	Valid until 1 July 2021

1.6.3 AIRWORTHINESS AND MAINTENANCE

Heli-Team has been responsible for continuous airworthiness and maintenance since the helicopter was imported to Norway in 2015.

The next main inspection was due to take place at 10,668.9 flight hours (including tolerance) at the latest. The inspection was planned in the near future. Just before the accident, the technical director had received information from operational personnel that the helicopter might need a balancing of its rotor systems. The plan was to carry out this work in connection with the main overhaul.

The NSIA has reviewed technical documentation without finding anything that can help explain why the accident occurred.

1.6.4 MASS AND BALANCE

The helicopter's maximum permissible mass when flying with a sling load is 2,800 kg. According to the Flight Operation Handbook Supplement[3] 13.2 and the company's own procedures, the helicopter was within the manufacturer's defined mass and balance limitations. The helicopter had an estimated unladen take-off weight of 1,593 kg, including fuel and pilot. The suspended load weighed about 730 kg.

1.6.5 THE HELICOPTER'S TECHNICAL SYSTEMS

1.6.5.1 Engine and rotor system drivetrain

The helicopter's engine of the type of Arriel 2B, was manufactured by Safran Helicopter Engines. The engine with the gas generator and free turbine consists of several modules. The engine output is between 450 and 497 kW, depending on the modification status. The engine is controlled by the pilot thru the collective, an anticipator and a digital engine control unit (Single Lane FADEC), see figure 4.

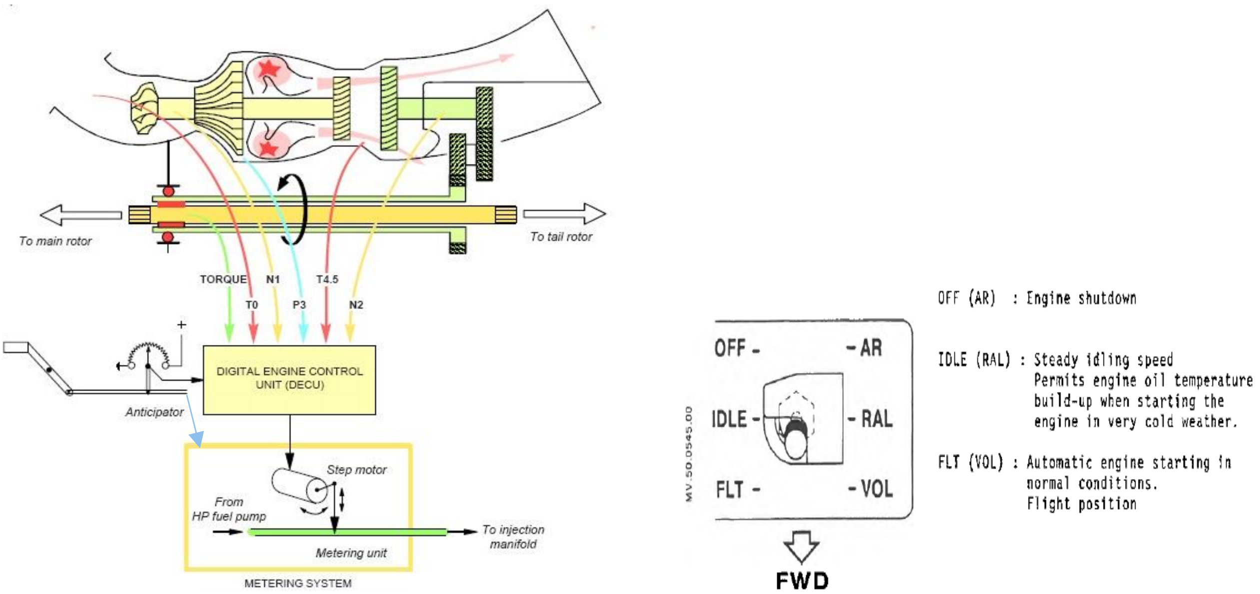

Figure 4: Schematic drawing of engine including DECU and Starting Selector. Illustration: Airbus Helicopters / NSIA

The pilot controls the engine using the collective and the starting selector with three positions: Off, Idle and Flight (FLT).

The collective is mechanically connected to an anticipator[4] and the hydromechanical fuel control unit.

An emergency control lever is mounted on the ceiling and mechanically controls the fuel shut-off valve.

In position FLT, the engine is automatically controlled by an electronic unit called the Digital Engine Control Unit (DECU) and an electrically controlled hydromechanical fuel control. When the fuel system functions normally, the DECU controls the hydromechanical fuel control so that the gas

[3] *Depending on the helicopter's configuration, a supplement to the aircraft manual can change or replace the manual's normal limitations.*
[4] *The anticipator signals the position of the collective to the DECU.*

generator is fed the correct amount of fuel. The gas generator varies the engine rpm according to the load, so that the free turbine rpm is kept approximately constant with varying loads.

The helicopter's rotor system and main gearbox, which is mechanically coupled to the free turbine, will, after downshifting from about 20,000 rpm, have an approximately constant rotor rpm of 390.

1.6.5.2 Flight controls and rotor system

The AS 350 B3 is equipped with conventional flight controls and servos that control a three-blade main rotor and a two-blade tail rotor. The pilot controls the main rotor with the cyclic and the collective; see Figure 5. The tail rotor is controlled by foot pedals.

Three servos are mounted between the main gearbox and controls the swash plate. The swashplate transfers the inputs to the main rotor. In addition, a fourth servo is mounted in the helicopter tail boom to control the tail rotor. The servos increase the pilot's ease of use and make the helicopter's flight controls easy to move.

A belt-driven hydraulic pump driven by the drive shaft between the engine and the gearbox provides hydraulic pressure to the servos to assist the pilot's movements. If the servos lose hydraulic pressure, each servo has a small accumulator that assists the pilot's movements. How long the controls are assisted when using the accumulator with no hydraulic pressure depends on how much the pilot uses the controls. When the accumulator is empty, the servos will act as mechanical stays, and the pilot will have to use significantly more power to control the helicopter.

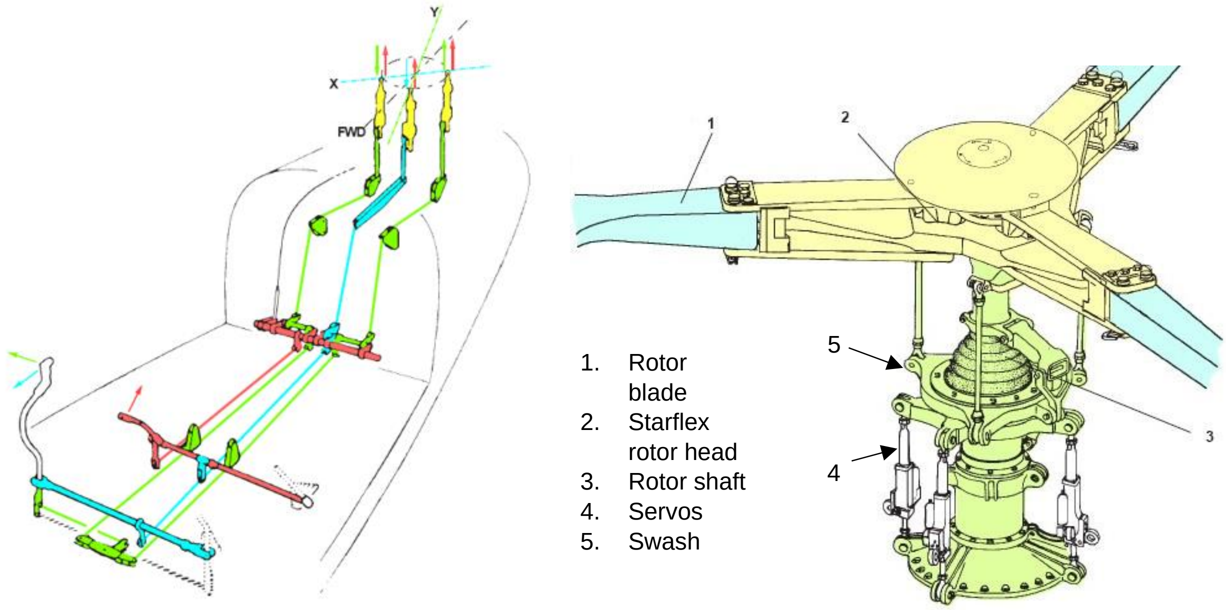

Figure 5: Rotor system's mechanical control stays and main rotor system. Illustration: Airbus Helicopters/NSIA

The AS 350 may have different configurations on the installed servos. The latest and current configuration was established in 2006. The configuration of the servo is determined by the length of the servos control arm, in addition to the cross-section of an installed banjo screw that regulates the amount of hydraulic fluid.

At the time when LN-OAX was delivered from the manufacturer in 2002, the configuration was established in connection with a test flight to determine whether the individual aircraft was sensitive to oscillations. During the test flight, LN-OAX was not defined as sensitive, and the aircraft was supplied from the manufacturer with a standard configuration at the time of delivery.

Since 2006, when the current configuration became standard, Airbus Helicopters has published several service bulletins (SB) for upgrading and modification of the servo configuration on older models.

In 2010, service bulletin SB AS350-67-00.41[5] (Installation of GOODRICH New-Generation Main Servo-Controls) was published. In the service bulletin, Airbus Helicopters recommended the installation of a new type of main servos. Switching to the latest generation servos improved the responsiveness of the flight controls and increased pilot ease of use. The modification corresponds to the servo configuration installed in helicopters delivered after 2006.

In 2018, Airbus published SB AS350-67.00.69, Main Servo Controls. Installation and verification of banjo screws with built-in restrictor. The reason for the service bulletin was that the wrong type of banjo screws could be installed, which could be at the expense of the pilot's ease of use. The modification was recommended by Airbus Helicopters, but not mandatory. Owners and operators were advised to check that the servo configuration was correct. At the same time, Airbus recommended that the operator upgrade the servo installation in accordance with Mod 073221 (SB AS350-67.00.41) or Mod 073178 (Banjo screws with reduced cross-section); see Figure 6.

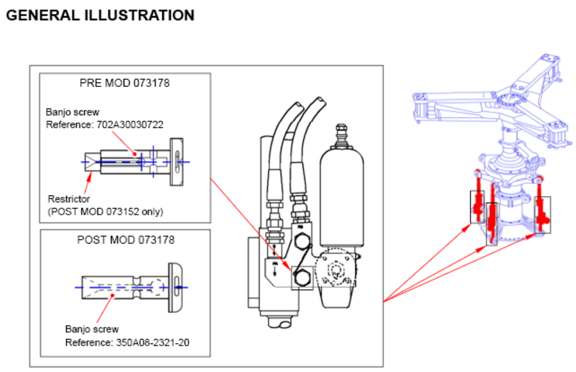

Figure 6: Image from SB AS350-67-30-0001 showing the change in the configuration of banjo screws, where the inside diameter has been reduced to reduce sensitivity to RPC. Illustration: Airbus Helicopters / NSIA

The helicopter company has stated that they had checked whether the configuration of LN-OAX's servos was correct, but that the servo installation had not been upgraded according to Mod 073221. Mod 073221 (AS350-67.00.41) was an optional installation.

In October 2023, Airbus Helicopters published a new service bulletin, AS350-67-30-0001, describes a modification in which the banjo screws on the main servos are replaced by screws with a smaller internal diameter. The SB which contains partly the same requirement as SB AS350-67.00.69 reduces the helicopter's sensitivity to pilot induced oscillation (PIO) or pilot assisted oscillation (PAO) during external sling load operations. Airbus Helicopters states that this can be done as a first measure, and then to subsequently, in connection with the main overhaul, upgrade the servos to the latest generation in accordance with SB AS350-67-00.41.

[5] *Equivalent to MOD 073221.*

1.6.5.3 Flight control friction system

The helicopter's mechanical flight controls are equipped with a friction system. One swivel wheel is mounted on both the collective; see Figure 7 and the cyclic; see Figure 8 so that the pilot can adjust the friction of the two controls individually. It is possible to adjust the friction setting and fly with no friction on the controls. The NSIA has been informed that the friction system may be affected by the helicopter's temperature and maintenance.

Collective:

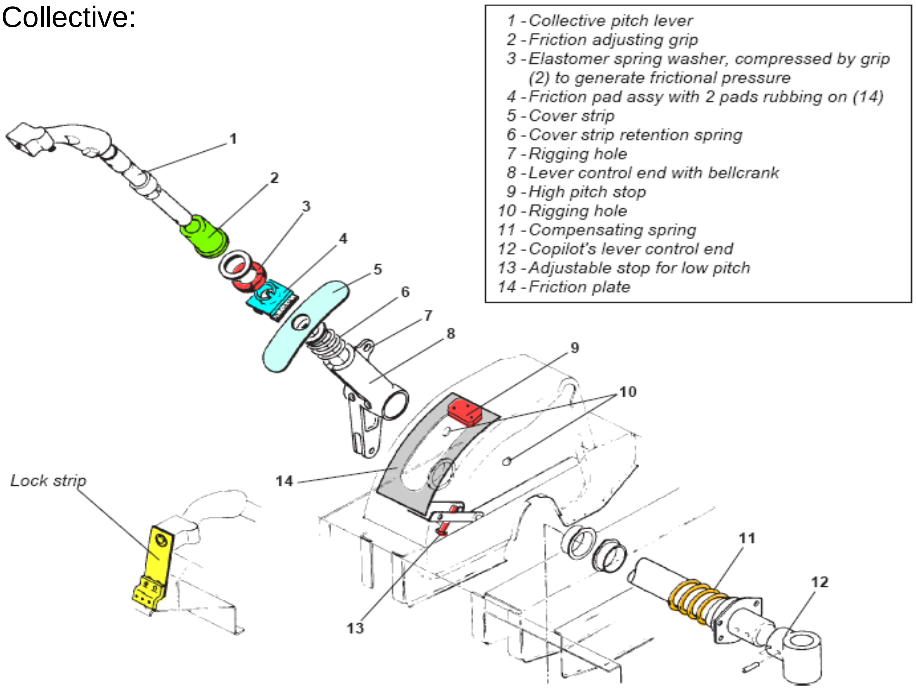

Figure 7: Overview of the collective's friction mechanism. By turning the grip (2), the pilot can adjust the friction between the collective's sliding plate (4) and the fixed sliding plate (14) in the console (cockpit). Illustration: Airbus Helicopters/NSIA

Cyclic

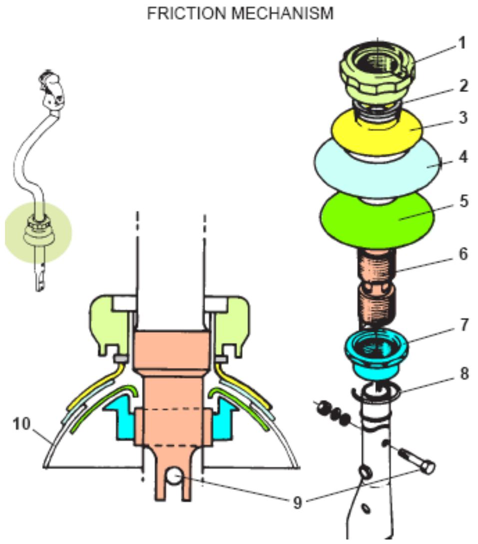

Figure 8: Overview of the cyclic's friction mechanism. The pilot can adjust the cyclic friction with the help of the light green (1) tensioning wheel mounted on the control. By turning the wheel clockwise, friction will increase steplessly between the friction cap, (3), the moving cup (5), the lower cup (4) and the stationary friction cup (10). Illustration: Airbus Helicopters/NSIA

1.6.5.4 Electronic units

LN-OAX (produced in 2002) was not equipped with a data recorder like the Appareo Vision 1000[6]. The helicopter had several units for storing some information, however, including a Vehicle and Engine Multifunction Display (VEMD) and an electronic flight bag (iPad, mini). There was also a Guard Systems tracking device installed, but that device is not discussed in this report.

The VEMD installed in the helicopter's instrument panel is used to display engine and flight information. It stores flight information, fault messages and limit value exceedances; see Figure 9.

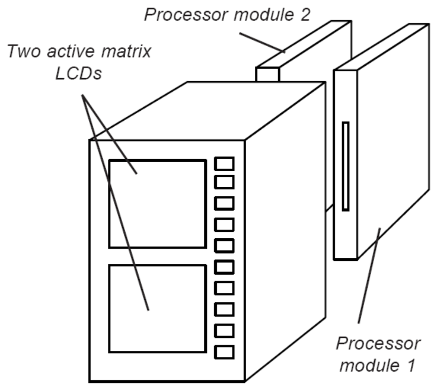

Figure 9: The helicopter's VEMD with two processor modules. Illustration: Airbus Helicopters / NSIA

The VEMD has three modules: two processor modules and one liquid-crystal display module. All modules are individually interchangeable. The two processor modules receive and process the same information, which is subsequently compared. In the event of differences in the presented data between the units, a fault code will be displayed. The modules work independently of each other; if one fails, the other one will still display information to the pilot. The VEMD also displays other parameters such as the First Limit Indicator (FLI), engine cycle counter, engine performance test and performance calculation; see Figure 10.

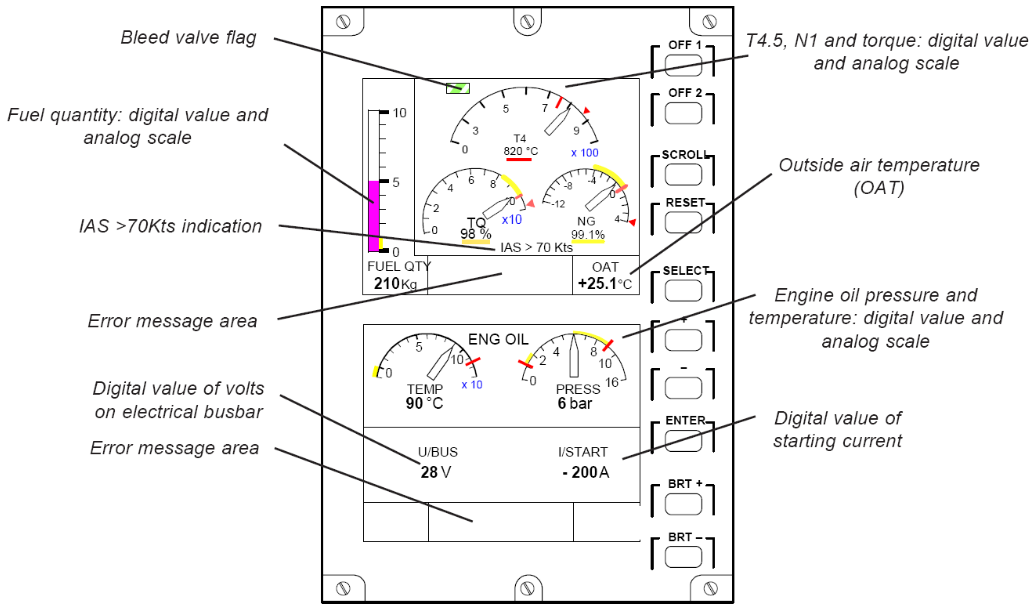

Figure 10: VEMD front with accompanying information. Illustration: Airbus Helicopters / NSIA

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[6] *The Appareo Vision 1000 is a simple recorder unit. It does not meet the requirements of a lightweight recorder set out in the EUROCAE Document ED-155 'Minimum Operational Performance Specification for Lightweight Recording System'.*

A loose iPad mini (Portable Electronic Device (PED)) containing the navigation software Air Navigation Pro was used during the flight when the accident occurred. It is not part of the helicopter's fixed equipment. Air Navigation Pro has several features that help pilots plan, execute and evaluate flights. The software also includes a flight recorder function that stores the aircraft's heading, speed and altitude every second. It is possible to download the helicopter's heading, altitude and speed data from one or more flights. The downloaded information from a loose mounted electronical unit must be evaluated with care for correct information.

1.7 Meteorological information

1.7.1 INFORMATION FROM THE NORWEGIAN METEOROLOGICAL INSTITUTE

The NSIA has obtained weather data from the Norwegian Meteorological Institute, which has analysed the weather situation at the time of the accident; see Figure 11.

The Norwegian Meteorological Institute's analysis describes the situation as follows:

> *The weather situation*
>
> *The analysis at 12 UTC (1400 local time) shows a low-pressure area in the Norwegian Sea with associated low-pressure fronts over Southern Norway, including an occlusion over Rogaland moving in a northeasterly direction. This will result in both wind and precipitation, first in the form of rain and then showers. In the morning, the wind direction will be east-southeasterly and will then turn southwest when the front passes. The accident probably happened just as the front was passing, and the pilot may have experienced demanding weather conditions, both in terms of turbulence and low cloud cover, as well as icing along the front.*

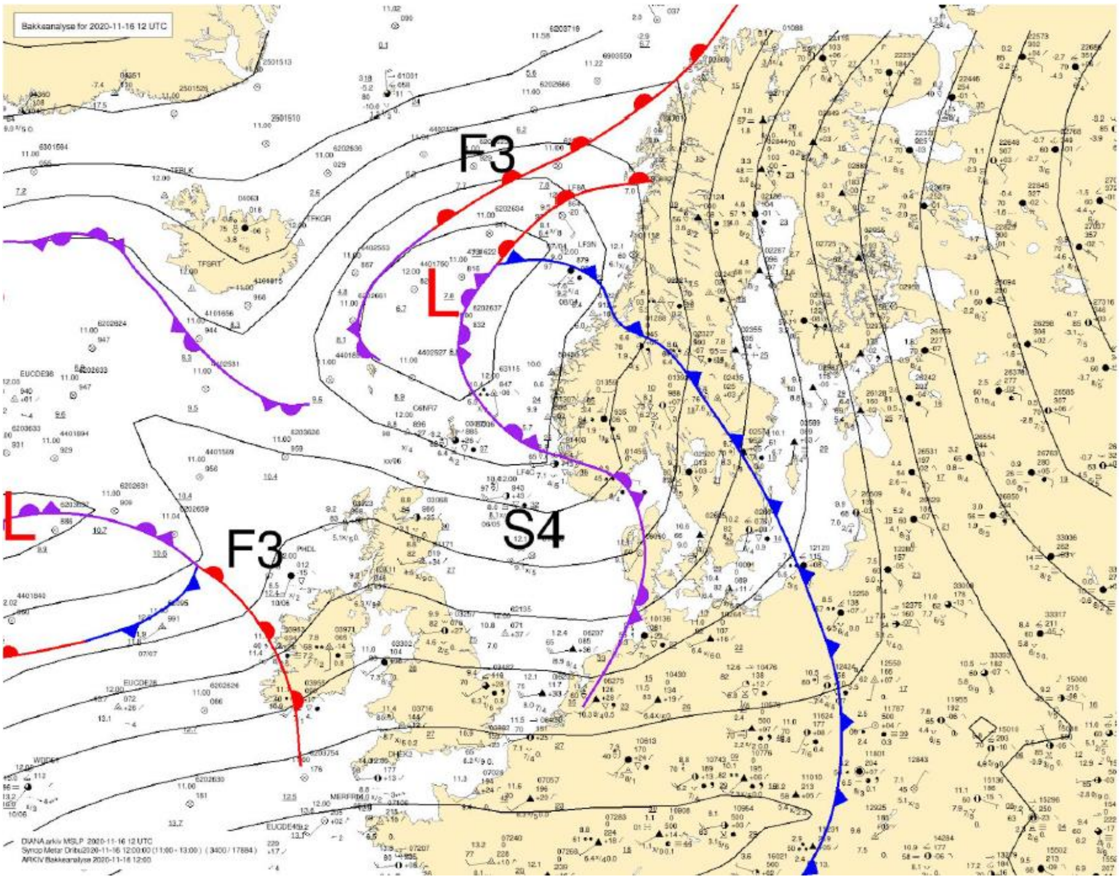

Figure 11: Weather forecast for the area where the flight took place. Source: Norwegian Meteorological Institute / NSIA

Topography

The Lysefjord is a long, narrow fjord, oriented in an east-west direction, surrounded by tall mountains to the south and north. When the wind blows from a southerly direction, gusts and turbulence are likely to occur. In this particular case, the wind direction has probably first been fairly easterly on the ground and southerly at altitude, which in itself creates wind shear. When the front passes, and the wind turns to a southwesterly direction, it will be fairly turbulent for a period of time. Finally, the ground wind may end up in a more westerly direction (moving into the fjord), while at altitude, the wind ends up in a southwesterly direction. The worst of it will then be over.

1.7.2 PILOT'S DESCRIPTION OF THE WEATHER

The pilot has explained to the NSIA that the weather deteriorated during the course of the day, with low cloud cover, heavy rain and variable winds. The gusts of wind were confirmed by the observation of blasts on the surface of the fjord. The pilot perceived the weather situation as increasingly demanding throughout the day and considered cancelling the operation several times.

1.7.3 TAF / METAR SOLA STAVANGER AIRPORT

The following TAF report was issued out at 0500 hours for Sola Airport (the nearest airport):

2020-11-16T05:00:00 ENZV 160500Z 1606/1706 15012KT 9999 BKN040 TEMPO

1607/1617 4000 SHRA BKN008 SCT015CB BECMG 1609/1612 16020G30KT BECMG

1612/1615 25018KT BECMG 1700/1703 17012KT TEMPO 1702/1706 4000 RA BKN012=

1.8 Aids to navigation

Not applicable.

1.9 Communications

The flight took place in uncontrolled airspace. The pilot communicated with personnel on the ground via radio.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

Flight recorders were neither installed nor required in the helicopter type at the time the accident occurred.

1.12 Accident site and wreckage information

1.12.1 ACCIDENT SITE

The accident site is approximately 252 meters above sea level, close to the FV 4668 road, Songesandsvegen.

After the NSIA's inspection of the accident site, the most appropriate departure route at the accident site was considered to be towards the east or west. These routes had fewer air obstacles compared with the north or south routes.

The formwork at pylon foundation 49 consisted of a wooden frame over a round black plastic formwork.

1.12.2 THE HELICOPTER WRECKAGE

The wreckage remained lying on its right side, with the individual pieces fairly close together. The cabin was still intact, while the tail section had broken into three parts. The two foremost portions of the tail boom remained tied to the helicopter by a hydraulic hose and panels of the tail boom structure. The rear of the tail, including the vertical fin and tail rotor gearbox with tail rotor, was found approximately 13 metres southwest of the main wreckage; see Figure 3.

The main rotor with three rotor blades, hydraulic servos and a rotor head was destroyed after the impact with the trees and the ground. One of the rotor blades ended up coiled around the main rotor shaft; see Figure 12. The remaining rotor blades were found severely damaged near the wreckage. The helicopter's tail rotor blades were still attached to the tail rotor gearbox and had sustained various degrees of damage.

Figure 12: The helicopter wreck looking southwest. One of the rotor blades has been coiled around the rotor mast. Photo: NSIA

1.13 Medical and pathological information

No special circumstances or findings.

1.14 Fire

No fire occurred at the crash site.

1.15 Survival aspects

The helicopter's cabin retained its original shape after the crash.

The pilot was wearing a helmet and was strapped into the right seat with a four-point seatbelt. He removed his own helmet before the evacuation. The helmet was found with some scratches on the right-hand side.

Both personnel representing the contractor and the helicopter operator quickly arrived at the scene of the accident to assist the pilot after the accident. The emergency services were notified immediately.

1.16 Other investigations

1.16.1 HELICOPTER FLIGHT CONTROLS

The NSIA has examined the helicopter's flight controls for function and wear. Due to damage to the servos, measurements of the control system had to be carried out using another method than the manufacturer's standard procedure. The measurement showed that the total slack between the collective and the servos was between 1.3 and 1.8 mm.

The NSIA has examined and measured the friction system. The actual value at the time of the accident was used in the measurement of friction on the collective. The friction was measured at 150 g. By turning the friction wheel a quarter of a turn, the value increased to 700 g. It was not possible to get the friction below 150 g. The friction was set to its lowest level, and no faults or defects have been detected in the system.

The main rotor servos were disassembled and sent to the manufacturer. The servos were examined and tested under the supervision of the French investigation authority (BEA) without finding any faults or defects that may have had an impact on the accident.

1.16.2 HELICOPTER FLIGHT MANUAL

The helicopter's flight manual (FLM) contains necessary information for flight personnel and operators. The manual is produced by the manufacturer, and some chapters have been approved by the European Union Aviation Safety Agency (EASA). Chapter 4 of the FLM for AS 350 contains checklists that the pilot must comply with. Point five of the checklists (Checks before Take-Off) indicates with a note that the friction loads should be adjusted so that they are felt by the pilot when moving the flight controls; see Figure 13.

FLIGHT MANUAL

4.2 CRANKING

The cranking procedure can be performed after an aborted start or for check or maintenance purposes.

Proceed as follows:

Check:

. Starting selector - - - - - - - - - - - - - OFF (AR)
. Emergency fuel
  shut-off lever- - - - - - - - - - - - - - - Forward
. "AUTO/MAN" selector - - - - - - - - - - - - AUTO
. Ng- Check ≤ 10 %
. "FUEL PUMP" (POMPE CARB)- - - - - - - - - - ON
. "CRANK" (VENTIL.) - - - - - - - - - - - - - Pressed in for 30 sec. max R
. "CRANK" (VENTIL.) - - - - - - - - - - - - - Released
. "FUEL PUMP" (POMPE CARB) - - - - - - - - - OFF

CAUTION: DO NOT CRANK THE ENGINE WITH THE EMERGENCY FUEL SHUT-OFF VALVE CLOSED OR WITH THE FUEL PUMP OFF AS THIS COULD DAMAGE THE ENGINE HIGH PRESSURE FUEL PUMP.

NOTE: Observe the engine starter limitation given in SECTION 2.1 § 19. R

5 CHECKS BEFORE TAKE-OFF

- Doors - - - - - - - - - - - - - - - - - - - Closed or sliding doors open locked

- Navigation *- - - - - - - - - - - - - - -
- Radio navigation * - - - - - - - - - - - - Tests, correct operation
- Radio communication * - - - - - - - - - -

- Collective and cyclic frictions - - - - - - - As required
- Landing light - - - - - - - - - - - - - - - - As required
- Temperatures and pressures - - - - - - - - - Normal range
- All warning and caution lights - - - - - - - OFF
- Collective - - - - - - - - - - - - - - - - - Unlock
- Heating system*, demister,
  air conditioning* - - - - - - - - - - - - - - As required

NOTE: Adjust collective and cyclic friction locks so that friction loads are felt by the pilot when moving the flight controls.

6 TAKEOFF

CAUTION: USE OF HEATING* AND DEMISTING IS FORBIDDEN ABOVE ENGINE MAXIMUM CONTINUOUS RATING (Ng or t4)

Take off by gradually increasing the collective pitch and maintain hover, head into wind, at a height of about 5 ft (1.5m).
Check that the engine and transmission monitoring instruments are within their normal operating ranges.
For transition from hover, increase speed without increasing the power demand (power required for hover IGE) and without climbing until IAS is 40 kt (74 km/h).

NOTE: The bleed valve flag disappears when the valve closes. The bleed valve is normally open when the engine is shut down, during starting and at low power.

* Optional

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Figure 13: Section from AS 350 flight manual where friction settings are defined. The NSIA has marked the relevant section with a blue outline. Source: Airbus Helicopters. Markings:NSIA

1.16.3 VEHICLE AND ENGINE MULTIFUNCTION DISPLAY (VEMD)

The helicopter’s VEMD was dismantled and sent to the manufacturer Airbus Helicopters under the auspices of the French investigation authority.

Information from the VEMD shows some exceedances of the main rotor rpm and torque during the flight in question. A rotor speed of 510 rpm and a torque of 146% were registered. A torque of 146% is compatible with the fact that the rotor blades hit trees or the ground, while the rotor speed of 510 rpm is unusually high considering that the drivetrain from the engine was still intact. The unusual high rpm lasted for one second.

1.16.4 SAFRAN HELICOPTER ENGINE (SHE) ARRIEL 2

The engine control unit (DECU) and the free wheel shaft; see Figure 14, were disassembled and sent to the engine manufacturer (Safran Helicopter Engines) for inspection together with the NSIA and BEA. Data from the DECU and markson the free wheel shaft show that the engine supplied power to the main gearbox when the rotor system was slowed down as a result of the accident.

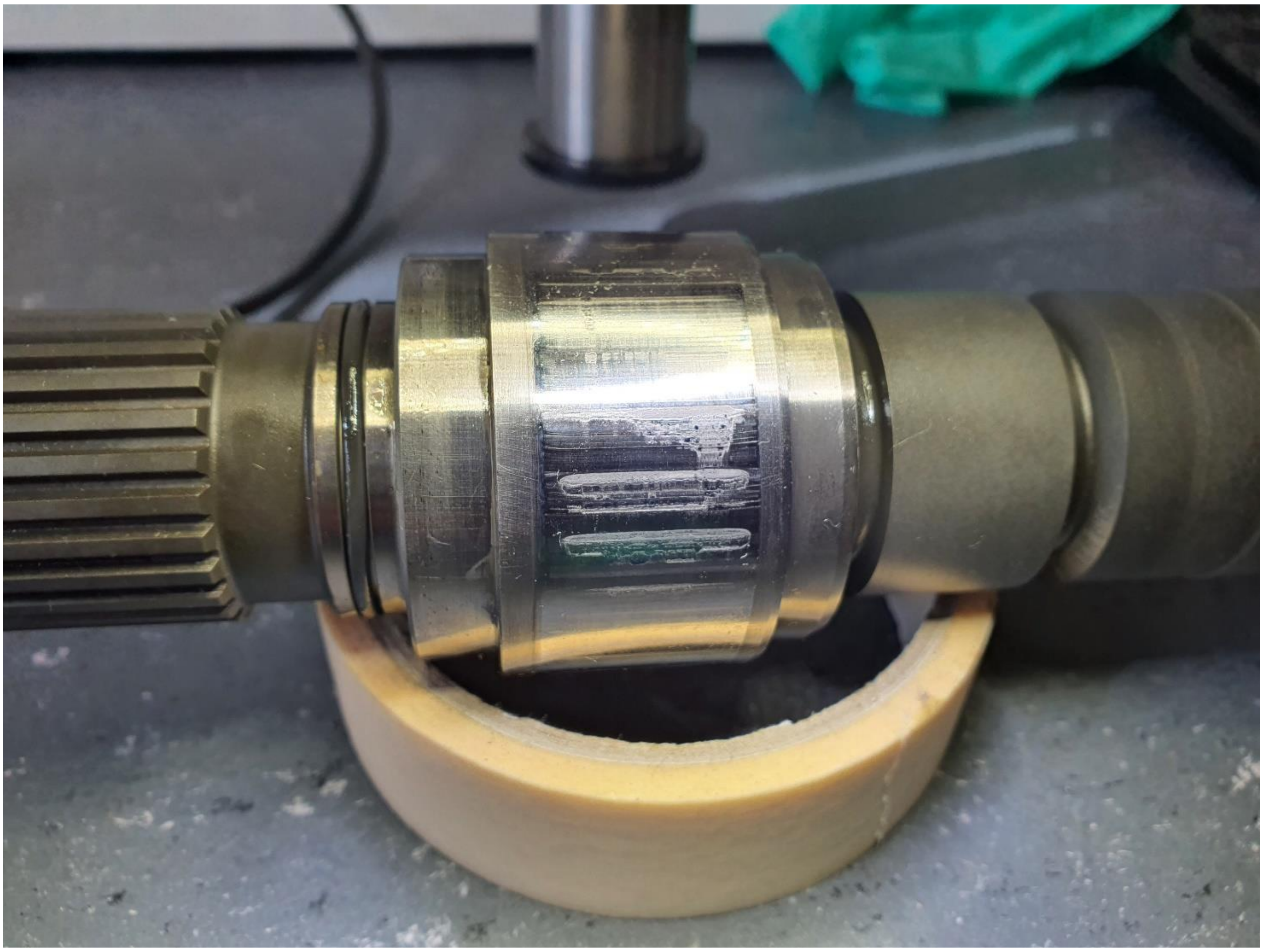

Figure 14: Marks on the helicopter's free wheel shaft. The marks are typical of a situation where the rotor rpm is reduced at the same time as the engine supplies power to the drive shaft. Photo: NSIA

1.16.5 MISCELLANEOUS TECHNICAL EXAMINATIONS

Fuel and hydraulic fluid tests did not identify any major deviations.

1.16.6 DATA FROM AIR NAVIGATION PRO

The NSIA has downloaded data from the iPad with the Air Navigation Pro software that was used during the flight. The flight is visualised in Figures 15 and 16.

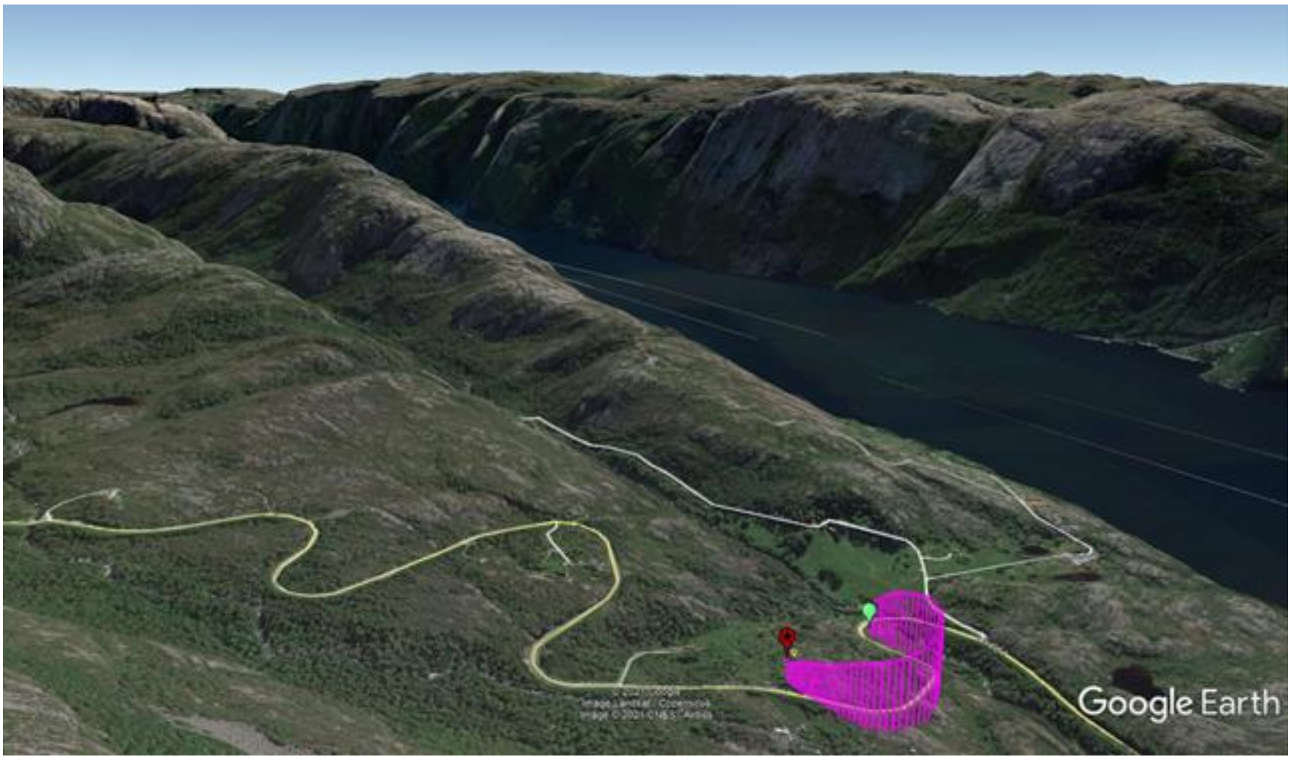

Figure 15: The illustration is seen in a 135° direction. The last flight is illustrated on the basis of data downloaded from Air Navigation Pro. The starting point is indicated by a green pin and the crash site by a red pin. Source: Air Navigation Pro / Google Earth / NSIA

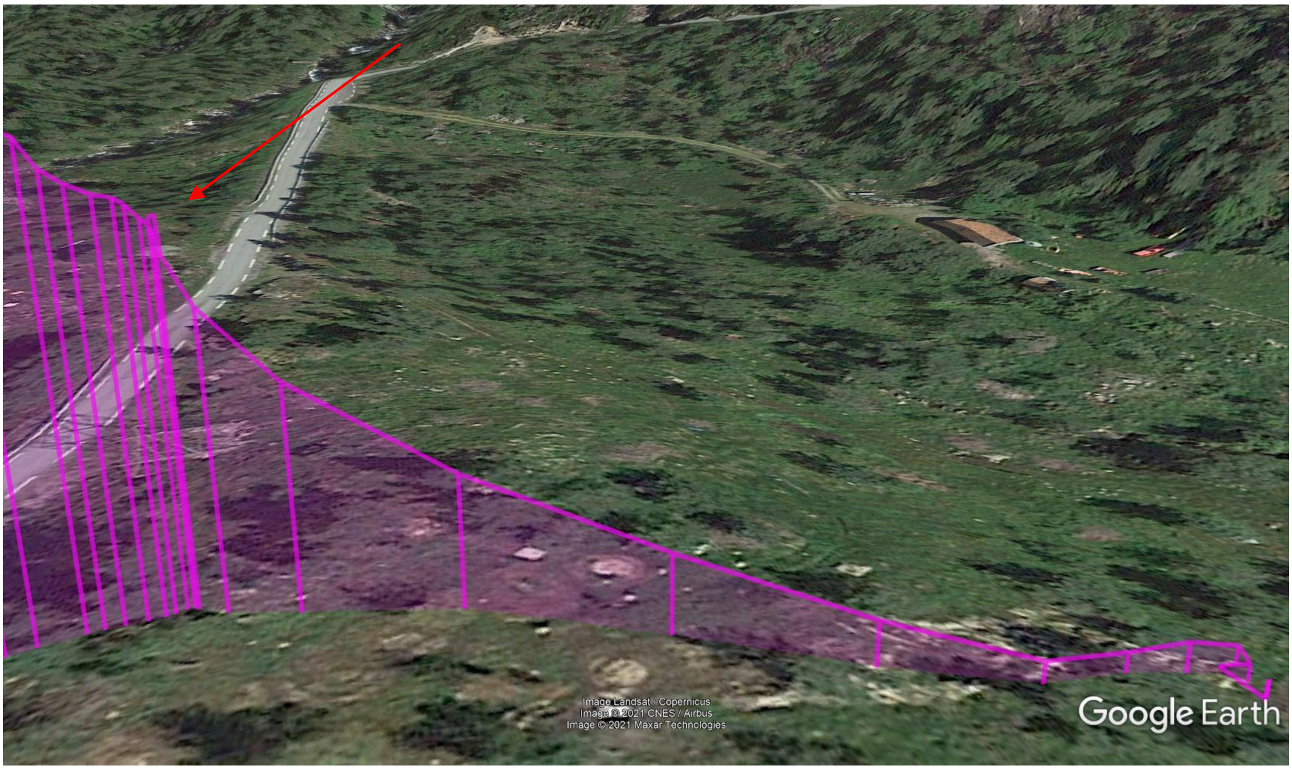

Figure 16: The illustration shows the last movements and crash site of the helicopter. The red arrow indicates a vertical movement just above pylon foundation 49. Each vertical reference line represents one second. The last four seconds of recording is judged as not reliable. Source: Air Navigation Pro / Google Earth / NSIA

1.17 Organisation and management

The company Heli-Team AS was established at Stangnesterminalen in Harstad in 1988.

Heli-Team AS has an Air Operator Certificate (AOC) issued by the Civil Aviation Authority (CAA) Norway for commercial helicopter operations. At the time of the incident, the company operated a total of eight helicopters, of which seven were of the type AS 350.

The company's operations manual system OM-A, B, C, D and E describes the company's operating procedures. CAA Norway as the competent authority approves and issues certificates and carries out company audits.

At the main base in Harstad, the company has its own technical workshop with EASA Part-145 approval to carry out maintenance of its helicopters.

1.18 Additional information

1.18.1 AIRCRAFT AND ROTORCRAFT COUPLINGS – PILOT-INDUCED OSCILLATIONS

Helicopters may be subjected to powerful oscillations during flight, particularly in connection with sling load operations.

Rotorcraft Pilot Couplings (RPC) is a collective term for phenomena where the pilot's unintended interaction with the helicopter can lead to powerful and sometimes uncontrollable oscillations. One definition of RPC is '*inadvertent, sustained aircraft oscillations which are a consequence of an abnormal joint enterprise between the aircraft and the pilot'.*[7] RPC can essentially be divided into two phenomena:

- Pilot-induced oscillation (Rigid Body, RPC)
- Pilot-assisted oscillation (Aeroelastic, RPC)

In order for these phenomena to occur, one or more triggering factors must be present. Triggering factors can be jerks from the suspended load, contact between the load and the ground or object, turbulence or gusts of wind, abrupt manoeuvres or sudden and unintentional changes in engine performance.

In addition, the risk of the phenomenon occurring is affected by the helicopter's natural frequency, sensitivity to oscillations, friction devices on flight controls, and the suspended load (weight, natural frequency, possible dampening between helicopter and load). The material of the cargo line – either fibre or steel – will only affect the risk of PIO marginally. A lightweight helicopter with a heavy suspended load will be at greater risk of vertical oscillations.

Pilot Induced oscillation (PIO) is a situation that occurs at low frequencies (0–2 Hz), where the pilot's voluntary-active control commands to the helicopter's control systems are out of phase with the helicopter's movements and the pilot's perception.

If PIO occurs, it is the pilot who keeps the phenomenon going. The pilot, and especially the arm holding the collective, is affected by the movement of the helicopter at the same time as the pilot consciously or unconsciously attempts to counteract the movement by giving the opposite control command through the collective. There will always be a delay before the helicopter responds to the pilot's control movements. If the pilot's control commands are out of phase, the phenomenon will be amplified. Tests at Airbus Helicopters shows that operation with low friction on the collective and hovering in tailwind will be major contributors to the development of PIO.

[7] *Kilde; ARISTOTEL Grant agreement ID: 266073.*

Pilot-assisted oscillation (PAO) is the result of the pilot's involuntary (passive) control commands to the helicopter control systems. This usually occurs at a frequency between 2 and 8 Hz. The involuntary control commands often result from the pilot being affected by the helicopter's vibrations. The pilot's muscular system will inadvertently act as a link between the movements of the helicopter and the helicopter seat, resulting in increasing oscillations.

Collective bounce is a phenomenon in which the helicopter's collective is out of phase with the helicopter's vertical movement. The phenomenon is caused by the coupling between the helicopter's vertical motion and the left arm of the pilot moving the collective. If not immediately corrected, the rapid movement at a frequency of around 3 Hz may cause the pilot to lose control or cause structural damage to the aircraft.

1.18.2 TYPE OF OPERATION – FRICTION ON FLIGHT CONTROLS

RPC can occur in several types of operations, and the oscillations are sometimes caused by the type of operation performed. If a pilot is flying a new type of aircraft, for example, oscillations may occur more or less intentionally at the beginning, where the pilot easily corrects the oscillations using the flight controls. In other operations, unintentional oscillations may occur and result in major vertical variations. This is a potentially dangerous situation where the aircraft can quickly spiral out of control or sustain structural damage.

The flight controls in a helicopter are designed with a friction system. High friction on the controls reduces the risk of RPC developing.

1.18.3 MEASURES TO RECOVER FROM RPC

There are three recommended methods for recovering from an RPC situation:

- Pilot releases flight controls.
- Pilot 'freezes' the flight controls.
- Pilot significantly reduces his movements to become less aggressive.

The most recognised method is for the pilot to reduce input to the flight controls by letting go of the collective. This is not a natural reaction for the pilot, especially when flying at low altitude. The natural response would normally be to continue operating the flight controls. This may in some cases amplify the oscillations that have already occurred.

The NSIA has previously investigated incidents that were likely caused by RPC. The phenomenon is mentioned in both report SL 2011/14 concerning an incident involving LN-OWB and report 2024/01concerning an incident involving LN-OGN. During the incident involving LN-OWB, the pilot experienced that PIO was occurring and he recovered from the situation by pulling markedly on the collective. The pilot then immediately felt the oscillations ceasing. The incident shows that recovery from PIO may be achieved by pulling resolutely on the collective, even though this has not been documented.

1.18.4 OTHER INFORMATION

In October 2023, Airbus Helicopters published a safety information notice of relevance to the investigation.

Safety Information Notice No 3890-S-00[8] describes oscillations that may arise during sling load operations. The notice describes RPC, including both PIO and PAO, and was published on the basis of several reports of significant oscillations, vertical vibrations and collective bounce. The purpose of the information is to share the lessons learned by Airbus Helicopters from these events. The safety information is relevant to many types of helicopters and for sling load operations. It provides useful information and recommends measures that can be taken in the event of RPC.

Safety Information Notice No 3899-S-97 applies to AS 350, AS 550 and EC 130. The document further advises operators to implement SB AS350-67-00.41/AS550-67.00.23[9] (switching to new-generation servos) or alternatively upgrade the servos in accordance with SB AS350-67-30.0001/AS550-67.30.000[10].

1.18.5 HELICOPTER EXTERNAL SLING LOAD OPERATIONS – HESLO

Sling load operations are regulated by the European Union Aviation Safety Agency (EASA) in EU Regulation (IR) 965/2012 SPO.SPEC. HESLO 100. The regulation applies as Norwegian law pursuant to Section 1 of Regulations No 956 of 7 August 2013 relating to air operations. Separate rules apply to the transport of persons suspended from a helicopter.

HESLO 1:	short line, 20 metres (m) or less
HESLO 2:	long line, more than 20 m
HESLO 3:	specialised sling load, such as: Logging, insulators and pullers, traverse mounting, spinning of fibre cable, ice and snow removal from power lines, sawing, geophysical surveys, cable laying onto the ground or into ditches, avalanche control, landslide control
HESLO 4:	Advanced sling load such as: Tower erecting, wire stringing, disassembly of masts and towers

Figure 17: The four HESLO categories. Source: EASA/NSIA

Helicopter operators carry out assignments according to their own procedures and risk assessments that are approved by CAA Norway. The operation in question was carried out as a HESLO 1 operation, and both the company and the pilot had the required privileges.

A cargo hook (or belly hook) that is attached to a helicopter must meet EASA's certification requirements. The equipment the operator uses that is attached to the hook is not subject to the same certification requirements.

1.18.6 CARGO LINE USED IN THE OPERATION

The wire used in the sling load operation was a non-rotating steel wire (Hyflex 35). It was 15 metres long with a diameter of 12 mm. A steel wire will always have a certain elasticity. The elongation of the wire will depend on the wire's length, diameter and type and the load attached to it. In this case, the elongation was calculated to be 13.4 mm. It has not been possible to obtain the

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[8] The document is included as an appendix to this report.
[9] Modification corresponding to MOD 073221
[10] Modification corresponding to MOD 073178

actual wire’s modulus of elasticity. The calculation has therefore been made based on standard values for the type of wire in question.

The importance of the load line for PIO, especially the load line, has been investigated. In a meeting with the helicopter manufacturer, it was concluded that the difference in elasticity between steel wire and fibre line does not affect the helicopter's sensitivity to RPC to any significant extent.

1.19 Useful or effective investigation techniques

No methods warranting special mention have been used in this investigation.

2. Analysis

2. Analysis

2.1 Introduction

The NSIA has conducted the analysis based on its own investigations at the accident site and examination of the helicopter. In addition, information from the pilot, witnesses, the police, the helicopter manufacturer Airbus Helicopters, the engine manufacturer Safran Helicopter Engines, the French investigation authority (BEA) and the helicopter company Heli-Team has contributed to the analysis.

The NSIA has conducted several analyses for the purpose of finding a cause, explaining the sequence of events and excluding the possibility that technical faults contributed to or caused the accident. The NSIA has analysed the incident from a probability perspective, as the investigation has not been able to determine the cause of the accident.

2.2 Sequence of events

The pilot chose to approach the pylon foundation from the west as he considered that this would provide a safer departure with fewer air obstacles and that the helicopter could be placed a little further away from the power line about 30 meters south of pylon foundation 49. The wind conditions at the time indicated that the wind would affect the helicopter from the rear in a south-westerly direction. At pylon foundation 49, it was possible to approach the foundation from the east or west. The NSIA believes it to be safer that the wind would come from ahead, which suggests that the pilot in this case should have chosen to approach the foundation from an easterly direction.

The approach above the pylon foundation appears normal, and electronic data from the helicopter's EFB, combined with statements from the pilot and ground personnel, indicate that an altitude correction was made above the pylon foundation. In this correction, the ground personnel observed that the bucket came into contact with the formwork. Shortly after the correction was made, the helicopter started developing strong vertical movements. The pilot's statement, in which he described how the helicopter started 'jumping', corresponds well with the occurrence of oscillations and RPC.

The sequence of events when LN-OAX crashed developed very rapidly, and the pilot had to make several decisions in quick succession. He first focused on manoeuvring away from the personnel on the ground, at the same time as the oscillations increased, reducing the helicopter's flight capabilities. It is not unlikely that, at this point in time, RPC was the reason why the pilot had a feeling that 'the helicopter was going down'. The situation got out of control and the helicopter crashed east of pylon foundation 49.

2.3 Rotorcraft-pilot coupling

The NSIA's analysis of the accident shows that several of the necessary factors for RPC to occur were present.

- In the NSIA's opinion, the fact that the helicopter had a low mass at the same time as the weight of the suspended load was approximately 700 kg led to an increased risk of RPC.
- Flight control friction had been adjusted to a low setting with no measurable friction after the accident.

- According to witnesses, the helicopter's load came into contact with the foundation frame as the bucket was being emptied.
- Electronic data show that an altitude correction was made at the pylon foundation during the unloading of the concrete. The correction may have been necessary as the wind was probably blowing from behind at the time.
- The helicopter had an older original servo configuration on the flight controls. The configuration meant that the helicopter was probably more sensitive to oscillations when flying with a suspended load compared with the upgraded flight control configurations.

Based on the facts and explanations from the pilot and witnesses, NSIA finds it probable that the RPC phenomenon occurred. It is also likely that more than one factor was the cause of the RPC occurrence.

The phenomenon may have arisen when the pilot had to correct the helicopter's altitude in connection with unloading the concrete. The correction may have been due to a gust of wind from behind in addition to contact between the bucket and the formwork of the foundation.

The vertical movements and the pilot's description, including the estimated amplitude of the oscillations of about 5 cm, correspond well with a PAO occurrence. Nor can a combination of PAO and PIO be ruled out.

The NSIA's investigation has shown that the use of friction on the flight controls can vary substantially from pilot to pilot, depending on the type of flight concerned and the phase of the flight. The measurement performed by NSIA after the accident show that the friction on LN-OAX was set to the low level. The NSIA believes that the risk of RPC developing would have been significantly lower with a higher friction setting on the helicopter's flight controls.

The analysis of downloaded electronic information from Air Navigation Pro shows a marked altitude correction at the same time as the concrete was being unloaded. The electronic information correspond well with the pilot's and fitters' statements and the resulting RPC development. The NSIA has judged the 4 latest recorded points in the downloaded information as not reliable.

2.4 Measures from Airbus Helicopters

During this investigation, Airbus Helicopters has published Safety Information Notice no. 3890-S-00 which provides important information about PIO and PAO. The safety information also provides information about the significance of friction on the helicopter's flight controls. The NSIA believes that the information is important and recommends that all operators ensure that this information is known to their flight and technical personnel.

In addition, Airbus has published a recommendation in its safety information no. 3899-S-67 to implement an upgrade of the helicopter's main servos if these are of an older generation. The NSIA supports this recommendation.

Airbus Helicopters has continued to work on tests on the AS 350 to see how the phenomenon occurs. In early 2025, Airbus Helicopters managed to provoke PIO during a test flight. Test results from the flight will now be analysed. The NSIA is pleased that Airbus Helicopters has continued to work on understanding the phenomenon and trying to find a technical measure to reduce the risk of PIO.

2.5 Other analyses

2.5.1 GENERAL INFORMATION

The NSIA has conducted several analyses for the purpose of finding a cause, explaining the sequence of events and excluding the possibility that technical systems contributed to or caused the accident.

2.5.2 HELICOPTER FLIGHT CONTROLS

The inspection and measurement of the helicopter’s flight controls, as a system, revealed some slack. The NSIA’s assessment, after consultation with the manufacturer Airbus Helicopters, is that the values are close to the maximum permitted limit. Although the measured slack was close to the maximum limit, the NSIA has concluded that the slack had no bearing on the accident.

The friction system of the collective and cyclic controls was inspected without any faults or defects being detected.

On delivery from the manufacturer, LN-OAX was not considered to be sensitive to vertical oscillations but had an older servo configuration than helicopters delivered after 2006.

The helicopter servos had not been upgraded to the latest version introduced by SB AS350-67-00.41 (published in 2010) or AS350-67.00.69 (published in 2018).

The NSIA cannot say whether the accident could have been prevented if the helicopter’s flight controls had been modified, but considers it likely that the helicopter would have been less sensitive to oscillations if the flight controls’ servo configuration had been up to date in accordance with SB AS350-67-30-0001.

When considering whether to perform an SB that is not mandatory, the operator will normally make a cost-benefit assessment in relation to operation and safety. The safety assessment will often be justified by the information provided in the documentation. The NSIA is of the opinion that the relevant SBs, published before 2023, do not contain a clear safety message that would assist the operator in their safety assessment.

SBAS350-67-30-0001 was published on 26 October 2023 during this investigation. It describes replacement of the banjo screws installed in the helicopter's main servos to a new screw with a smaller cross-section to reduce the sensitivity of the helicopter's control system.

The NSIA share Airbus Helicopters recommendation to incorporate this modification.

An inspection was carried out of the helicopter’s rotor system, servos and rotor head. The Starflex rotor hub was broken at a 45-degree angle. This is a typical fracture pattern seen in situations where the rotor blade rpm is reduced abruptly, for example when hitting the ground or another hard object. The rotor head frequency adapter and liners were inspected without any faults or defects being detected. The remains of the rotor blades were inspected, but they were so severely damaged that it was not possible to identify any possible faults or defects in them. The NSIA has concluded that the rotor system was in operation and controllable at the time of the accident. In addition, the NSIA has concluded that the engine was in operation and was operating the helicopter’s rotor blades when it hit the ground.

2.5.3 VEHICLE AND ENGINE MONITORING DISPLAY

The analysis of the downloaded information concludes that the data corresponds with both the pilot's statement and the sequence of events, except for the fact that the rotor speed temporarily increased to 510 rpm one second. The rpm, especially considering that the drivetrain was still intact, is abnormally high compared with other similar accidents. The NSIA cannot rule out that the indication of high rpm was an error in connection with the accident.

2.5.4 ENGINE, SAFRAN HELICOPTER ENGINES – ARRIEL 2B

The engine's free wheel shaft underwent inspection by the engine manufacturer Safran Helicopter Engines together with the engine's DECU. The purpose of the inspection was to determine whether an engine failure could have caused or contributed to the accident. The inspection of the free wheel shaft found clear marks indicating that the engine was running normally when the accident occurred. The analysis of information downloaded from the DECU indicated the same. The NSIA has thus concluded that the engine functioned normally at the time of the accident.

2.6 Survival aspects

The helicopter's cabin retained its original shape after the accident and this, together with the fact that the pilot was wearing a helmet, was significant to him not sustaining serious injuries. The pilot's helmet sustained minor damage after having been in contact with the helicopter structure. The helmet has thus protected the pilot in the collision.

The fact that the pilot succeeded in manoeuvring the helicopter away from the place of delivery reduced the danger for those on the ground.

3. Conclusion

3. Conclusion

3.1 Main conclusion

The NSIA believes that control of the helicopter was lost in a situation where the phenomenon known as RPC had developed, resulting in strong vertical oscillations.

RPC may have occurred due to gusts of wind, over-correction of altitude, contact between the bucket and the pylon foundation, or a combination of the above factors.

The phenomenon developed very quickly, and the pilot did not have the time nor the altitude to regain control before the helicopter crashed.

3.2 Investigation results

A. The NSIA has not been able to detect any technical faults or defects in the helicopter that may have contributed to the accident. The fact that the engine control system had some slack will not have contributed to the accident, as this could have had the opposite effect in relation to RPC.

B. The helicopter's flight controls were set to low or no friction at the time of the accident.

C. The helicopter had the original servo configuration from 2002 and was probably more sensitive to oscillations compared to the establish 2006 configuration.

D. In the period since 2010, Airbus Helicopters has published several safety bulletins. The safety message has not been clearly communicated in all the relevant safety bulletins.

E. Airbus has after the accident published three documents during the course of the investigation:

   a. Safety Information Notice 3890-S-00, Oscillations and/or vibrations during Helicopter External Sling Load.

   b. Safety Information Notice 3899-S-67, Sensitivity of Pilot Induced Oscillation (PIO) / Pilot Assisted Oscillation (POA) phenomenon during Helicopter External Load Operation (HESLO).

   c. AS350-67-30-0001, recommending that operators modify their servos to a new type of banjo screw with a smaller internal diameter to reduce the helicopter's sensitivity to oscillations.

F. The company and the pilot held valid privileges for the operation performed.

4. Safety recommendations

4. Safety recommendations

The Norwegian Safety Investigation Authority will not publish any safety recommendation related to this accident.

Norwegian Safety Investigation Authority
Lillestrøm, 10 February 2025

Appendices

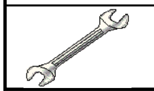
No. 3890-S-00

SAFETY INFORMATION NOTICE

SUBJECT: GENERAL

Oscillations and/or vibrations during Helicopter External Sling Load Operations (HESLO)

For the attention of

AIRCRAFT CONCERNED	Version(s)	
	Civil	Military
EC120	B	
AS350	B, BA, BB, B1, B2, B3, D	L1
AS550		A2, C2, C3, U2
AS355	E, F, F1, F2, N, NP	
AS555		AF, AN, SN, UF, UN, AP
EC130	B4, T2	
SA365 / AS365	C1, C2, C3, N, N1, N2, N3	F, Fs, Fi, K, K2
AS565		MA, MB, SA, SB, UB, MBe
SA366		GA
EC155	B, B1	
SA330	J	Ba, L, Sm
SA341	G	B, C, D, E, F, H
SA342	J	L, L1, M, M1, Ma
ALOUETTE II	313B, 3130, 318B, 318C, 3180	
ALOUETTE III	316B, 316C, 3160, 319B	
LAMA	315B	
EC225	LP	
EC725		AP
AS332	C, C1, L, L1, L2	B, B1, F1, M, M1
AS532		A2, U2, AC, AL, SC, UE, UL
EC175	B	
H160	B	
EC339		KUH/Surion
BO105	C (C23, CB, CB-4, CB-5), D (DB, DBS, DB-4, DBS-4, DBS-5), S (CS, CBS, CBS-4, CBS-5), LS A-3	CBS-5 KLH, E-4
MBB-BK117	A-1, A-3, A-4, B-1, B-2, C-1, C-2, C-2e, D-2, D-2m, D-3, D-3m	D-2m, D-3m
EC135	T1, T2, T2+, T3, P1, P2, P2+, P3, EC635 T1, EC635 T2+, EC635 T3, EC635 P2+, EC635 P3, T3H, P3H, EC635 T3H, EC635 P3H	

INTRODUCTION

Airbus Helicopters has been informed about several incidents during Helicopter External Sling Load Operations (HESLO) where pilots reported significant vertical bouncing, vibrations, and/or oscillations.

The purpose of this Safety Information Notice (SIN) is to share some lessons learned from the analysis of these incidents.

This SIN does not address pendulum oscillations or spinning of the load, which is another phenomenon that commonly occurs during HESLO.

BACKGROUND

A load slung underneath a helicopter behaves somewhat like a mass hanging on a spring - it is known by scientists as a mass-spring system. The sensitivity of the helicopter-load-sling combination to vertical oscillations and the frequency of the oscillation will depend on parameters such as the elasticity of the long line, the damping of the line and connectors, the mass of the load, and the aerodynamic characteristics of the load. Especially when the load is quite heavy compared to the helicopter, a vertical oscillation of the load will also cause the helicopter to oscillate and vice versa.

Any disturbance to the helicopter or load (due to e.g. turbulence, control input, rotor airflow on the load, ground contact) can trigger a vertical oscillation of the helicopter and load. Normally, these motions are well damped. However, some factors may cause these oscillations to become very severe and even divergent.

In most cases, releasing the external load was the only way to get rid of the bouncing. This SIN will provide some insight into possible causes of vertical oscillations and provide some recommendations to avoid and reduce them.

PILOT INDUCED OSCILLATION (PIO) / PILOT ASSISTED OSCILLATION (PAO) PHENOMENON

One possible cause of severe or divergent oscillations are pilot induced or assisted oscillations. They occur when the pilot is tightly grasping the controls (especially the collective lever) when the aircraft is oscillating vertically. In this case, the helicopter's vertical motion can be introduced back into the control system. This control input then creates an even larger disturbance, which further excites the mass-spring system. This kind of excitation can become divergent. It is what is commonly known as a Pilot Induced Oscillation (PIO) or Pilot Assisted Oscillation (PAO).

PIO is a phenomenon in which the pilot has an active participation in the control loop. It occurs at very low frequency (up to 2Hz) corresponding to an adverse control due to lead–time between pilot actions and the helicopter reactions. The pilot tries to control a rapidly oscillating parameter and is unable to keep up with the fast oscillation.

PAO is a phenomenon in which the pilot has a passive involvement in the control loop through involuntary input. It occurs at low frequency (2Hz to 8Hz) corresponding to a pilot shaken by the helicopter oscillations while holding the sticks and thus reinjecting these oscillations on the flight controls. The pilot's muscular system (involuntary) acts like its own spring mass that amplifies the up and down motion of the seat.

The good thing is: The pilot does not need to know whether it is a PIO or PAO that is causing the vertical oscillation. Releasing the collective or loosening the grip on the controls is often enough to stop a PIO or PAO. Of course, this is not always possible due to operational conditions (environment, obstacles…).

One way of preventing PIO/PAO is to make sure that the collective lever has sufficient friction if the helicopter is equipped with an adjusting device. Friction has a dampening effect and may prevent PIO/PAO. On helicopters with a force trim release (FTR), avoid flying with the FTR permanently pressed (especially in the collective axis).

AERODYNAMIC EXCITATION

Load and/or longline can generate significant aerodynamic excitations depending on the aerodynamic shape, size, mass, and mass distribution. External loads may bounce up-and-down, oscillate, rotate, and swing. It is very difficult to predict how a load will react. At low speed, excitations can be caused by the helicopter's downwash. In forward flight, the excitations are usually caused by the airflow and will typically degrade with increasing airspeed.

If excitations occur in forward flight, slowing down the helicopter often reduces or stops aerodynamic excitation.

USE OF THE AUTOPILOT

The autopilot is designed to provide additional stability and damping. However, the autopilot cannot be designed to cope with all possible load and sling combinations. Especially when the external load is quite heavy compared to the helicopter mass, autopilot upper modes may not be able to cope with a load "yanking" the helicopter and may contribute to oscillations. This is particularly critical in forward flight, but may also be an issue in hover and low speed. On some helicopters models, the use of AFCS upper modes may be prohibited (refer to FLM).[LV1]

If oscillations occur, disconnect all upper modes and fly the helicopter using attitude mode. (On some models, disconnecting the A.TRIM may be recommended as a further means to reduce oscillations.)

AIRBUS HELICOPTERS DESIGN

When designing a helicopter for use with external sling loads, it is impossible to consider and test all imaginable combinations of loads and slings.

The most recent certification regulation requires Airbus Helicopters to test with loads up to the maximum load.

Airbus Helicopters is working continuously to improve its products, which includes trying to reduce the sensitivity to PIO/PAO and improving the low frequency damping when slung loads are attached.

AIRBUS HELICOPTERS RECOMMENDATIONS

To minimize the risk of vibrations/oscillations during HESLO:

- Avoid clasping the flight controls tightly (especially the collective lever),
- Adjust the friction of the controls to an appropriate level if equipped.

In case of vibrations/oscillations appearance during HESLO:

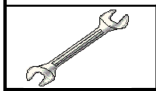
- Disconnect any AFCS upper modes if equipped,
- Relax your grip on the controls (especially collective), release the force trim release (FTR) pushbutton if equipped, and avoid jerky control inputs,
- If operationally possible, release the collective lever until the oscillations disappear,
- Reduce airspeed in cruise flight,
- As an ultimate measure release/jettison the external load.

No. 3899-S-67

SAFETY INFORMATION NOTICE

SUBJECT: ROTOR FLIGHT CONTROLS - PRODUCT SAFETY ENHANCEMENT

Sensitivity of Pilot Induced Oscillation (PIO) / Pilot Assisted Oscillation (POA) phenomenon during Helicopter External Load Operation (HESLO):
- New banjo screw (MOD 073178)
- New servo-controls (MOD 073221)

For the attention of	
	

AIRCRAFT CONCERNED	Version(s)	
	Civil	Military
AS350	B, BA, BB, B1, B2, B3, D	L1
AS550		A2, C2, C3, U2
EC130	B4, T2	

Airbus Helicopters is working to minimize by design (low frequency damping) as much as possible the sensitvity of his fleet to the Pilot Induced Oscillation (PIO) / Pilot Assisted Oscillation (PAO) phenomenon during Helicopter External Load Operation (HESLO. See Safety Information Notice 3890-S-00).
As the safety of our customers is always our highest priority, Airbus Helicopters has developed a design modification (MOD 073221) to the SAMM/Goodrich/UTAS/Collins servo-controls for the AS350/AS550 versions equipped with single hydraulic assistance.
Airbus Helicopters strongly recommends that customers take advantage of this important safety enhancement by applying the Service Bulletin (SB) No. AS350-67.00.41 / No. AS550-67.00.23 replacing the SAMM/Goodrich/UTAS/Collins former servo-controls by the Goodrich new generation ones (MOD 073221) on AS350/AS550 versions equipped with single hydraulic assistance.
An alternative for the customers with aircrafts equipped with the SAMM/Goodrich/UTAS/Collins former servo-controls (single hydraulic assistance) is to:

- Install the Banjo screw P/N 350A08-2321-20 corresponding to the modification MOD 073178 (SB No. AS350-67.30.0001 / No. AS550-67.30.0001),
- Request during the next overhaul, the application of last configuration corresponding to the modification MOD 073221.

The different configurations of servo-controls & banjo screws are presented in the SB No. AS350-67.00.41 / AS550-67.00.42.
The Dunlop servo-controls or the SAMM/Goodrich/UTAS/Collins & Novintec dual hydraulic servo-controls have already demonstrated a good behaviour to the PIO/PAO phenomenon.

SERVICE BULLETIN

TITLE: Servo-control system - Installation of banjo screws of a smaller internal diameter

SB Type: Product improvement

APPLICABILITY

Model:	AS350
Version:	B, B1, B2, B3, BA, BB, D, L1
Helicopters PREMOD:	073178 and 073221
Component affected:	SC5081 (704A44831123) or SC5081-1 (704A44831137) or SC5082 (704A44831124) or SC5082-1 (704A44831136) or SC5083 (704A44831141) or SC5084 (704A44831140) or 702A30030722

COMPLIANCE: RECOMMENDED

Airbus Helicopters recommends that you comply with this Service Bulletin during one of the next maintenance inspections aligned to your operational availabilities / constraints.

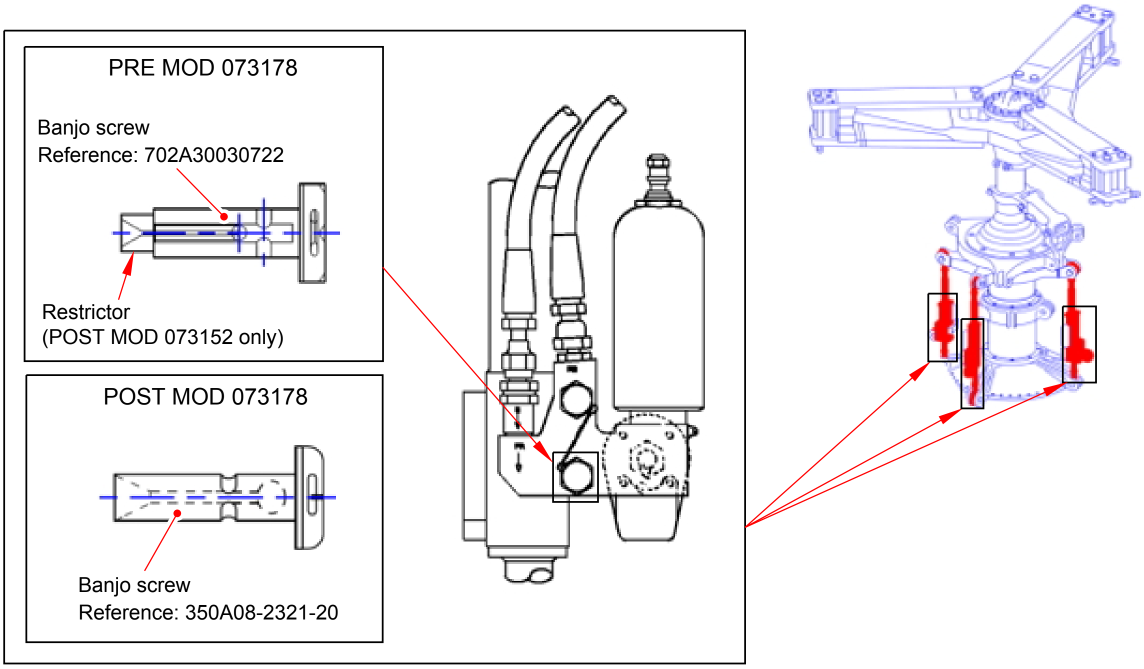
SUMMARY

This Service Bulletin changes the banjo screws on the main servo-controls with new banjo screws of a smaller internal diameter (equivalent to a restrictor). This reduces the helicopter's sensitivity to the Pilot Induced Oscillation (PIO) or the Pilot Assisted Oscillation (PAO) phenomenon during Helicopter External Sling Load Operations (HESLO).

GENERAL EVALUATION

Evaluation table			
Perform once	YES	Accomplish recurring	NO

GENERAL ILLUSTRATION



NOTE

The banjo screw reference: 350A08-2321-20 is painted in blue.

PLANNING INFORMATION

1. REASON

Airbus Helicopters' objective is to keep the helicopter's sensitivity to the PIO or the PAO phenomenon during HESLO to a minimum. Thus, Airbus Helicopters published Safety Information Notice (SIN) No. 3899-S-67 to give information to replace the main servo-controls (single hydraulic only) with the new generation GOODRICH main servo-controls. Customers can first apply this Service Bulletin, then, do the replacement of their main servo-controls at the next overhaul.
This Service Bulletin changes the banjo screws on the main servo-controls with new banjo screws of a smaller internal diameter (equivalent to a restrictor). This reduces the helicopter's sensitivity to the PIO or PAO phenomenon during HESLO.
The technical data or instructions contained in this Service Bulletin refer to modification (MOD) 073178.

2. DESCRIPTION

This Service Bulletin provides instruction to:
– Remove PRE MOD banjo screws from the main servo-controls
– Install POST MOD banjo screws from the main servo-controls.

3. CONCURRENT REQUIREMENTS

Not applicable.

4. APPROVAL

The technical content of this document is approved under the authority of the Design Organization Approval ref. EASA. 21J.700. For helicopters operated outside the terrain regulated by the EASA, the application of this document is subject to validation provided by the responsible aviation authority of the state of registry.
The technical content of this document is approved under the prerogatives of the recognition of design capability ref. FRA21J-002-DGA for French Government helicopters.
The technical content of this document is approved by Airbus Helicopters Airworthiness Department for export military versions.

5. MANPOWER

NOTE
The purpose of Man Hours is to give Airbus Helicopters customers a guideline for maintenance scheduling. It is not a contractual information.

5.1. Manpower for procedure

Number of Persons	Qualification	Estimated Man Hours
1	Mechanical technician	3 h
1	Pilot	1 h
Total Man Hours		4 h

NOTE
The pilot is required for post-installation ground run-up to pressurize the hydraulic system.

6. WEIGHT AND BALANCE

There is no change in weight and moment.

7. ELECTRICAL LOAD DATA

Not applicable.

8. DOCUMENTATION AFFECTED

Not applicable.

9. MATERIAL INFORMATION

9.1. Price

For information about the price of the modification kits and/or components, or for aid, contact the Airbus Helicopters Network Sales and Customer Relations Department.

9.2. Availability

Contact the Sales and Customer Relations Department to know the delivery lead times.

9.3. Procurement

Send an order for the necessary quantities to the Airbus Helicopters Network Sales.

9.4. Mixability

No mixed solutions and combinations of parts from before modification solution and after modification solution are permitted.

9.5. LIST OF NEW MATERIALS

Individual Spares List				
Item	Designation	Reference	MFC	QTY
1	Banjo screw	350A08-2321-20	F0210	3

Consumables, Materials and Expendables			
Designation	Reference	MFC	QTY
None			

Special Tools				
Item	Designation	Reference	MFC	QTY
None				

9.6. LIST OF EXISTING PARTS

INTERCHANGEABLE PARTS				
Old Reference	**Designation**	**New Reference**	**Interch**	**See Notes**
702A30030722	Banjo screw	350A08-2321-20	one way	(1)
NOTE(S)				
(1) Discard the part with the old reference.				

10. ACCOMPLISHMENT INSTRUCTION

Comply with the accomplishment procedure 67-30-0001, 933

11. ADDITIONAL INFORMATION

Not applicable.

End of section

ACCOMPLISHMENT PROCEDURE 67-30-0001, 933

1. APPLICABILITY

Model:	AS350
Version:	B, B1, B2, B3, BA, BB, D, L1
Helicopters PREMOD:	073178 and 073221
Component affected:	SC5081 (704A44831123) or SC5081-1 (704A44831137) or SC5082 (704A44831124) or SC5082-1 (704A44831136) or SC5083 (704A44831141) or SC5084 (704A44831140) or 702A30030722

2. GENERAL INFOS

AMM - Aircraft Maintenance Manual
FOD - Foreign Object Damage
HESLO - Helicopter External Sling Load Operations
IN - Information Notice
MET - Maintenance Manual
MOD - Modification
MTC - Standard Practices Manual
PAO - Pilot Assisted Oscillation
PIO - Pilot Induced Oscillation
SIN - Safety Information Notice

3. PRELIMINARY REQUIREMENTS

3.1. Applicable Documents

- Handling of helicopters in a hangar and in a prepared area - Handling MTC 20-07-01-201
- Recommendations for working at height - Human factors approach - Safety instructions MTC 20-07-02-212
- Appearance checks on an aircraft after inspection or repair - Technical instructions MTC 20-07-03-408
- Drafting and updating the log card (FM) - General rules applicable to aircraft MTC 20-08-05-101
- General safety instructions - Hydraulic assemblies - General AMM 29-00-00, 3-1
- Stripping / Dressing - Main servocontrol - Rotor actuators (Single hydraulic) AMM 67-32-00, 4-2
- General hydraulic instructions - Hydraulic systems MET 29-00-00-301
- Accessories installed on the main rotor actuator: Removal - Installation - Rotor actuators / Load compensator MET 67-30-00-401

3.2. Set up

- Handling of helicopters in a hangar and in a prepared area - Handling MTC 20-07-01-201
- Install the applicable access means.
- Remove and/or open all applicable cowlings, panels, doors and other items of equipment to get access to the different work areas.

3.3. Special tools

None

3.4. Materials

None

3.5. Spares

Designation	Reference	MFC	QTY
Banjo screw	350A08-2321-20	F0210	3

3.6. Safety conditions

WARNING

OBEY THE RECOMMENDATIONS FOR WORKING AT HEIGHT. REFER TO RECOMMENDATIONS FOR WORKING AT HEIGHT - HUMAN FACTORS APPROACH - SAFETY INSTRUCTIONS MTC 20-07-02-212.

CAUTION

MAKE SURE THAT YOU PREVENT ALL POSSIBLE FOD.

4. PROCEDURE

4.1. Remove the banjo screws (2) (Figure 1) from the manifold assemblies (3) of the main servo-controls (4) and (5):

- For helicopter version B2 or B3, refer to Stripping / Dressing - Main servocontrol - Rotor actuators (Single hydraulic) AMM 67-32-00, 4-2.
- For helicopter version B, BA, BB, B1, D or L1, refer to Accessories installed on the main rotor actuator: Removal - Installation - Rotor actuators / Load compensator MET 67-30-00-401.

4.2. Discard the banjo screws (2) and, if installed, their restrictors (6).

NOTE

For helicopters POST MOD 073152, a restrictor (6) is installed in the banjo screw (2).

4.3. Install the Banjo screw 350A08-2321-20 (1) on the manifold assemblies (3) of the main servo-controls (4) and (5):

- For helicopter version B2 or B3, refer to Stripping / Dressing - Main servocontrol - Rotor actuators (Single hydraulic) AMM 67-32-00, 4-2.
- For helicopter version B, BA, BB, B1, D or L1, refer to Accessories installed on the main rotor actuator: Removal - Installation - Rotor actuators / Load compensator MET 67-30-00-401.

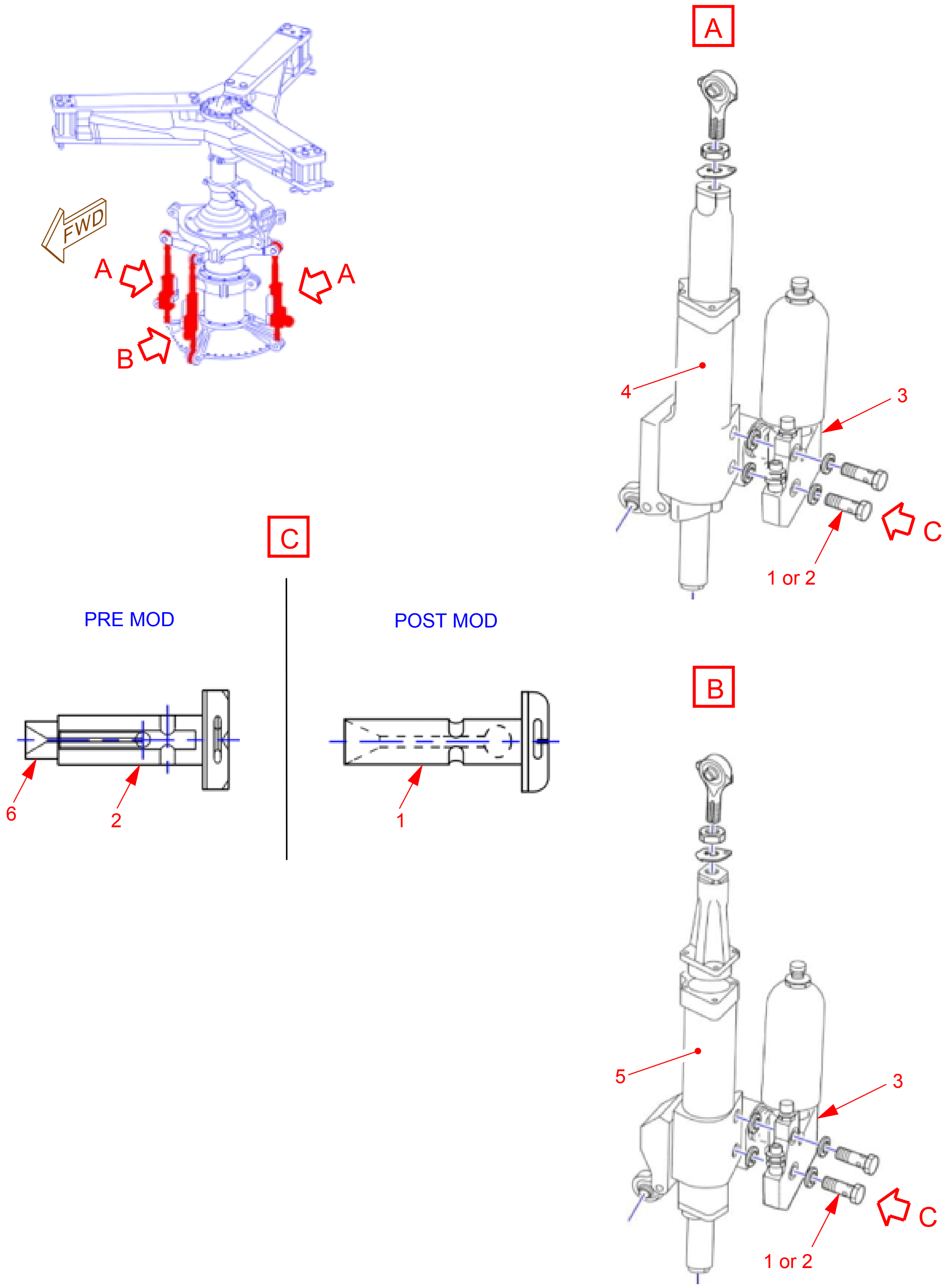


Figure 1

5. CLOSE UP

5.1. Remove all the tools, the materials and the equipment from your work area.

5.2. Install or close all cowlings, panels, doors and items of equipment that you removed and/or opened during the set-up.

5.3. Appearance checks on an aircraft after inspection or repair - Technical instructions MTC 20-07-03-408

5.4. Set the helicopter to flight condition.

5.5. For helicopter version B2 or B3, do the ground run-up operations in the paragraph "After installation". General safety instructions - Hydraulic assemblies - General AMM 29-00-00, 3-1

5.6. For helicopter version B, B1, BA, BB, D or L1, do the ground run-up operations in the paragraph "After assembly". General hydraulic instructions - Hydraulic systems MET 29-00-00-301

5.7. Record compliance with this Service Bulletin, in the helicopter documents.

5.8. Record the full integration of modification 073178 in the helicopter documents.

5.9. Record compliance with this Service Bulletin and full integration of modification 073178, in the Log Card of the main servo-controls. Refer to Drafting and updating the log card (FM) - General rules applicable to aircraft MTC 20-08-05-101

5.10. Record compliance with this Service Bulletin (see IN 3785-I-00 for instructions): QR code or hypertext link.

SB AS350-67-30-0001

End of service bulletin