Statens haverikommission
Swedish Accident Investigation Authority

Final report RL 2016:07e

Serious incident during approach to Visby Airport on 30 November 2014 involving the aircraft SE-MDB of model ATR-72-212A, operated by Braathens Regional AB.

File no. L-148/14

19-10-2016

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigations do not deal with issues of guilt, blame or liability for damages.

The report is also available on SHK´s web site: www.havkom.se

ISSN 1400-5719

This document is a translation of the original Swedish report. In case of discrepancies between this translation and the Swedish original text, the Swedish text shall prevail in the interpretation of the report.

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Contents

General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies.

The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation.

Investigations of aviation incidents are governed mainly by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and by the Accident Investigation Act (1990:712). The investigation is carried out in accordance with Annex 13 of the Chicago Convention.

The investigation

SHK was informed on 2 December 2014 that a serious incident involving an aircraft with registration SE-MDB had occurred upon approach to Visby Airport, Gotland county, on 30 November 2014 at 12.20.

The incident has been investigated by SHK represented by Mr Jonas Bäckstrand, Chairperson, Mr Sakari Havbrandt, Investigator in Charge and Technical Investigator, and Mr Nicolas Seger, Operations Investigator.

The investigation team of SHK was assisted by Ulf Ringertz and Kristoffer Danèl as technical experts.

Arnaud Toupet from BEA[1] participated as an accredited representative for France, the state in which the aircraft was designed and manufactured, and

[1] BEA (Bureau d'Enquêtes et d'Analyses pour la securité de l'aviation civile) – the French authority for safety investigations in the field of civil aviation.

Carol Horgan from NTSB[2] participated as an accredited representative of the USA, where the propeller was designed.

Björn Pettersson has participated as advisor of the Swedish Transport Agency, and Alexandre Peytouraux has participated as advisor of the European Aviation Safety Agency (EASA).

The following organisations have been notified: The International Civil Aviation Organisation (ICAO), EASA, the European Commission, BEA (France), NTSB (USA), TSB[3] (Canada) and the Swedish Transport Agency.

Investigation material

An initial technical investigation was carried out by SHK in Visby on 2 December 2014.

Interviews have been conducted with the commander.

The Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) have been analysed.

A technical investigation of the propeller mechanism has been carried out.

Two factual information meetings with the interested parties were held on 11 November and 1 December 2015. At the meetings, SHK presented the facts available at the time.

[2] NTSB (National Transportation Safety Board) – the USA's authority for safety investigation in civil aviation.
[3] TSB (Transportation Safety Board of Canada) – Canada’s authority for safety investigation in civil aviation.

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Aircraft:	
Registration, type	SE-MDB, ATR72
Model	ATR-72-212 A
Class, Airworthiness	Normal, Certificate of Airworthiness and valid ARC[4]
Serial number	822
Operator	Braathens Regional AB
Time of occurrence	2014-11-30, at 12.20 hrs. in daylight Note: all times are given in Swedish standard time (UTC[5] + 1 hr)
Place	Visby, Gotland county, (position 5753N, 01816 E, 2,100 metres above mean sea level)
Type of flight	Commercial air transport
Weather	According to SMHI's analysis: wind east-southeast 5-8 kts, visibility >10 km, varying cloud mass with base 1 500 – 1 800 feet, temperature/dewpoint 0/-1°C, QNH[6] 1030 hPa
Persons on board:	55
Crew including cabin	4
Passengers	51
Injuries to persons	None
Damage to aircraft	Limited
Other damage	None
Commander:	
Age, licence	50 years, ATPL(A)[7]
Total flying hours	7,074 hours, of which 2,920 hours on type
Flying hours previous 90 days	152 hours, of which 144 hours on type
Number of landings previous 90 days	104 on type
Co-pilot:	
Age, licence	36 years, CPL(A)[8]
Total flying hours	2,381 hours, of which 2,162 hours on type
Flying hours previous 90 days	97 hours, all on type
Number of landings previous 90 days	59

[4] ARC (Airworthiness Review Certificate).
[5] UTC (Coordinated Universal Time) – is a reference for the exact time anywhere in the world.
[6] QNH – indicates barometric pressure adjusted to mean sea level.
[7] ATPL(A) – Airline Transport Pilot Licence Aeroplane.
[8] CPL (A) (Commercial Pilot License Aeroplane).

SUMMARY

The incident occurred during a scheduled flight from Bromma to Visby.

The commander has stated that small vibrations were felt during descent, at around 7,000 feet. The indicated speed was 250 kts and the power levers were set to idle.

The vibrations increased in intensity and the commander reduced the rate of descent to 2,500 feet per minute.

The vibrations became so severe that the cabin crew had difficulties moving in the cabin and that there were difficulties reading the instruments in cockpit.

Information from the flight recorders shows that the left propeller was first feathered momentarily. The right propeller was feathered thereafter, after which the right engine was shut off. The flight continued with the left engine in operation. The information also reveals that the communication between the pilots did not include confirmation of which engine’s power levers were manoeuvred. A number of warning signals were activated during the sequence of events. The signals were not reset during the acute phase of the event.

When the commander moved the right propeller control to feather position, he was unable to push it all the way to fuel shut-off position. The control was therefore returned to the “auto” position and then pushed back via the feather position to fuel shut-off, whereby the vibrations subsided.

The co-pilot explained the situation to the air traffic controller in the Visby tower and declared an emergency situation. The air traffic controller triggered the alert signal.

The approach and landing were executed without problems.

The investigation revealed following damages:

- The eccentric trunnion pin on blade no. 2 was ruptured.
- The front propeller pitch change actuator plate was severely bent on all six positions.
- The engine mounts had received damage from contact with metal.
- The engine's compressor housing was cracked along half of its circumference.
- The shaft of the AC generator was ruptured.

SHK has been unable to establish the cause of the serious incident.

Safety recommendations

SHK's assessment is that additional extensive engineering initiatives are necessary in order to find the cause of the incident and that such initiatives should be the responsibility of the aircraft and propeller type certificate holders, under supervision of the certifying authorities. It has also been possible to establish that the known incidents of a similar nature have taken place under similar circumstances. In light of this, the following recommendation is issued. EASA is recommended to:

- Consider introducing temporary limitations in the manoeuvring envelope, or limitations of the power ranges within the latter, until the problem is resolved and rectified. *(RL 2016:07 R1)*

FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Preconditions

The incident occurred during a scheduled flight from Bromma to Visby. The flight, which was conducted with an aircraft of model ATR-72-212A, had flight number DC929 and was operated by Braathens Regional AB.

Four crew members and 51 passengers were on board.

Preparations and planning were carried out in accordance with standard procedures.

1.1.2 Sequence of events

The cruising altitude for the flight was Flight Level 140, (4,300 metres). There were clouds at this altitude, and the temperature was -7°C. The pilots established that ice was forming on the aircraft and decided to activate the de-icing systems. The systems had the intended effect, and it was established that the ice which had formed on the front edge of the wings disappeared.

The commander has stated that small vibrations were felt during descent, at around 7,000 feet. The descent rate at this point was 3,200 feet per minute, the indicated speed was 250 kts and the power levers were set to idle. The commander pushed forward first the left and then the right power levers, as previous experience had taught him that the vibrations tend to cease when moving the power levers forward from idle position. However, the measure had no effect on the level of vibrations.

The vibrations increased in intensity and “PEC[9] fault” was indicated via the aircraft's warning system. The commander reduced the rate of descent to 2,500 feet per minute.

The vibrations became severe and the pilots noted the triggering of the red “master warning” light. The commander moved the right propeller control to feather position but was unable to push it all the way to fuel shut-off position. The control was therefore returned to the “auto” position and then pushed back via the feather position to fuel shut-off, whereby the vibrations subsided.

Information from the flight recorders shows that the left propeller was first feathered momentarily. The right propeller was feathered thereafter, after which the right engine was shut off. The flight continued with the left engine in operation. The information also reveals that the communication between the pilots did not include

[9] PEC – Propeller Electronic Control.

confirmation of which engine's power levers were manoeuvred. A number of warning signals were activated during the sequence of events. The signals were not reset during the acute phase of the event.

The commander informed the cabin crew that one engine had been shut down and that the landing would be normal. The co-pilot explained the situation to the air traffic controller in the Visby tower and declared an emergency situation. The air traffic controller triggered the alert signal.

The approach and landing were executed without problems. The roll-out was conducted without reversing. Once the aircraft had been parked, the commander informed the passengers about the incident. He then conducted a debriefing with the crew.

The rescue services at Visby Airport attended the scene with three vehicles but did not need to take any action.

Following the incident, the commander has submitted an incident report in which he explains that the vibrations were so severe that the cabin crew had difficulties moving in the cabin and that there were difficulties reading the instruments in cockpit. He also mentions that the landing, which was performed using visual references, was prioritised over reading through the checklists for abnormal procedures.

The incident occurred at 12.20 local time during the day in position 5753N 01816E, 2,100 metres above sea level.

1.2 Injuries to persons

	Crew members	Passengers	On board, total	Others
Fatal	-	-	0	-
Serious	-	-	0	-
Minor	-	-	0	Not applicable
None	4	51	55	Not applicable
Total	4	51	55	-

1.3 Damage to aircraft

Limited.

1.4 Other damage

None.

1.4.1 Environmental impact

None.

1.5 Personnel information

Commander

The commander was 50 years old and had a valid ATPL(A) with flight operational and medical eligibility. At the time, the commander was PF[10].

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	0.6	5	152	7,074
This type	0.6	5	144	2,920

Number of landings this type previous 90 days: 104.
Type rating concluded on 8 December 2008.
Latest PC[11] performed on 28 November 2014 on this type.

Co-pilot

The co-pilot was 36 years old and had a valid CPL(A) with flight operational and medical eligibility. At the time, the pilot was PM[12].

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	0.6	12	97	2,381
This type	0.6	12	97	2,162

Number of landings this type previous 90 days: 59.
Type rating concluded on 31 August 2010.
Latest PC performed on 28 August 2014 on this type.

Cabin crew members

The cabin crew consisted of two persons.

1.6 Aircraft information

The aircraft is a twin-engine, high-wing turboprop aircraft with a short range. The aircraft is equipped with two adjustable six-blade propellers.

1.6.1 Aircraft

TC-holder	ATR-GIE Avions de Transport Régional
Model	ATR 72-212 A
Serial number	822
Year of manufacture	2008
Gross mass, kg	Max permissible take off/landing mass 22,800/22,350, actual 20,238/19,822

[10] PF (Pilot Flying) – the pilot who is manoeuvring the aircraft.
[11] PC (Proficiency Check).
[12] PM (Pilot Monitoring) – the pilot who monitors the flight.

Centre of gravity	Within permitted limits. CG -1.0 Aircraft Nose Up (27% MAC)
Total operating time, hours	10,036.8
Operating time since latest inspection, hours	68
Number of cycles	99
Type of fuel loaded before event	JET A-1
Engine	
TC-holder	Pratt and Whitney Canada Corp
Engine type	PW127M
Number of engines	2
Engine	No 2
Serial number	FR20080 755
Total operating time, hours	8,615.9
Operating time since latest inspection, hours	8,615.9
Propeller	
TC-holder	Hamilton Sundstrand
Type	568F-1
Propeller	No 2
Serial number	FR20080
Total operating time, hours	10,036
Operating time limitations, hours/cycles	10,500
Hold items	None which have had an influence on the event

The aircraft had a Certificate of Airworthiness and a valid ARC.

1.6.2 *Description of parts or systems related to the occurrence*

The propeller system

The propeller blade spars consist of carbon fibre and a shell of aramid fibre. The blade root consists of steel and has two bearing races and an eccentric trunnion pin. A plain bearing is mounted on the pin.

In the propeller hub, which is made of steel, there are six propeller blade mounts. Each mount features two bearing races. Between the bearing races of the hub and the propeller blades are steel ball bearings separated by ball separators. The assembled unit forms two angular contact ball bearings that permit propeller blade pitch change and transmit radial and axial forces into the hub when the propeller rotates.

The propeller hub also mounts a hydraulic actuator on its’ forward flange consisting of a dual-acting piston connected to front and aft steel plates. The propeller blades' eccentric trunnion pin bearings lie between the steel plates. When the actuator piston moves forwards or backwards, this affects the pitch of the blades.

The actuator is mechanically and hydraulically connected to a Propeller Valve Module (PVM) via what is known as a transfer tube.

The pitch of the propeller blades are controlled hydromechanically by the PVM, which in turn is controlled by a Propeller Electronic Control (PEC). The PEC is connected to the propeller controls in the cockpit via a Propeller Interface Unit (PIU).

The PVM is mounted on the engine's reduction gear, and enables the following functions:

- Governing of the RPM
- Beta control[13]
- Reversing
- Synchronisation
- Feathering
- Protection against low blade pitch in-flight

The PEC is an electronic unit with two channels which via a closed circuit controls changes in the propellers' blade pitch. It also monitors the propeller’s response to its commands to assess the system performance. When the PEC software detects sufficiently degraded performance, “faults” are created and the warning “PEC fault” is triggered.

[13] Beta – blade pitch lower than the finest pitch during flight.

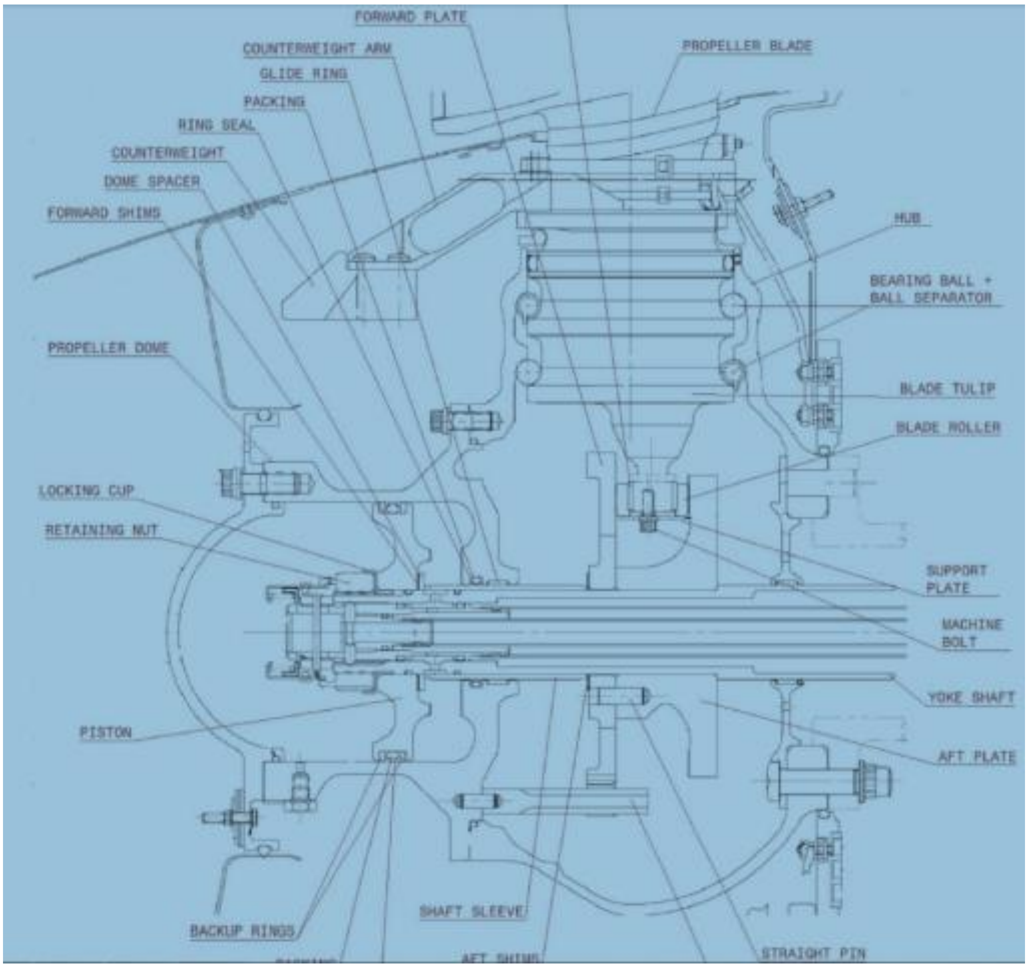

Figure 1. Exploded diagram of the propeller hub. Source: The propeller type certificate holder (HS).

The propeller controls

Two propeller levers, also known as condition levers, (see figure 2), one for each engine, are found on the mid pedestal between the pilots. The control has four positions: 100 OVRD (100% override), AUTO, FTR (Feather) and FUEL SO (Fuel shut-off).

The OVRD can be selected to increase the propeller's RPM to 100 %, corresponding to 1,200 RPM during take-off and go-around and in the case of certain malfunctions. AUTO is used during normal flight. The propeller RPM is 82 %, corresponding to 984 RPM during climb, level flight and descent. FTR is used to feather the propeller. The FUEL SO position is used to shut off the engine.

In order to move the power levers from AUTO to FTR, and from FTR to FUEL SO and vice-versa, a trigger must be used. The trigger is located on the side of the control shaft.

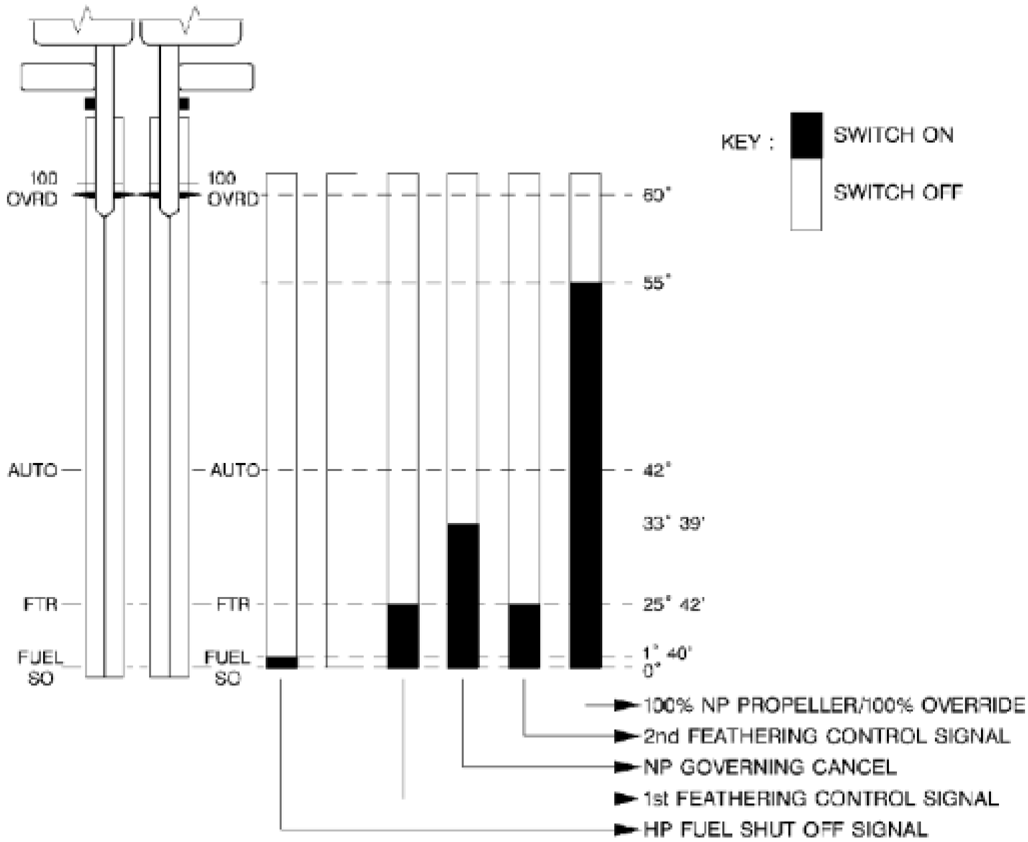

Figure 2. The propeller controls.

Warning system

The description below is limited and only affects the warnings during the incident in question.

The aircraft is equipped with what is known as a Centralized Crew Alerting System (CCAS). The system uses a type of audio-visual warning and three types of visual warnings:

- Master Warning (MW) and Master Caution (MC) consist of a flashing red and amber light respectively in front of each pilot. The audio signal is a Continuous Repetitive Chime (CRC) for MW and a Single Chime (SC) for MC.
- The Crew Alerting Panel (CAP) consists of a number of lights used to identify the origin of a fault.
- Local warning lights placed in connection to the associated reset function.

There are also specific audio warnings, including:

- Overspeed (clacker) when the speed exceeds the maximum permitted.

- AP disconnection (cavalry charge) when the autopilot is disconnected.

AC generator

Each engine is fitted with an AC generator used to power the electrical de-icing systems for the propeller as well as other AC powered electrical systems on the aircraft.

1.7 Meteorological information

According to SMHI's analysis: Wind 5-8 knots, visibility >10 km, variable cloud mass with base at 1 500 – 1 800 feet, temperature / dewpoint 0/-1 °C, QNH 1030 hPa.

1.8 Aids to navigation

Not applicable.

1.9 Communications

The crew communicated with the air traffic controller in the Visby tower during the sequence of events, declared an emergency situation and informed the tower that the right engine had been shut off.

1.10 Aerodrome information

Visby Airport is an approved instrument aerodrome. The airport had operational status in accordance with the Swedish AIP[14].

1.11 Flight recorders

The aircraft was equipped with flight recorders that SHK has secured for readout and analysis. The units have subsequently been returned to the operator.

1.11.1 FDR[15]

The FDR was of the model FA2100 from L3 Communications with the serial number 000550028. The unit is digital and can store data for at least 25 hours.

The FDR was transported to SAAB AB in Linköping where data readout was performed.

Binary data have then been converted by the French accident authority, BEA, into engineering units by means of the French manufacturer's parameter list. The converted data have then been presented in the form of numerical values in table data and plots, which are described in more detail in Section 1.16.5.

[14] AIP – Aeronautical Information Publication.
[15] FDR – Flight Data Recorder.

1.11.2 Cockpit Voice Recorder (CVR[16])

The CVR was of the model FA2100 from L3 Communications with the serial number 000547158. The unit is digital and has a recording time of up to two hours.

The CVR was transported to SAAB AB where data readout took place under the supervision of SHK's Investigator in Charge. Audio data have then been transferred to a digital medium and transcribed.

The information from the voice recorder is found in section 1.1.2 in the sections which concern the sequence of events and in section 1.16.6 in the parts concerning the background noise from CAM[17].

1.12 Site of incident and the aircraft after the incident

1.12.1 Site of incident

The incident occurred approximately 30 km north of Visby Airport at an altitude of 7,000 feet.

1.12.2 The aircraft after the incident

Initially, the event was not considered to be a serious incident. Due to this, the operator's maintenance organisation commenced fault isolation and disassembled the right propeller. This work was interrupted when SHK decided to investigate the incident.

The disassembly and investigation resumed when SHK and representatives of BEA, UTAS[18] and ATR[19] were present.

The following damages were established:

- The eccentric trunnion pin on blade no. 2 was ruptured (see figure 3).
- The front actuator plate was severely bent on all six positions (see figure 4).
- The engine mounts had received damage from contact with metal.
- The engine's compressor housing was cracked along half of its circumference.
- The shaft of the AC generator was ruptured.

[16] CVR – Cockpit Voice Recorder.
[17] CAM – Cockpit Area Mike.
[18] UTAS – The type certificate holder of the propeller.
[19] ATR – The type certificate holder of the aircraft.

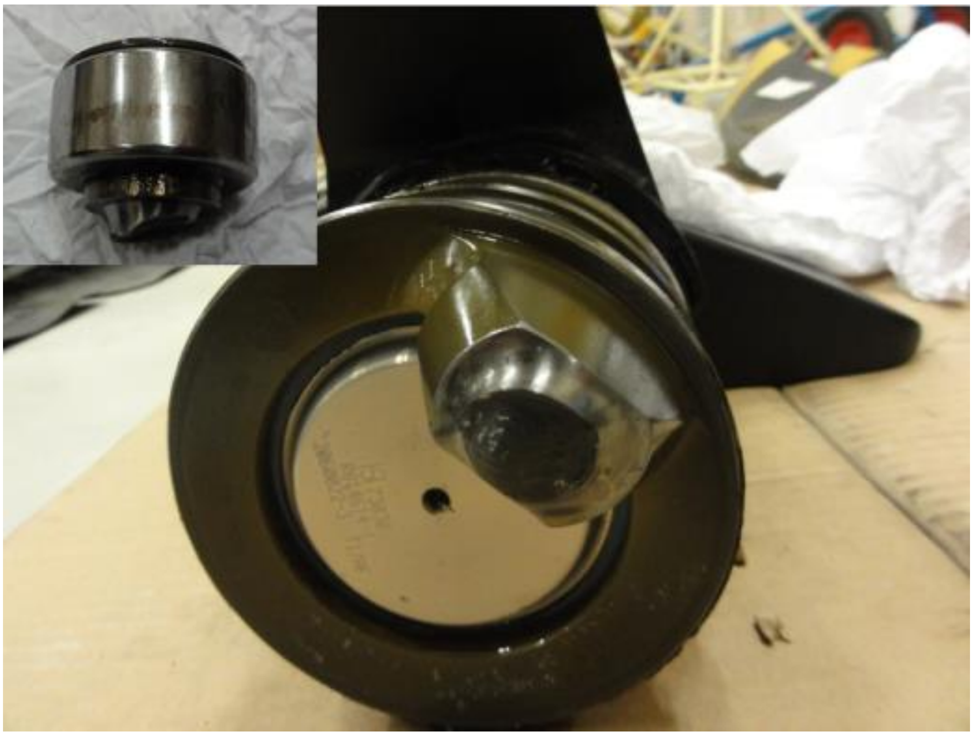

Figure 3. The ruptured eccentric trunnion pin.

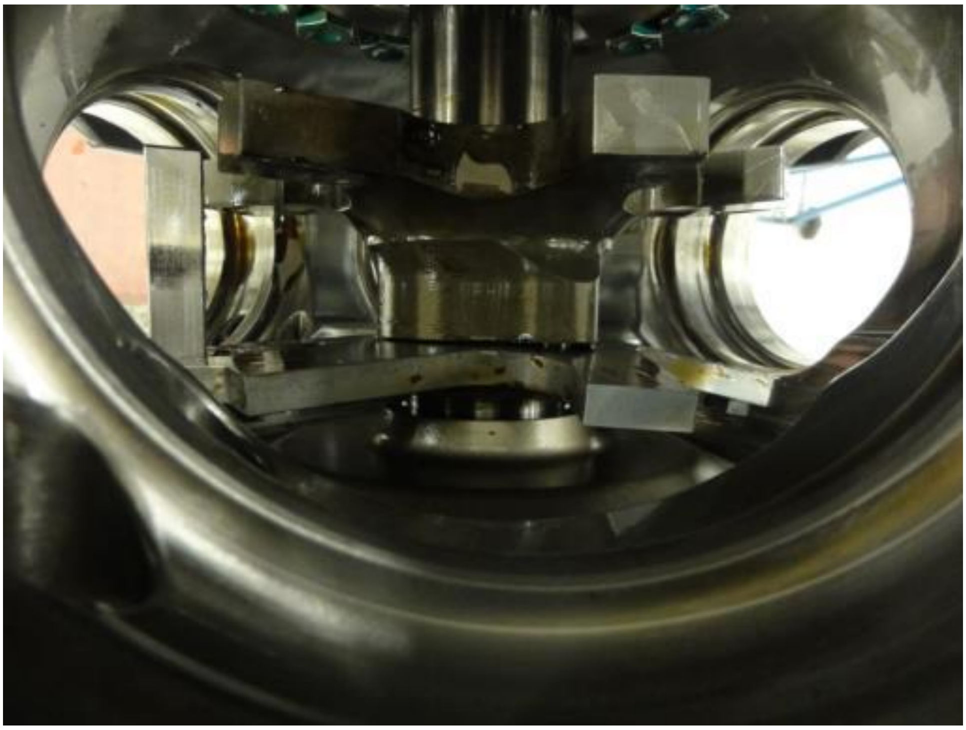

Figure 4. The bent actuator plate at the bottom of the picture is the front plate.

1.13 Medical information

Nothing indicates that the mental or physical condition of the pilots were impaired before or during the flight.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Rescue operation

The airport's rescue services were alerted and prepared, but were not required to perform any action as the landing was normal.

The ELT[20] was not activated.

1.15.2 Position of and injury to those on board, and use of seat belts

Not applicable.

1.16 Tests and research

1.16.1 Propeller examination

After the initial investigation at the scene, the propeller was disassembled and sent to the propeller production certificate holder's facility in Figeac, France. The technical examination was performed under the guidance and supervision of the French safety investigation authority (BEA). Personnel from SHK were present.

In addition to the damages reported under 1.12.2 above, non-destructive testing revealed that the other five trunnion pins had crack indications on both sides.

The broken trunnion pin showed signs of multiple bilateral overloads.

The play of the bearings for the six trunnion pins was measured by SHK and varied between 0.4 and 0.8 mm.

The ball bearings and the ball bearing separators from the blades retentions were investigated by UTAS in the USA under the NTSB’s supervision, where it was established, from a practical point of view, that they were in airworthy condition.

1.16.2 Engine examination

The engine was examined by an authorised maintenance body under BEA's supervision. The crack in the compressor housing was found to have occurred as a result of the overloads produced by the propeller during the event.

[20] ELT – Emergency Locator Transmitter.

1.16.3 *Stress calculation of the actuator and trunnion pin*

The manufacturer's FEM[21] analysis reveals that the trunnion pin reaches its tensile yield limit at 2,500-3,000 daN and that the front actuator plate protuberances reaches this limit at 3,000 daN.

SHK's strength calculations have essentially shown identical values.

1.16.4 *Examination of actuator*

With the assistance of a materials laboratory, SHK has investigated the mechanical damages to the actuator plates' surface which may be in contact with the bearing of the trunnion pin.

There are two types of damage (see figure 5). One is gentle wear, without deformation of the material, which has occurred over time. The other is a plastic deformation caused by impact or indentations.

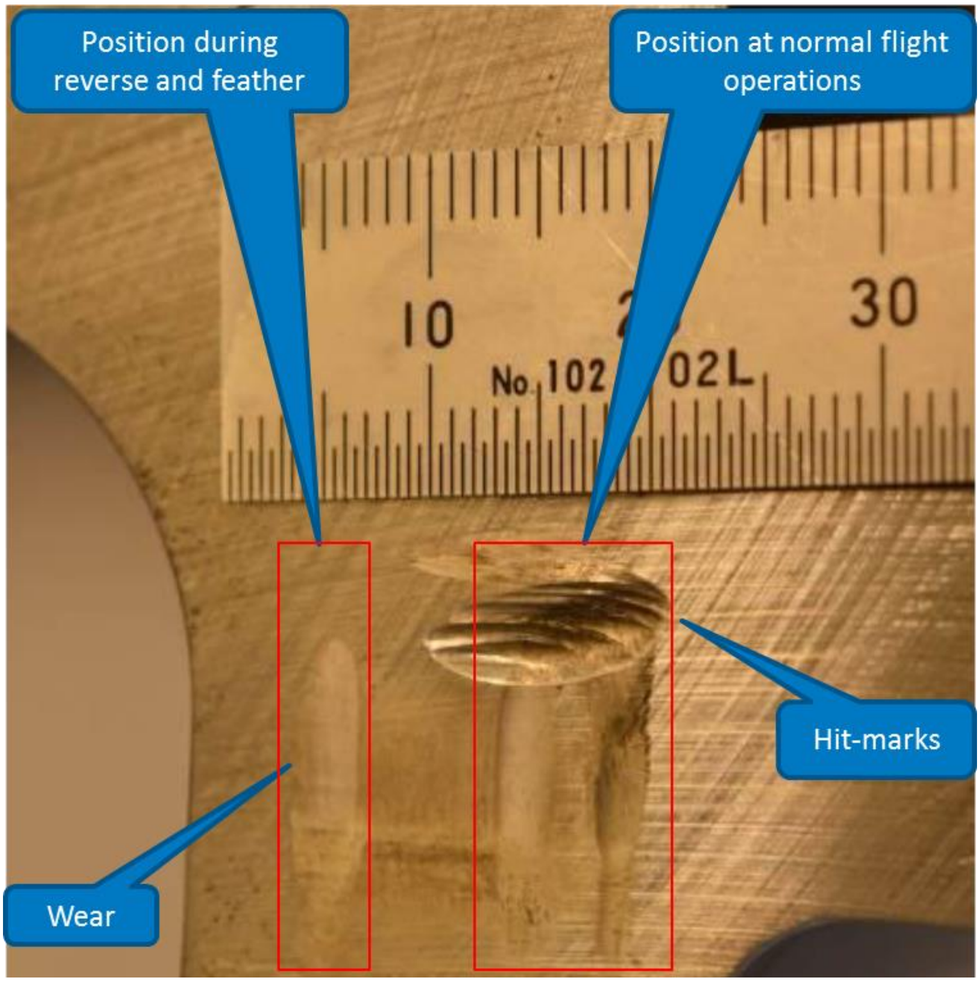

Figure 5. The image shows the two types of surface damage and the contact point when reversing and in normal operation, respectively, on one of the protuberances on the front actuator plate.

[21] FEM – Finite Element Method; computer-based calculation using a three-dimensional model.

1.16.5 Analysis of FDR and CVR data

The FDR and CVR were removed from the aircraft and could be read. The French investigation authority BEA assisted in the validation and analysis of the data.

The analysis shows that the sequence of events commenced in connection with the power levers being reduced to idle and the severe vibrations beginning one minute and 20 seconds later. The indicated air speed was between 241 and 254 kts during the sequence of events.

The timescale in figure 6 below begins three seconds before the severe vibrations began.

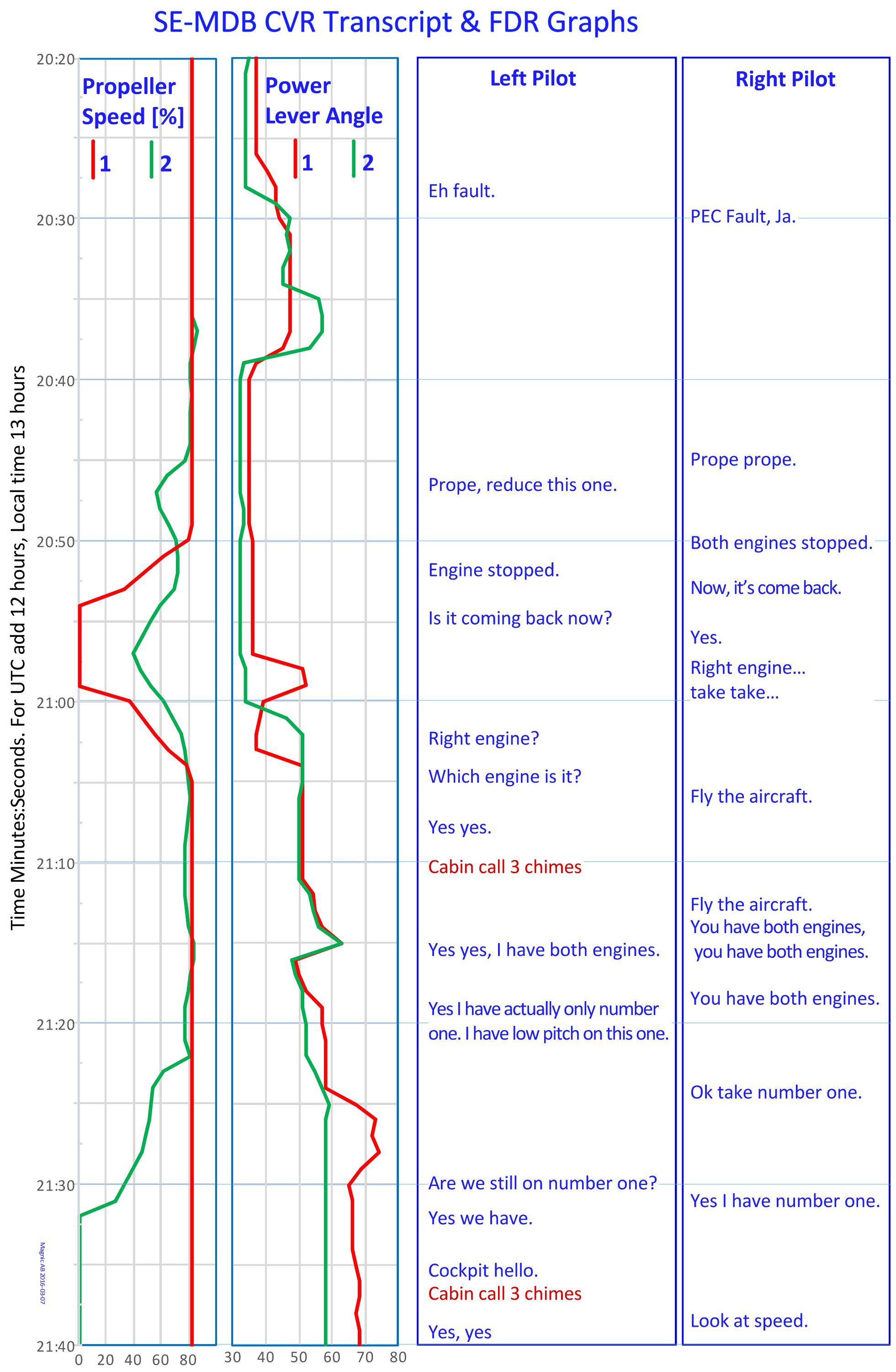

Figure 6. The figure shows a CVR printout combined with the power levers position and propeller RPM. 35 degrees power levers angle corresponds to the flight idle position. The times to the left are given in minutes and seconds. (The transcript above of the communication in cockpit has been translated from Swedish to English.)

1.16.6 Analysis of background noise from the CVR

When analysing the background noise from the CVR, three sounds with different frequency families have been established. A frequency family of 16 Hz, which is consistent with the propeller shaft's RPM, one at 99 Hz, which is consistent with the propeller shaft's RPM multiplied by six, and a frequency of 39 Hz from a source which could not be identified.

The sound with the frequency of 99 Hz persists throughout. The frequency of 16 Hz appeared when the power levers was pulled back to idle at 12:19:03. The sound with the frequency of 39 Hz apperared in conjunction with the severe vibrations commencing at 12:20:23 and ceasing at 12:20:36. The vibrations and the sounds with frequencies 16 Hz and 39 Hz ceased when the right propeller was feathered.

1.16.7 Simulator tests

SHK has participated in simulator tests at the manufacturer in Toulouse, France. The purpose of the tests was partly to investigate the functionality of the propeller control and partly to gain general knowledge of different methods of performing a descent.

The condition lever was manoeuvred from the AUTO position by lifting the trigger and keeping it in its raised position whilst moving it towards the FTR position. The lever then stopped a few millimetres above the FTR position. The only means of moving on towards the FTR position was to let the trigger drop back into position and pull the control further back.

Descent was performed with varying rates of descent and speeds. The manufacturer explained that a normal descent could be carried out with either a rate of descent of 1,500 feet per minute or with a gradient of three degrees and an indicated speed of 200, 220 or 240 kts.

1.16.8 The manufacturer's flight tests

Flight tests have been carried out, with equipment to allow the measurement of forces on the trunnion pins, during different phases of flight.

Data has been analysed and it has been established that at a speed close to 250 kts and in flight idle, the forces on the trunnion pins are low. Furthermore, the pins may have contact with either of the actuator plates in this position.

1.17 Organisational and management information

Braathens Regional AB is a commercial aviation company that principally operates passenger flights within Sweden.

The company has a valid operating certificate issued by the Swedish Transport Agency.

1.18 Additional information

1.18.1 Previous incidents of a similar nature

Six other incidents of a similar nature involving this aircraft type have occurred between 2007 and 2014. Two of these are under investigation by foreign safety investigation authorities. The others have not been investigated by any authority, However they have been adressed by the aircraft and propeller type certificate holders.

1.18.2 Incident involving SE-MDC

An investigator from SHK participated as an observer on a flight from Bromma to Visby Airport. The flight was conducted with a sister aircraft with registration SE-MDC. The purpose was to gain knowledge of the flight operations environment in the cockpit.

Following take off from Bromma and during the climb to cruising altitude, weak vibrations were detected, which produced deflections in the form of movement to the left and right on both control wheels. During descent to Visby, with the power levers on idle, the vibrations increased in intensity when the speed approached 245 kts. At this point, the vibrations could be felt in the feet and on the sidewall to the door post. The vibrations ceased when the power levers were increased slightly and the engines' torque (Tq) increased to a reading in the region around 7-8 %.

The operator attempted to resolve the problem by performing a dynamic balancing of the propellers. This was however unsuccessful. The propeller blades were disassembled with the intention of weighing them in order to check for a potential source of the fault. In conjunction with this, a play in the trunnion pins' bearings was discovered.

The bearings were replaced, after which the propellers could be successfully balanced, meaning the vibrations did not return.

1.18.3 Basic principles for aeroelastic vibrations

All aircraft are flexible and change form as a result of the aerodynamic forces caused by the flight. Long and slender aeroplane wings are very flexible, and the lift created by the wings in order to carry the weight of the aircraft produce relatively large deformations during flight. The deformations of the wings change the aircraft's shape, thereby changing the aerodynamic forces. This interaction is known as aeroelasticity. The wings' deformations and movement during flight can in different ways influence the aircraft's manoeuvrability and flight safety.

If the deformation of the wings changes quickly, this aeroelastic interaction becomes dynamic and the aircraft's distribution of mass also affects the sequence of events via the inertial forces which arise.

At a sufficiently high speed, this aeroelastic interaction between the aircraft's elastic deformation, aerodynamic forces and inertial forces becomes instable to the extent that fluctuations or vibrations become instable and quickly increase in severity.

This form of aeroelastic instability is known as “flutter” and all aircraft are investigated thoroughly in order to ensure flutter cannot arise at the speeds at which the aircraft is intended to fly.

If the speed is high, it may be enough that a part of the aircraft's structure is damaged, or breaks, for flutter or other aeroelastic vibrations to occur. Certain serious types of faults are analysed when the aircraft is designed, but far from all faults are investigated.

The aircraft's propellers and engines also work in unison with the aircraft's other parts and make aeroelastic phenomena even more complicated. Moving parts of the aircraft, such as control surfaces and propellers, cannot be mounted without a certain amount of play. This play can lead to aeroelastic vibrations which do not cause the aircraft to come apart but which cause undesirable vibrations which can be severe.

As aeroelastic phenomena are affected by the aircraft's rigidity, the aerodynamic forces and the aircraft's mass distribution, this means that every change in the aircraft's shape, rigidity or mass distribution can affect the aircraft's aeroelastic properties. Small changes can also lead to severe vibrations in the aircraft, which in turn can result in damage or even an accident.

The manufacturer's investigation of the aircraft's aeroelastic qualities has been limited to frequencies below 30 Hertz, which made it difficult to establish the way in which the aircraft's aeroelastic properties may have affected the sequence of events.

1.18.4 Actions taken

BEA

On 23 December 2014, BEA submitted four recommendations to EASA concerning information on these problems to the operators.

EASA

On 30 January 2015, EASA published a safety information bulletin, SIB No.: 2015-03 with information about the vibration problems.

EASA is capturing any new occurrence through an Airworthiness Review Sheet (ARS 61.0003), in order to immediately launch the proper measures to ensure the relevant hardware is secured.

On 19 January 2016, EASA revised the safety information bulletin, SIB No.: 2015-3R1.

The propeller's type certificate holder

The type certificate holder issued a service bulletin (568F-61-67, dated 2 Oct 14) prior to the event in question, which included an instructions for measuring the total amount of play in the actuator and blade trunnion pin bearing mechanism interfaces. The intention with the bulletin was to facilitate the detection of excessive backlash caused by bent actuator plates following vibration incident in combination with the indication of PEC fault codes 67 and 68 (sensed blade angle fault, on the primary and secondary channels).

The type certificate holder is of the opinion that the damages to the propeller mechanism occurred by means of the friction in the blades' retention bearings becoming too high and that the force of the hydraulic actuator caused the damages. The magnitude of the friction increase results in high actuator pitch change forces applied to the blade trunnion pins and actuator plates.

The vibrations which the crews reported are considered to be a result of the blades achieving different angles depending on the deformation in the mechanism.

Consistent with the propeller type certificate holder’s likely cause theory, an improved ball bearing separator has been designed which is being introduced to the propellers currently in operation and has been incorporated in new production propellers.

The aircraft's type certificate holder

The aircraft's type certificate holder has published a bulletin (OEB – Operations Engineering Bulletin) based on the current incident and previous incidents. The purpose of the bulletin is to inform and provide operators with recommendations for flight operations in terms of events of sudden and severe vibrations on the engine installation originating from mechanical damage to the propellers.

The bulletin explains that investigations have revealed that all reported incidents occurred under the following circumstances:

- On engine no. 2 (right engine)
- During descent, at a speed of close to 250 kts
- When the power levers (PL) were reduced to flight idle (FI)

The bulletin contains a procedure for identifying and shutting down the affected engine.

1.19 Useful or effective investigation techniques

None.

2. ANALYSIS

2.1 The flight

SHK has established that preparations and planning for the flight in question followed normal procedures.

The formation of ice which occurred at cruising altitude is not considered to have had an impact on the incident as the de-icing system had the intended effect.

The crew attempted to rectify the problem with the initial vibrations by manoeuvring the power levers; a measure which was based on previous experience. However, the measure had no effect. SHK considers it natural to use previous experience to solve a task, especially when there is no published procedure for handling the problem.

The commander decided to prioritise the flight – which was performed using visual references – over reading through the checklists for abnormal procedures. SHK considers this to be a correct prioritisation as the level of vibrations was so high that there were difficulties reading the instruments in the cockpit.

Clearer communication between the pilots, in terms of which power levers was manoeuvred, would likely have contributed to solving the task even quicker. The “PEC fault” warning, which indicated which side the vibrations originated from, was not used as guidance for the measures taken.

Initially, the right engine's propeller control could not be moved into the shut-off position, which was likely caused by the trigger unintentionally being in its upper position as the control reached the feather position.

2.2 Damage to the propeller mechanism

The fracture surface of the ruptured blade trunnion pin reveals that there have been multiple instances of overload, in both directions, prior to the final rupture.

The damage to the actuator plates also shows evidence of multiple instances of overload.

In figure 5, indentations from the support plate on the trunnion pin's bearing is visible. These indentations have occurred as a result of the protuberance of the actuator plate being bent. In the area for reversing, there are no signs of contact with the washer, which shows that the protuberance was not bent at the time of the previous landing. The image also shows wear on the front actuator plate, which is evidence that the trunnion pin bearing has had contact with it over time.

The evidence above shows that the non-wear damage took place during the incident flight.

As the crew did not perceive vibrations before the power levers were reduced to flight idle, it is likely that all the non-wear damage occurred after this reduction in power

It has not been possible to firmly establish the logic and the mechanics behind the damages, but it cannot be ruled out that they may have been a result of aeroelastic vibrations.

2.3 Damages to the engine, etc.

The damages to the engine and the engine mounts are deemed to have been caused by the high level of vibrations that occurred during the incident.

2.4 Measures taken by the propeller type certificate holder

As indicated previously, the propeller type certificate holder has assessed that the likey cause of the incident was the development of excessive friction in the blades' retention bearings. An improved ball bearing separator has been designed and introduced as a correcting action.

SHK establishes that the hydraulics can produce up to 12,000 daN at the AFT plate and 10,300 daN on the forward plate. In order for the actuator's forward protuberance to reach its tensile yield limit, a force of 3,000 daN is required. This means that not all protuberances can bend at the same time.

In order to achieve such damages via excessive friction in the blade retention bearing, all of the following factors must occur, or already be present, within the space of approximately one minute:

- Uneven distribution of ball bearings and increased friction in all six blade retentions.
- The increased friction shall act in both directions.
- A maximum of three blades may have higher friction at one time.
- The hydraulics must make around 20 movements in both directions.

SHK does not consider it likely that this could happen within such a short period of time.

2.5 Measures taken by the aircraft type certificate holder

The measures taken by the aircraft type certificate holder will likely lead to pilots being able to identify and rectify severe propeller vibrations in a more systematic way.

2.6 Overall assessment

SHK is able to establish that the incident occurred during descent at high speed when the power levers were reduced to idle and only the right engine (engine no. 2) was affected. The investigations of similar incidents carried out by other safety investigation authorities reveal that they too occurred under similar circumstances. Via the measures taken by BEA, EASA and the aircraft type certificate holder, the operators of the aircraft type have been informed of this and a procedure has been developed for identifying and shutting off the affected engine in similar situations.

SHK does not share the propeller type certificate holder's opinion on what caused the incident. According to SHK, it is not likely that the measures taken by the propeller type certificate holder are such that they sufficiently prevent the occurrence of a similar incident.

SHK's opinion is that further extensive engineering work in the form of thorough calculations and tests is required to find the cause of the incident.

The motive for this includes matters such as the registered and unidentified frequency of 39 Hz. It has also been established that the trunnion pins' bearing may be in contact with the front actuator plate during normal operation.

The propeller type certificate holder has indicated that the trunnion pin bearing by design should typically be against the aft plate protuberances during normal operation.

The forward plate should normally be loaded during isolated operating conditions, such as reverse operation.

The propeller type certificate holder has explained that the wear observed on the forward actuator plate protuberances is due to increased friction in the retention bearings.

SHK has established that both the aircraft type and propeller type have undergone a number of small changes since their original certification. There is nothing to suggest that any particular change has constituted the cause of the accident. It would however be valuable to investigate in greater detail whether the combined effect of the changes which have been made are such that they have a negative impact on the aircraft type's properties.

SHK considers such further investigative measures to be the responsibility of the aircraft and propeller type certificate holders, under supervision of the certifying authorities.

2.7 Flight safety assessment

SHK has assessed the event as a serious incident, which means that there was a high probability that an accident would occur.

The motive for this conclusion is that the resulting damages were of such a nature that they could have developed into structural damages in the engine installation. The fact that the incident occurred under visual weather conditions has likely allowed for control of the aircraft to be maintained despite the pilots' difficulties reading the instruments.

3. CONCLUSIONS

3.1 Findings

a) The crew was qualified to conduct the flight.
b) The aircraft had Certificate of Airworthiness and valid ARC.
c) The planning of the flight and the operation were normal until the incident occurred.
d) There was no specific procedure for handling engine vibrations.
e) The sequence starting with the vibrations and ending in the feathering of the propeller lasted just over a minute.
f) Six similar incidents have occurred, two of which are under investigation by foreign safety investigation authorities.
g) The mechanisms that caused the propeller damage could not be established.
h) Information on the situations in which similar incidents can occur and how they should be handled has been communicated to the concerned operators.

3.2 Causes of the serious incident

SHK has been unable to establish the cause of the serious incident.

4. SAFETY RECOMMENDATIONS

SHK's assessment is that additional extensive engineering initiatives are necessary in order to find the cause of the incident and that such initiatives should be the responsibility of the aircraft and propeller type certificate holders, under supervision of the certifying authorities. It has also been possible to establish that the known incidents of a similar nature have taken place under similar circumstances. In light of this, the following recommendation is issued.

EASA is recommended to:

- Consider introducing temporary limitations in the manoeuvring envelope, or limitations of the power ranges within the latter, until the problem is resolved and rectified. *(RL 2016:07 R1)*

SHK respectfully requests to receive, by **20 January 2017** at the latest, inshapeation regarding measures taken in response to the safety recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Jonas Bäckstrand Sakari Havbrandt

Appendices

Submission to the final report by BEA (The French authority for safety investigations in the filed of civil aviation).

BEA

BEA's submission to the final report – October 2016

Two previous similar incidents are still under investigation.

The first occurred on 18th September 2013, an ATR 72-212A registered PK-WFV that encountered severe vibrations on engine #2 propeller during descent at a speed of 251 kt as the crew was moving power levers to the Flight Idle position. Vibrations persisted until the engine #2 was shut down after landing. The blade angle actuator forward plate was found bent and one blade was turning freely as its trunnion pin was broken. Two engine fittings were found broken. The investigation is led by the Indonesian safety investigation authority – KNKT.

The second occurred on 4th May 2014, an ATR 72-212A registered 9Y-TTC that encountered severe vibrations on engine #2 propeller during descent at a speed of 246 kt as the crew was moving power levers to the Flight Idle position. Vibration ceased during the flight and on ground maintenance did not evidence anything abnormal. On 5th May 2014, right propeller vibrations were reported by the crew after landing. Propeller pitch change mechanism was found severely damaged after maintenance performed test runs on the ground. The blade angle actuator forward plate was found heavily bent and one blade was turning freely as its trunnion pin was broken.

Trinidad and Tobago authorities delegated the investigation on the second incident to the BEA. In the framework of the investigation, the manufacturers performed numerous tests and analysis including a flight test campaign. Full sampled relevant flight test data should be made available to BEA in the coming days. BEA considers that access to those data and their review are necessary to conclude the investigation and clarify the possible causes of the severe vibrations.