KOMITE NASIONAL KESELAMATAN TRANSPORTASI
REPUBLIC OF INDONESIA

FINAL

KNKT.15.03.08.04

Aircraft Accident Investigation Report

PT. Hevilift Aviation Indonesia

Sikorsky S-76C+; PK-FUP

Delta Mahakam River, East Kalimantan

Republic of Indonesia

21 March 2015

2018

This final investigation report was produced by the Komite Nasional Keselamatan Transportasi (KNKT), Transportation Building, 3rd Floor, Jalan Medan Merdeka Timur No. 5 Jakarta 10110, Indonesia.

The report is based upon the investigation carried out by the KNKT in accordance with Annex 13 to the Convention on International Civil Aviation, the Indonesian Aviation Act (UU No. 1/2009) and Government Regulation (PP No. 62/2013).

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Jakarta, May 2018

KOMITE NASIONAL
KESELAMATAN TRANSPORTASI
Chairman

SOERJANTO TJAHJONO

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ABBREVIATIONS AND DEFINITIONS

AMM	:	Aircraft Maintenance Manual
AOC	:	Airline Operator Certificate
ATPL/H	:	Airline Transport Pilot License/Helicopter
ATS	:	Air Traffic Services
ATSB	:	Australia Transport Safety Bureau
BEA	:	Bureau d'Enquetes et d'Analyses
BMKG	:	*Badan Meteorologi Klimatologi Geofisika* / Meteorological Climatological and Geophysics Agency
CAMP	:	Continuous Airworthiness Maintenance Program
C of A	:	Certificate of Airworthiness
C of R	:	Certificate of Registration
Contributing factors	:	Contributing factors are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the accident or incident occurring, or mitigated the severity of the consequences of the accident or incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability. (Refer to ICAO Doc 9756 Part IV)
CPL/H	:	Commercial Pilot License/Helicopter
CPU	:	Central Processing Unit
CVR	:	Cockpit Voice Recorder
DGCA	:	Directorate General Civil Aviation
FAA	:	Federal Aviation Administration
FCOM	:	Flight Crew Operating Manual
Finding(s)	:	The findings are statements of all significant conditions, events or circumstances in the accident sequence. The findings are significant steps in the accident sequence, but they are not always causal or indicate deficiencies. Some findings point out the conditions that pre-existed the accident sequence, but they are usually essential to the understanding of the occurrence. The findings should be listed in a logical sequence, usually in a chronological order. (ref to ICAO Doc 9756 Part IV)
FOO	:	Flight Operation Officer
ICAO	:	International Civil Aviation Organization
IPC	:	Illustrated Part Catalogue
KIAS	:	Knots-Indicated Air Speed
KNKT	:	Komite Nasional Keselamatan Transportasi
kW	:	Kilo Watt
LT	:	Local Time

MPFR	:	Multi-Purpose Flight Recorder
NF	:	Engine free turbine rotation speed in term of % RPM (100% NF RPM = 39095 RPM)
NG	:	Engine gas generator rotation speed in term of % RPM (100% NF RPM = 52110 RPM)
NR	:	Main Rotor rotation speed in term of percent RPM (100% NR RPM = 293 RPM)
NTSB	:	National Transport Safety Bureau
PF	:	Pilot Flying
PIC	:	Pilot in Command
PM	:	Pilot Monitoring
PSI	:	Pound Square Inch
RPM	:	Rotation Per Minute
SHP	:	Shaft Horse Power
SIC	:	Second in Command
UTC	:	Universal Coordinated Time

SYNOPSIS

A Sikorsky S-76C+ helicopter, registration PK-FUP was being operated by PT. Hevilift Aviation Indonesia, on 21 March 2015 in day light conducted unscheduled charter flight by PT. Total E & P Indonesia. The flight was planned from Sepinggan Airport, Balikpapan to Handil helipad than continued flying over Central Processing Unit (CPU) to conduct pipe line inspection and return to Sepinggan.

At 0118 UTC, the helicopter departed Sepinggan with destination Handil helipad. On board in this flight were eight occupants consisted of two pilots, one engineer, one flight operation officer (FOO) and four passengers. The Pilot in Command (PIC) acted as Pilot Flying (PF) and Second in Command (SIC) acted as Pilot Monitoring (PM). At 0136 UTC, the helicopter landed at Handil helipad and refueled up to approximately 1,600 lbs for the preparation to the pipe line inspection flight that was estimated would take 2 hours. The passenger doors on both sides of the cabin were removed to ease the inspection.

At 0205 UTC, the helicopter departed from Handil helipad to CPU. On board this flight were seven occupants from Sepinggan consist of two pilots, one flight operation officer (FOO) and four passengers, while the engineer stayed at Handil.

After reached the cruising altitude of 1,000 feet the PIC handed over the control to the SIC. The SIC engaged the autopilot and flew maintain cruise altitude and speed of 95 knot. The weather was clear, wind condition was westerly at speed of 5 knots and visibility approximately 8 km. At position approximately 8 Nm from CPU the PIC asked the SIC to descend to 600 feet with the rate of 200 feet/minute. While passing 800 feet the helicopter attitude became un-commanded. The helicopter rolled to the left and pitch up then rolled to the right and pitch down. The SIC lowered the collective and reduced the helicopter speed with intention to recover the helicopter attitude with no success. The PIC took over the control to recover the helicopter until impacted the tree and crash into swamp. All the occupants were survived.

KNKT conducted several tests and research and concluded that the separation of rod end bearing from the push rod resulted to the helicopter enters un-commanded attitude.

The investigation determined the contributing factor was the helicopter un-commanded attitude caused by loosening of the jam nut on the forward rod end bearing which subsequently separated from the push rod, resulted in the un-commanded servo movement.

As result of these accidents FAA issued the Airworthiness Directive related to inspection of push rod.

KNKT was informed that safety action had been taken by the operator and considered relevant to the occurrence. However, as result of the investigation KNKT issued the recommendation to the operator and Sikorsky which is relevant to the safety issue.

1 FACTUAL INFORMATION

1.1 History of the Flight

A Sikorsky S-76C+ helicopter, registration PK-FUP, was being operated by PT. Hevilift Aviation Indonesia, on 21 March 2015, on an unscheduled charter flight by PT. Total E & P Indonesia. The flight was planned from Sepinggan[1] Airport, Balikpapan to Handil helipad then continued flying over Central Processing Unit (CPU) to conduct a pipe line inspection and return to Sepinggan. The Handil helipad location is approximately 34 Nm at bearing 039° from Sepinggan with coordinate 0° 49’ 17.232” S, 117° 15’ 7.1819” E. The CPU location is at approximately 28 Nm from Handil at bearing 028° with coordinate 0° 34’ 59.44” S, 117° 22’ 40.37” E.

Figure 1: Archive photo of PK-FUP

At 0918 LT (0118 UTC[2]), the helicopter departed Sepinggan with destination Handil helipad. On board the flight was eight occupants consisting of two pilots, one engineer, one flight operation officer (FOO) and four passengers. The Pilot in Command (PIC) acted as Pilot Flying (PF) and Second in Command (SIC) acted as Pilot Monitoring (PM)

At 0936 LT, the helicopter landed at Handil helipad. While transit at Handil helipad, the helicopter refueled up to approximately 1,600 lbs for the preparation for the pipe line inspection flight that was estimated would take approximately 2 hours. The passenger doors on both sides of the cabin were removed to ease the inspection. Without the passenger doors, the maximum speed of the helicopter was limited to maximum of 125 knot.

At 1005 LT, the helicopter departed from Handil helipad to CPU. On board this flight was seven occupants from Sepinggan consisting of two pilots, one flight operation officer (FOO) and four passengers, while the engineer stayed at Handil.

After reaching the cruising altitude of 1,000 feet, the PIC handed over the control to the SIC. The SIC engaged the autopilot and flew maintaining cruise altitude and a

1 Sepinggan Airport Balikpapan will be named as Sepinggan for the purpose of this report

2 The 24-hour clock used in this report to describe the time of day as specific events occurred is in Coordinated Universal Time (UTC). Local time that be used in this report is Waktu Indonesia Tengah (WITA) or Indonesia Central Time Standard which is UTC +8 hours.

speed of 95 knots. Investigation did not find the active mode of the autopilot at the time of occurrence. The weather was clear, wind condition was westerly at speed of 5 knots and visibility approximately 8 km.

At a position of approximately 8 Nm from CPU, the PIC asked the SIC to descend to 600 feet. The helicopter descended with the rate of 200 feet/minute. While passing 800 feet, the helicopter attitude became un-controllable. The helicopter rolled to the left and pitched up then rolled to the right and pitch down.

The SIC lowered the collective and reduced the helicopter speed with intention to recover the helicopter attitude with no success. The PIC took over the handling and attempted to the control to the helicopter.

The helicopter impacted trees and crashed into a swamp at coordinate 0° 39’ 22.76” S, 117° 20’ 39.75” E. After impact, the PIC set the fuel levers to the OFF position, set the engine control lever full backward position and pulled the engine emergency and fire (T-Handles). The flight track and the crash site location are shown in the figure below.

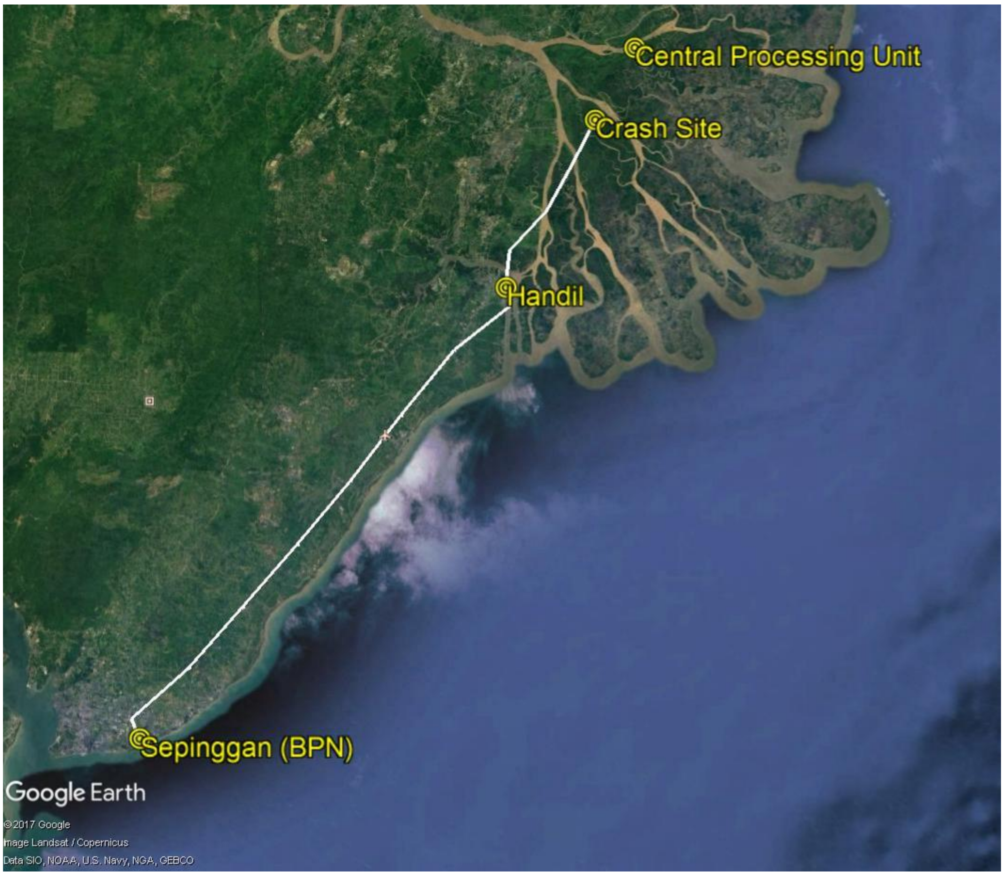

Figure 2: The flight track and crash site location based on SkyNet data

The witnesses, who were standing on the deck of Palong 3 located at approximately 600 meters from the accident site, saw the helicopter was spinning while flying low and suddenly pitched down.

1.2 Injuries to Persons

Injuries	Flight crew	Passengers	Total in Helicopter	Others
Fatal	-	-	-	-
Serious	1	-	1	-
Minor/None	1	5	6	-
TOTAL	2	5	7	-

All occupants were Indonesian.

1.3 Damage to Helicopter

The helicopter was substantially damaged beyond repair.

1.4 Other Damage

There was no other damaged reported.

1.5 Personnel Information

1.5.1 Pilot in Command

Gender	:	Male
Age	:	58 years old
Nationality	:	Indonesian
Marital status	:	Married
Date of joining company	:	11 December 2014
License	:	ATPL/H
Date of issue	:	9 September 1998
Helicopter type rating	:	Sikorsky S-76C+
Instrument rating	:	31 July 2015
Medical certificate	:	Class 1
Last of medical	:	4 December 2014
Validity	:	4 June 2015
Last line check	:	28 January 2015
Last proficiency check	:	7 January 2015
Flying experience		

Total hours	:	10,640.55 hours
Total on type	:	1,132.15 hours
Last 90 days	:	131.8 hours
Last 60 days	:	85.6 hours
Last 24 hours	:	3.8 hours
This flight	:	19 minutes

1.5.2 Second in Command

Gender	:	Male
Age	:	34 years old
Nationality	:	Indonesian
Marital status	:	Married
Date of joining company	:	4 April 2014
License	:	CPL/H
Date of issue	:	26 May 2009
Helicopter type rating	:	Sikorsky S-76C+
Instrument rating	:	31 May 2015
Medical certificate	:	Class 1
Last of medical	:	26 February 2015
Validity	:	26 August 2015
Last line check	:	5 March 2015
Last proficiency check	:	29 May 2014
Flying experience		
Total hours	:	2,338.5 hours
Total on type	:	469.5 hours
Last 90 days	:	137 hours
Last 60 days	:	70.4 hours
Last 24 hours	:	1.9 hours
This flight	:	19 minutes

1.6 Helicopter Information

1.6.1 General

Registration Mark	:	**PK-FUP**
Manufacturer	:	Sikorsky
Country of Manufacturer	:	United States of America

Type/ Model	:	S-76C+
Serial Number	:	760582
Year of manufacture	:	2005
Certificate of Airworthiness		
Issued	:	31 October 2014
Validity	:	30 October 2015
Category	:	Transport
Limitations	:	None
Certificate of Registration		
Number	:	3514
Issued	:	31 October 2014
Validity	:	30 October 2015
Time Since New	:	3,820 hours
Cycles Since New	:	19,651 cycles
Last Major Check	:	Equalized "C" Airframe inspection (1500 Hours)
Last Minor Check	:	25 Hours Airframe Inspection

The orientation of main rotor blade rotation of this helicopter was counterclockwise when viewed from above of the helicopter.

The helicopter was maintained by operator refer to Indonesia Director General of Civil Aviation (DGCA) approved Continuous Airworthiness Maintenance Program (CAMP) S-76C/C+/C++ incorporated the Sikorsky Model S-76C/C+/C++ Limitation and Inspection Requirement revision 22 dated 31 October 2013.

The last 300 hours inspection, including inspection on the main rotor servo actuators, was conducted by the operator with work order No. IDLC-0075-2015 on 27 February 2015 at 3,766.9 total hours and 19,461 total cycles. There was no significant finding on each main rotor servo input control rod.

The forward servo actuator part number 76650-09805-111 serial number B345-01673XD was installed on 5 February 2014 by previous operator. The reason for replacement of the forward servo actuator was due for overhaul.

1.6.2 Engines

Manufacturer	:	Turbomeca, France
Type/Model	:	Arriel 2S1
Serial Number-1 engine	:	20555TEC
▪ Engine Total Time Since New	:	9,935.3 hours

- Engine Cycles NG Since New : 13,487 cycle
- Engine Cycles NF Since New : 11125 cycle

Serial Number-2 engine : 20607TEC

- Engine Total Time Since New : 7,034.3 hours
- Engine Cycles NG Since New : 8,616 cycle
- Engine Cycles NF Since New : 7815 cycle

1.6.3 Main Rotor Blade

Manufacturer : Sikorsky, United States of America

Type/Model : 76150-09100-053

Main Rotor Gearbox

Manufacturer : Sikorsky

Type/Model : 76351-09600-044

Serial Number : A231-00104

- Time Since New : 16,727.9 hours
- Last major Inspection : 6 July 2013
- TBO : 3,200 hours
- TSO : 1,956 hours
- Last shop visit : 6 July 2013

Rotor Blade 1

- S/N : A086-03056
- Installed : 23 June 2005
- Time Since New : 4,113.1 hours

Rotor Blade 2

- S/N : A086-03059
- Installed : 12 June 2006
- Time Since New : 3,828.1 hours

Rotor Blade 3

- S/N : A086-03074
- Installed : 12 June 2006
- Time Since New : 3,828.2 hours

Rotor Blade 4

- S/N : A086-03075

- Installed : 12 June 2006
- Time Since New : 3,828.2 hours

1.6.4 Tail Rotor

Manufacturer : Sikorsky, United States of America

Type/Model : 76101-05501-042

Rotor Blade 1

- S/N : A245-00552
- Installed : 9 October 2014
- Time Since New : 1,298.5 hours
- Cycles Since New : N/A

Rotor Blade 2

- S/N : A245-00551
- Installed : 9 October 2014
- Time Since New : 1,298.5 hours
- Cycles Since New : N/A

1.6.5 Flight Control System

The description of the Sikorsky 76 flight control system as extracted from the Rotorcraft Flight Manual (RFM) document number SA 4047-76C-15 Part 2, Section I: System Description is as follow.

MECHANICAL FLIGHT CONTROL SYSTEM

Conventional helicopter flight controls consist of a collective pitch lever and a cyclic control stick to control main rotor blade angles, and tail rotor pedals to control tail rotor blade angles. A two-stage servo system reacts to the loads imposed on the rotor system and reduces control forces required by the pilot.

Collective and cyclic trim and a force gradient system permit trimming of the controls in the cockpit to the desired position. A set of dual controls for a copilot may be installed as optional equipment.

MAIN ROTOR FLIGHT CONTROLS

Control movements from the collective pitch lever for vertical control and from the cyclic for longitudinal and lateral control are transmitted by mechanical linkage to a mixing unit, which combines the inputs. The combined input is then transmitted to the stationary ring of the swashplate by mechanical linkage, and through the two-stage hydraulic servo system. Movement is transmitted from the stationary to the rotating ring of the swashplate to vary the pitch of the main rotor blades. A collective to yaw coupling automatically changes tail rotor blade angle and thrust to compensate for changes in main rotor torque when collective pitch is increased or decreased. The collective control and cyclic longitudinal and lateral controls have viscous dampers *attached at the bottom of the controls closet. The dampers have a share device that allows the dampers to be bypassed in the event of a jam. Typical force required for shear is collective 55-62 pounds, pitch 17-20 pounds, and roll 35-40 pounds.*

Collective Pitch Lever

The collective pitch lever (Figure 1-47) increases or decreases the collective pitch of the main rotor blades. The collective pitch lever may be trimmed to any desired position by use of the trim system. Collective pitch lever movement from the trimmed position is resisted by a gradient spring.

Collective Pitch Lever Trim and Force Gradient Spring

The collective pitch lever may be trimmed to any desired position and held there with magnetic brake. The trim system operates from the DC essential bus through a circuit breaker marked CLTV TRIM on the lower circuit breaker panel. The trim is controlled by the STICK TRIM CLTV switch on the center console with positions marked ON and OFF and a switch on the collective pitch grip marked TRIM REL. When the magnetic brake is energized electrically, it holds the lever position. When the magnetic brake is de-energized, the lever is released. With the master switch ON, pressing the pushbutton switch to deenergize the brake, moving the lever to the desired position, and then releasing the pushbutton may trim the collective lever. The lever will remain trimmed to that position. Any movement from the trimmed position will be resisted by the force gradient spring, which creates a stick "feel".

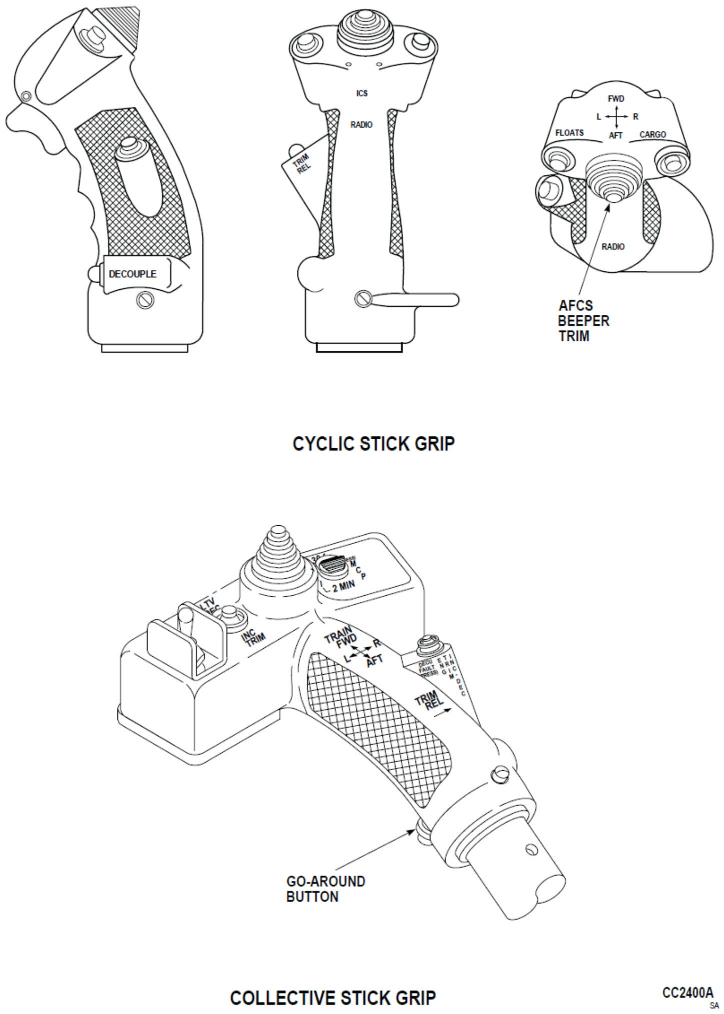

Figure 1-47. Cyclic and Collective Stick Grips

Cyclic Control Stick

The cyclic control stick (Figure 1-47) changes the pitch of the main rotor blades to provide longitudinal and lateral control. The cyclic control stick may be trimmed to any desired position by use of the magnetic brakes. Cyclic control stick movement from the trimmed position will be resisted by a gradient spring.

Cyclic Control Stick Trim and Force Gradient Spring

The cyclic control stick trim system functions similar to the collective trim system, except that two magnetic brakes, one for pitch control, and one for roll control, are used. The trim system operates from the DC essential bus through a circuit breaker marked CYC BRK. The master switch on the master switch panel is marked STICK TRIM-CYCLIC and has positions marked ON and OFF. A pushbutton switch is on the cyclic stick grip and is marked TRIM REL.

TAIL ROTOR FLIGHT CONTROLS

Tail Rotor Pedals

The tail rotor pedals control the pitch and thrust of the tail rotor blades to compensate for main rotor torque and to provide a means of changing the heading of the helicopter. Control rods and cables connect the pedals to the pitch changing mechanism at the tail rotor. Control forces are relieved by the two stage tail-rotor servo. A pedal damper provides "feel" in the tail rotor pedals by resisting pedal movements, to prevent over control. Toe-operated wheel brakes are part of the tail rotor pedals.

Tail Rotor Pedal Adjustment Knobs

A tail rotor pedal adjustment knob is below the instrument panel and centered between the pedals. The knob is marked PEDAL ADJUST-TURN. Arrows indicate direction to turn for FWD and AFT adjustments.

COLLECTIVE TO YAW COUPLING

Mechanical collective to yaw coupling incorporated in the flight control system provides automatic tail rotor pitch (thrust) changes proportional to collective pitch (torque changes). The coupling reduces pilot workload by automatically compensating for main rotor torque as collective pitch is increased or decreased. Though mechanical stops prevent tail rotor pitch limits from being exceeded, mechanical feedback can be felt in the controls at certain control extremes. Full down collective and application of full right pedal will result in upward movement of the collective. Further movement of the right pedal, however, produces no further change in tail rotor pitch, since the tail rotor servo is at its mechanical stop. Likewise, at high collective settings, application of left pedal may result in system limits being attained before the pedal stops are reached. Further application of left pedal will result in downward movement of collective and no change in tail rotor pitch. The extreme control positions where the collective to yaw feedback occurs are not normally encountered within the normal flight envelope but may be felt during dynamic maneuvers (e.g., arresting a rapid descent rate in a right crosswind at maximum gross weight).

SELF-CENTERING TAIL ROTOR CONTROL QUADRANT

The self-center aft quadrant will return the tail rotor blade pitch to -2 in case of a dual control cable failure or single failure unopposed by the remaining cable. The quadrant uses two pivoting arms with concentrically-mounted torsion springs at the base end and reaction rollers at the outer end. When control cable tension is lost, the respective torsion spring pivots its arm to a fixed reaction plate imparting a rotational force to the quadrant. In the case of the singe cable failure, this force may be reacted by the pilot through the remaining cable to retain a desired trim condition dependent upon pre-failure pedal position and failed cable combination. In the case of the dual cable failure, the quadrant will rotate unopposed to the -2 setting. The -2 setting is a compromise that results in coordinated level flight at about 40 KIAS in addition to varied combinations of trimmed and untrimmed climbs, descents, autorotative descents, and level flight conditions up through Vne. Flight conditions at airspeeds less than 20 knots may be considered outside a recoverable envelope using -2.

A single cable failure affecting the right cable will retain normal left yaw control from the -2 setting to full left pedal. In level flight the helicopter will yaw left between 40 and 135 KIAS requiring right lateral cyclic to maintain track. A left cable failure will retain normal right yaw control from the -2 setting to full right pedal. The helicopter will trim normally in level flight at airspeeds 40-135 KIAS but yaw right at airspeed outside the band. Left cyclic input will maintain track during right yaw conditions. During single cable failure conditions normal collective to yaw coupling will be available through the remaining cable varies from near zero at -2 to as much as 20 pounds at the control extremes.

Helicopter response to a cable (or cables) failure will depend upon airspeed and flight condition (level, climb, or descent) at the time of the failure.

FLIGHT CONTROL HYDRAULIC SERVO SYSTEM

Dual servo units in the main and a tandem servo unit in the tail rotor flight control systems, react to flight loads from the rotor system and reduce the force required to operate the flight controls. The dual servo units consist of a first stage and a second stage, each of which operate on 3,000 PSI hydraulic pressure from separate hydraulic pumps. The main gear box drives the pumps. Full pressure is available at about 10% Nr. Three main rotor dual servo units are mounted on the main gear box and attached to the stationary swashplate. The tail rotor tandem servo is mounted on the tail rotor gear box. Hydraulic pressure for extending and retracting the landing gear is supplied by the second stage hydraulic pump. The first and second stage servo systems are controlled electrically by switches on the collective stick grips. Electrical interlocks between the first and second stage systems prevent one system from being shut off unless there is 1,600 PSI in the opposite system. If one stage is shut off and a pressure loss occurs in the system in operation, the interlocks will switch on the system that was originally shut off.

TAIL ROTOR SERVO SHUTOFF VALVE

A solenoid shutoff valve, tube assembly and check valve are installed in the first stage hydraulic system tail rotor servo pressure line. A hydraulic fluid level switch is installed on the No. 1 hydraulic system module. If there is a leak in the first stage hydraulic system, the fluid level switch activates the solenoid shutoff valve blocking flow to the No. 1 tail rotor servo, and the #1 SERVO SYSTEM caution light illuminates. In the unlikely event both tail rotor hydraulic lines are severed, No. 1 hydraulic system pressure will be available to the main rotor servos. The solenoid valve and hydraulic fluid level switch are powered through the No. 1 SVO SHUT OFF circuit breaker located on the DC essential bus.

FLIGHT CONTROL SERVO SWITCH

A three-position SERVO switch on the collective pitch grip controls the first and second stage servo systems (Figure 1-40). The switch has positions marked NO. 1 OFF and NO. 2 OFF. The switch is normally centered, with both stages operating. To turn off either stage, the switch is placed to the corresponding OFF position. If there is at least 1,600 PSI hydraulic pressure in the other stage, the selected system will go off. The shutoff system is connected to the DC essential bus by circuit breakers marked SVO SHUT OFF - NO. 1 and NO. 2. When dual flight controls are installed, the copilot's collective grip has a similar switch. Either switch may be used *to shut off one stage; however, the same switch must be used to turn that stage back on again. When one stage has been shut off, the opposite switch cannot shut off the other stage.*

NOTE

If a DC electrical system failure has occurred, a malfunctioning servo system cannot be shut off. If a malfunctioning servo system has been shut off, it will be reactivated if a DC failure occurs.

FLIGHT CONTROL SERVO HYDRAULIC PRESSURE INDICATOR

A dual indicator marked HYD PRESS - PSI X 1,000 has scales marked 1 and 2 for first and second stage hydraulic pressure. The indicator is connected to the DC essential bus by two circuit breakers marked PRESS, HYD 1 and HYD 2.

FLIGHT CONTROL SERVO LOW PRESSURE CAUTION LIGHTS

The #1 SERVO SYSTEM and #2 SERVO SYSTEM caution lights, on the engine and composite displays (Figures 1-54 and 1-55) go on when the hydraulic pressure in the corresponding stage drops to 1,600 PSI. The light will go off when pressure increases to 2,200 PSI. The same caution lights also sense a jam in one or more of the servo units. When a servo becomes jammed, the corresponding caution light will go on. During flight, the caution light will be kept on through a holding circuit even if the jammed pilot valve returns to normal operation. The holding relay operates through the landing gear interlock and therefore will only function when the helicopter is airborne. To differentiate between a system pressure loss or a jammed servo, note the pressure on the system hydraulic pressure indicator of the affected system. A loss in indicated pressure with the caution light on indicates a loss in system pressure. Normal indicated pressure with the caution light on could indicate a jammed servo. The caution light circuits are connected to the DC essential bus by circuit breakers marked SVO PRESS-2 WARN 1 and SVO JAM-2 WARN 1.

1.6.6 Main Rotor Flight Control Main Servo Inspection Procedure

The illustration of the main rotor flight control system is shown in the figure below.

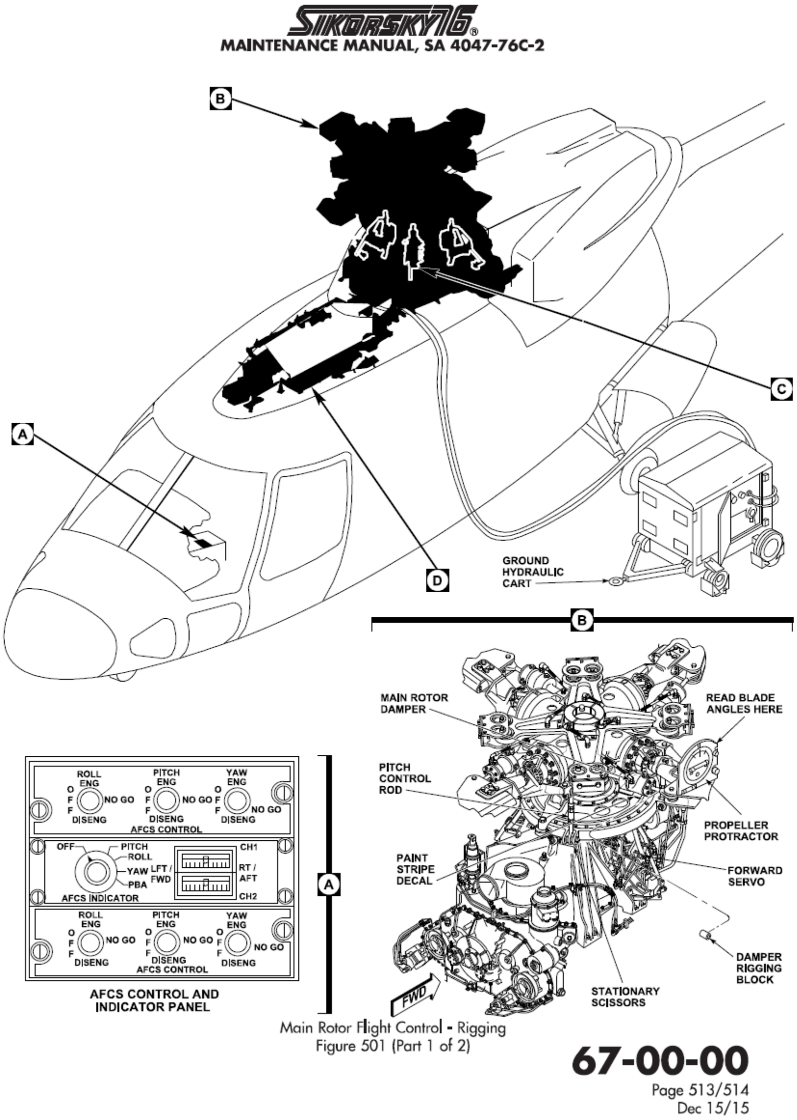

Figure 3: Main Rotor Flight Control System

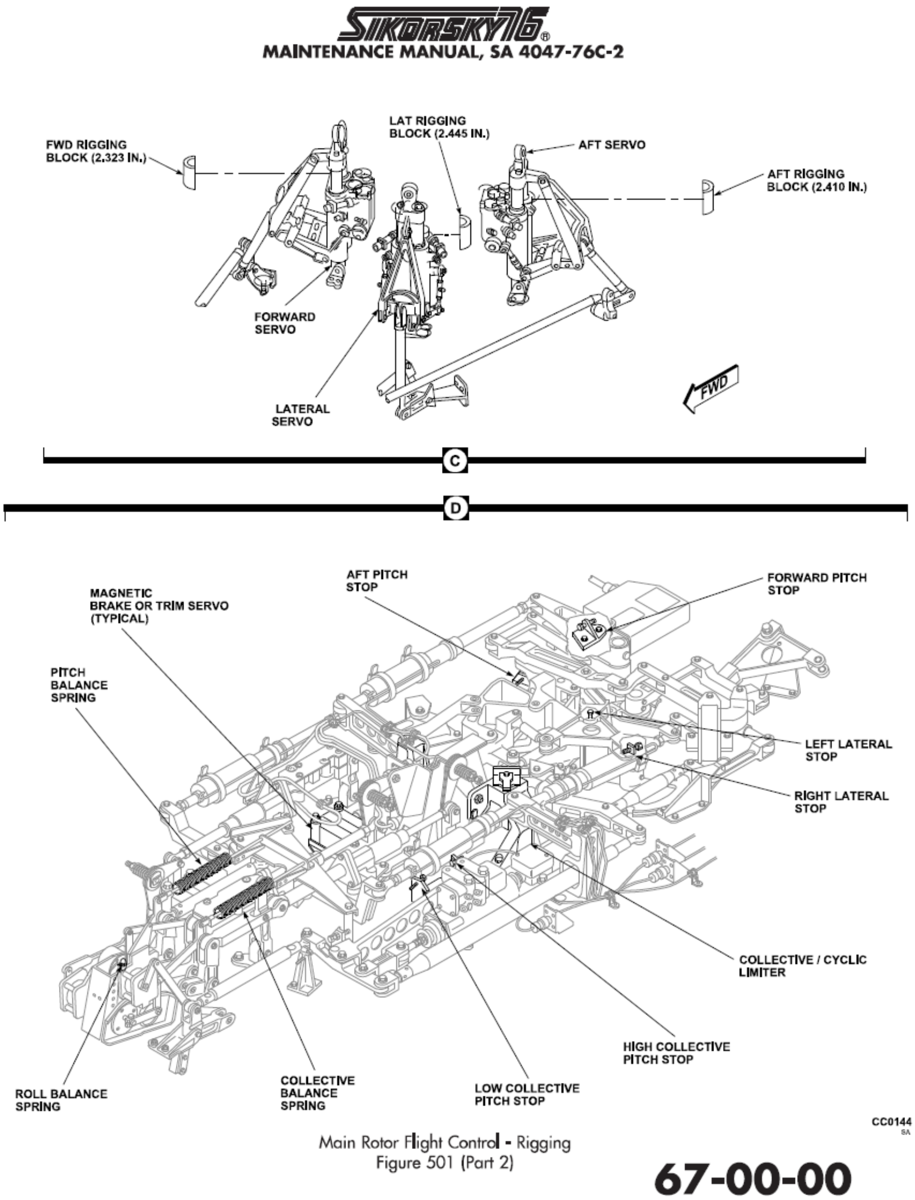

Figure 4: Servo Actuator and Main Rotor Flight Control System

The manual mentioned the push rod and the rod end bearing assembly as servo input control rod. The inspection of main rotor servo input control rod was mentioned the Inspection Manual S-76 Series Rev Oct 13 in the chapter 5-20-00 under the 300-hour inspection checklist item 30 on page 31. The figure below shows the inspection checklist in the chapter 5-20-00.

300-HOUR INSPECTION CHECKLIST	CHAPTER/ SECTION/ SUBJECT/ *HELOTRAC	ZONE	INIT	REMARKS
30. Using a clean lint free cloth moistened with dry-cleaning solvent, P-D-680 Type II or equivalent, wipe clean the surface of the aluminum tube portion of each main rotor servo input control rod, 76400-00034-056. Visually inspect the entire control rod surface (all around) for cracks, perforations, or evidence of tube corrosion. Special attention should be given to the aluminum tube in the vicinity of the rivets and the tube just above the lower set of rivets. Use a mirror and flashlight, as required. Disconnecting the upper end of control rod from servo may allow better visual access to the back side of the rod. Remove and replace any control rod showing evidence of cracking, perforations, or tube corrosion.	67-15-02 *671502A	5		
31. First and second stage hydraulic lines for chafing, security, and leakage. When inspecting for chafing, pay particular attention to main rotor servo return manifolds between lateral and aft servos, and hydraulic pumps flexible lines. Main rotor servo hydraulic manifold attachment brackets for security (bonding) to main gear box webs. Inspect hydraulic tubes under main gear box for leakage, proper retention in tube blocks, chafing, and proper clearance.	29-10-04 29-20-04 *290001	5		
32. Arriel 1S1 engine collective bias cable release joint (mechanical fuse) for condition and security. Inspect engine collective bias control cable for proper position of red paint stripe. Maximum space between aft side of clamp and point stripe shall not be over 0.125 inch. Reclamp cable if required.	76-11-00 *761101A	5		Not applicable to helicopters with Arriel 2S1 or 2S2 engines.
33. Check spindle/cuff-to-main rotor blade attachment nuts for specified torque. If torque is stabilized, repeat check at specified interval. If loss of torque is found, retorque nuts. (Refer to Removal/Installation, 65-11-00.) Repeat check at 5 to 15 flight hours. If torque has not stabilized after (3) times, replace hardware and repeat torque checks.	65-11-00 *651119A *651119B *651119C *651119D	5		

Figure 5: The inspection of main rotor servo input control rod

The basic length of the servo input control rod is mentioned in the Sikorsky Maintenance Manual chapter 67-15-02. The manual identified the input control rod as servo pushrod.

SIKORSKY 76®
MAINTENANCE MANUAL, SA 4047-76C-2

(1) Following is a list of pushrods and their basic lengths, measured from bolt-hole-center to bolt-hole-center. These lengths are only basic and may change at time of rigging:

PUSHROD	LENGTH (INCHES)
Forward	35.14
Lateral	6.75
Aft	46.00
Servo	9.14

(2) At aft servo position, insulate mating surfaces of support and main gear box with corrosion inhibiting sealant, M6856K or equivalent, and install support on main gear box using washers and nuts. Torque nuts to 50 - 100 inch-pounds and install cotter pins.

(3) Apply sealing compound, MIL-S-8802, Class A, around joining area for support and gear box.

(4) Install aft bellcrank on support using washer and nut. Torque nut to 60 - 100 inch-pounds and install cotter pin. (Refer to Self-Retaining Bolt Installation/Inspection, 20-04-00.)

(5) Bolt servo pushrod to aft servo and aft bellcrank using bolts, washers, and nuts. Torque nuts to 30 - 50 inch-pounds and install cotter pins. (Refer to Self-Retaining Bolt Installation/Inspection, 20-04-00.)

(6) With aft pushrod adjustable rod end facing aft, bolt aft pushrod to aft output bellcrank and aft bellcrank using bolts, washers, and nuts. Torque nuts to 30 - 50 inch-pounds and install cotter pins. (Refer to Self-Retaining Bolt Installation/Inspection, 20-04-00.)

NOTE: Drain hole must be on forward underside of aft pushrod after installation.

(7) At lateral servo position, insulate mating surfaces of support and main gear box with corrosion inhibiting sealant, M6856K or equivalent, and install support on main gear box using washers and nuts. Torque nuts to 100 inch-pounds.

(8) Apply sealing compound, MIL-S-8802, Class A, around joining area of support and gear box.

CAUTION: MAKE SURE THAT THE LATERAL BELLCRANK IS INSTALLED WITH THE TWO DECAL INBD ARROWS POINTING INBOARD AND THE DECAL POSITION NUT THIS SIDE FACING OUTBOARD.

(9) Install lateral bellcrank with arrows pointing inboard on support using bolt, washer, and nut. Torque nut to 30 - 50 inch-pounds and install cotter pin. (Refer to Self-Retaining Bolt Installation/Inspection, 20-04-00.)

(10) Bolt servo pushrod to lateral servo and lateral bellcrank using bolts, washers, and nuts. Torque nuts to 30 - 50 inch-pounds and install cotter pins. (Refer to Self-Retaining Bolt Installation/Inspection, 20-04-00.)

(11) Bolt lateral pushrod to lateral output bellcrank and lateral bellcrank using bolts, washers, and nuts. Torque nuts to 30 - 50 inch-pounds and install cotter pins. (Refer to Self-Retaining Bolt Installation/Inspection, 20-04-00.)

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Figure 6: Push rod and rod end bearing assembly (Servo input control rod) basic length

The illustration of the servo push rod is shown in the figure below

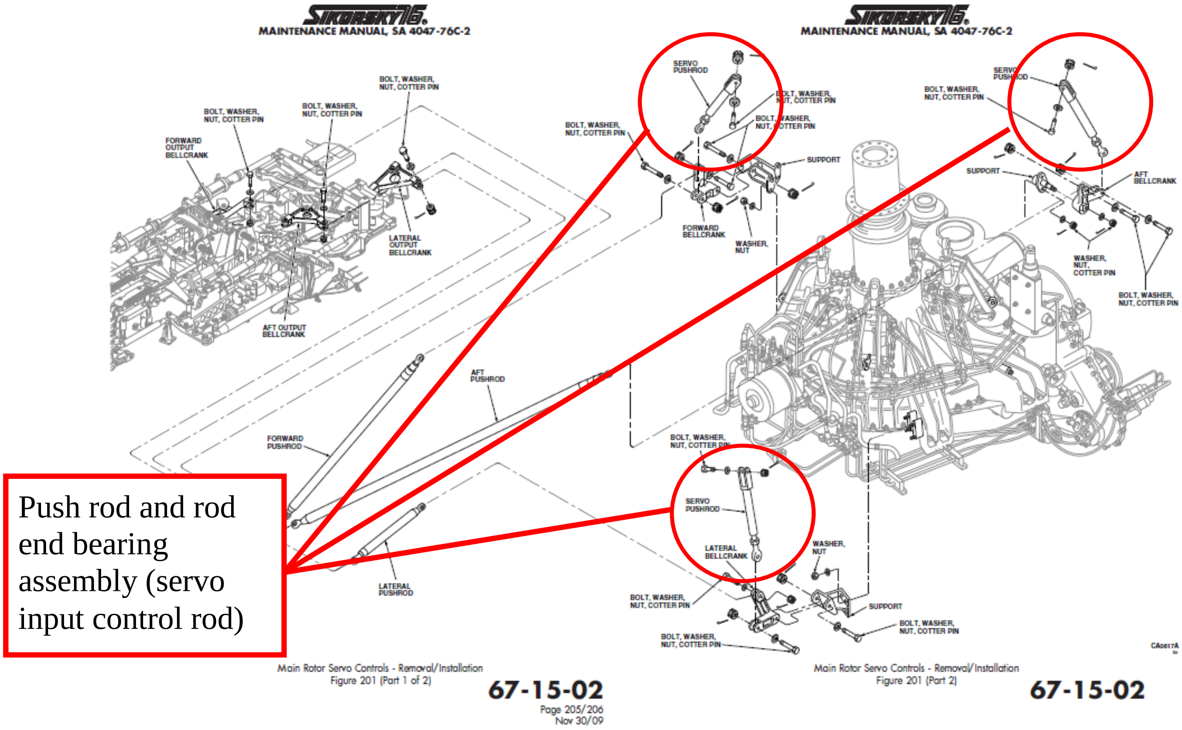


Figure 7: Illustration of the basic length of push rod and rod end bearing assembly

1.7 Meteorological Information

The detail weather information on the accident site was unknown, however based on the video footage taken by onboard passenger, indicated that the weather met the requirement of Visual Meteorological Condition (VMC).

The weather information at Sepinggan provided by Balikpapan Meteorological Office issued 21 March 2015, at that 23.00 LT was follow:

Wind	:	330 / 03 knots
Visibility	:	9 Km
Weather	:	NIL
Cloud	:	Few CB 1800
Temperature	:	25°C
Dew point	:	24°C
Aerodrome Pressure (QFE)	:	1010 hPa/29.85 Inch Hg
Altimeter Setting (QNH)	:	1011 hPa/29.87 Inch Hg
Remark	:	CB to East

The weather information at Handil provided by the personnel standby at this location issued on 21 March 2015, at that 00.00 LT was as follow:

Wind	:	330 / 03 knots
Visibility	:	9 Km
Weather	:	NIL
Cloud	:	Few CB 1800
Temperature	:	25°C
Dew point	:	24°C

1.8 Aids to Navigation

Not relevant to this accident.

1.9 Communications

The pilot communicated with the air traffic services (ATS) Sepinggan was conducted normally along the flight.

The helicopter equipped with flight recorder which capable to record 120 minutes recording voice data. The pilot communication was recorded on the flight recorder. Detail description of the flight recorder will be discussed on chapter 1.11 of this report.

1.10 Aerodrome Information

Not relevant to this accident.

1.11 Flight Recorders

1.11.1 Flight Data Recorder

The helicopter was equipped with Penny & Giles solid state Multi-Purpose Flight Recorder (MPFR). The MPFR was recovered from the accident site and received at the KNKT recorder laboratory on 24 March 2015. The details information of the MPFR was:

Manufacturer	:	Penny & Giles Aerospace Ltd.
Type/Model	:	Multi-Purpose Flight Recorder
Part Number	:	D51612-102 ISS:1
Serial Number	:	18038-004

The MPFR downloaded process was conducted on 7 April 2015 at the Australian Transport Safety Bureau (ATSB) recorder facility in Canberra, Australia under supervision of KNKT investigator. The download process successfully retrieved 70 parameters of 80 hours of flight data comprising the accident flight and previous flights. The flight recorder also contained 30 minutes of audio recording data on four channels consisted of Public Address (P/A), Co-pilot, Pilot and Cockpit Area

Microphone (CAM) channels and 120 minutes of audio on two channels (Combined Crew Audio and CAM).

Figure 8: The Multi-Purpose Flight Recorder (MPFR)

The KNKT sent the FDR raw data for analysis to Bureau d'Enquetes et d'Analyses (BEA) France who participate in the investigation as State of Manufacture of the engine.

On 9 September 2015, BEA provided KNKT the result of raw data process. The results of the raw data process are as follows:

Note: The time in the following chart is data frame sequence and not LT time.

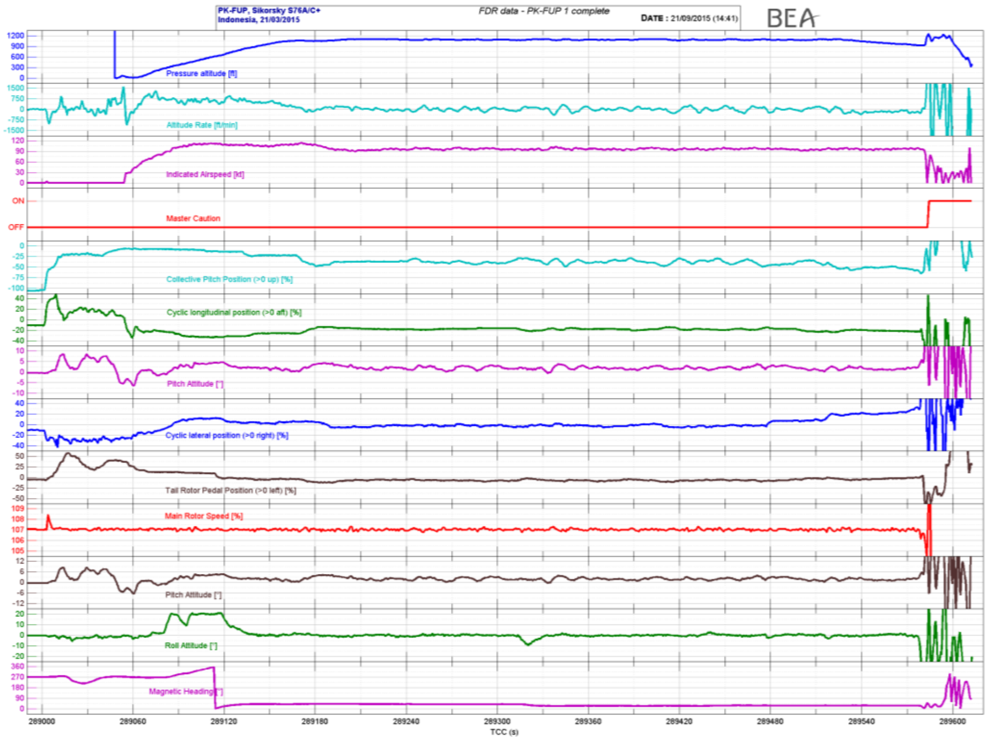


Figure 9: MPFR data including flight control information

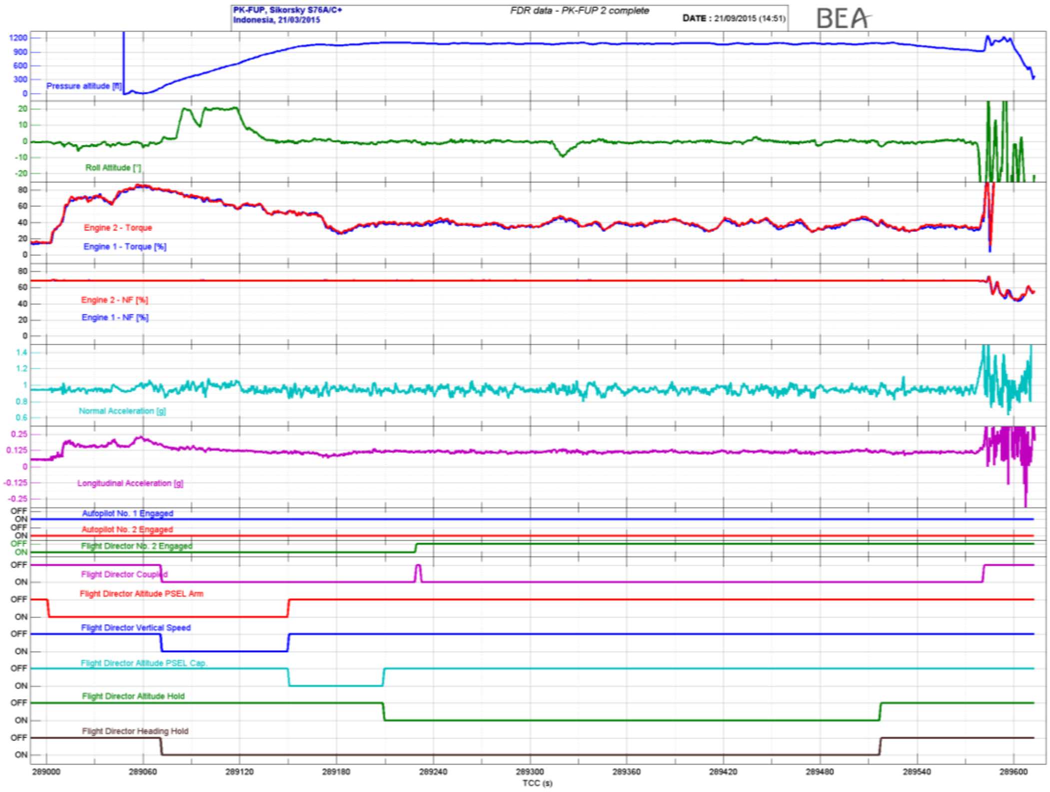


Figure 10: MPFR data including flight director and autopilot engagement

The investigation also analyzed a video recording that was made by an onboard passenger. The audio of the video recorder was converted. The spectrum of the converted audio data was analyzed. The detail of the analysis of the video is described in chapter 1.16.3 of this report.

The audio sound revealed the information of NR (Main Rotor rotation) and NG (gas turbine engine rotation). The results of the audio analysis were compared to the MPFR data. The comparisons are shown on the following graphs.

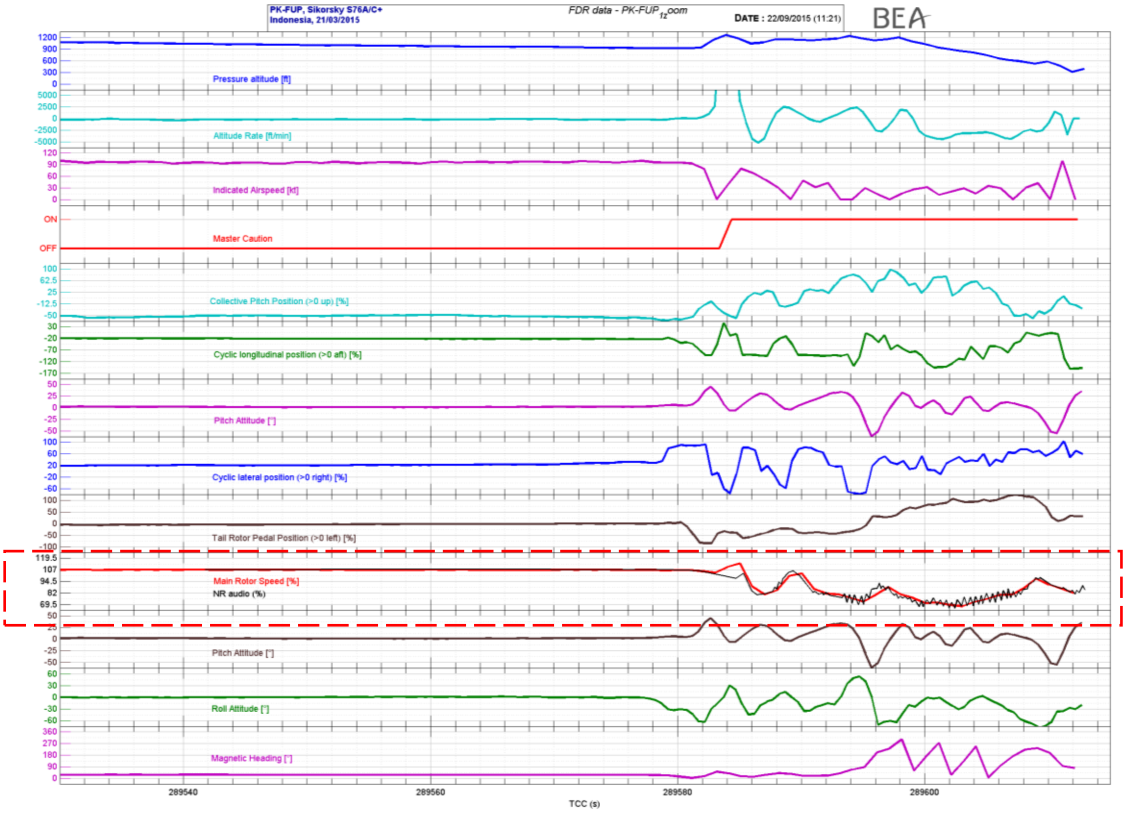


Figure 11: The comparison of the NR information based on the MPFR and audio data (black line).

The comparison of the NR information based on audio was similar with NR information based on the MPFR. The detail examination of NR information based on the audio is described in the test and research of video recorded information in chapter 1.16.3 of this report.

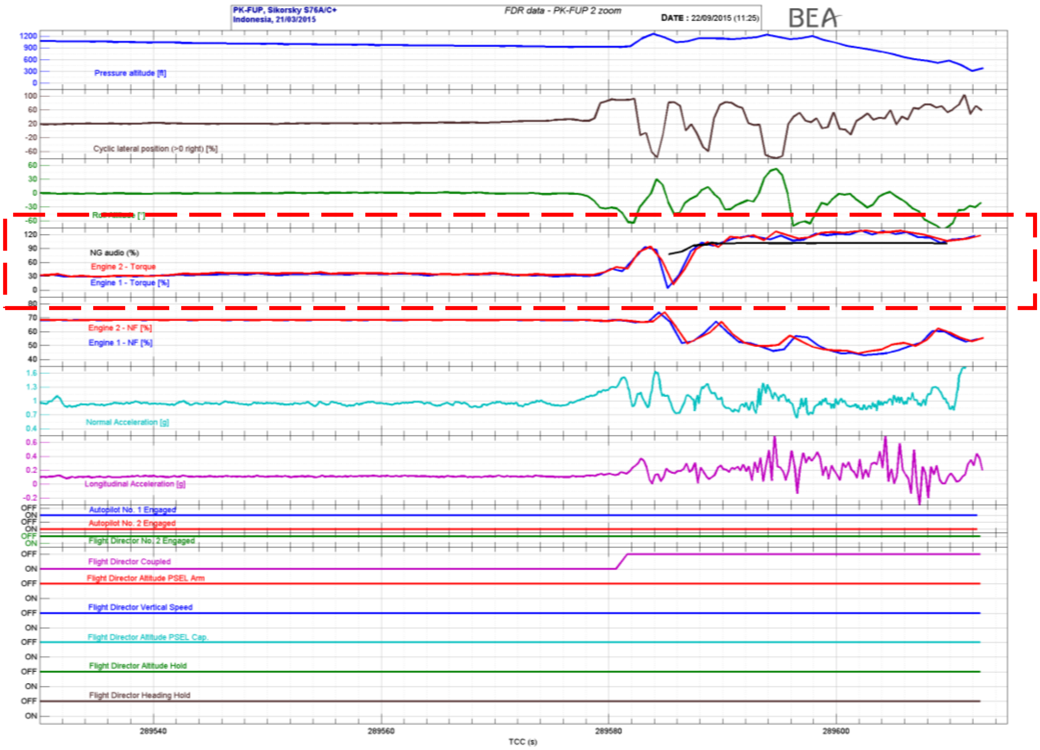


Figure 12: The comparison of the NG information based on the MPFR and audio data (black line).

Significant events prior to occurrence are as follow (the time is MPFR data frame converted to MPFR elapse time).

- 80:11:23, engine 2 was started
- 80:11:53, engine 1 was started
- 80:11:54, torque engine 1 was alive
- 80:13:13, torque engine 2 was alive
- 80:16:03, autopilot 1 and 2 engage
- 80:17:30, the helicopter took off
- 80:19:12, the helicopter reaching altitude of 1000 feet with heading of 038, the pitch attitude was 1.67 degrees and roll attitude was -0.09 degrees.
- 80:26:23 – until the end of recording, the helicopter descending from altitude 1000 feet, then entered un-commanded attitude, indicated by recorded the roll to the left up to 77.71 degrees, and roll to the right recorded up to 52.84 degrees, pitch up of 45.27 degrees and pitch down up to -61.98 degrees.
- 80:26:25, the master caution light illuminated.
- 80:26:54, end of recording.

1.11.2 Voice Recorder

Transcript excerpt from the voice recorder
P1 : Captain pilot
P2 : Co-pilot
CPU : CPU radio station
The time recorded was voice recorder elapse time.

Time (CVR time)	Recorded Voice
1:53:37 - 1:53:44	The pilots discussing about the initial flight altitude
1:53:46 - 1:53:49	The pilots confirming the direction to the observation location
1:54:05 - 1:54:09	The pilots discussing auto pilot readiness
1:54:21 - 1:55:52	The pilots discussing cabin noisy and initiating left turn
1:56:09 - 1:56:39	The P2 reporting to CPU radio controller that the helicopter reaching 1,000 feet and the estimated time to arrive at CPU was at 1216 LT. The CPU radio controller acknowledged and asked the number of passenger on board (POB). The SIC replied that there were 7 persons on board
1:57:33	The P1 handover the helicopter control to P2
1:57:41	The pilot discussing the speed whether in this speed was comfortable or not.
2:01:14	The P2 communicated to the P1 that the drilling site (TMP) as reference point had reached.
2:02:05 - 2:02:30	The pilot and one of the passenger discussed about the location and the pilot initiating descend
2:03:02 - 2:03:09	One of the passenger informed to the pilot that the observation location (GTS 4) was below the helicopter
2:03:27	The P2 asked about the direction to turn.
2:03:30	The P1 exclaimed about the un-commanded attitude of the helicopter
2:03:33	(EGPWS) “Bank angle”
2:03:34	(EGPWS) “Bank angle”
2:03:35 - 2:03:38	The P2 repeated the un-commanded attitude of the helicopter
2:03:42	The P1 take over the helicopter control from P2
2:03:43 - 2:03:45	The P2 exclaimed about the autopilot engagement and the P1 commanded to disengage the autopilot
2:03:49	(EGPWS) “Bank angle”
2:03:53 - 2:03:59	The P2 suggesting to check and set the collective.
2:04:00 - 2:04:02	(EGPWS) “Bank angle”
2:04:03	(EGPWS) “Altitude…. Altitude”
2:04:05	(EGPWS) “Too low …”
2:04:06	*End of recording*

1.12 Wreckage and Impact Information

The helicopter was found at coordinates 0°39'22.76" S, 117°20'39.75" E approximately 50 meters from Mahakam River.

The following are the pictures of aerial view of the helicopter at crash site.

Figure 13: Aerial view of helicopter at crash site

Prior to impact, the helicopter hit several treetops. Some trees were cut and collapsed due to impact by the main rotor blades. The tail boom broke and the tail rotor detached. The helicopter stopped in position and tumbled to the left side and up-side down.

Figure 14: Main fuselage with the cockpit upside down position

Figure 15: Broken tail boom

1.12.1 Wreckage examination

The wreckage was transported to Balikpapan for further examination. The investigation conducted wreckage examination in hangar at Kariangau Balikpapan. The examination found that the forward push rod of the main rotor which was connected to the forward servo actuator was separated from the rod end bearing. The investigation removed three servos for further examination. The servos are as follows:

1. Forward servo actuator part number (PN) 30006760-111 and serial number (SN) B345-0163XD
2. Lateral servo actuator PN 30006760-111 and SN B345-01758
3. Aft servo actuator PN 30006760-111 and SN B345-01690

Along with the servos, all push rod connecting the servo to the flight control linkage were dismantled from the helicopter. The three push rods (forward, lateral and aft) had same part number of 76400-00034-059 complete with rod end bearing part number MS21151-8 and the jam nut part number AN316-6R.
The further examination to the servo actuators and the push rods is described in chapter 1.16 of this report.

1.12.2 Engine examination report Turbomeca

The engine examination was performed by Turbomeca who acted as adviser to the investigation. The engine examination report is as follows.

The Arriel 2S1 engine was a turbo shaft engine with a single-stage axial compressor, a single-stage centrifugal compressor, an annular combustion chamber, a single stage high pressure turbine, a single stage power turbine, and a reduction gearbox with a nominal output at 6409 RPM.

The engine rated at 857 SHP (639 kW) at take-off power and 794 SHP (592 kW) at maximum continuous power. The dimensions of the engine were 1.12 m long, 0.412 m wide and 0.609 m tall. The dry weight was 131 kg.

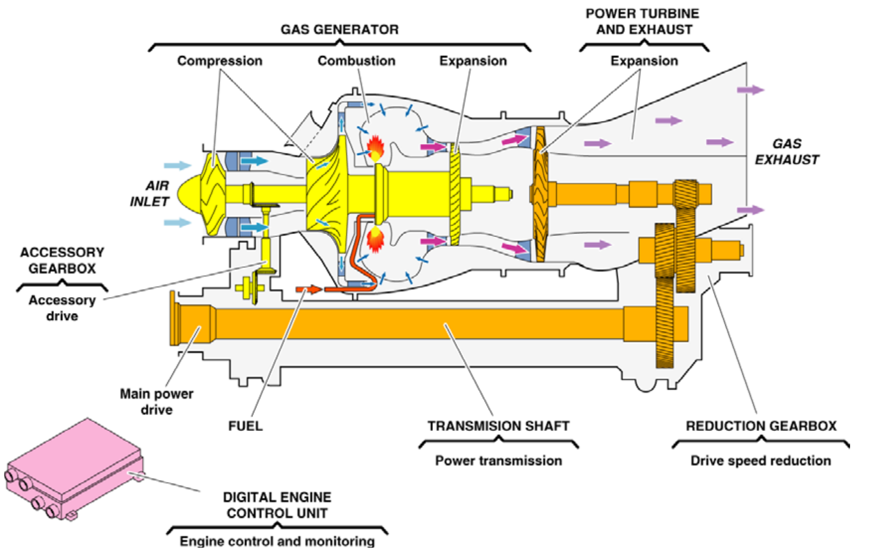


Figure 16: Engine Arriel 2S1 lay out

The engine consists of five modules as shown in the following figure.

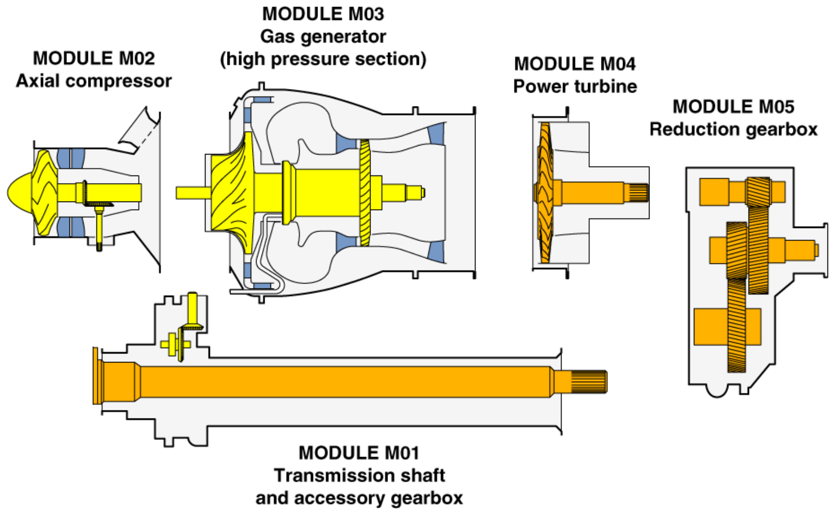


Figure 17: Arriel 2S engine module

The helicopter wreckage recovered to a hangar in Balikpapan for examination. The engines were found intact.

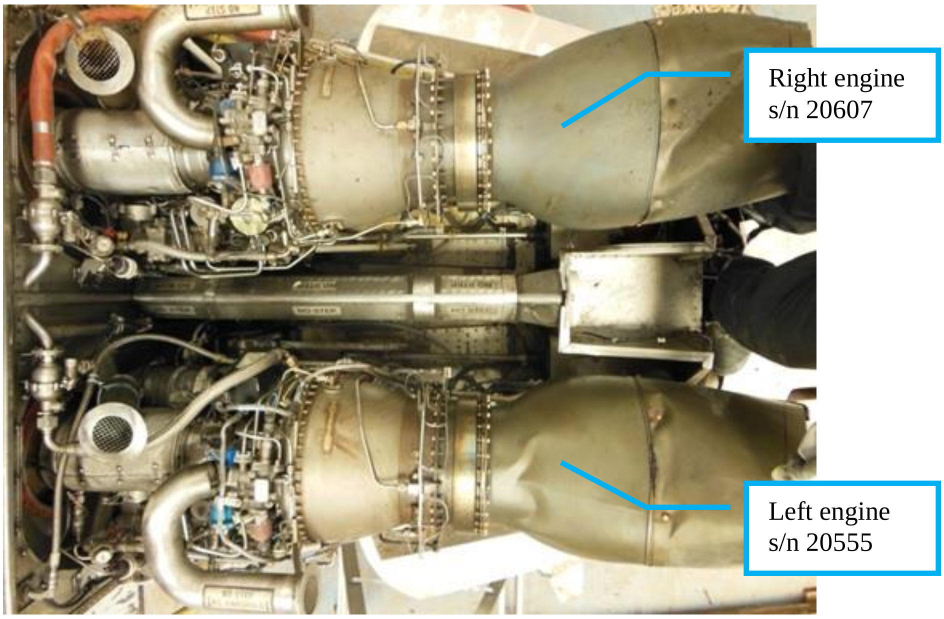


Figure 18: Both engines still intact as recovered

The rotor head showed damage in the direction of rotation indicative of power at the time of impact.

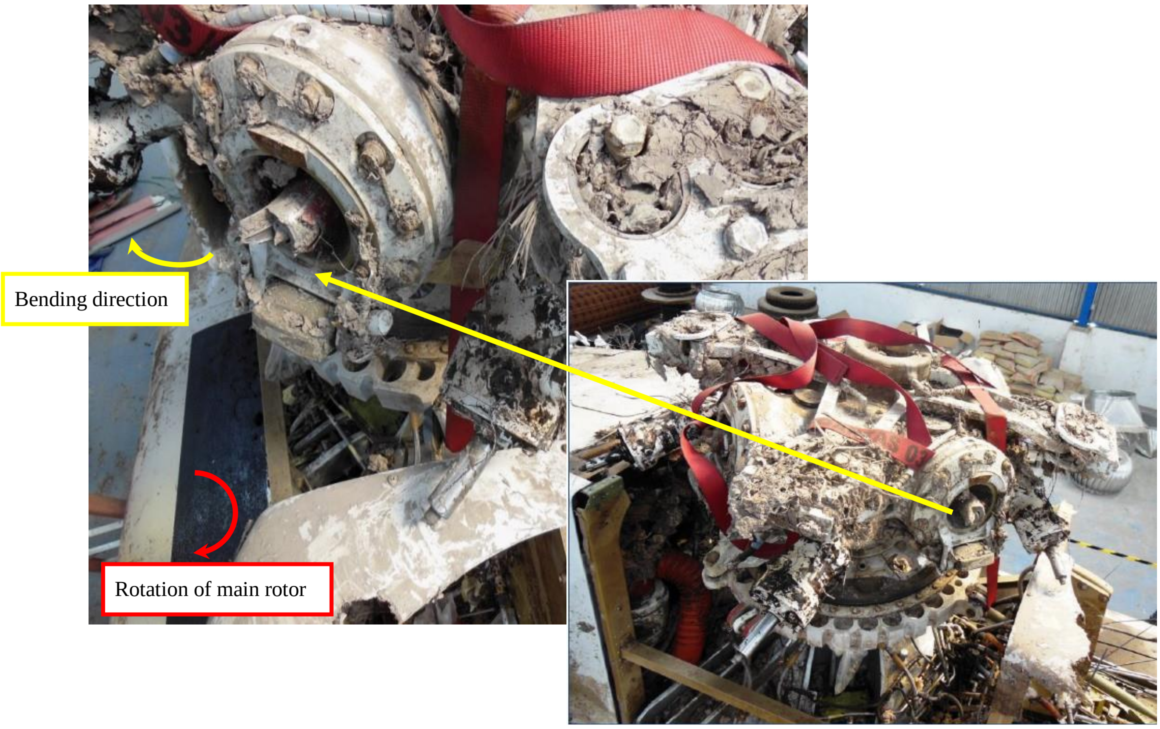


Figure 19: Rotor head

The power lever was recovered as during the wreckage examination on the site of the accident. The fuel levers were in the OFF position, the power levers were in backward position and the shut-off T-Handles were in the activated position (pulled back). This information corroborates the pilots report that they shut-down the engines after the accident by pulling all the levers back.

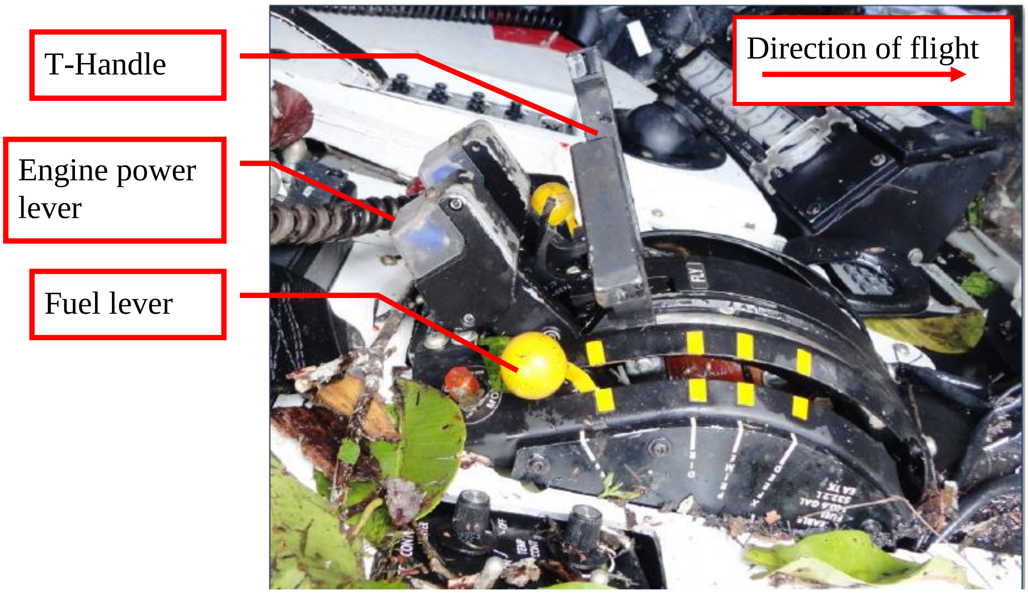
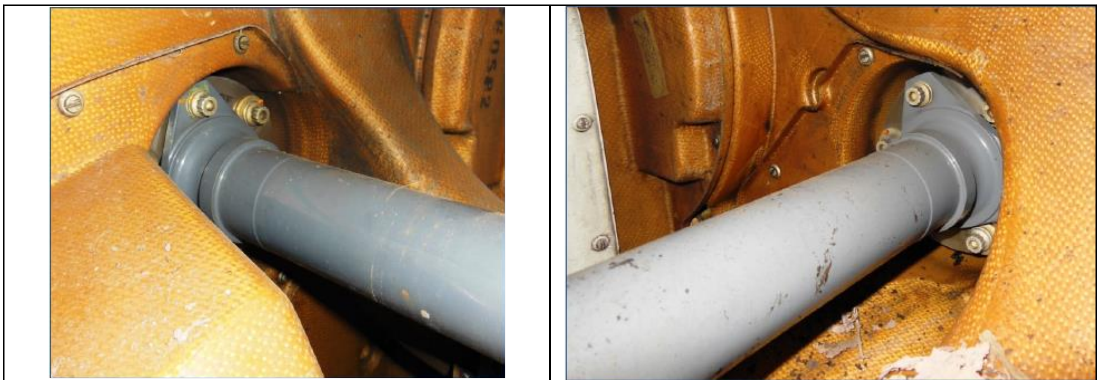


Figure 20: Power lever condition found on the accident site

General view of the left and right engine mounts indicated no significant finding. Both engines were attached to the aircraft by the front and rear supports. The fixings did not exhibit any sign of play.

Both engine air intakes were in place on both sides. The left air intake contained small fragments of vegetation and soil. The right hand one was free of any contamination.

The drive shafts were in place on both sides with no signs of misalignment, damage or deterioration.



Left engine drive shaft	Right engine drive shaft

Figure 21: Engine drive shaft observation.

Left Engine Observation

The left engine was attached to the helicopter and appeared in good general condition.

Figure 22: The whole engine as recovered.

- Module 1 (Accessories Gearbox and Link tube)

The module 1 was in good condition with no particular findings to report.

The starter generator rotated in synchronicity with the rotation of the gas turbine engine rotation thus confirming the continuity of the accessories gearbox gear train. Similarly, the output power drive rotated with the rotation of the Power Turbine thus confirming the continuity of the reduction gearbox gear train.

Figure 23: Play at the support yoke and casing

The accessories gearbox front casing exhibited some play with respect with the front support and five fixing screws (out of 11) were sheared and they were found on the engine bay floor along with their associated dowels thus indicating excessive lateral or vertical load at the time of impact.

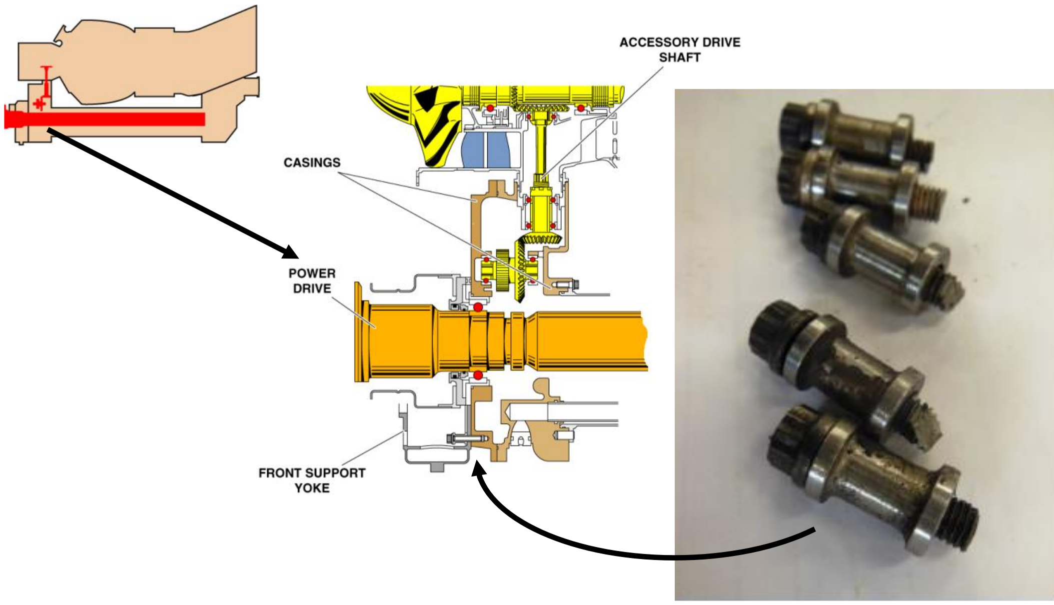


Figure 24: Five shear bolts recovered at engine bay.

- Module 2 (Axial Compressor)

The module 2 was in good condition with no particular findings to report. The Gas Generator could be rotated by hand. The rotation was smooth without noise. A close inspection of the axial compressor showed that all the blades were in good condition with no visible traces of impacts, erosion or top of blades rubbing. Similarly, the borescope inspection showed that the centrifugal impeller was also in good condition.

- Module 3 (Combustion Chamber and High Pressure (HP) Turbine)

The module 3 was in good condition with no particular findings to report. The borescope inspection showed the presence of soil in the combustion chamber and in the High Pressure (HP) Turbine. The combustion chamber was otherwise in good condition. Similarly, the HP Turbine was in good condition with no visible signs of impacts or top of blades rubbing. Six adjacent blades were covered with shiny layer of oil indicating that oil dripped out of the rear bearing chamber after engine shut-down when the engine was upside-down after the accident.

- Module 4 (Power Turbine)

The module 4 was in good condition with no particular findings to report. The Power Turbine could be rotated by hand. The rotation was smooth and without noise. A close inspection of the Power Turbine wheel showed that all the blades were in good condition with no visible impacts or traces of top of blade rubbing. They were covered with oil.

- Exhaust pipe

The exhaust pipe was locally bent and distorted either as a consequence of the accident or of the salvage operation. An area in the exhaust's upper inner surface was covered with coked oil. This area was the low point when the engine was upside-down after the accident thus indicating that oil dripped from the bearing casings and into the main air path and exhaust and was consumed by the high heat that prevailed in the area shortly after engine shut-down.

Figure 25: Left engine exhaust condition

- Dressing (pipes and harnesses)

The engine dressing was in place with no loose or broken pipes or harnesses. The connectors were checked and found tight.

- Fuel filter and clogging indicator

The fuel filter cartridge was removed and the visual inspection showed that it was clean. The clogging indicator did not pop out.

- Oil filter and clogging indicator

The oil filter was removed and the visual inspection showed that it was clean. The clogging indicator did not pop out.

- Magnetic plug checks

The magnetic plugs were checked and found clean or with non-significant amounts of particles.

- Equipment

The HMU was fixed to the engine with no particular findings to report.

- Bleed valve

The bleed valve was fixed to the engine and the butterfly valve was in the open position which is the normal position when the engine is stopped.

Right Engine Observation

The right engine was attached to the helicopter and appeared in good general condition.

Figure 26: Right engine as recovered

- Module 1 (Accessories Gearbox and Link tube)

The module 1 was in good condition with no particular findings to report. The starter generator rotated in synchronicity with the rotation of the gas generator thus confirming the continuity of the accessories gearbox gear chain. Similarly, the output power drive rotated with the rotation of the Power Turbine thus confirming the continuity of the reduction gearbox gear chain.

The accessories gearbox's front casing exhibited some play with respect with the front support and four fixing screws (out of 11) were sheared and they were found on the engine bay floor along with their associated dowels thus indicating excessive lateral or vertical load at the time of impact.

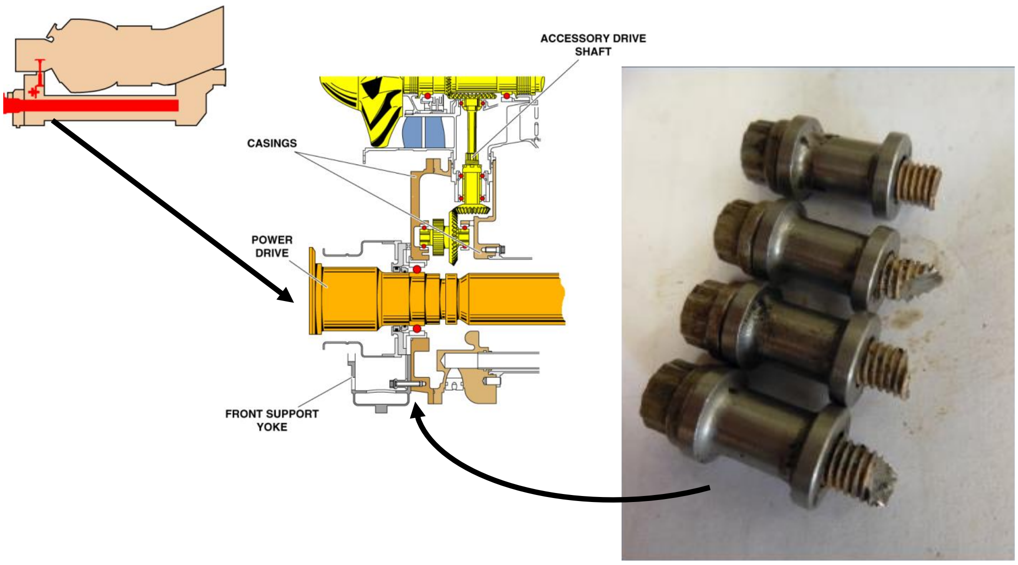


Figure 27: Four shear bolts recovered at engine bay.

- Module 2 (Axial Compressor)

The module 2 was in good condition with no particular findings to report. The Gas Generator could be rotated by hand. The rotation was smooth without noise. A close inspection of the axial compressor showed that all the blades were in good condition with no visible traces of impacts, erosion or top of blades rubbing. Similarly, the borescope inspection showed that the centrifugal impeller was also in good condition.

- Module 3 (Combustion Chamber and HP Turbine)

The module 3 was in good condition with no particular findings to report. The borescope inspection showed the presence of soil in the combustion chamber and in the HP Turbine. The combustion chamber was otherwise in good condition. Similarly, the HP Turbine was in good condition with no visible signs of impacts or top of blades rubbing. Six adjacent blades were covered with shiny layer of oil indicating that oil dripped out of the rear bearing chamber after engine shut-down when the engine was upside-down after the accident.

- Module 4 (Power Turbine)

The module 4 was in good condition with no particular findings to report. The Power Turbine could be rotated by hand. The rotation was smooth and without noise. A close inspection of the Power Turbine wheel showed that all the blades were in good condition with no visible impacts or traces of top of blade rubbing. They were covered with oil.

- Exhaust pipe

The exhaust pipe was locally bent and distorted either as a consequence of the accident or of the salvage operation. An area in the exhaust upper inner surface was covered with coked oil. This area was the low point when the engine was upside-down after the accident thus indicating that oil dripped from the bearing casings and into the main air path and exhaust and was consumed by the high heat that prevailed in the area shortly after engine shut-down.

Figure 28: Right engine exhaust condition

- Dressing (pipes and harnesses)

The engine dressing was in place with no loose or broken pipes or harnesses. The connectors were checked and found tight.

- Fuel filter and clogging indicator

The fuel filter cartridge was removed and the visual inspection showed that it was clean. The clogging indicator did not pop out.

- Oil filter and clogging indicator

The oil filter was removed and the visual inspection showed that it was clean. The clogging indicator did not pop out.

- Magnetic plug checks

The magnetic plugs were checked and found clean or with non-significant amounts of particles.

- Equipment

The HMU was fixed to the engine with no particular findings to report.

- Bleed valve

The bleed valve was fixed to the engine and the butterfly valve was in the open position which is the normal position when the engine is stopped.

Overall engine examination summary

Some of the screws that secure the front supports to the accessories gearboxes of both engines were sheared thus suggesting that the helicopter suffered a high lateral or vertical shock at the time of impact.

Oil escaped from the bearing chambers of both engines and into the main air paths when the aircraft was upside down after the accident. The oil made its way to the exhaust and was consumed by the high heat prevailing in the main air path after the accident thus explaining the smoke seen by the passengers.

There were no other significant findings to report and both engines appeared in good condition inside and outside. Findings on the main rotor head were indicative of presence of power at the time of impact.

1.13 Medical and Pathological Information

After the occurrence, all the occupants were examined at the nearest hospital and no further treatment required.

1.14 Fire

There was no evidence of in-flight or post impact fire.

1.15 Survival Aspects

After the helicopter stopped, all passengers evacuated of the aircraft followed by the pilots. The crash site was approximately 50 meters from the Mahakam river and close by the CPU station. The CPU station sent a patrol boat to the crash site to evacuate the occupants.

At 0223 LT, the SIC reported to the operator flight operation manager via phone call that the helicopter had crashed on route of Handil helipad to CPU and all occupants had survived.

At 0230 LT, the Emergency Command Center (ECC) was activated by the airport operator at Sepinggan to conduct rescue.

At 0242 LT, the location of the helicopter was identified and followed by preparation to evacuate the occupant. The aircraft operator prepared a helicopter for evacuation. At this time, all occupants had onboard to the CPU patrol boat heading to CPU clinic from the crash site.

At 0325 LT, the rescue helicopter could not depart from Sepinggan to the location due to weather conditions. At 0340 LT, the ECC received information that all occupants were rescued to CPU and medical treatment was performed.

At 0540 LT, flight operation manager of the aircraft operator received information that all occupants were transported to Balikpapan using boat and the evacuation plan by the helicopter was cancelled.

At 1015 LT, all occupants arrived at hospital in Balikpapan for further medical treatments.

1.16 Tests and Research

1.16.1 Push rod examination

Examination to the servo actuators and the push rods including the rod end bearing was conducted by KNKT in coordination with Institute Technology of Bandung (ITB). The aft-ward push rod and the rod end bearing were found in good condition. Furthermore, the forward and lateral push rod including the rod end bearing were examined at NTSB facility.

The rod end bearing connected to the push rod via threaded shank and locked by mean of jam nut. There was no locking device to secure the jam nut to prevent loosening from the push rod during the operation. The Aircraft Maintenance Manual (AMM) chapter 20 stated that the jam nut part number AN316-6R should be tightened by force of 165 inches pound for proper locking of the jam to the push rod.

The figure below is the detail of push rod and the rod end bearing.

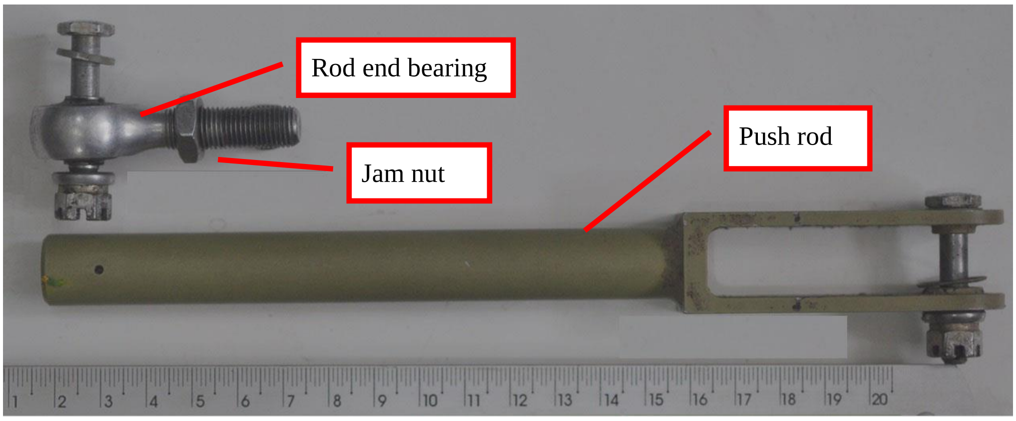


Figure 29: Push rod and rod end bearing with the jam nut

The figure below illustrated the servo actuators and the push rods including the position on the aircraft.

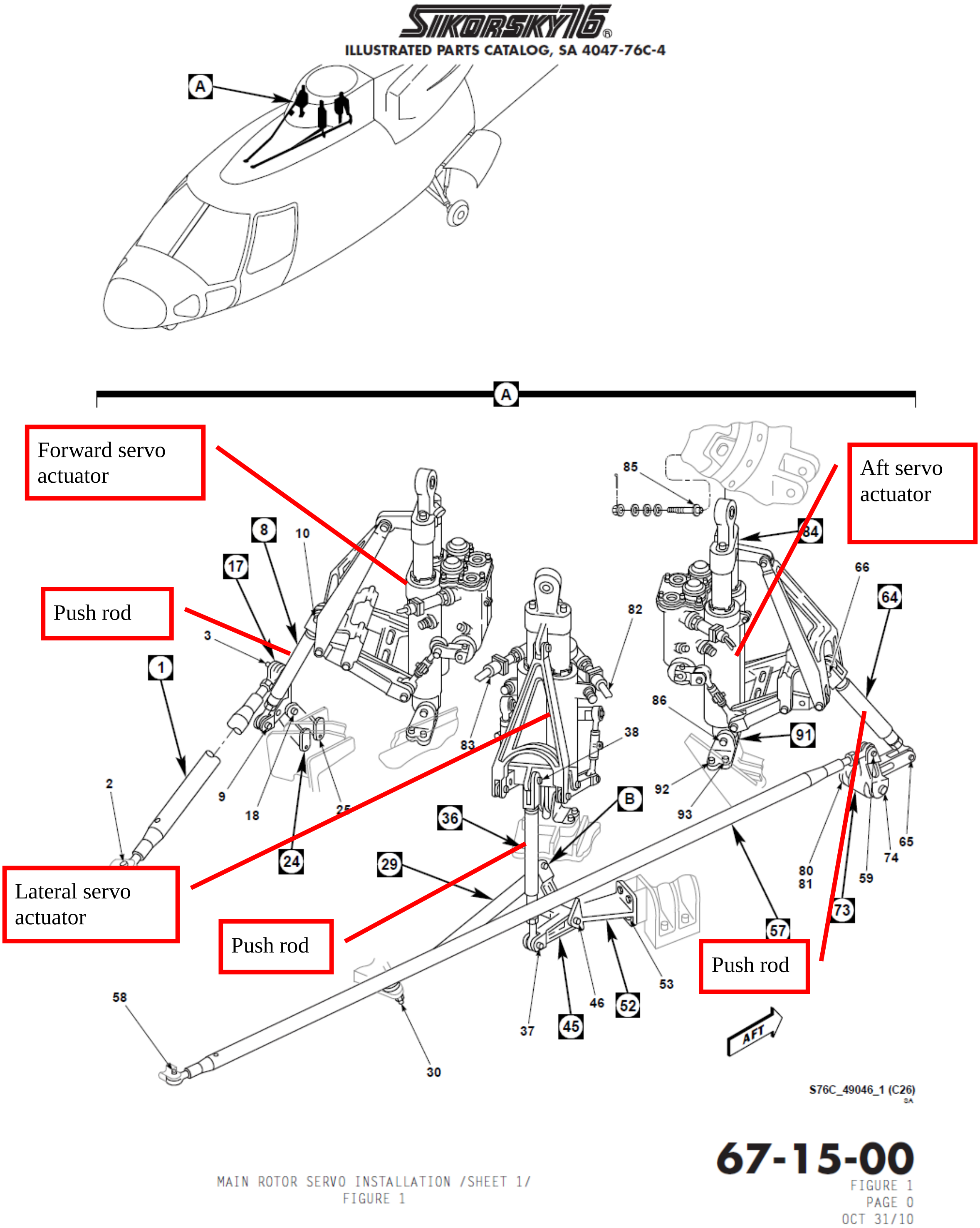


Figure 30: Illustrated servo actuator taken from Sikorsky Illustrated Part Catalogue (IPC)

Forward Push Rod Assembly

The examination of the push rod utilized stereo microscope to determine the nature of the damage and the failure mode. The profile projector was utilized to measure the dimensions of thread on push rod tube and rod end bearing.

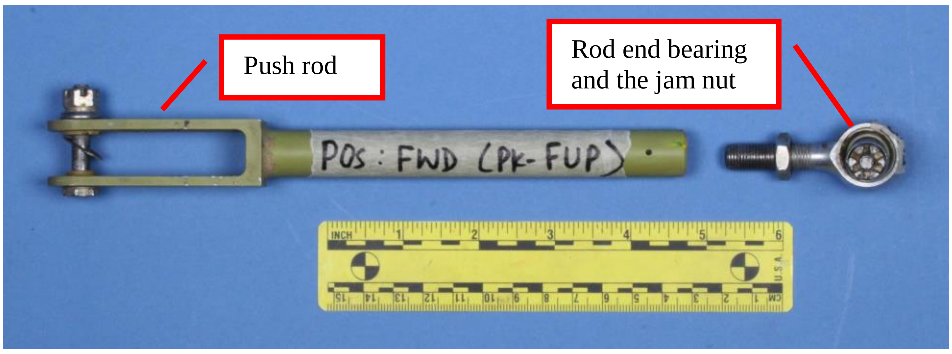


Figure 31: Forward rod end and the rod end bearing

The material composition test of the push rod found that the material composition was consistent with the specified material.

Visual inspection on the push rod found that the internal thread of the forward push rod and the rod end bearing thread were deformed as shown in the figure below.

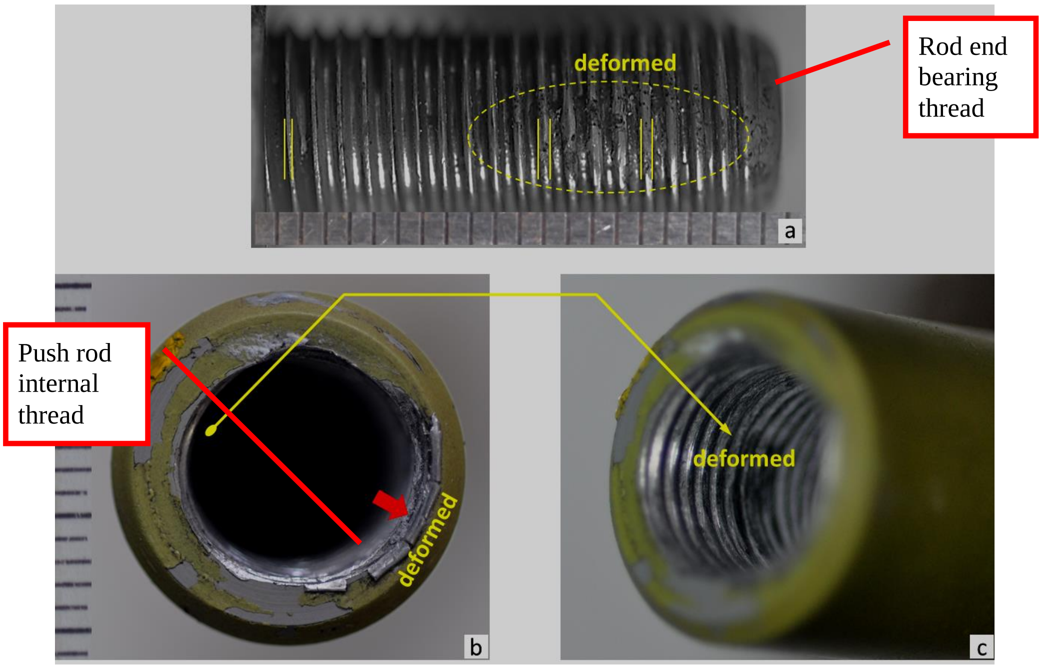


Figure 32: Deformation on the push rod and rod end bearing thread

To define the deformation, the investigation measures the pitch of the push rod and rod end bearing thread.

The push rod and rod end bearing thread area are circular in shape similar with the fastener thread area. The diameter of the thread was measured side by side (AFT and FWD face) in lateral direction and end to end (INBOARD (UP) and OUTBOARD (DOWN) face) in longitudinal direction.

The orientation for the purpose of measurement is as follow:

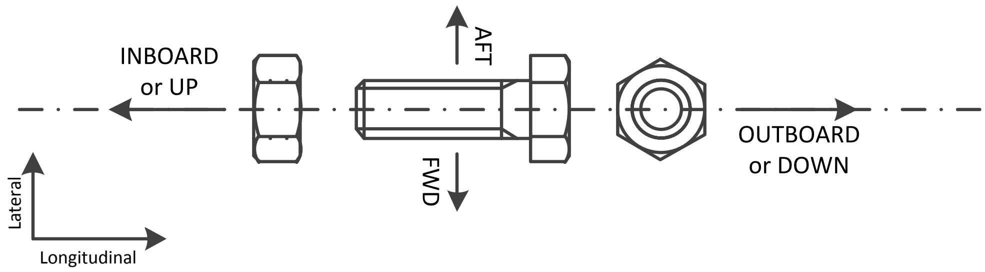
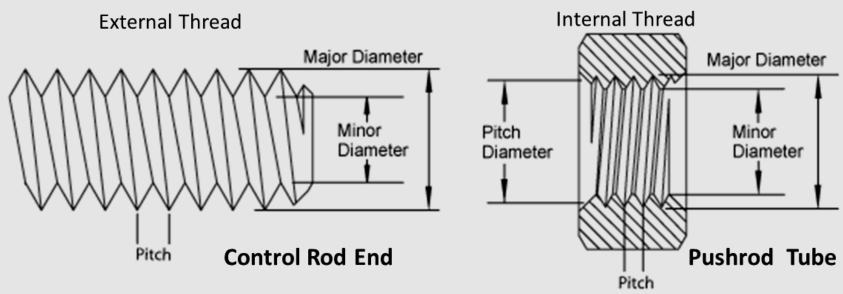


Figure 33: The orientation of nut and fastener (or push rod or rod end bearing in this case) for the measurement purposes

The recorded pitch measurement of internal thread of the forward push rod and the external thread of the rod end bearing is shown in the figure below.



	Specification	Control Rod End	Pushrod Tube
	UNF 3/8”-24	External Thread	Internal Thread
Major Diameter (Inch)	**0.3750**	**0.3697**	-
Minor Diameter (Inch)	-	-	**0.3741**
Pitch Diamter (Inch)	**0.3479**	-	-
Thread per Inch	**24**	-	-

Figure 34: Pitch measurement

The major diameter of external thread on rod end bearing was 0.3697 inch that was smaller than the minor diameter of internal thread on push rod (0.3741 inch). The report stated that the major diameter of the rod end bearing below the jam nut was found 0.3718 inch. This showed that part of the rod end bearing thread that never contacted with the push rod or jam nut had bigger diameter.

In the worn area (area that contacted with push rod or jam nut) at the upper end, the diameter of rod end measured 0.3713 inch forward to aft, and 0.3682 inches inboard to outboard. The rod end bearing exemplar of new forward push rod assembly had diameters ranging from 0.3709 inch to 0.3717 inch with an average of 0.3713 inch as measured at multiple locations along the shank. The worn area of the rod end bearing thread is shown in the figure below.

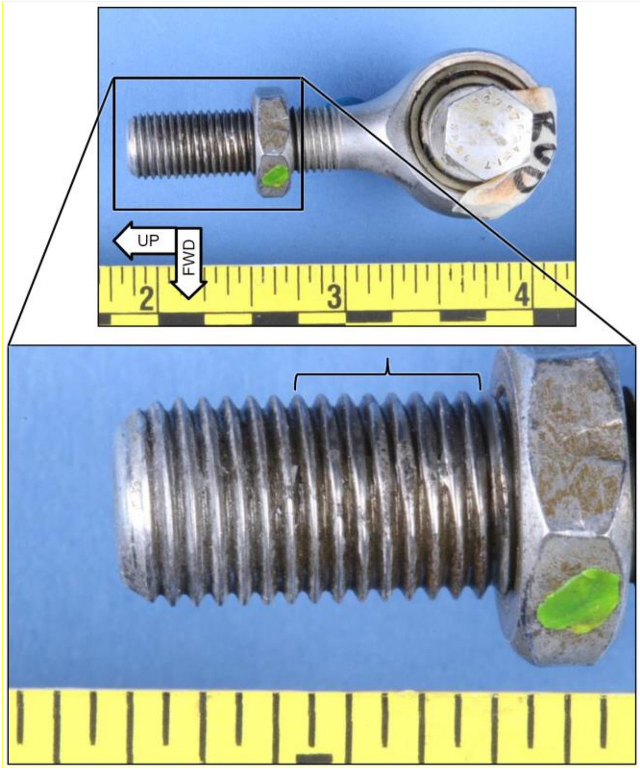


Figure 35: The deformation rod of end bearing (forward push rod)

The examination reconnected the rod end bearing to the push rod and found that rod end bearing bent with an angle approximately of 5°. This indicated that the push rod experienced transverse load in the direction as shown with red arrows in figure below.

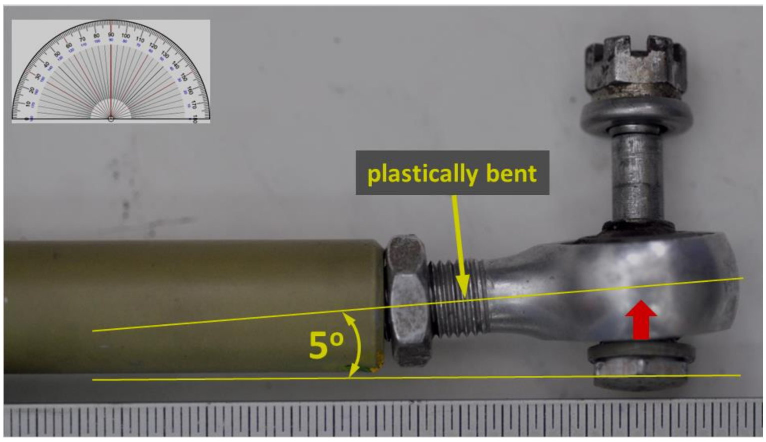


Figure 36: Illustrated bend measurement of the rod end bearing with the push rod

The origin of bending of rod end bearing could not be determined whether occur before or after the crash.

To expose to the internal thread of the forward push rod, the transverse cut of the rod near the lower end of the forward push rod followed by a longitudinal cut through the center of the end fitting attachment hole was conducted.

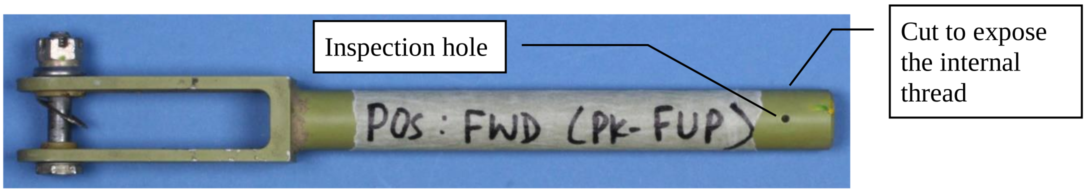


Figure 37: Original condition of the forward push rod before being sectioned

The cut orientation of the forward push rod tube is as follow:

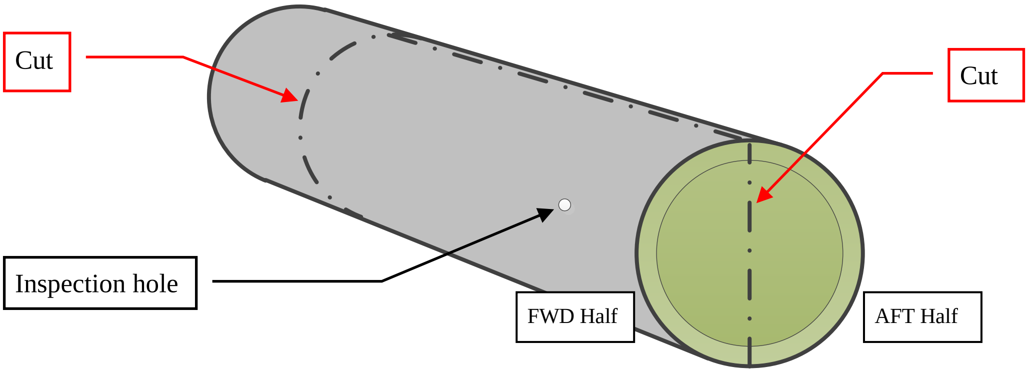


Figure 38: The schematic diagram of cut orientation.

The sectioned pieces resulting from the cuts exposed the internal thread of forward push rod is shown in figure below.

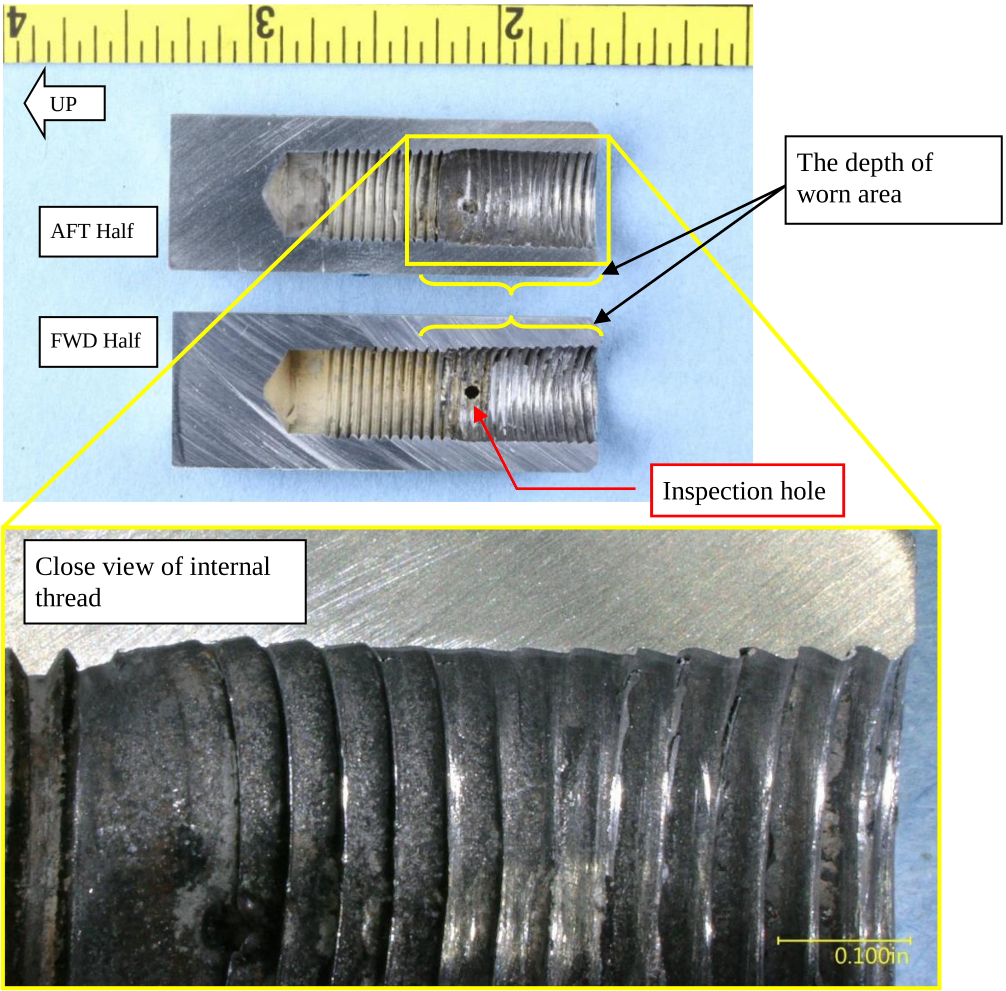


Figure 39: Close view of internal thread in the forward push rod assembly

As shown in the detail view in figure above, most of the threads were missing in the worn area. Asymmetric deformation was also observed on the edge of push rod internal thread. This finding explained the cause of detached rod end bearing from the push rod and found in separate pieces.

Lateral Push Rod Assembly

The following figure is the lateral push rod and the rod end bearing attached.

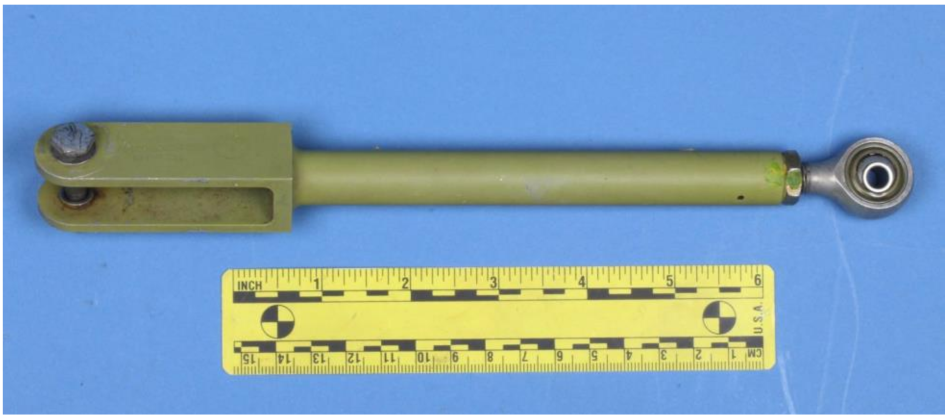


Figure 40: Lateral push rod assembly

The close view of the lower end of the lateral rod end bearing assembly is shown in figure below.

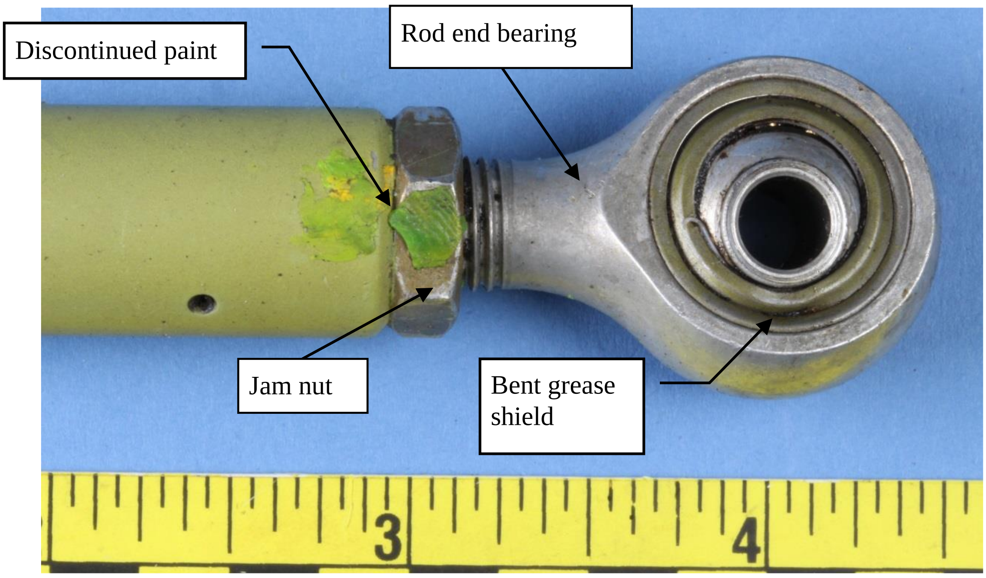


Figure 41: Rod end bearing of lateral push rod assembly

Green torque paint with underlying yellow torque paint was observed on the lower end of the lateral push rod and on the adjacent jam nut. The torque paint mark discontinued across the joint in figure above indicated there was torque change to the jam nut.

The inspection hole in the push rod was blocked consistent with sufficient rod end bearing thread engagement. Approximately 2 or 3 threads were exposed on the rod end bearing shank below the jam nut. The bearing inner race on the rod end bearing was received contacting the bearing grease shield, and the grease shield was bent on both sides of the bearing in the corresponding contact areas.

Figure 42: Rod end bearing was unscrewed from the push rod assembly

The external threads on the rod end bearing showed no evidence of damage. The corresponding internal threads in the push rod assembly were intact and showed no evidence of wear damage of the thread. The outer diameter of the rod end bearing threads measured 0.3726 inch. The internal threads of the push rod assembly had an inside diameter of 0.337 inch.

The examination lateral push rod assembly concluded that there was no significant damage on the lateral push rod assembly except there was change in the torque.

1.16.2 Servo actuator examination

KNKT conducted the servo actuators (forward, aft and lateral) examination in the Indo Aero Semesta workshop to define the serviceability of the servo actuators. The figure below shows two servo actuators condition as received in the workshop facility.

Figure 43: Two of three servo actuators

The servo actuators were examined with reference to the effective Component Maintenance Manual (CMM) chapter 67-15-02: Testing and Fault Isolation.

The purge system tested the servo by moving the piston extend and retract several times. The forward servo actuator found stuck at the first attempt but the unit move freely after several exercises. The aft-ward and lateral servo actuators were functioning properly.

The proof pressure test found that there was no evidence of leak on all the servo actuators.

During the leak test found that all of the servo actuators found wetting on the surface of the piston but in the static leak test were unremarkable.

Test Summary

The overall test showed that all the servo actuators were considered serviceable. The detail of the test is available on the appendix.

1.16.3 Video Recording

On board on this flight, one passenger documented the trip in video media for the inspection purposes. The video recorder was recovered and contained the visual and audio data including the unusual sound when the helicopter entering un-commanded attitude.

The Bureau d'Enquetes et d'Analyses (BEA), France conducted the sound spectrum analysis of the audio data on the recorded video media and onboard recording. The audio track was separated from the video file in order to provide an audio file (.wav) suitable for the sound analysis tools of the BEA facility. The 30 minutes cockpit area mic (CAM) audio file of the voice recorder and the video audio track files were both analyzed.

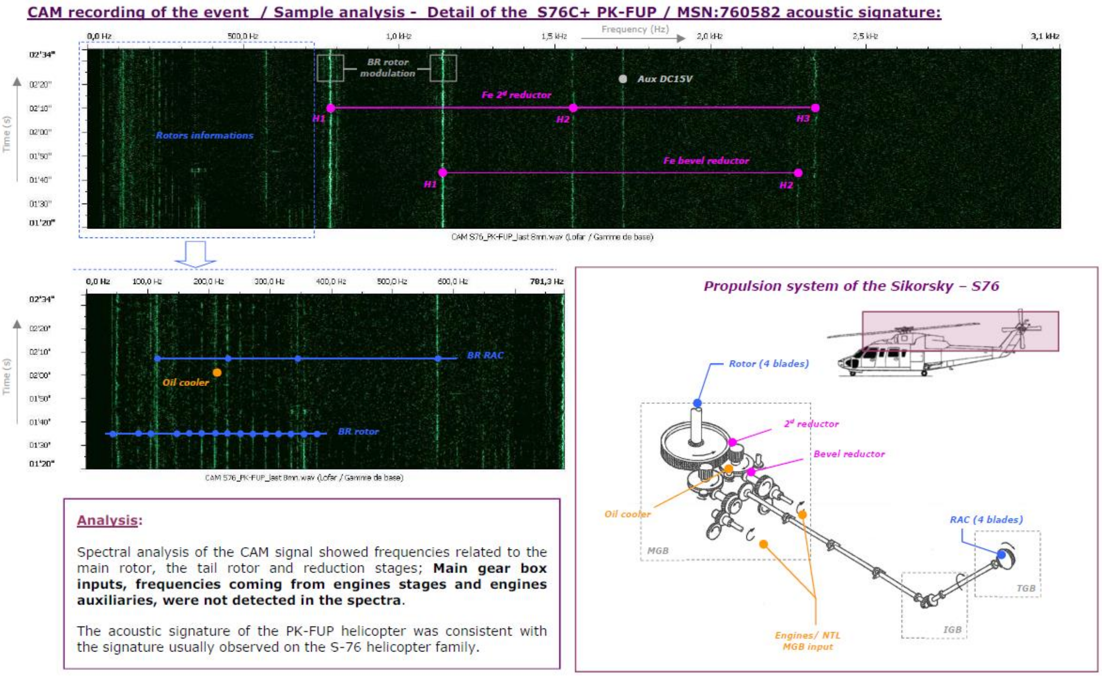


Figure 44: CAM Spectrum analysis

The frequency tracking was done to determine the rotor speed (NR) and when possible the gas turbine engine rotation (NG), taking into account the noise level changes.

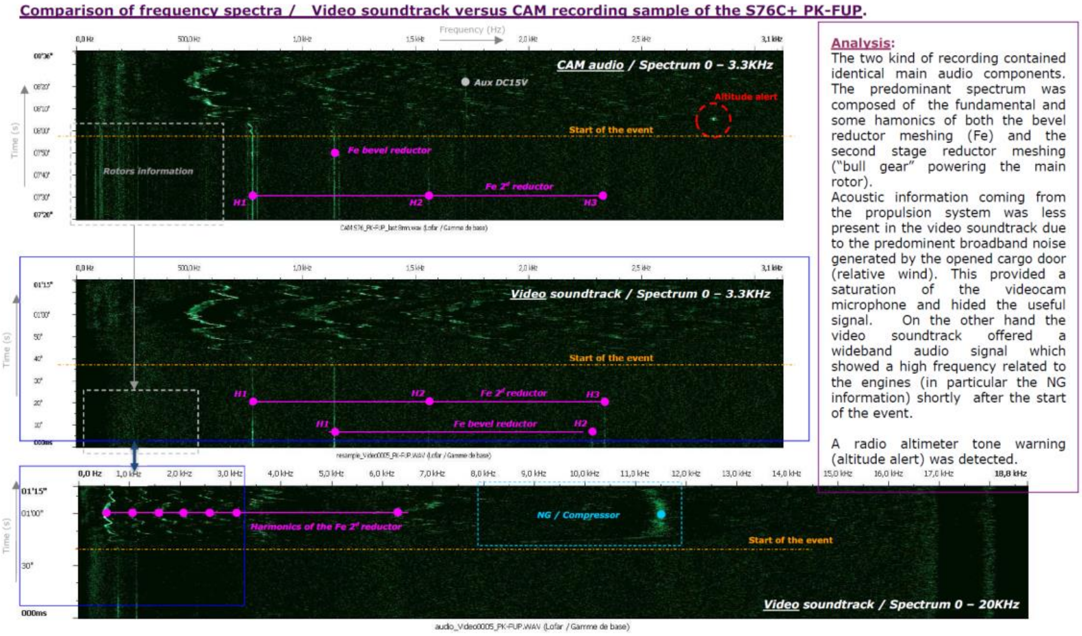


Figure 45: NG and NR spectrum analysis

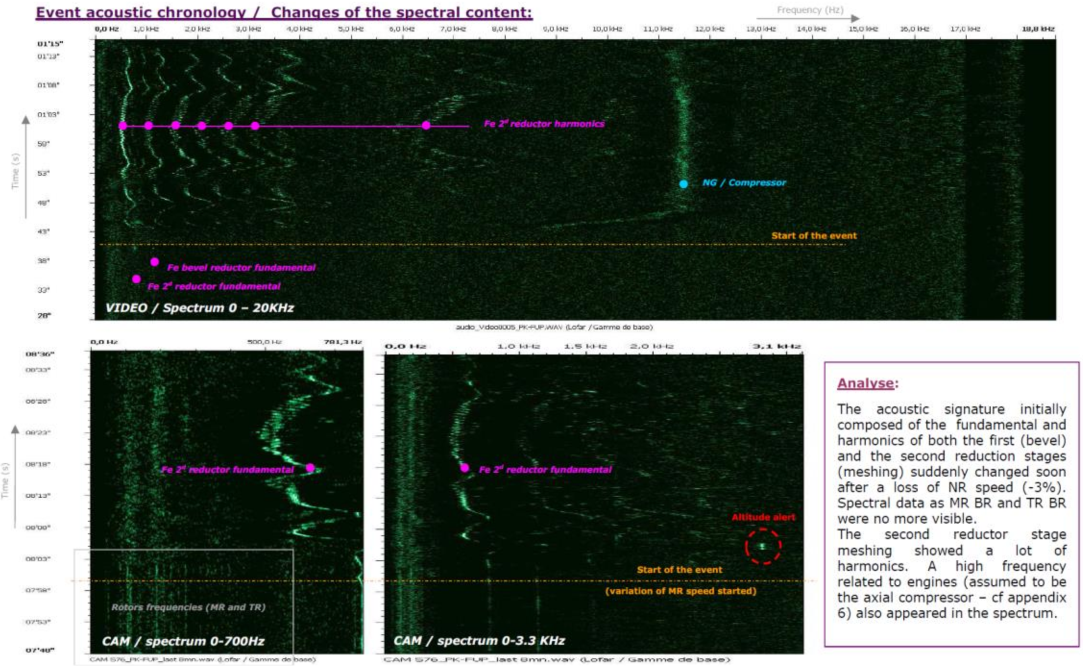


Figure 46: NG behaviour extracted from the video and CAM spectrum

To compare the spectrum normal engine with the occurrence, the following chart represents the axial and centrifugal compressor behavior.

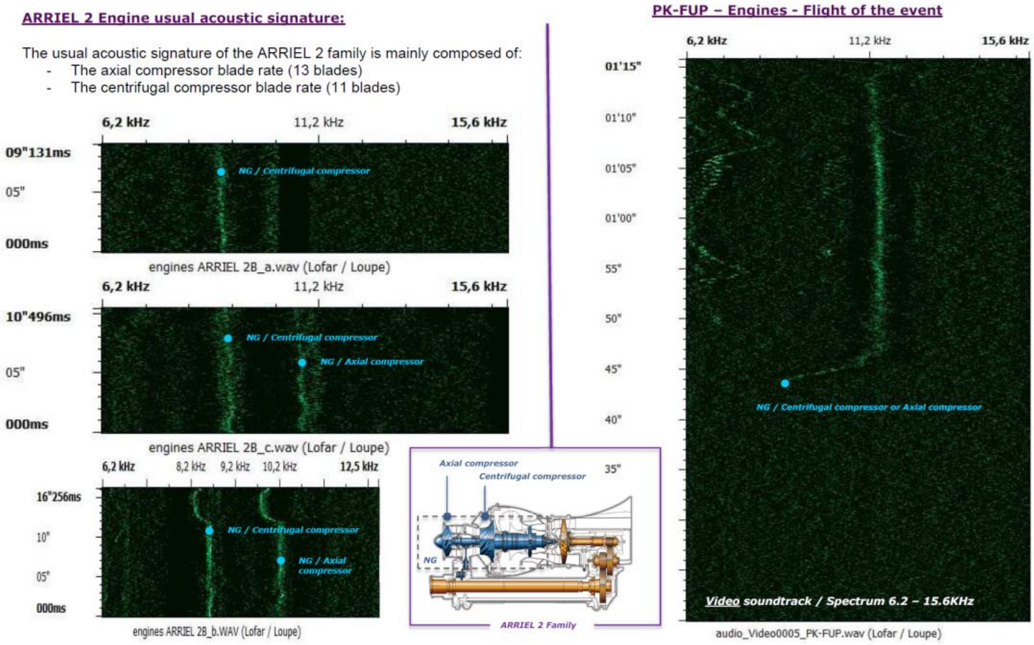


Figure 47: The comparison of normal engine with the occurrence

The unusual sound was recorded several seconds before the occurrence. The following figure represents the signature of the NG and NR of the last 76 seconds of the flight.

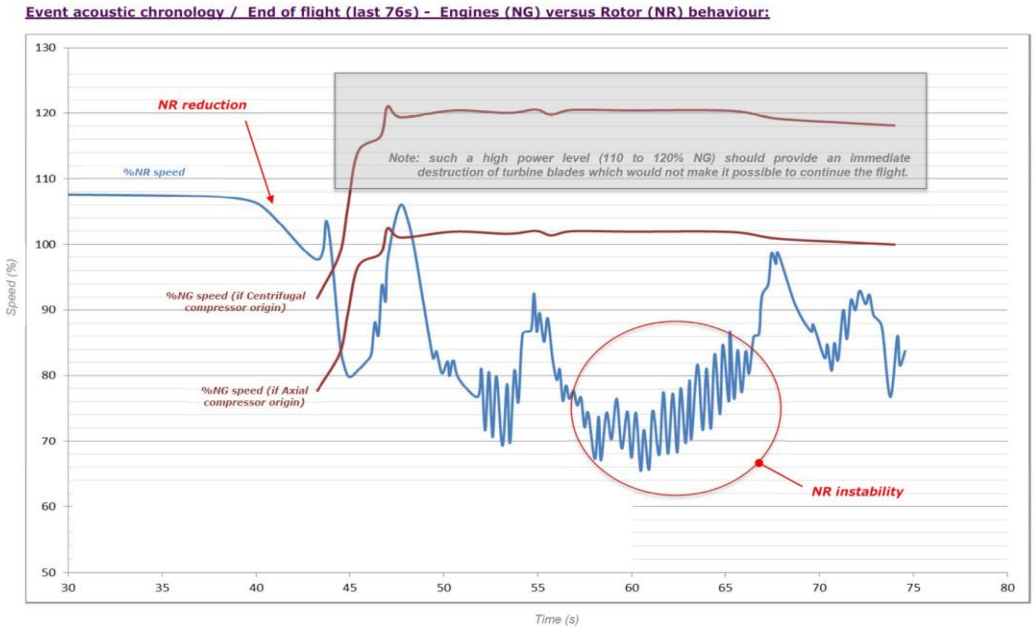
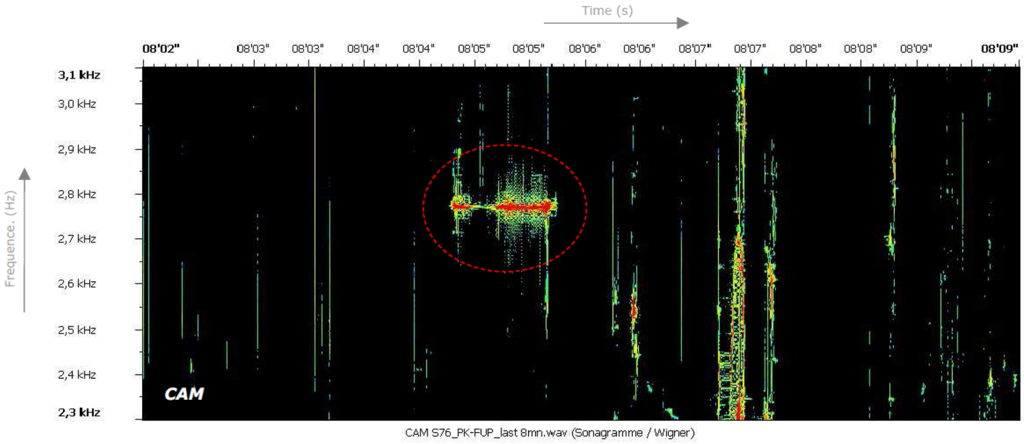


Figure 48: The spectrum signature of last 76 seconds of the flight.

There was an audio warning which correlated with the altitude alert was recorded 32 second prior to occurrence. The spectrum of altitude alert is as follow:



Analysis:

One audio warning was heard 6 seconds after the start of the NR un-stability, i e at 32 seconds before the end of the CAM recording.

The warning audio signal was a pure 2820Hz steady tone with a 980ms duration. This tone called '*altitude alert*' is generated when the current altitude is crossing the selected altitude +/- 1000ft.

Figure 49: Altitude alert spectrum

Summary of Spectrum analysis

The test and research regarding the sound spectrum analysis concluded that there was no evidence or progressive damage of propulsion system part except there was NR instability observed during the last 35 seconds of the flight.

1.17 Organizational and Management Information

1.17.1 PT. Hevilift Aviation Indonesia

Helicopter Owner	:	Wells Fargo Bank Northwest National Association
Helicopter Operator	:	PT. Hevilift Aviation Indonesia
Address	:	Hanggar B6 Sepinggan International Airport Jl. Marsma R. Iswahyudi Balikpapan, East Kalimantan 76115 Indonesia
Operator Certificate Number	:	AOC/135-042

The Company operates five helicopter Sikorsky S-76C+ including the accident flight, three helicopter AS350 Squirrel and two DHC-6-300.

The company is focusing in acquiring commuter aircrafts for charter, offshore operation, rescue and logistic supply.

1.17.2 Continuous Airworthiness Maintenance Program

2.1. SCHEDULE MAINTENANCE

2.1.2.1. Arriel 1S1 Scheduled Maintenance

5. 300 Hours/1 Year Engine Inspection

This inspection shall be complied in every 300 hours or 1 year interval, whichever occurs first. All inspection items are incorporated in 300 Hours/1 Year – Engine Inspection form.

2.1.2.2. Arriel 2S1 Scheduled Maintenance

5. 300 Hours/1 Year Engine Inspection

This inspection shall be complied in every 300 hours or 1 year interval, whichever occurs first. All inspection items are incorporated in 300 Hours/1 Year – Engine Inspection form.

2.1.2.3. Arriel 2S2 Scheduled Maintenance

5. 300 Hours/1 Year Engine Inspection

This inspection shall be complied in every 300 hours or 1 year interval, whichever occurs first. All inspection items are incorporated in 300 Hours/1 Year – Engine Inspection form.

The inspection of servo actuator including rod attached to it were included in this scheduled maintenance task.

1.18 Additional Information

1.18.1 Similar Accident in Nigeria

During the course of investigation, on 12 August 2015, similar occurrence involving Sikorsky S-76C+ was happened in Nigeria. The point of departure was an offshore oil rig and the destination was Murtala Muhammed Airport (DNMM), Lagos.

The investigation report available on:
www.aib.gov.ng/media/1034/prebristowhelicopters12082015.pdf

At 15:31 LT, 5N-BGD, Sikorsky S-76C+, a domestic chartered flight operated by Bristow Helicopters (Nig.) Limited, crashed into the lagoon at Oworonshoki area of Lagos, Nigeria. Visual Meteorological Conditions (VMC) prevailed at the time and a Visual Flight Rule (VFR) flight plan was filed. The two flight crewmembers and four of the ten passengers were fatally injured. The helicopter was destroyed and there was no fire.

The investigation found that the push rod tube separated from rod end bearing. The jam nut was loose and was not seating against the push rod.

The figure below showed the push rod including the rod end bearing which was recovered during the investigation.

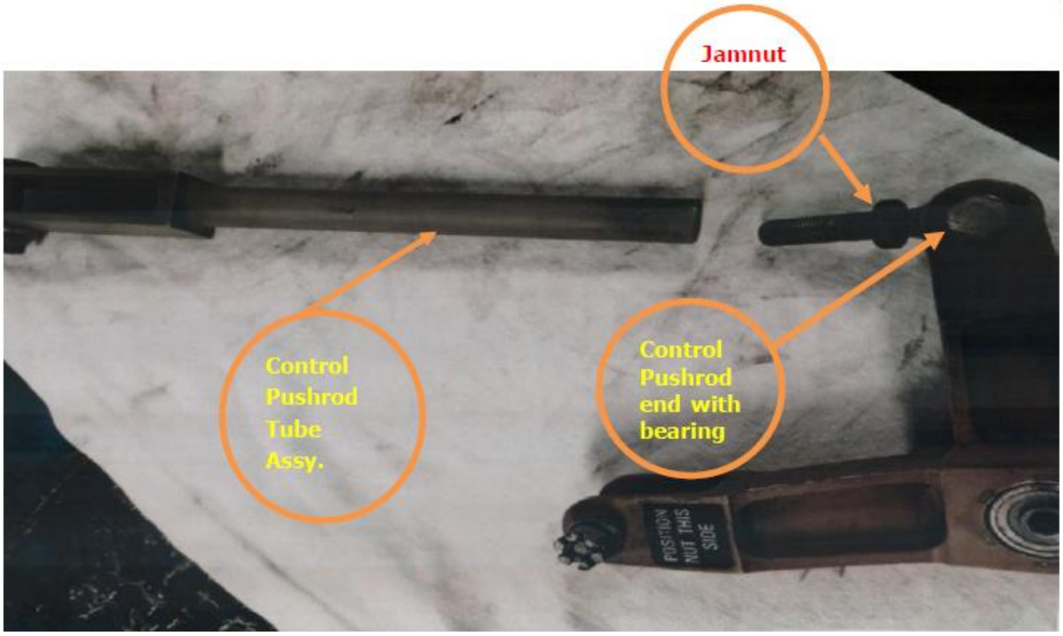


Figure 50: The rod end bearing was separated from the push rod

1.18.2 Sikorsky Alert Service Bulletin (ASB) 76-67-57

On 10 September 2015, Sikorsky issued alert service bulletin (ASB) identified number ASB 76-67-57 with subject of “FLIGHT CONTROLS – Main and Tail Rotor Servo Input Control Pushrods – One-Time Inspection and Application of Slippage Mark”.

The effectivity of the alert service bulletin applied to all S-76 model helicopters equipped with control pushrod assemblies, part number 76400-00034-059 and 76400-00014-071, delivered as of the issue date of this ASB.

The purpose of the ASB is to perform a one-time inspection of installed forward, aft and lateral main servo input control pushrods and jam nuts and tail rotor servo input control pushrods and jam nuts for proper installation, condition, and security followed by application of slippage mark on all main and tail rotor servo input control pushrod jam nuts.

The instructions outlined in the ASB shall be accomplished prior to next flight originating from a maintenance facility or not to exceed 5 flight hours from issue date of the ASB.

The ASB ordered to all Sikorsky S-76 helicopters to verify the inspection hole at the push rod using the lock wire with diameter of 0.020 inch, whether it can pass through the inspection hole at the push rod. If the lock wire passed through the inspection hole, the operator shall replace the push rod assembly. The illustrated of the inspection hole is shown in the figure below.

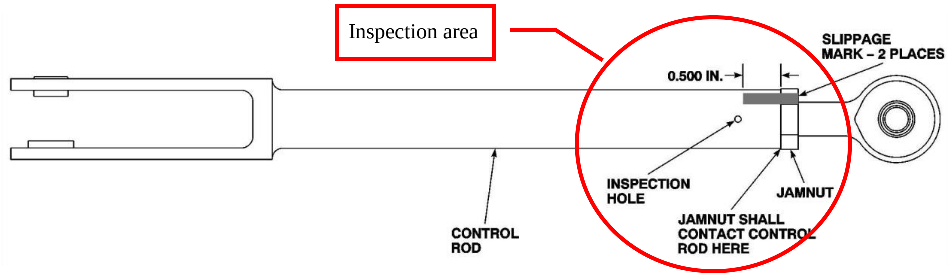


Figure 51: Illustration of push rod assembly to ensure the inspection hole is covered with the thread of rod end bearing

If lock wire does not pass through inspection hole the ASB requires the operator to inspect whether the jam nut it is seated against the control pushrod using the finger pressure for looseness. Finally, if the jam nut is properly seated against the push rod, the operator requested to provide torque paint (slipped mark) to the push rod and the jam nut.

1.18.3 Airworthiness Directive (AD)

On 14 September 2015, Federal Aviation Administration (FAA) issued Airworthiness Directive (AD) concerning the occurrence of Sikorsky. The AD identified as AD 2015-19-51. The AD was categorized as Emergency AD (EAD). The EAD was distributed to owners and operators of Sikorsky Aircraft Corporation Model S-76A, S-76B, S-76C, and S-76D helicopters.

The EAD was prompted by an accident of a Sikorsky Aircraft Corporation Model S-76C helicopter. During preliminary investigation, a failed servo input control pushrod (pushrod) assembly was identified. Separation of the pushrod tube and the control rod end with bearing was found. The EAD actions are intended to prevent loss of main rotor (M/R) or tail rotor (T/R) flight control and subsequent loss of control of the helicopter.

The EAD requires inspecting the main rotor (M/R) forward, aft, and lateral pushrod assemblies, the tail rotor (T/R) pushrod assembly, and the jam nuts, and applying slippage marks across the pushrod tubes and jam nuts.

Within five-hour time-in-service, the EAD requires inspecting each M/R and T/R pushrod assembly by inspecting the position of the control rod end in the pushrod tube. If the lock wire passes through the inspection hole, this EAD requires replacing the pushrod assembly. If the lock wire does not pass through the inspection hole, this EAD requires inspecting the jam nut to determine seating position against the pushrod and whether the jam nut can be turned with finger pressure. If the jam nut is not seated against the pushrod or is loose, this EAD requires replacing the pushrod assembly.

This EAD also requires the application of slippage marks across each M/R and T/R pushrod tube and jam nut.

The FAA AD was adopted by Directorate General of Civil Aviation (DGCA) Indonesia identified as AD 15-09-11 issued on 17 September 2015.

1.18.4 Sikorsky Aircraft Maintenance Manual Revision

On 19 November 2015, Sikorsky issued the revision of aircraft maintenance manual chapter 5 to re- inspect of the jam nut every 300 hours. The inspection includes the re-torque the jam nut to 140 inch-pounds if it loose.

The figure below is the cropped page of the aircraft maintenance manual chapter 5-20-0.

SIKORSKY S-76®
SA 4047-76C-2-1

300-HOUR INSPECTION CHECKLIST	CHAPTER/ SECTION/ SUBJECT/ *HELOTRAC	ZONE	INIT	REMARKS
29. Main gear box oil cooler inlet and outlet hoses for leakage, chafing, and security; hose fittings for proper installation torque. Main gear box oil inlet and oil outlet fluid fittings for local corrosion pitting and/or corrosion products at the interface of the fluid fitting lockring and housing. If corrosion is found, remove any loose corrosion products with a stiff nylon brush and apply corrosion preventative compound, ACF-50 or equivalent.	66-10-00 66-11-06 *661102	5		Main gear box fluid fitting side to side motion, major corrosion damage, wear gap or evidence of movement (loosening or tightening direction) of the serration teeth at the lockring/housing interface or obvious oil leakage from the housing threaded joint is cause for immediate corrective action.
29A. Perform a Spectrographic Oil Analysis Program (SOAP) analysis of main gear box oil. A review of the titanium parts-per-million (ppm) count shall be evaluated per the criteria in Inspection/Check, 66-10-00, SOAP Analysis of Main Gear Box Oil.	66-10-00 *661011	5		Perform SOAP analysis every 300 Hours or before a scheduled MGB oil change, whichever occurs first. Refer to Inspection/Check, 66-10-00, SOAP Analysis of Main Gear Box Oil.
30. Deleted 30A. Main rotor servo pushrod assemblies, 76400-00034-059, 76400-00014-074, -076, and -077, inspect torque stripe on jamnut. If torque stripe is broken, check jamnut for looseness with finger pressure. Remove and replace any main rotor servo pushrod assembly found with a loose jamnut. Apply torque stripe on replacement main rotor servo pushrod assembly and jamnut. (a) If torque stripe on jamnut is broken, but jamnut is not loose, retighten jamnut. To prevent damage to bearings, slide a nonmetallic shim or scraper in-between the rod end bearing and mating clevis while torque is applied. Torque jamnut to 140 inch-pounds. Reapply torque stripe.	67-15-02 *671512	5		For torque stripe application, refer to 20-04-00.

5-20-00
Page 10
Nov 19/15

Figure 52: Sikorsky Aircraft Maintenance Manual chapter 5-20-0 revision

1.19 Useful or Effective Investigation Techniques

The investigation was conducted in accordance with the KNKT approved policies and procedures, and in accordance with the standards and recommended practices of Annex 13 to the Chicago Convention.

2 ANALYSIS

The MPFR data showed that the helicopter attitude was stable when reaching the altitude of 1,000 feet with heading of 038 degrees. Five minutes later, during descent, the helicopter entered un-commanded attitude. A second after the helicopter started to bank to the left, there was pilot input recorded in the MPFR to counter the aircraft attitude however, the flight control did not respond as expected. The helicopter entered the un-commanded attitude for 31 seconds before ground impact. The MPFR recorded the roll to the left up to 77 degrees, roll to the right up to 52 degrees, pitch up to 45 degrees and pitch down up to 61 degrees.

The analysis will discuss to the related component resulted in the helicopter entered un-commanded attitude.

Engine System

During the un-commanded attitude, unusual sound recorded in video media and MPFR. The sound spectrum analysis concluded that there was no evidence or progressive damage of propulsion system except there was NR instability observed during the last 35 seconds of the flight. The engine examination revealed that the engines were rotating during impact and no evidence of engine abnormality. The investigation concluded that the engines did not contribute to the un-commanded attitude.

Helicopter Main Rotor Flight Control

Helicopter main rotor flight controls consist of collective pitch lever and cyclic control stick to control main rotor blade angles. The pilot cyclic control connected to the main rotor blades through servos via push rod. All three servos and push rods recovered from the crash site were examined. The examination of the servos concluded that all servos were operating normally.

The aft push rod and the rod end bearing were found in good condition. The lateral push rod was no significant damage except there was change in the torque indicated by the broken torque paint mark. The broken torque paint indicated that the lateral push rod jam nut had loosened..

The forward push rod examination shown that most of the threads inside the push rod were missing at the worn area. Asymmetric deformation was also observed on the edge of push rod internal thread. The asymmetric deformation might be caused by the loosening of the jam nut and resulted in the rod end bearing not being properly seated against the push rod. Continuous operation with such condition led to deterioration of the engagement of the forward push rod and the rod end bearing which subsequently the rod end bearing detached from the push rod.

The detached rod end bearing from the forward push rod led to un-commanded servo movement to the main rotor. This supported by the result of the audio analysis of the recorder video which indicate instability of the main rotor. The un-commanded servo movement resulted in the helicopter entering un-commanded attitude and uncontrollable main rotor. The pilots attempted to recover the condition with no success as the flight control system became uncontrollable.

The investigation of another Sikorsky accident on 12 August 2015 in Nigeria found similar symptom of the pitch and roll un-commanded attitude. The investigation found that the push rod separated from rod end bearing.

Maintenance of the Main Rotor Flight Control System

The torque change of the jam nut in lateral push rod was observed during the examination indicated by the torque paint discontinued between jam nut and the lateral push rod. There was no locking device to secure the jam nut at the rod end bearing therefore there was possibility that the rod end bearing loosening from the push rod during the operation. The periodic inspection of the push rod was included in the Sikorsky Inspection Manual however the inspection is conducted by the visual inspection of the push rod which probably lead to oversight for the maintenance personnel during periodic maintenance inspection for any looseness or improper engagement of the rod end bearing to the push rod.

The forward servo actuator was installed on 5 February 2014 by a previous operator. The reason replacement of the previous forward servo actuator was due for overhaul. On 27 February 2015, the operator conducted the 300-hour inspection. There was no significant finding on each main rotor servo input control rod during the inspection as reported by the operator, however most probably the looseness of the rod end bearing might not be detected since the inspection conducted by visual inspection. The accident occurred on 21 March of 2015 which was approximately 54 hours after the 300-hour inspection and the accident at Nigeria occurred on 12 August 2015.

On 10 September 2015, Sikorsky issued alert service bulletin (ASB) identified as ASB 76-67-57 which ordered the operator to inspect the push rod assembly of main rotor and tail rotor for all Sikorsky model S-76 with the push rod part number of 76400-00034-059 and 76400-00014-071. The ASB was applicable to the accident helicopter as the push rod part number was included in the ASB.

The ASB contain instruction to inspect the rod end bearing to ensure it is properly engage in the push rod and secured by the jam nut. The inspection utilized the lock wire with diameter of 0.020 inch. If the lock wire is not passed through the inspection hole of the push rod, means that the rod end bearing is properly engage to the push rod. To ensure that the jam nut is properly seated against the push rod, the ASB requires the operator to inspect whether the jam nut it is seated against the control pushrod using the finger pressure for looseness. Finally, the ASB requested the operator to provide the torque paint (re-paint if previously painted) along with the push rod and the jam nut. However, the threaded shank of the rod end bearing may only block a bit on the inspection hole which was not detected by the maintenance personnel. It means that the total length of push rod and rod end bearing assembly probably exceeding the basic length as mentioned in the maintenance manual. In this case, the rod end bearing may be visually engaged to the push rod and the jam nut may be properly seated while the rigging and adjustment was required to correct the length of the servo input control rod assembly.

On 17 September 2015, the DGCA Indonesia issued Airworthiness Directive (AD) 15-09-11 to prevent loss of main rotor or tail rotor flight control subsequent loss of control of the helicopter. The AD requires the operator to inspect each main rotor and tail rotor pushrod assembly by inspecting the position of the control rod end in the pushrod tube within five hours-time in service.

On November 2015, Sikorsky revised the maintenance manual to include the inspection of all push rod assembly in 300-hour inspection package. The revision also to include the torque requirement for the jam nut against push rod at value of 140 inch-pounds.

Summary

The engine examination and the audio analysis revealed that the engines were operating normally during the accident flight. The investigation concluded that the engine did not contribute to the un-commanded attitude.

The loosening jam nut of the forward push rod was undetected during the daily operation and led to the rod end bearing was not engage properly against the push rod. The condition of rod end bearing did not properly engage against the push rod resulted in the asymmetric deformation of the internal thread in the push rod during the operation. Continuous operation with such condition led to deterioration of the engagement of the forward push rod and the rod end bearing which subsequently the rod end bearing separated from the push rod.

The separation of the rod end bearing from the push rod resulted in the un-commanded servo movement to the main rotor control that led the helicopter enter un-commanded attitude and uncontrollable main rotor (flight control) system.

3 CONCLUSIONS

3.1 Findings[4]

1. The helicopter was airworthy prior to the occurrence and was operated within the weight and balance envelope.
2. The crew held valid licenses and medical certificates.
3. In this flight, the Pilot in Command (PIC) acted as Pilot Flying (PF) and Second in Command (SIC) acted as Pilot Monitoring (PM).
4. The helicopter transited at Handil helipad for refueling and removed the both side passenger doors to ease the inspection. Without the passenger doors, the maximum speed of the helicopter was 125 knots.
5. The flight from Balikpapan to Handil and continue to the Central Processing Unit was uneventful until commencing to descend from 1000 feet with no significant weather.
6. The helicopter was equipped with a Penny & Giles solid state Multi-Purpose Flight Recorder (MPFR). The MPFR is combined flight data and voice recorder.
7. The helicopter entered un-commanded attitude. During the un-commanded attitude, MPFR recorded the roll to the left up to -77.71 degrees, roll to the right up to 52.84 degrees, pitch up of 45.27 degrees and pitch down up to -61.98 degrees.
8. One of the passengers documented the trip in video media for the inspection purposes. The video recorder was recovered and contained the visual and audio data including the unusual sound when the helicopter entering un-commanded attitude.
9. The audio track was separated from the video file in order to be analyzed to determine the rotor speed (NR) and gas turbine engine rotation (NG). The sound spectrum analysis concluded that there was no evidence or progressive damage of propulsion system part except there was NR instability observed during the last 35 seconds of the flight.
10. Investigation conducted examination to the servo actuator, push rod and the rod end bearing to determine the nature of damage. The overall test showed that all the servo actuators were considered serviceable.
11. The aft-ward push rod and the rod end bearing were found in good condition.
12. The lateral push rod was no significant damage except there was change in the torque indicated by the discontinue torque paint across the joint between push rod, jam nut and rod end bearing.
13. The forward rod end bearing found detached from the push rod.

4 Findings are statements of all significant conditions, events or circumstances in the accident sequence. The findings are significant steps in the accident sequence, but they are not always causal, or indicate deficiencies. Some findings point out the conditions that pre-existed the accident sequence, but they are usually essential to the understanding of the occurrence, usually in chronological order.

14. The forward push rod internal thread was worn out in some area. The asymmetric deformation was also observed on the edge of push rod internal thread that might be caused by the loosening or insufficient torque of the jam nut and resulted in the rod end bearing did not properly remain seated against the push rod. Continuous operation with such condition led to deterioration of the engagement of the forward push rod and the rod end bearing which subsequently the rod end bearing detached from the push rod.
15. The rod end bearing connected to the push rod via threaded shank and locked by mean of jam nut. There was no locking device to secure the jam nut to prevent loosening from the push rod during the operation.
16. The engine examination concluded that both engines were in good condition.
17. On 12 August 2015, another Sikorsky S-76C+ accident at Oworonshoki area of Lagos, Nigeria. KNKT coordinated with Nigeria Accident Investigation Bureau (AIB) to have access to the FDR information. KNKT found that the FDR signature was similar to the occurrence.
18. On 10 September 2015, (six months after the accident and following the investigation of a second accident in Nigeria on 12 August 2015), Sikorsky issued Alert Service Bulletin ASB 76-67-57 to conduct one-time inspection of the push rod assembly and application of slippage mark to jam nut to provide looseness indication.
19. On 14 September 2015, FAA issued Airworthiness Directive (AD) identified as AD 2015-19-51 which was categorized as Emergency AD (EAD) concerning the occurrence of Sikorsky. On 17 September 2015 DGCA issue AD identified as AD 15-09-11 with the same issue.
20. The AD requires inspecting the main rotor (M/R) forward, aft, and lateral pushrod assemblies, the tail rotor (T/R) pushrod assembly, and the jam nuts, and applying slippage marks across the pushrod tubes and jam nuts.
21. On 19 November 2015, Sikorsky issued the revision of aircraft maintenance manual chapter 5 to repeat the push rod assembly inspection every 300 hours, including the re-torque of the jam nut to 140 inch-pounds if the jam nut was loose.

3.2 Contributing Factors[5]

The helicopter un-commanded attitude was a result of loosening of the jam nut on the forward rod end bearing which subsequently separated from the push rod, resulted in the un-commanded servo movement and loss of control of the helicopter.

5 Contributing factors is defined as events that might cause the occurrence. In the case that the event did not occur then the accident might not happen or result in a less severe occurrence.

4 SAFETY ACTION

As a result of this accident, KNKT was informed of safety actions that had been taken by related parties.

4.1 Hevilift

1. Automation Usage.

   Company Operation Manual (COM) revised to add chapter 5.15.8 to restrict the usage of automation during special type of operations i.e. Under-slung, Aerial photography with open doors

2. Simulator Recurrent Syllabus.

   Recurrent Sikorsky S-76C+ training syllabus added to Company Training Manual Chapter 2.16. The objective of recurrent training syllabus is to provide a standardized program for the initial and transition ground and flight training of Company Check Pilot and Flight instructors, to ensure their qualifications, competency and to maintain their proficiency.

4.2 Sikorsky

On 19 November 2015, Sikorsky issued the revision of Aircraft Maintenance Manual chapter 5 which include the requirement for inspection of the jam nut every 300 hours. The inspection includes ensuring the torque of the jam nut is 140 inch-pounds.

5 SAFETY RECOMMENDATIONS

As result of this investigation and considering the safety actions taken by related parties, the Komite Nasional Keselamatan Transportasi (KNKT) considers that the safety actions are sufficient to prevent similar occurrence, therefore KNKT is not issuing safety recommendations in this report.

▪

6 APPENDICES

6.1 Sound analysis BEA

Technical document

CVFDR MPFR audio data and video Spectral analysis report

Document ID:	**BEA2015-0127_tec02**
Date of occurrence:	21/03/2015
Place of occurrence:	Mahakam river delta (Indonesia)
Aircraft type:	SIKORSKY - S76C++
Engines:	Turbomeca ARRIEL-2S2
Registration number:	**PK-FUP**
Operator:	Hevilift (operating for Total)
Data analysed:	- CVFDR Cam file 'cv4_30m_hqc.wav' / provided by KNKT - Video file '00005.avchd' / provided by Total Company

Circumstances and objectives of the spectral analysis:
During a photo flight for pipelines inspection the helicopter experienced a reported un-commanded change of attitude; the crew conducted an emergency landing. The helicopter impacted the three and crashed into a swamp. Spectral analysis was performed to try to determine the engines and gear boxes condition during the event.

Work performed:

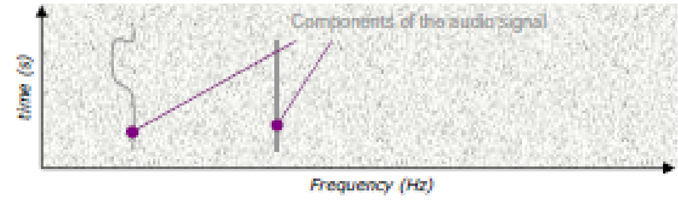
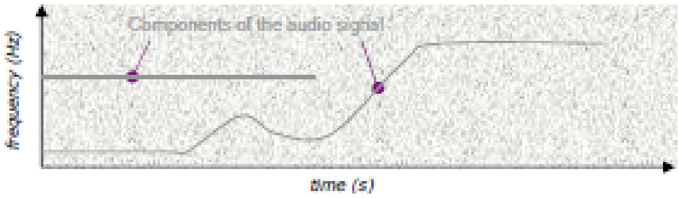
The sound track was separated from the video file in order to provide an audio file (.wav) usable with the sound analysis tools of the BEA's laboratory. The 30 min CAM audio file and the video sound track file were both analysed (see appendix 1 and 2). A frequencies tracking was done to determine the rotor speed (NR) and when possible the gas generator speed (NG), taking into account the noise level changes (see appendix 3 and 4).
The appendix 6 presents the NR and NG speeds during the last 76s of flight. An audio warning (Radio altimeter tone '*altitude alert*') was recorded 32s before the end of the flight (see appendix 7).

Results:

The acoustic signature of the PK-FUP was consistent with the signature usually observed on the S-76 family. The frequency generated by the second stage of reduction was identified and used to compute the main rotor speed. The frequency generated by the engine axial compressor was used to determine the gas generator speed.

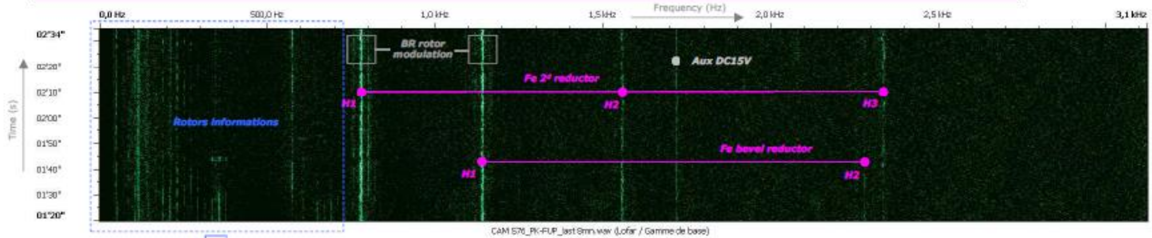
Spectral analysis didn't raise any relevant changes of spectra. No evidence of sudden or progressive damage of a propulsion system part was found based on the spectral analysis.
An unusual NR instability was observed during the last 35s of the flight.

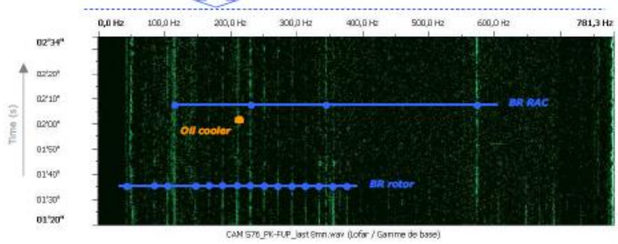
Glossary

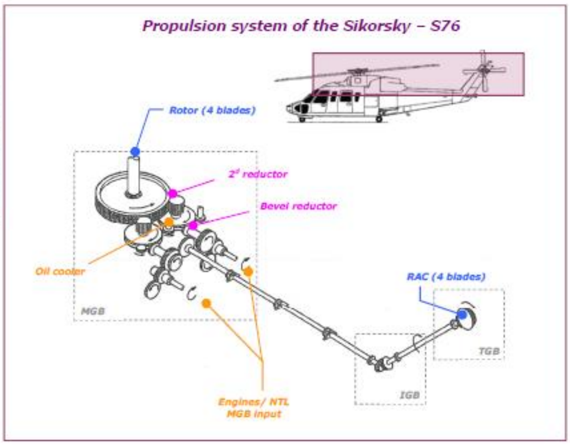
Rpm	Revolutions per minute
H(x)	Harmonic rank (x) of the fundamental frequency.
Modulation	Frequency value modulating an other frequency .
	(LOFAR) spectrum view / frequency on X-axis and time on Y-axis
Lofargramme	
	(SONA) spectrum view / time on X-axis and frequency on Y-axis
Sonargramme	
BR	Blade Rate / frequence of rotation of the propeller blade (Hz)
NR	Rotation speed of the main rotor (Rpm) / power 100% = 293 Rpm
NG	Engine / Rotation speed of the gaz generator / power 100% = 52110 Rpm
NF	Engine / Rotation speed of the free turbine / power 100% = 39095 Rpm
Rpm	Revolution per minute
Propulsion system	Whole assembly composed with rotors, reductors, shafts and engines
MGB	Main Gear Box reduction
TGB	Tail Gear Box reduction
IGB	Intermediate Gear Box
MR	Main Rotor (4 blade propeller)
TR	Tail Rotor (4 blade propeller)
N/A	Non identified
SPL	Sound Power Level / signal view (power per frequency sample)
AGC	Automatic Gain Control
Fe	Meshing frequency = gear or pinion rotation speed * gear or pinion number of teeth

APPENDIX 1

CAM recording of the event / Sample analysis - Detail of the S76C+ PK-FUP / MSN:760582 acoustic signature:







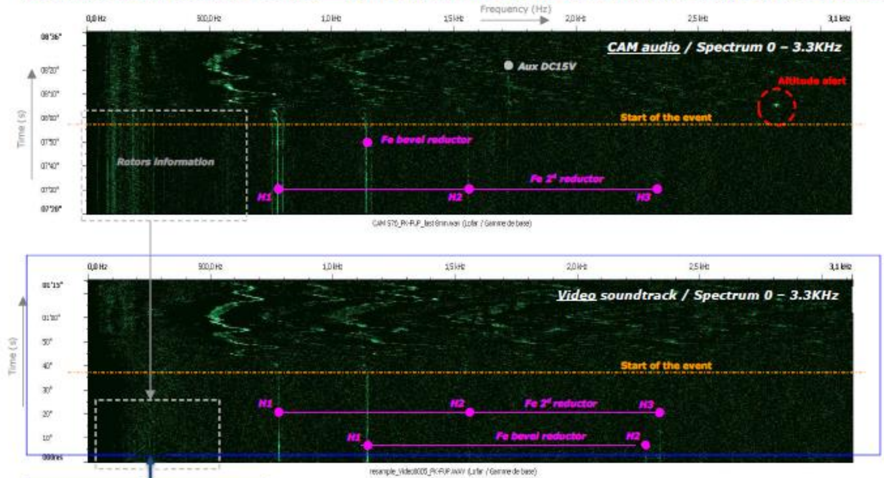
Analysis:

Spectral analysis of the CAM signal showed frequencies related to the main rotor, the tail rotor and reduction stages; **Main gear box inputs, frequencies coming from engines stages and engines auxiliaries, were not detected in the spectra.**

The acoustic signature of the PK-FUP helicopter was consistent with the signature usually observed on the S-76 helicopter family.

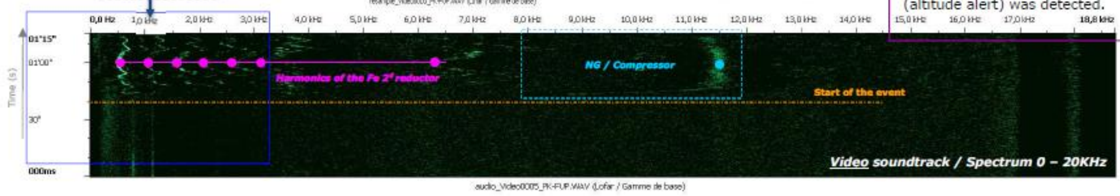
APPENDIX 2

Comparison of frequency spectra / Video soundtrack versus CAM recording sample of the S76C+ PK-FUP.



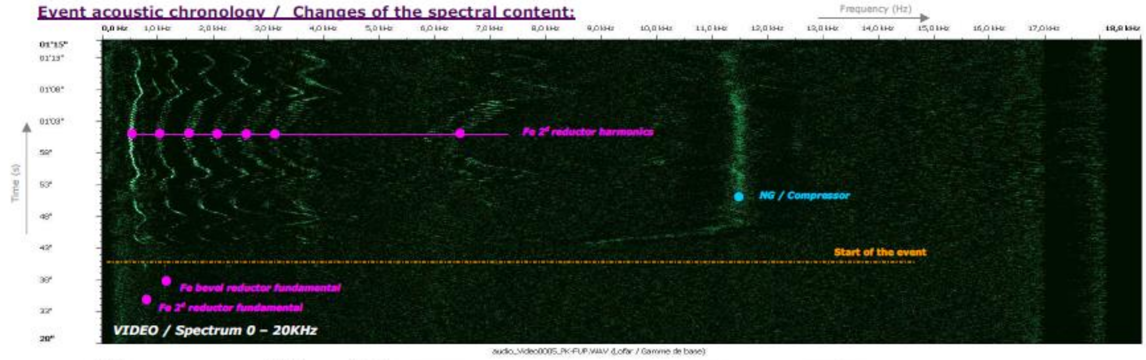
Analysis:
The two kind of recording contained identical main audio components. The predominant spectrum was composed of the fundamental and some hamonics of both the bevel reductor meshing (Fe) and the second stage reductor meshing ("bull gear" powering the main rotor).
Acoustic information coming from the propulsion system was less present in the video soundtrack due to the predominent broadband noise generated by the opened cargo door (relative wind). This provided a saturation of the videocam microphone and hided the useful signal. On the other hand the video soundtrack offered a wideband audio signal which showed a high frequency related to the engines (in particular the NG information) shortly after the start of the event.

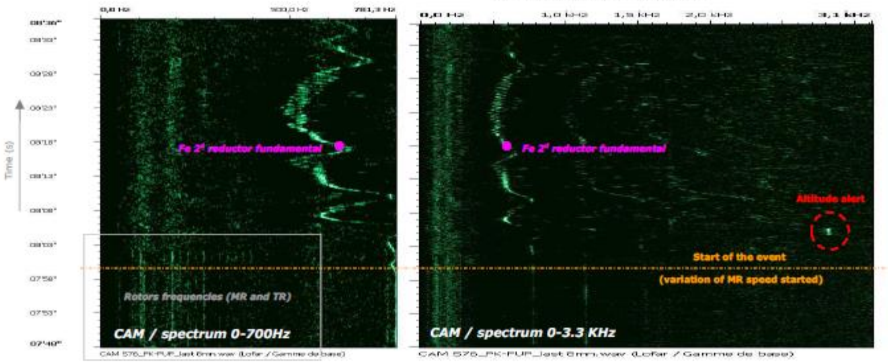
A radio altimeter tone warning (altitude alert) was detected.



APPENDIX 3

Event acoustic chronology / Changes of the spectral content:



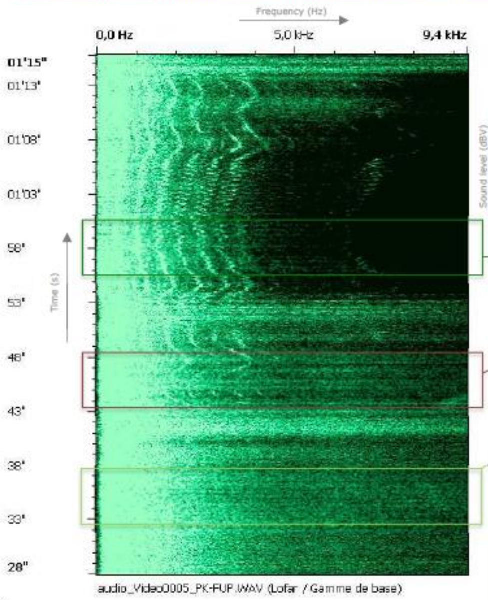


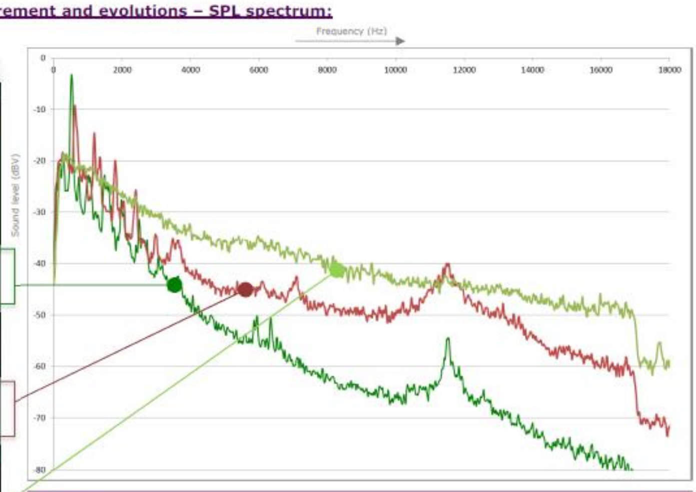
Analyse:

The acoustic signature initially composed of the fundamental and harmonics of both the first (bevel) and the second reduction stages (meshing) suddenly changed soon after a loss of NR speed (-3%). Spectral data as MR BR and TR BR were no more visible.
The second reductor stage meshing showed a lot of harmonics. A high frequency related to engines (assumed to be the axial compressor – cf appendix 6) also appeared in the spectrum.

APPENDIX 4

Event acoustic chronology / Wideband noise measurement and evolutions – SPL spectrum:





Analysis:

The noise level progressively reduced as the relative wind changed. Thus some previously hidden frequencies could appear thanks to this sudden noise reduction. Furthermore it's important to take into account the sharp wide dynamic control applied by common AGC systems integrated to most of videocam devices.

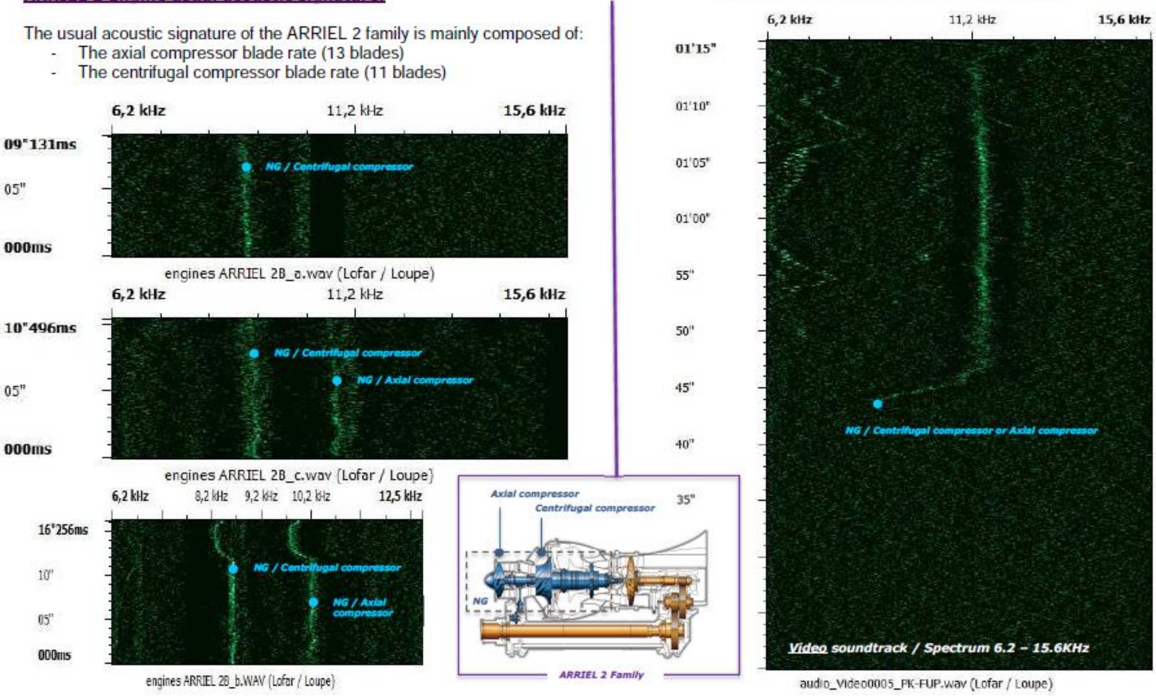
The sudden appearance of several meshing harmonics from the 2nd stage reductor could be explained by these associated effects on the audio signal.

APPENDIX 5

ARRIEL 2 Engine usual acoustic signature:

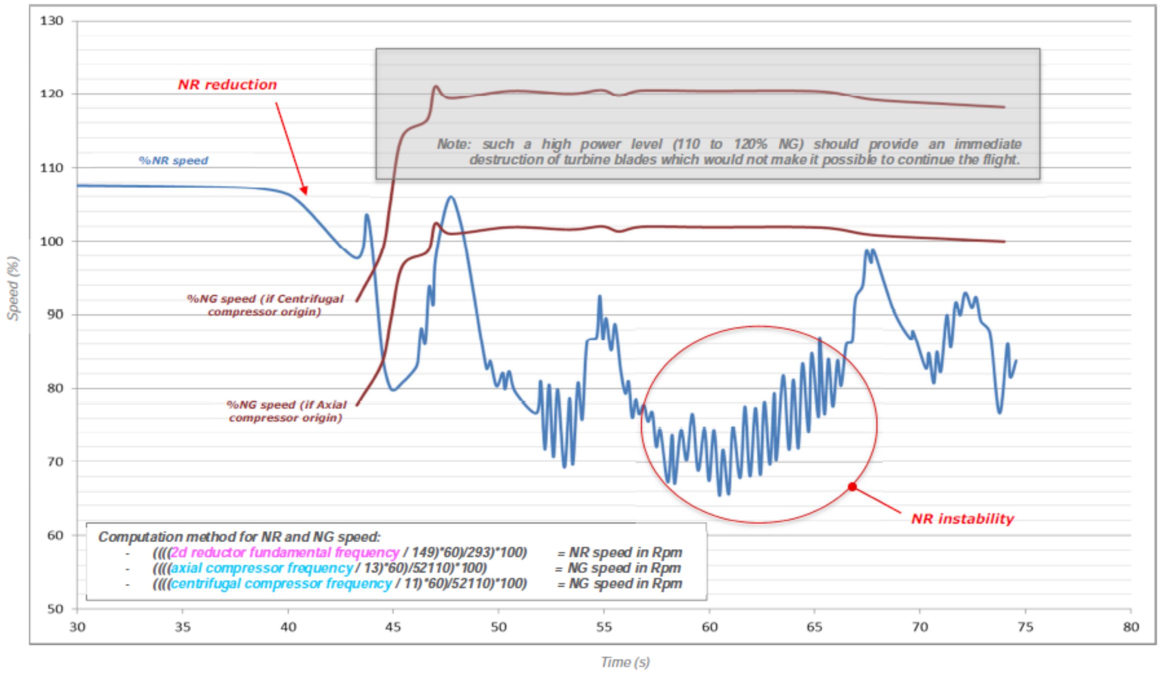
The usual acoustic signature of the ARRIEL 2 family is mainly composed of:
- The axial compressor blade rate (13 blades)
- The centrifugal compressor blade rate (11 blades)

PK-FUP – Engines - Flight of the event



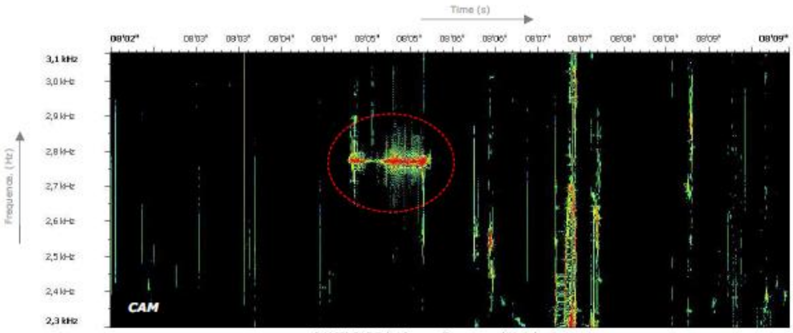
APPENDIX 6

Event acoustic chronology / End of flight (last 76s) - Engines (NG) versus Rotor (NR) behaviour:



APPENDIX 7

Event acoustic chronology / Audio warning :



CAM S76_PK-PUP_last 8mn.wav (Sonagramme / Wigner)

Analysis:

One audio warning was heard 6 seconds after the start of the NR un-stability, i e at 32 seconds before the end of the CAM recording.

The warning audio signal was a pure 2820Hz steady tone with a 980ms duration. This tone called '*altitude alert*' is generated when the current altitude is crossing the selected altitude +/- 1000ft.

6.2 PK-FUP Test Resume of Servo Actuators

Indo Aero Semesta
DGCA AMO 145D-577

Test Resume of Servo Actuators ex Sikorsky S-76 Reg. PK-FUP

No	Test Procedure Description (Ref. CMM 67-15-02 Testing and Fault Isolation)	Requirement	Test Result FORWARD SN.B345-0163 XD	AFT SN.B345-01690	LATERAL SN.B345-01758
A.	**PURGE PROCEDURE :** - Purge System – 1	- Cycle unit 30 times, pistons has to move from extend to retract.	On the first attempt number 1 piston stucked. After shifting input lever several times, piston moved slowly.	Piston moved properly.	Piston moved properly.
	- Purge System – 2	- Cycle unit 30 times, pistons has to move from extend to retract.	On the first attempt number 1 piston stucked. After shifting input lever several times, piston moved slowly.	Piston moved but slower than system-1	Piston moved properly.

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Indo Aero Semesta
DGCA AMO 145D-577

Test Resume of Servo Actuators ex Sikorsky S-76 Reg. PK-FUP

No	Test Procedure Description (Ref. CMM 67-15-02 Testing and Fault Isolation)	Requirement	Test Result FORWARD SN.B345-0163 XD	AFT SN.B345-01690	LATERAL SN.B345-01758
B.	**PRELIMINARY ADJUSTMENT :**	- Pistons has to remain at zero within 0.0015 inch	No adjustments applied	No adjustments applied	No adjustments applied
C.	**PROOF PRESSURE TEST :**	- Shall be no evidence of exter-nal leakage, perma-nent deformation or loosening of parts.	Not required. (No housing / piston removal)	Not required. (No housing / piston removal)	Not required. (No housing / piston removal)
D.	**DYNAMIC LEAKAGE TEST :**	There shall be : a) no more than a slight wetting, insufficient to form a drop, at any external seal, b) no leakage at any joint or boss.	a) Slight wetting on the both piston b) No leak at any joint or boss	a) Slight wetting on the both piston b) No leak at any joint or boss	a) Slight wetting on the both piston b) No leak at any joint or boss

Page | 2

No	Test Procedure Description (Ref. CMM 67-15-02 Testing and Fault Isolation)	Requirement	Test Result		
			FORWARD SN.B345-0163 XD	AFT SN.B345-01690	LATERAL SN.B345-01758
E.	STATIC LEAKAGE TEST :	There shall be : a) no more than a slight wetting, insufficient to form a drop, at any external seal, b) no leakage at any joint or boss.	a) No slight wet b) No leak at any joint or boss	a) No slight wet b) No leak at any joint or boss	a) No slight wet b) No leak at any joint or boss
F.	SYSTEM 1 LEAKAGE TEST :	Leakage rate at RTN-1 port shall not exceed 350 (700) – 600 (950) ml/min. on temp. 37,8ºC-60ºC. (Number In parenthesis indicate maximum in service leakage allowed)	17 cc/minute at 51ºC	18 cc/ minute at 44ºC	20 cc/minute at 40ºC

Indo Aero Semesta
DGCA AMO 145D-577

Test Resume of Servo Actuators ex Sikorsky S-76 Reg. PK-FUP

No	Test Procedure Description (Ref. CMM 67-15-02 Testing and Fault Isolation)	Requirement	Test Result		
			FORWARD SN.B345-0163 XD	AFT SN.B345-01690	LATERAL SN.B345-01758
G.	SYSTEM 2 LEAKAGE TEST :	Leakage rate at RTN-2 port shall not exceed 350(700) – 600(950) ml/min. on temp.37,8ºC-60ºC. (Number In parenthesis indicate maximum in service leakage allowed)	10 cc/minute at 51ºC	30 cc/minute at 46ºC	30 cc/minute at 43ºC
H.	SYSTEM – 1 HARDOVER LEAK-AGE TEST :	Leakage rate at RTN – 1 port shall not exceed +50cc/min of actual neutral leak-age recorded in step F.	18 cc / minutes	18 cc / minutes	70 cc / minutes
I.	SYSTEM – 2 HARDOVER LEAK-AGE TEST :	Leakage rate at RTN - 2 port shall not exceed +50cc/min of actual neutral leak-age recorded in step G.	16 cc / minutes	18cc / minutes	35 cc / minutes

No	Test Procedure Description (Ref. CMM 67-15-02 Testing and Fault Isolation)	Requirement	Test Result		
			FORWARD SN.B345-0163 XD	AFT SN.B345-01690	LATERAL SN.B345-01758
J.	STROKE TEST :	Output piston stroke shall be 4.58 to 4.68 inch.	4.60 Inch	4.60 Inch	4.60 Inch
K.	PISTON VELOCITY TEST :	Piston velocity shall be 5.0 to 5.8 inch / second.	3.0 inch/sec.	2.8 inch/sec.	2.01 inch/sec.
L.	INPUT FORCE TEST :	Force required to shift input lever in either directions shall not exceed 8 ounces.	7.05 Ounces	7.00 Ounces	7.00 Ounces
M.	HYSTERESIS TEST :	Hysteresis measu-red on piston output axis shall not exceed 0.004 inch.	0.003 Inch	0.0025 Inch	0.003 Inch

Indo Aero Semesta
DGCA AMO 145D-577
Test Resume of Servo Actuators ex Sikorsky S-76 Reg. PK-FUP

No	Test Procedure Description (Ref. CMM 67-15-02 Testing and Fault Isolation)	Requirement	Test Result		
			FORWARD SN.B345-0163 XD	AFT SN.B345-01690	LATERAL SN.B345-01758
N.	INTERSTAGE POSITION ERROR TEST :	- The steady-state output piston change shall not exceed 0.003 inch. - The resulting tran-sient overshoot shall not exceed 0.005 inch.	- 0.002 inch - 0.004 inch	- 0.002 inch - 0.004 inch	- 0.002 inch - 0.004 inch
O.	PRESSURE SWITCH TEST :	SYS-1 & SYS-2 press low and press high lamps shall be lit.	SYS-1 & SYS-2 press low & pressure high lit	SYS-1 & SYS-2 press low & pressure high lit	SYS-1 press low & high lit, SYS-2 press low did not lit, press. high lit
P.	BALANCE TUBE OPERATION TEST :	Pistons shall extend at 31 psi min. & 125 psi max. for each system. Pistons that extend at pressures less than 30 psi (for either system) shall have differential pressure (between both systems) which does not exceed **30 psi.**	10 psi	10 psi	10 psi

No	Test Procedure Description *(Ref. CMM 67-15-02 Testing and Fault Isolation)*	Requirement	Test Result		
			FORWARD SN.B345-0163 XD	AFT SN.B345-01690	LATERAL SN.B345-01758
Q.	**BYPASS VALVE OPERATION TEST :**	a) Unit shall actuate. b) Unit shall not actuate. c) Unit shall actaute	a) Actuated b) Not actuated c) Actuated	a) Actuated b) Not actuated c) Actuated	a) Actuated b) Not actuated c) Actuated
R.	**FINAL STEPS :**	Check Filter Assembly of LH & RH Manifold of Forward Servo Avtuator only. Remove Linkake of Lateral Servo Actuator and install to Forward Servo Actuator	LH & RH Manifold disassem - bled & checked the filter - No metal or carbon debris found on the filter.	Servo actuator removed from fixture, cleaned, dried, packaged	Servo actuator removed from fixture, cleaned, dried, packaged -

Reported by :	Approved by :	Date Reported :

6.3 Hevilift Comment and Proposal

No	Report Section	Concerns from the Report	Hevilift Comments	Hevilift Proposal	KNKT Response
	4. Safety Action	Safety Action	As a result of this accident, the aircraft operator informed the KNKT of safety actions that they had taken. 1. Automation Usage. Company Operation Manual (COM) revised to add chapter 5.15.8 to restrict the usage of automation during special type of operations i.e. Under-slung, Aerial photography with open doors 2. Simulator Recurrent Syllabus. Recurrent Sikorsky S-76 training syllabus added to Company Training Manual Chapter 2.16. The objective of recurrent training syllabus is to provide a standardized program for the initial and transition ground and flight training of Company Check Pilot and Flight instructors, to ensure their qualifications, competency and to maintain their proficiency.	Add the safety action 1. Flight Data Monitoring Program Reemphasizing of the Flight Data Monitoring (FDM) program to enhance safe and efficient operations by monitoring the flight performance. 2. Health Usage Monitoring System (HUMS) Program Reemphasizing of Health Usage Monitoring System (HUMS) to monitor the health and performance of the aircraft. HUMS is a sensor-based monitoring system by measuring the health and performance of critical components in helicopter 3. Crew Refresher Training on Standard Operating Procedure (SOP) Refresher training for all S76 Pilots on Standard Operating Procedures and managing aircraft malfunctions. 4. DGCA AD 15-09-11/FAA AD 2015-19-51/Sikorsky ASB 76-67-57 Inspection to the main rotor	Rejected. No evidence has been provided to KNKT for these safety actions.

No	Report Section	Concerns from the Report	Hevilift Comments	Hevilift Proposal	KNKT Response
				pushrod assemblies, the tail rotor pushrod assembly, and the jam nuts, and applying slippage marks across the pushrod tubes and jam nuts. Inspection has been performed on all S76 fleet and found satisfactory	
	5. Recommendation	5.1 PT. Hevilift Aviation Indonesia • 04.O-2017-08.01 The DGCA Advisory Directive requires the inspection to the main rotor pushrod assemblies, the tail rotor pushrod assembly, and the jam nuts, and applying slippage marks across the pushrod tubes and jam nuts. KNKT recommend to ensure the Airworthiness Directive DGCA AD 15-09-11 properly implemented.		Propose to be deleted. DGCA AD 15-09-11/FAA AD 2015-19-51/Sikorsky ASB 76-67-57 has been performed on all S76 fleet and found satisfactory. See Hevilift comment/proposal on Chapter 4 item 6 above. See attachment A- Implementation of DGCA AD 15- 09-11/FAA AD 2015-19-51/Sikorsky ASB 76-67-57	Accepted
	5. Recommendation	5.1 PT. Hevilift Aviation Indonesia • 04.O-2017-08.02 The rod end bearing connected to the push rod via threaded shank and locked by mean of jam nut. There was no locking device to secure the jam nut	The purpose of this maintenance monitoring system would be to monitor very small change in the length of the control rod. To get an accurate and consistent method for measuring this would the removal of each control rod and placing it in a fixture to measure with	In line with Sikorsky Inspection Manual chapter 5.20-00 item 30a, Hevilift propose to perform inspection torques stripe on jam-nut. See attachment B – Inspection Manual 5-20-00. If torque strip is broken / missing or jam-nut is below the specified torque, the rods be	Accepted

No	Report Section	Concerns from the Report	Hevilift Comments	Hevilift Proposal	KNKT Response
		to prevent loosening from the push rod during the operation therefore it required maintenance monitoring system to detect any change of the push rod. KNKT recommend to develop the maintenance control sheet to record the length of the push rod and rod end bearing assembly (servo input control rod) refer to the basic length as mentioned in the maintenance manual including the correction required during the periodic inspection.	precision equipment. By doing this require human interference of the flight control system and an added risk for human error.	removed and replace prior to the next flight. Sikorsky has set the interval for this at the 300 hours, Hevilift propose to de-escalate the interval into every 100 hours.	

6.4 NTSB Comments

No	Report Section	Concerns from the Report	NTSB Comments	NTSB Suggestion	KNKT Response
	Title	The helicopter type S76 C+	Incorrect helicopter type	Replace with S-76C+	Accepted
	Synopsys	Sikorsky S76C+	Incorrect helicopter type	Replace with S-76C+	Accepted
	Synopsys	During the course of investigation, the similar accident happened in Nigeria and all occupants were fatally injured.	Missing of the occurrence date	Insert “on 12 August 2015”	KNKT decided to delete this statement.
	Synopsys	KNKT had been informed safety action taken by the operator and considered relevant to the occurrence. However, as result the investigation KNKT issued the recommendation to the operator and Sikorsky which relevant to the safety issue.	Editorial matter	KNKT was informed that safety action had been taken by the operator and considered relevant to the occurrence. However, as result of the investigation KNKT issued the recommendation to the operator and Sikorsky which is relevant to the safety issue.	Accepted
	History of Flight	A Sikorsky S76C+ helicopter	Incorrect helicopter type	A Sikorsky S-76C+ helicopter	Accepted
	History of Flight	The SIC engaged the autopilot	The active autopilot mode was not explained	This should state what mode of the flight director was selected. e.g. ALT HOLD, etc	KNKT add the statement “Investigation did not find the active mode of the autopilot at the time of occurrence”.
	1.3, Damage to the helicopter	The helicopter was substantially damaged	Editorial matter	The helicopter was substantially damaged beyond repair.	Accepted

No	Report Section	Concerns from the Report	NTSB Comments	NTSB Suggestion	KNKT Response
	1.5, Pilot information	Type rating of the pilot	If making reference to a type rating - it should be specific to the Make / Model. There is no "S-76" type rating.	Revise the type rating to S-76 C+	Accepted
	1.6.5 Flight Control System	The description of the Sikorsky 76 flight control system as extracted from the Flight Crew Operation Manual (FCOM) Part 2, Section I: System Description is as follow	There is no FCOM in the helicopter Sikorsky S-76 C+	Please site revision reference for the FCOM. There is no FCOM for this model aircraft.	Accepted.
	1.6.5 Flight Control System	Collective and cyclic trim and a force gradient system permit trimming of the controls in the cockpit to the desired position. A set of dual controls for a copilot may be installed as optional equipment.	Standard OEM configuration is dual controls. There are no known options for removing a set of controls in the S-76.		The statement is cited as is from the helicopter manual.
	1.6.5 Flight Control System, COLLECTIVE TO YAW COUPLING	Further application of left pedal will result in downward movement of collective and no yaw feedback occurs are not normally encountered within the normal flight envelope but may be felt during dynamic maneuvers (e.g., arresting a rapid descent rate in a right crosswind at maximum gross weight)	Incomplete citing the manual	It looks like there are words missing here: "...feedback occurs are not normally...". Please consider revising this sentence.	Accepted.
	1.6.5 Flight Control System	FLIGHT CONTROL SERVO HYDRUALIC PRESSURE INDICATOR	Typo	FLIGHT CONTROL SERVO HYDRAULIC PRESSURE INDICATOR	Accepted
	1.12.2 Engine	… gearbox gear chain…	… gearbox gear train…	Consider to revise the chai with	Accepted

No	Report Section	Concerns from the Report	NTSB Comments	NTSB Suggestion	KNKT Response
	examination report Turbomeca			train	
	Figure 37: Original condition of the forward push rod before sectioned	The title of figure 37	Figure 37: Original condition of the forward push rod before being sectioned	Consider to add the “being”	Accepted
	1.16.2 Servo actuator examination	The test result	There is no mention of the low piston velocity.	Sikorsky would like to see these servos tested at HRT/Woodward.	KNKT consider that the overall test was sufficient, based on the examination in which refer to the component maintenance manual (CMM)
	1.18.1 Similar Accident in Nigeria	The investigation found that the push rod tube separated from rod end bearing. The jam nut was loose and was not seating against the push rod.	The investigation made this finding on 22 August, within ten days of the accident. Had the Indonesian investigation not been extensively delayed, this accident would have been prevented.		
	1.19 Useful or Effective Investigation Techniques		It should be noted that a more efficient and rapid investigation could have prevented the accident in Nigeria, which occurred 144 days after the Indonesian accident.		
	2. Analysis, Engine System	The sound spectrum analysis concluded that there was no	NR instability needs to be explained (if it actually occurred and was not a		KNKT considered that the examination was

No	Report Section	Concerns from the Report	NTSB Comments	NTSB Suggestion	KNKT Response
		evidence or progressive damage of propulsion system except there was NR instability observed during the last 35 seconds of the flight.	recording anomaly)		sufficient, based on the engine examination result and the sound spectrum from BEA.
	2. Analysis, Helicopter Main Rotor Flight Control	The examination of the servos concluded that all servos were operating normally	The piston velocities indicated that they were not operating normally. Needs further explanation.		KNKT consider that the overall test was sufficient based on the examination in which refer to the component maintenance manual (CMM)
	2. Analysis, Helicopter Main Rotor Flight Control	The asymmetric deformation might be caused by the loosening of the jam nut and resulted in the rod end bearing not being properly seated against the push rod.	Extensive testing by Sikorsky in a simulated, more severe vibration environment demonstrated that a properly torqued jam nut will not loosen in service		The forward servo actuator was installed on 5 February 2014 by a previous operator. On 27 February 2015, the operator conducted the 300-hour inspection. The periodic inspection of the push rod was included in the Sikorsky Inspection Manual however the inspection is conducted by the visual inspection of the push rod. There was no maintenance activity related to loosening the jam nut since the installation on 2014.
	2. Analysis, Maintenance of the Main Rotor Flight Control System	There was no locking device to secure the jam nut at the rod end bearing therefore there was a possibility that the rod end bearing loosening from the push rod during the operation.	Extensive testing by Sikorsky in a simulated, more severe vibration environment demonstrated that a properly torqued jam nut will not loosen in service. The torque may have broken on impact or it may have been intentionally loosened during maintenance and not replaced, since it was not required at the time.		

No	Report Section	Concerns from the Report	NTSB Comments	NTSB Suggestion	KNKT Response
	3.1 Findings Point 8	One of the passengers documented the trip in video media for the inspection purposes. The video recorder was recovered and contained the visual and audio data including the unusual sound when the helicopter entering un-commanded attitude.	Previous comments on NR instability.		KNKT considered that the examination was sufficient, based on the engine examination result and the sound spectrum from BEA.
	3.1 Findings Point 10	Investigation conducted examination to the servo actuator, push rod and the rod end bearing to determine the nature of damage. The overall test showed that all the servo actuators were considered serviceable.	Previous comments on servo velocity.		KNKT consider that the overall test was sufficient based on the examination in which refer to the component maintenance manual (CMM)
	3.1 Findings Point 12	12. The lateral push rod was no significant damage except there was change in the torque indicated by the discontinue torque paint across the joint between push rod, jam nut and rod end bearing.	Previous comments on lateral torque paint.		
	3.1 Findings Point 14	The forward push rod internal thread was worn out in some area. The asymmetric deformation was also observed on the edge of push rod internal thread that might be caused by the loosening of the jam nut and resulted in the rod end bearing did not properly seated against the push rod. Continuous	Correction to add "or insufficient installation torque" and "remain"	The forward push rod internal thread was worn out in some area. The asymmetric deformation was also observed on the edge of push rod internal thread that might be caused by the loosening **or insufficient torque** of the jam nut and resulted in the rod end bearing did not properly **remain** seated	Accepted

No	Report Section	Concerns from the Report	NTSB Comments	NTSB Suggestion	KNKT Response
		operation with such condition led to deterioration of the engagement of the forward push rod and the rod end bearing which subsequently the rod end bearing detached from the push rod.		against the push rod. Continuous operation with such condition led to deterioration of the engagement of the forward push rod and the rod end bearing which subsequently the rod end bearing detached from the push rod.	
	3.1 Findings Point 17	On 10 September 2015, (six months after the accident), Sikorsky issued Alert Service Bulletin ASB 76-67-57 to conduct one-time inspection of the push rod assembly and application of slippage mark to jam nut to provide looseness indication.	Correction to add "and following the investigation of a second accident in Nigeria on 12 August,"	On 10 September 2015, (six months after the accident **and following the investigation of a second accident in Nigeria on 12 August**), Sikorsky issued Alert Service Bulletin ASB 76-67-57 to conduct one-time inspection of the push rod assembly and application of slippage mark to jam nut to provide looseness indication.	Accepted
	3.1 Findings Point 21	On 12 August 2015, another Sikorsky S-76C+ accident at Oworonshoki area of Lagos, Nigeria. KNKT coordinated with Nigeria Accident Investigation Bureau (AIB) to have access to the FDR information. KNKT found that the FDR signature was similar to the occurrence.	This should be finding #17. It needs to be right before the ASB release.		Accepted
	3.2 Contributing Factors	The helicopter un-commanded attitude was a result of loosening of the jam nut on the forward rod end bearing which subsequently separated from the push rod,		Requested rewording. It was a result of the separation of the forward rod end from the push rod, which occurred due to insufficient torque on the jam nut.	Rejected

No	Report Section	Concerns from the Report	NTSB Comments	NTSB Suggestion	KNKT Response
		resulted in the un-commanded servo movement and loss of control of the helicopter.			
		KNKT recommend to consider the installation of locking device to the jam nut or other method to prevent loosening of the jam nut.	Through extensive testing, Sikorsky determined that using a higher torque and applying a torque mark is sufficient to ensure the integrity of this connection.		Accepted. KNKT is not issuing safety recommendation in this report.
	Appendix 6.2	Piston velocity	These are significantly low piston velocities.	Sikorsky recommends that the servos be sent to HRT/Woodward for testing	

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