Statens haverikommission
Swedish Accident Investigation Authority

Final report RL 2014:07e

Serious incident at Sveg Airport on May 3, 2013 involving aircraft ES-PJR of the model Jetstream 3200, operated by AS Avies.

File number L-46/13

6/9/2014

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring again, 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.

Postadress/Postal address	*Besöksadress/Visitors*	*Telefon/Phone*	*Fax/Facsimile*	*E-post/E-mail*	*Internet*
P.O. Box 12538 SE-102 29 Stockholm Sweden	Sveavägen 151 Stockholm	+46 8 508 862 00	+46 8 508 862 90	info@havkom.se	www.havkom.se

Content

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 again, 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 May 3, 2013 that a serious incident involving one aircraft with the registration ES-PJR, Jetstream 3100 / 3200 series had occurred at Sveg Airport (ESND) in Jämtland county, on the same day at 07.21 hrs.

The incident has been investigated by SHK represented by Mr Mikael Karanikas, Chairperson, Mr Kristoffer Danèl, Investigator in Charge until August 31 2013, thereafter Mr Stefan Christensen and Mr Peter Swaffer, Operational Investigator.

The investigation team of SHK was assisted by Mr Henrik Elinder as a technical expert and by Magnic AB specialising in sound.

Accredited representatives have been Mr Jens Haug from the Estonian Safety Investigation Bureau (ESIB), Mr John McMillan from the United Kingdom Air Accidents Investigation Branch and Mr Robert Hunsberger from the National Transportation Safety Board (NTSB) in the United States has participated.

The investigation was followed by Mr Lars Kristiansson of the Swedish Transport Agency.

The following organisations have been notified: the Swedish Transport Agency, the International Civil Aviation Organisation (ICAO), the Estonian Safety Investigation Bureau (ESIB), the Air Accidents Investigation Branch (AAIB), the National Transportation Safety Board (NTSB), the European Aviation Safety Agency (EASA) and the European Commission.

Investigation material

A meeting with the interested parties was held on December 18, 2013. At the meeting SHK presented the facts discovered during the investigation, available at the time.

Final report RL 2014:07e

Aircraft:	
Registration, type, model	ES-PJR, Jetstream 3100 / 3200 series,
Class, Airworthiness	Normal, Certificate of Airworthiness and Valid Airworthiness Review Certificate (ARC)[1]
Owner/Operator	Aviesair AS/AS Avies
Time of occurrence	May 3, 2013, 07.21 hrs in daylight Note: All times are given in Swedish daylight saving time (UTC + 2 hrs)
Place	Sveg Airport, Jämtland county, (position 62025N 01425E, approximately 150 metres above sea level)
Type of flight	Commercial air transport (commissioned traffic)
Weather	According to the airport: wind 100°, 02 kts, CAVOK[2], temperature/dewpoint -4/-9 °C, QNH[3] 1016 hPa
Persons on board:	16
crew members	2
passengers	14
Injuries to persons	None
Damage to aircraft	No damage
Other damage	None
Commander:	
Age, licence	41 years, ATPL[4]
Total flying hours	5 146 hours, of which 3 203 hours on type
Flying hours last 90 days	87 hours, all on type
Number of landings last 90 days	164
Co-pilot:	
Age, licence	26 years, CPL[5]
Total flying hours	630 hours, of which 175 hours on type
Flying hours last 90 days	25 hours, all on type
Number of landings last 90 days	45

[1] ARC (Airworthiness Review Certificate).
[2] CAVOK (Ceiling And Visibility OK).
[3] QNH.Indicates barometric pressure adjusted to sea level.
[4] ATPL (Airline Transport Pilot License).
[5] CPL (Commercial Pilot License).

SUMMARY

The aircraft departed from Sveg airport for a scheduled flight to Stockholm/Arlanda airport. Shortly after takeoff, at an altitude of about 500 feet, engine problems occurred on both engines with substantial fluctuations in power (torque) and engine speed (RPM). The commander stated that during the time that the disturbances lasted it was hard to keep the aircraft flying and that an emergency landing in the terrain could be necessary. The disturbances ceased however after about a minute and the aircraft could return to Sveg airport and perform a normal landing.

After the incident the airplane's FDR (flight data recorder) and CVR (cockpit voice recorder) was cared for by the SHK. The recorded parameters from the FDR however showed unrealistic values depending on the fact that the operator did not have the required documentation to convert the recorded values into useful units. The cockpit voice recorder had not been shut down after the incident which meant that the records in connection with the incident had been recorded over.

SHK carried out a correction and analysis of recorded data from the flight data recorder. Together with a sound analysis from a private film taken at the time, it was found that the take-off was most likely performed with a too low RPM. The dialogue with the airplane manufacturer revealed that it was a previously known problem that a start with a too low RPM in some cases could cause engine problems. There has previously been a serious accident in which a too low RPM setting was found to be the root cause.

The operational documentation of the operator did not contain a requisite level of information on potential risks when starting with too low RPM. The aircraft type has no warning system to identify a faulty engine configuration and the checklist does not contain a “memory item” procedure for immediate action by the crew.

At the examination carried out in connection with the incident, technical deficiencies were also found. Corrosion damage and temporary repairs in some of the aircraft systems were noted at the technical investigation. Furthermore, it was found that there where technical remarks that had not been entered in the aircraft logbook.

The incident was likely caused by a too low RPM during take-off. A contributing factor was that the aircraft type has no warning system for take-off with an incorrect engine configuration.

Safety recommendations

EASA is recommended to:

- Investigate the conditions for installation of a warning system on the aircraft type in question which notifies the pilots of an incorrect engine configuration in connection with take-off. *(RL 2014:07 R1)*
- Endeavour to revise the emergency checklist for this aircraft type so that measures in the event of engine oscillations in connection with take-off are changed so as to be included as “memory items”. *(RL 2014:07 R2)*
- Take measures to ensure that initial and recurrent training on this aircraft type are supplemented with information and training regarding the risks of incorrect engine configurations during take-off. *(RL 2014:07 R3)*

1. FACTUAL INFORMATION

1.1 History of the flight

The intention was to conduct a commercial flight from Sveg Airport to Stockholm/Arlanda Airport. The aircraft, which was a model BAe Jetstream 3200 (J32) - see Figure 1 - had been parked in a hangar overnight and then towed out to the apron for boarding. It was a dry, clear and cold morning. According to information from the pilots, the engine start procedure went as normal and taxiing to runway 09[6] was performed according to applicable procedures. The crew did not observe any technical malfunction or anything else unusual.

Figure 1. ES-PJR, BAe Jetstream 32. Photo: Avies AS.

The aircraft accelerated to rotation speed and took off as normal, according to the commander. Shortly thereafter, at an altitude of around 500 feet (150 metres), the crew experienced severe problems with both engines. It started in the left engine, and shortly thereafter also in the right engine. The engine instruments displayed abnormal values and the aircraft yawed to the left and to the right alternately. The sequence of events is illustrated in Figure 2.

The commander has stated that he had difficulties keeping the aircraft flying and that it was necessary to focus on maintaining altitude, speed and heading. He has explained that he and the co-pilot feared the aircraft was headed towards the ground and therefore began looking for a suitable place for an emergency landing. However, the surrounding terrain consisted solely of forest and waterways, with no open area to land. They therefore made the decision to perform a right turn in order to attempt to return for landing on the same runway they took off from.

The oscillations continued with unchanged effect and the crew carried out a number of measures in order to resolve the situation. The commander stated

[6] The Figure 09 indicates that the runway's magnetic heading is roughly 90°, i.e. East-facing.

that he checked the position of the RPM Levers, reduced the thrust somewhat and shut off the TTL system (Torque Temperature Limiter). A detailed description of the TTL system and its effect can be found in section 1.6.9. However, the measures did nothing to change the situation.

During this sequence of events, the co-pilot declared an emergency to the tower and informed of the situation and the crew's intention to return for landing. In light of the information submitted, the tower triggered the alert signal, whereby the rescue services were activated.

After performing a right turn, with the aircraft on a westerly course, the oscillations suddenly ceased. In Figure 2, the yellow line represents the part of the total six-minute flight during which the oscillations occurred. They lasted for approximately one minute. The blue line indicates the phases of the flight during which no disruptions were noticed and when the flight could be conducted under normal technical and operational conditions. The remainder of the flight was undramatic in the sense that it was possible to perform a normal landing. However, the emergency status remained until the aircraft had been parked on the apron, when the air traffic controller and the commander agreed it could be established that there was no longer any risk.

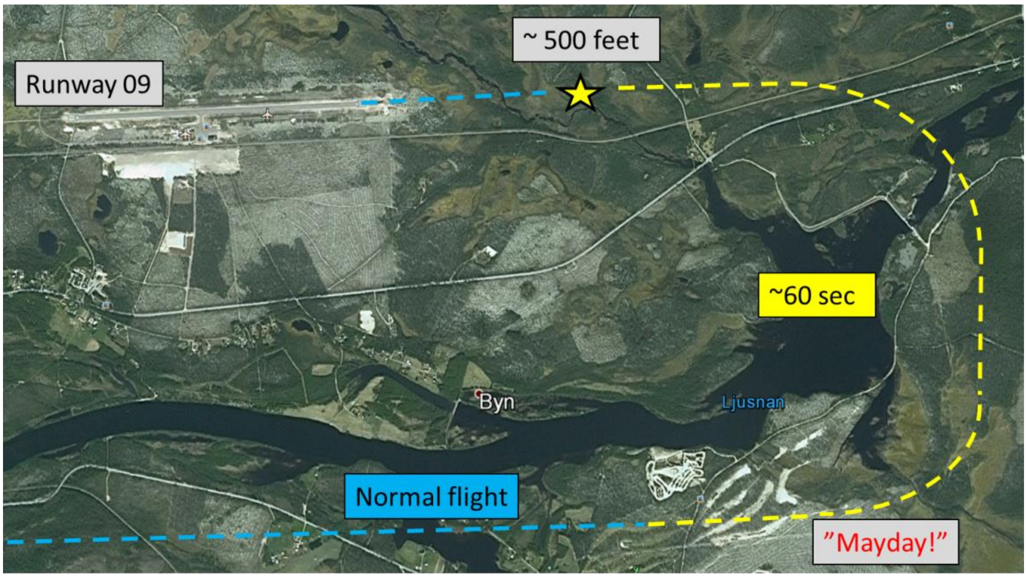


Figure 2. Schematic of the sequence of events. Photo: Google Earth™.

According to what SHK has been able to establish, there was no injury to persons and no damage to aircraft or any other property. Immediately after the passengers had left the aircraft, a briefing was given. This involved a conversation with the commander during which he informed about the event.

The incident occurred in the approximate position 62025N, 01425E and at around 500 feet (150 metres) above sea level.

1.2 Injuries to persons

	Crew	Passengers	Total in the aircraft	Others
Fatal	-	-	0	-
Serious	-	-	0	-
Minor	-	-	0	-
None	2	14	16	-
Total	2	14	16	-

1.3 Damage to aircraft

No damage.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 General

The commander had long experience on the aircraft type in question and also served as an instructor on J31/32. The first officer did not have as long experience but had served together with the commander on a number of occasions. Both pilots had undergone their Proficiency Checks on this type and passed. None of the pilots had undergone training in the scenario of engine failure/disruptions on both engines at the same time.

1.5.2 Commander

The commander was 41 years old and had a valid ATPL Licence with valid operational and medical eligibility. At the time, the commander was PF[7].

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	2	8	87	5 146
This type	2	8	87	3 203

Number of landings this type previous 90 days: 164.
Type rating concluded on 13 November 2003.
Latest PC (proficiency check) carried out on 4 March 2013 on Jetstream 32.

1.5.3 Co-pilot

The co-pilot, 26 years, had a CPL with valid operational and medical eligibility. At the time, the co-pilot was PM[8].

[7] PF (Pilot flying).
[8] PM (Pilot Monitoring).

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	2	10	25	630
This type	2	10	25	175

Number of landings this type previous 90 days: 45.
Type rating concluded on 5 November 2012.
Latest PC carried out on 13 April 2013 on Jetstream 32.

1.5.4 Cabin crew

The flight in question was operated without a cabin crew. Some of the operator's flights on this aircraft type were however conducted with cabin crew on board.

1.5.5 The pilots duty schedule

The flight was the first of the day. The commander was on the last of five working days and the co-pilot was on the last of six.

1.6 Aircraft information

1.6.1 General

The aircraft model BAe Jetstream 3200 is a further development of BAe Jetstream 3100 and was certified for commercial aviation in 1982. It is a twin-engine passenger aircraft with space for 19 passengers. The model has two turboprop engines, is fitted with a pressurised cabin and is used for short and medium haul flights. A total 386 aircraft of this type have been manufactured.

1.6.2 Aircraft data

Aircraft	
TC-holder	BAe Systems (Operations) Ltd.
Type	Jetstream 3100 / 3200 series
Serial number	949
Year of manufacture	1991
Gross mass, kg	Max authorised take-off mass 7 350 actual 6 750
Centre of gravity	Within permitted limits, 213.98 inches behind the datum
Total operating time, hrs	18 045
Operating time since overhaul, hrs	11
Number of cycles	30 010
Type of fuel loaded before event	Jet A1

Engine		
TC-holder	Honeywell	
Engine type	TPE331-12UHR-702H	
Number of engines	2	
Engine	No 1	No 2
Serial number	P-66330C	P-66329C
Total operating time, hrs	13 055	14 559
Flying time since latest overhaul, hrs	6 029	2 661
Cycles since latest overhaul	9 706	4 777
Operating time since inspection, hrs	14	14
Propeller		
TC-holder	McCauley	
Type	4HFR34C653	
Propeller	No 1	No 2
Serial number	011389	911615
Total operating time, hrs	3 457	9 592
Operating time since overhaul, hrs	1 585	589

Outstanding remarks	No remarks were noted in the aircraft's logbook. According to information from the commander, remarks from the previous flight were noted in the “Maintenance request” document, see section 1.6.3-4.

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

1.6.3 Provisions concerning technical remarks

Commission Regulation (EC) No 2042/2003 M.A. 403 states that any defect not rectified before flight shall be recorded in the operator's technical log system in accordance with M.A. 306 in the same regulation. It also states that any defect on an aircraft that constitutes a serious hazard to flight safety must be rectified before recommencing flight and that as a rule only authorised certifying staff can make such an assessment of a defect and thereby decide when and which rectification action should be taken before further flights can be conducted and which defect rectification can be deferred.

The technical log system shall also be set up so that deferred defects or remarks appear in the HIL[9], where it will also be specified as to when the defect will be rectified.

[9] HIL (Hold Item List) – List of outstanding technical remarks.

In the “Maintenance request” document, the following remarks concerning this particular aircraft (ES-PJR) were found, dated 2 May 2013:

- Replace circulation fan.
- Crew reported: RH propeller heating U/S. Investigate and rectify.
- Crew reported: Power levers are in different position to maintain equal torque. Check and rectify.

Remark.
The statement above concerning Power Levers (see 1.6.8) was found to be caused by the rigging of the engines. The problem was rectified and had no connection with the incident.

1.6.4 The operator's handling of technical remarks

The operator in question has deviated from the provisions of M.A. 306, see 1.16.3. Technical remarks are not normally noted in the aircraft's logbook; they are instead transferred to a document entitled “Maintenance request”. This document is sent in an appropriate manner to the operator's maintenance organisation for a decision concerning appropriate measures.

The pilots are instructed not to write any technical remarks before the defect/problem which has arisen has been confirmed by certified technician. The routes that the operator's aircraft flies in the Swedish line network entail that the aircraft meet a technician once per week on average.

The operator has stated that the system works well in general and that there have only been a few instances of misunderstandings. The reason for the pilots being instructed not to write the technical remarks in the logbook is - according to a statement made by the operator's representative - that this entails a greater risk that the aircraft will be grounded.

1.6.5 Turboprop engine

The turboprop engine, of type TPE 331-12UHR-702H, consists of a turboshaft engine which is connected to a propeller gearbox. Engine and propeller gearbox together constitute an integrated drive system for the propeller.

1.6.6 Turboshaft engine

The turboshaft engine (Figure 3) has a rotor shaft with double centrifugal compressors and a three-stage turbine and an intermediate combustion chamber. The engine RPM is controlled via the engine's Fuel Control Unit (FCU) which regulates the fuel flow from two fuel pumps to the fuel nozzles in the engine's combustion chamber. The FCU has a mechanical regulatory function which automatically delivers a regulated Fuel Flow (FF) to the engine for different pilot selected RPMs and engine power settings. The FCU is operated via a lever (Power Lever) in the cockpit but also receives signals from a Speed Governor and sensors which measure pressure and temperature in the engine's air intake and turbine exhaust.

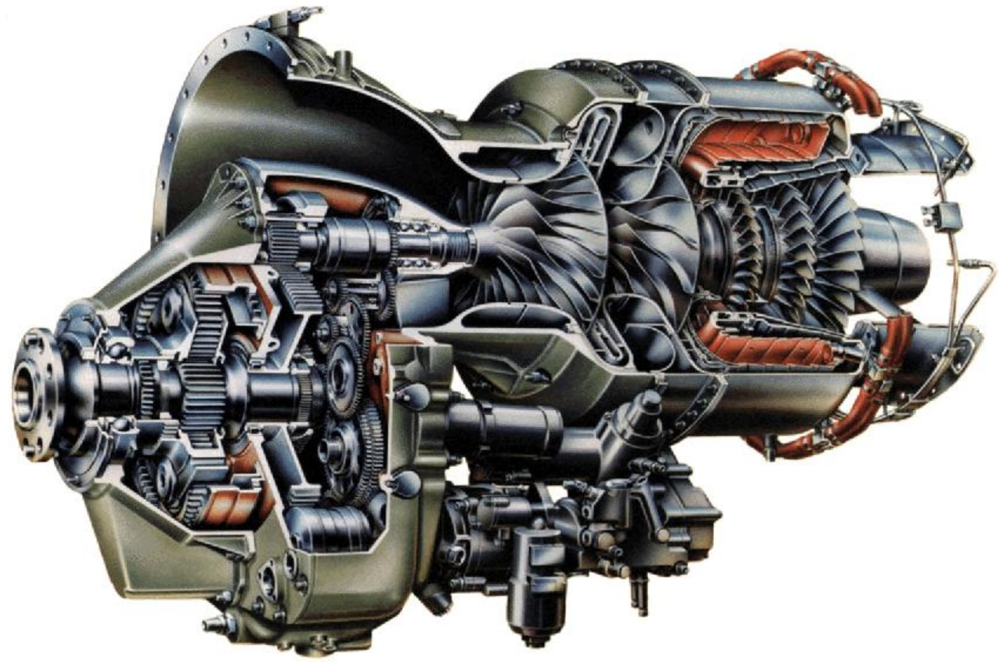


Figure 3. TPE 331-12UHR-702H. Photo: Honeywell.

1.6.7 Propeller gearbox and propeller

The propeller gearbox consists of a planetary gear which shifts down the output shaft RPM from the turboshaft engine to the propeller's RPM at a ratio of approximately 26:1. On the propeller gearbox is mounted a 4-blade propeller with adjustable blade angle. Adjustment of the blade angle is controlled by a Propeller Governor in the propeller gearbox. The engine- and propeller -RPM is displayed as percent (%) where 100% corresponds to a propeller speed of 1591 RPM.

1.6.8 Levers for regulating engine RPM and power

The engine RPM and power (torque) is regulated by the pilots with the use of two engine levers; the RPM Lever (also designated Speed Lever) and the Power Lever, respectively, which are located in a console between the seats in the cockpit. The pairs of levers each have a mechanical friction brake which can be controlled by the pilots using a knob. The knob for the RPM Levers is on the right-hand side of the console. The knob for the Power Levers is on the left-hand side of the console. See Figure 4.

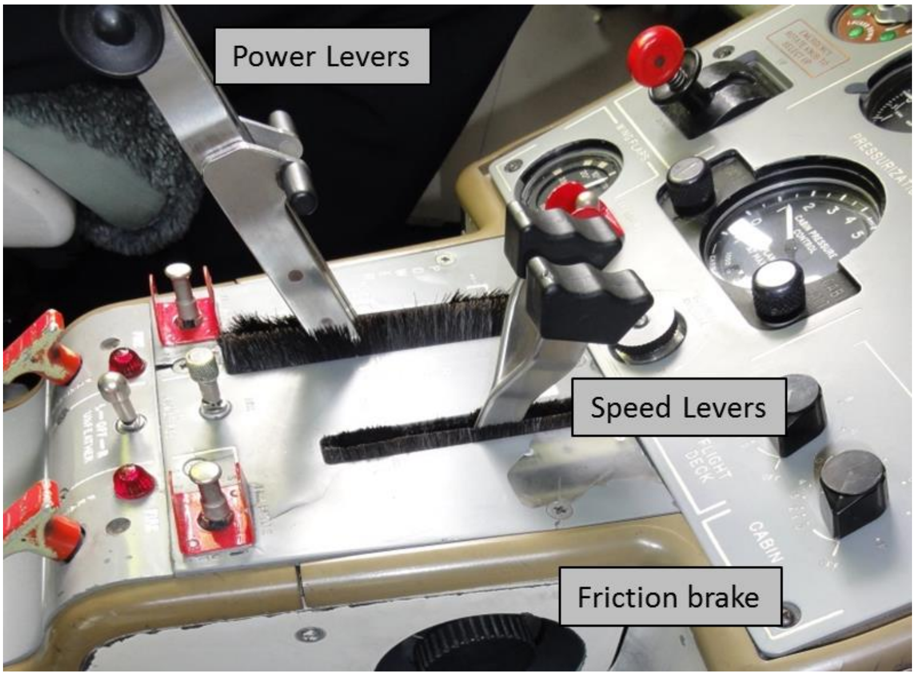


Figure 4. Power Lever and RPM Lever (Speed Lever).

The RPM Lever and the Power Lever are mechanically linked to each Propeller Governor and FCU, see Figure 5. The RPM Lever is normally operated within two ranges of revolutions; TAXI (Low) RPM (55% - 72%) and a FLIGHT (High) RPM (96% - 100%).

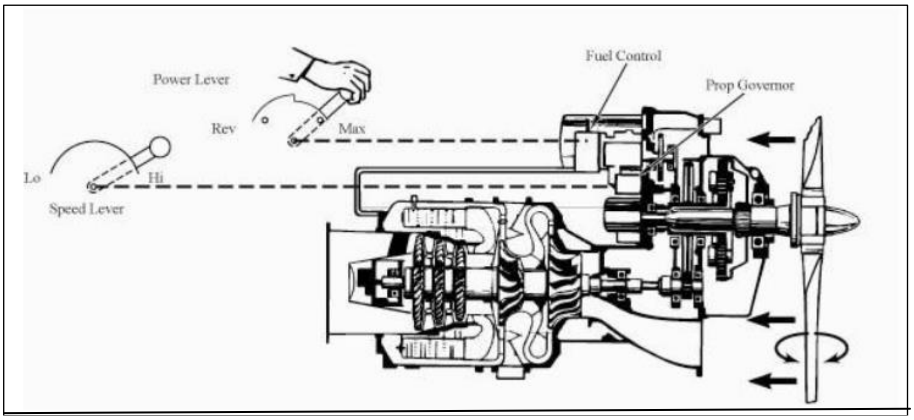


Figure 5. Engine levers. Photo: Honeywell.

Engine control with the RPM Lever and the Power Lever (Figure 5) is done in two operative modes:

1. "Beta Mode" - for controlling the engine when the aircraft is on the ground.
   In this mode, the engine RPM and propeller pitch change are in principle adjusted manually with the two levers. The propeller blade angle can be regulated so that negative thrust is achieved (reversing). In order to get into reverse, a mechanical catch on the Power Lever must be lifted and the lever pulled back.

2. “Propeller Governing Mode” - for controlling the engine during flight.
   In this mode, the engine RPM is set with the RPM Lever and the thrust with the Power Lever. Changes in thrust, when the RPM is constant, are achieved by changing the FF, Fuel flow, and via adjustment of the angle of the propeller blades. The adjustment is managed automatically by the Propeller Governor. The engine thrust is measured in Torque (Tq) in the propeller gearbox at FLIGHT RPM.

1.6.9 Power Management

During take-off and in flight, the RPM Lever must be set at a high engine RPM corresponding to a constant 96% – 100% RPM. In “Propeller Governing Mode”, the engine's thrust can only be controlled via the Power Lever, which affects the FF to the engine via a valve in FCU called the Main Metering Valve (MMV). If the FF increases, the Propeller Governor automatically regulates the angle of the propeller blades so that the engine thrust increases without any changes to the set RPM.

To avoid engine surge in connection with an increase in RPM and power output, there is a RPM-dependent regulatory function called the acceleration schedule. This schedule allows only a certain maximum FF to the engine, depending on the current RPM. The acceleration schedule is an integral part of the FCU.

1.6.10 Single Red Line System

The Single Red Line (SRL) System is a function that supports the pilots not to exceed maximum turbine inlet temperature during flight.

The engines Exhaust Gas Temperature (EGT) is influenced externally by several factors. The SRL System corrects the raw EGT signal to Compensated (or Conditioned) EGT, representative for the turbine inlet temperature, and is presented on an instrument in the cockpit.

The SRL System receives inputs from raw EGT, inlet temperature (T2), RPM, engine inlet total pressure (PT2) and burner static pressure (PS5). See Figure 6.

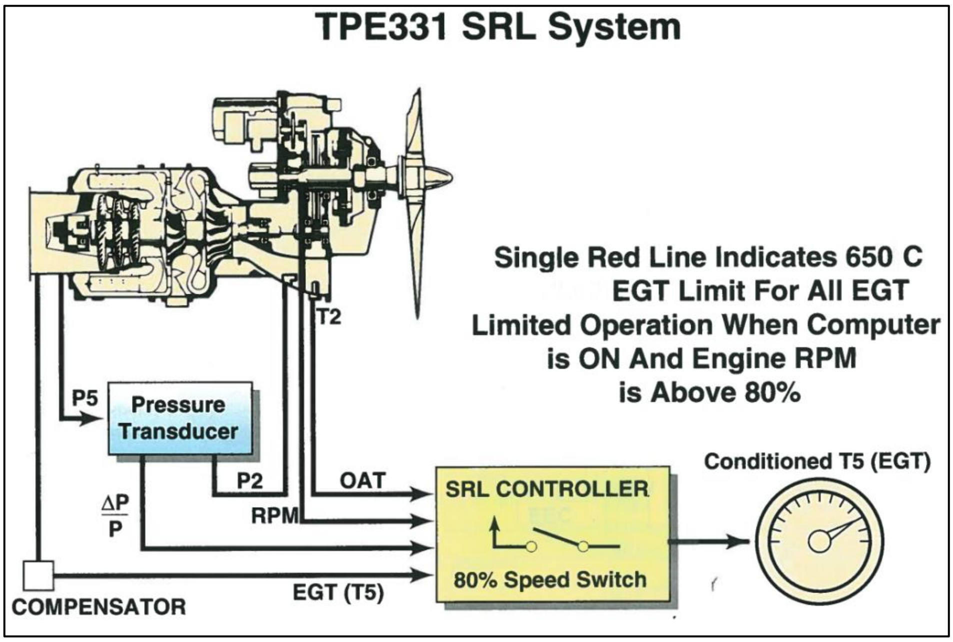


Figure 6. TPE331 SRL System. Photo: Honeywell.

1.6.11 Torque/Temperature Limiting System

This engine type is fitted with a system known as a Torque/Temperature Limiting (TTL) System, the purpose of which is to prevent Tq and EGT from exceeding their respective maximum permitted values during operation. The system consists of a control unit, T/T Limit Controller, which receives RPM, Tq, and Compensated EGT signals. If one or both of these maximum allowed values are exceeded, the FF to the fuel nozzles will be reduced via the Torque/Temp Limiter Assembly (Bypass Valve) thereby reducing Tq and EGT. The constant RPM is remained via the Propeller Governor. See Figure 7.

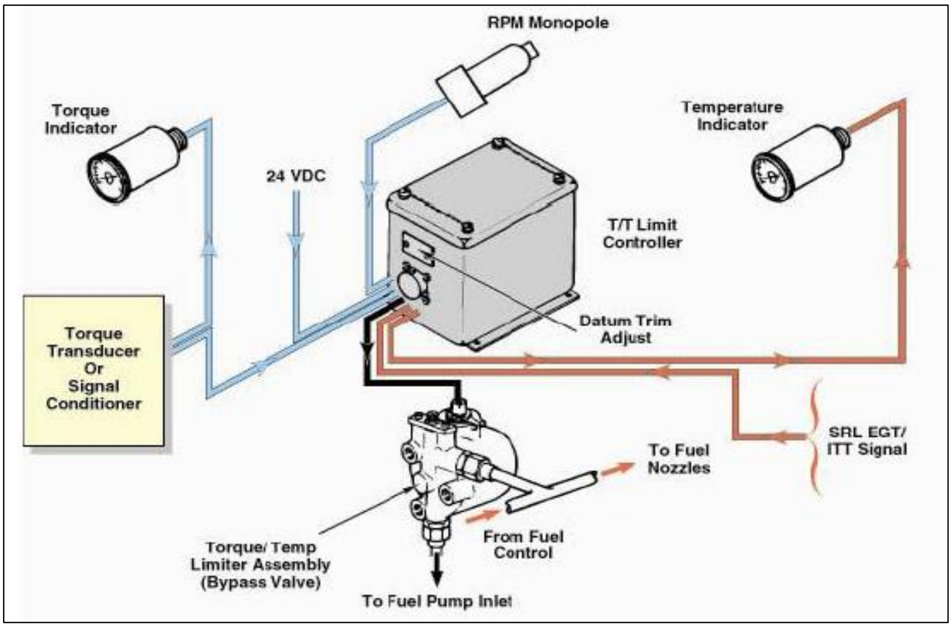


Figure 7. TTL System. Photo: Honeywell.

1.6.12 Propeller Synchronizing System

This aircraft type is fitted with a system for the automatic synchronization of the engine's RPM during flight (Propeller Synchronizing System). The purpose of the system is to avoid the occurrence of fluctuations in the sound from the two propellers during flight, which can be perceived as disruptive by those on board in the cabin. The system may not be used during take-off and landing and can adjust the RPM by a maximum ± 0.5% RPM.

1.6.13 Manuals and operative routines

The manual on hand at an airline, which pilots can primarily consult regarding operational flight related questions, is known as OM-B - Operating Manual B. In AVIES' manual structure, OM-B in turn refers to four underlying documents (see also Figure 8).

- Manufacturer's manuals.
- MEL - Minimum Equipment List (a document which shows the lowest level at which the aircraft can be operated, in terms of equipment).
- QRH - Quick Reference Handbook
- S.O.P - Standard Operating Procedures.

The manufacturer's manuals are in turn composed of a number of different manuals;

- AFM - Aircraft Flight Manual.
- MOM 1 - Manufacturers Operating Manual 1.
- MOM 2 - Manufacturers Operating Manual 2.
- MOM 3 - Manufacturers Operating Manual 3.
- M.MEL – Master Minimum Equipment List.

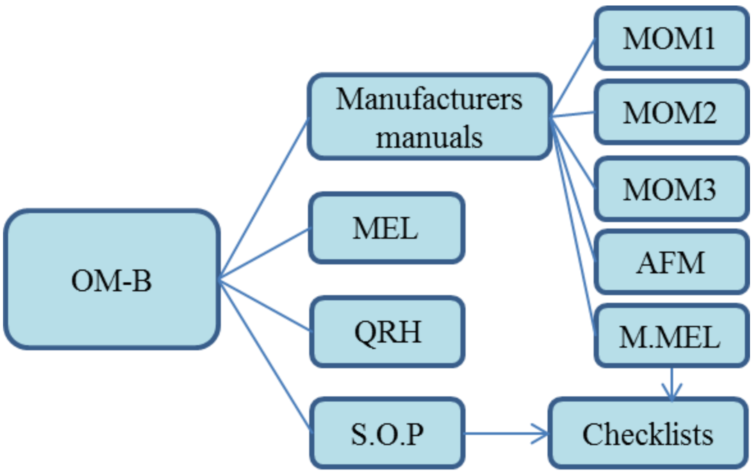


Figure 8. AVIES manual structure. Source: AVIES OM-B.

During the course of the investigation, it has been of interest to investigate what support the pilots had in the manuals in terms of instructions for how to use the RPM Levers. In a comparison of four different texts, to which AVIES refers its pilots, it is clear that there is a lack of consistency in their instructions. SHK has summarised the differences between the texts in a table in Figure 9. It is primarily the differences in the "Before Take-Off" phase that are of interest. Some of these different designations are also to be found in the AFM.

Phase of the flight.	AFM.	MOM1.	S.O.P from OM-B rev 2.	Checklist.
Before engine start	Taxi	Taxi	SET	SET
After engine start	-	-	-	-
Taxi	-	-	Taxi position	-
Before Take-Off	Fully advanced	Fully advanced	HIGH or FLIGHT	Max

Figure 9. Table of terms

In practice, pilots, irrespective of airline, follow the operational flight routines and procedures found in the S.O.P, Standard Operating Procedures. Normally, this text is also available as a separate document so that it is easily accessible to the pilots both during normal operations and during training.

1.6.14 AVIES S.O.P for the take-off in question

According to AVIES' S.O.P, it was the co-pilot's task to carry out certain measures according to the checklist prior to take-off. These included setting the RPM Levers to HIGH. It is clear from the document that the company uses two different terms for this procedure. Initially it is referred to as HIGH, but later in the instructions the term FLIGHT is used. Irrespective of the term used, AVIES' S.O.P states that the measure is to achieve an RPM of 96% on both engines when the Power Levers are in ground idle.

Once the co-pilot has announced that he/she has gone through all points on the checklist and take-off clearance has been received, the commander will announce that he/she intends to commence take-off by saying "rolling". In connection with this, the co-pilot is to confirm that the RPM reads 100% as a result of the increased throttle. Where necessary, he/she will thereafter adjust the throttle to the pre-determined and desired torque. The co-pilot continues thereafter, and throughout the take-off, to monitor the instruments in order to ensure they are displaying normal values.

According to information from the crew, this procedure was followed during the take-off in question, which was otherwise performed in accordance with the S.O.P.

1.6.15 Emergency checklist

The emergency checklist for the J32 is referred to as the QRH (Quick Reference Handbook) and is the document from which pilots obtain instructions and information in emergency or abnormal situations with the aircraft. The QRH for the situation in question contains procedures and measures in the event of malfunction, for all of the aircraft's systems.

Some of the procedures are “memory items”, which means that the pilots must know them by heart. There are a number of procedures in the checklist for J32 which are wholly or partly classed as memory items. For cases of oscillating thrust on one or two engines, there is a list of measures under point 8.1 of the operator's QRH - see Figure 10. The measures are divided into procedures for “Erratic Torque/EGT” and procedures for “Erratic RPM”. Neither of these procedures are however marked as “memory items”.

During the incident in question, the commander stated that he checked the RPM, reduced the power and shut off the TTL system. The commander said that his experience of this aircraft type was the reason why he took these measures.

ERRATIC ENGINE INDICATION 8.1

<u>ERRATIC TORQUE/EGT</u>

BOTH RPM LEVERS…………………FULLY FORWARD

AFFECTED POWER LEVER………...RETARD

PROP SYNC ……………………OFF

TTL ……………………………………OFF

MONITOR TORQUE AND EGT AND ENGINE RESPONSE.

IF SITUATION DETERIORTES OR IF TORQUE FLUCTUATIONS EXCEED ± 7.5% (15% TOTAL) AND IS CONFIRMED BY AIRCRAFT RESPONSE.

FEATHER LEVER…………………… TURN/PULL

PROCEED TO EMERGENCY DRILL: ENGINE FAILURE OR IN-FLIGHT SHUT DOWN

ERRATIC RPM 8.1

IF RPM FLUCTUATIONS EXCEED ± 7.5% (15% TOTAL) AND IS CONFIRMED BY ENGINE NOISE:

PROP SYNC…………………………………..OFF
FEATHER LEVER……………………………TURN/PULL

PROCEED TO EMERGENCY DRILL: ENGINE FAILURE OR IN-FLIGHT SHUT DOWN

Figure 10. Except from QRH.

1.7 Meteorological information

According to information from the airport: Wind 100°, 02 kts, CAVOK, temperature/dewpoint -4/-9 °C, QNH 1016 hPa.

There was no precipitation in connection with the event or during take-off. As the aircraft was parked in the hangar overnight, there was no reason to perform de-icing. The manoeuvre area was clear of ice and snow. The runway had good braking values.

1.8 Aids to navigation

Not applicable.

1.9 Communications

SHK has reviewed the communication between the aircraft's crew and the air traffic controller. Communication that is of interest for the investigation is shown in the table below.

Tid	Station	Kommunikation
05:21:50	ES-PJR	Avies 2071, mayday, mayday, mayday. Left engine is not working properly. We are coming back for landing now.
05:21:59	Tornet	Avies 2071 copy that. You are on one engine now?
05:22:04	ES-PJR	Negative (only) not working properly.
05:23:30	Tornet	Avies 2071, just to clarify. Do you declare an emergency?
05:23:36	ES-PJR	Affirm, Avies 2071.
05:23:39	Tornet	Avies 2071. And fire and rescue is standing by and I will alert the external forces.

Figure 11. Table showing selected parts of the communication between ES-PJR and the tower.

1.10 Aerodrome information

The airport had operational status in accordance with the Swedish AIP[10].

1.11 Flight recorders

1.11.1 Flight Data Recorder (FDR)

The aircraft was equipped with a FDR of type Fairchild F1000 with the capacity to record up to 19 different parameters. Information from the last 25 recorded hours is saved digitally in a protected memory unit.

[10] AIP (Aeronautical Information Publication).

Data from the flight in question has been recorded and saved. An analysis of this information revealed that the operator was missing necessary and mandatory documentation to convert the digitally saved information into engineering units. When using the standard documentation provided by the aircraft manufacturer it also turned out that some parameters showed unrealistic values which were initially unusable.

SHK has been unable to obtain the required documentation for this conversion. To use the available FDR information on the engines' RPM and Tq during flight, a special correction-polynomial for these parameters has been developed. Using this, the original and partly inaccurate FDR readings could be corrected to relevant performance information. The approach to producing this table is reported in section 1.16.3.

With the use of this table, the below graph (Figure 12) has been produced. It shows the engines' RPM and Tq from taxiing prior to take-off until landing.

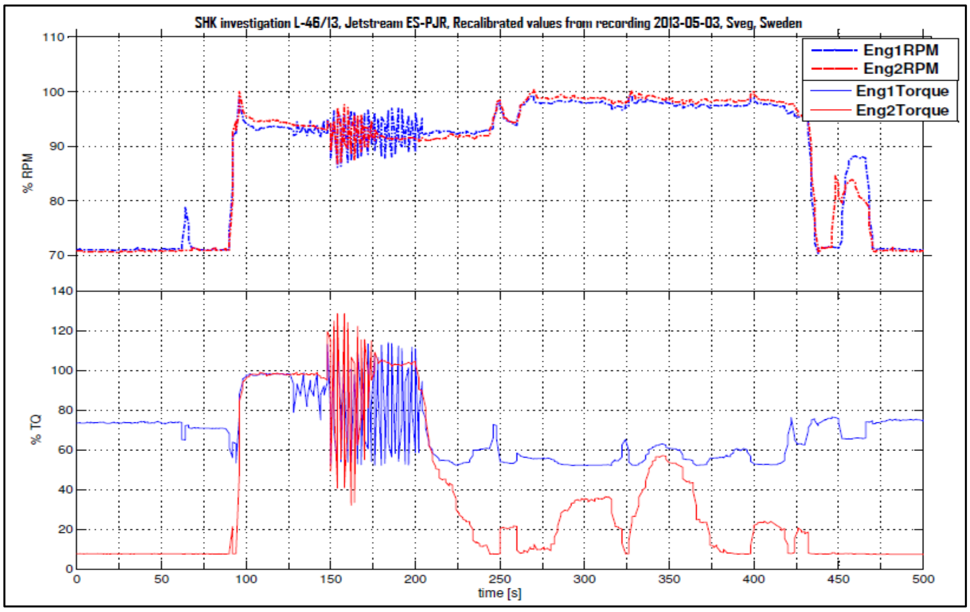


Figure 12. FDR printout of corrected RPM and Tq.

The graph shows that the RPM of both engines, at a time of roughly 90 seconds, increased from idle RPM - around 72% - to a maximum value of around 100%, to then reduce to around 95%. Thereafter, the RPM slowly decreased to around 94%. The RPM of the left engine followed roughly the same profile but was somewhat lower.

At around 125 seconds, both RPM and Tq began to oscillate on the left engine. After around 35 seconds, the amplitude of the oscillations increased considerably whilst similar oscillations of both RPM and Tq began on the right engine.

At around 210 seconds, the oscillations ceased in both engines and the RPM stabilised at around 93% whilst Tq decreased considerably.

1.11.2 Cockpit Voice Recorder (CVR)

The aircraft was equipped with a CVR of type Fairchild A100A. The sound picked up by microphones in the cockpit was recorded and saved on a protected magnetic tape. The tape consists of a closed loop with 30 minutes' recording time. All sound recorded from the flight in question was however overwritten as the power supply to the sound recorder was not turned off following completion of the flight.

Section 11 of the OM-A[11] contains instructions for both pilots and maintenance personnel to cut the power supply to the aircraft's CVR in the event of an incident deemed to be “serious” in order to avoid stored information being recorded over the next time the unit is powered up.

During the incident in question, the take-off was recorded by a passenger on their mobile telephone. Apart from the film sequence, the recorded sound has been used by SHK for analysis of certain parts of the sequence of events

1.12 Site of occurrence

The incident occurred east of Sveg Airport, following take-off from runway 09, in the approximate position N62025, E01425 and at an altitude of around 500 feet (150 metres). Landing was performed without further problems on runway 09 after around six minutes' flying.

1.13 Medical and pathological information

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

1.14 Fire

There was no fire.

1.15 Survival aspects

A situation involving engine disruptions on both engines immediately after take-off is a very serious event. The aircraft was relatively heavily loaded and in a low speed area. The area around the airport offers no suitable places for a controlled emergency landing.

1.15.1 Rescue operation

Provisions on rescue services are found primarily in the Civil Protection Act (2003:778, Swedish abbrev. LSO) and the Civil Protection Ordinance (2003:789, Swedish abbrev. FSO).

According to Chapter 1, Section 2, first paragraph of LSO, the term “rescue services” denotes the rescue operations for which central

[11] OM-A (Operations Manual A).

government or municipalities shall be responsible in the event of accidents and imminent danger of accidents in order to prevent and limit injury to persons and damage to property and the environment. Central government is responsible for mountain rescue services, air rescue services, sea rescue services, environmental rescue services at sea, and rescue services in case of the emission of radioactive substances and for searching for missing persons in certain cases. In other cases, the municipality concerned is responsible for the rescue services (Chapter 3, Section 7, LSO).

Just after take-off, a call of “MAYDAY MAYDAY MAYDAY” was announced from the aircraft. The crew reported to the air traffic controller in the tower (TWR[12]) that they had problems with the left engine and intended to return to the airport. The air traffic controller alerted the airport's rescue services, using an alert signal, of the risk of an accident, and a fire service vehicle with personnel readied themselves at a predetermined location.

The air traffic controller called SOS Alarm in accordance with the checklist and requested a three-party conversation with the Swedish Maritime Administration's JRCC[13]. During the telephone call, the aircraft landed as normal and taxied to the airport terminal without difficulty. No rescue operation was required and the alerting of additional rescue services was aborted.

ELT[14] of type PN: 500-12Y was not activated in connection with the incident.

1.16 Tests and research

1.16.1 Technical investigation

After the incident, a technical inspection of the aircraft was carried out in the presence of investigators from SHK. The investigation began with the test-run on ground. No fault or anything else abnormal could be noted. The aircraft was thereafter investigated by a certified technician with the intention of finding any technical faults or shortcomings that could have affected the sequence of events. During the investigation, corrosion damage was noted in the aircraft's tubing, see Figure 13.

[12] TWR (Aerodrome Control Tower).
[13] JRCC (Joint Rescue Coordination Centre).
[14] ELT (Emergency Locator Transmitter).

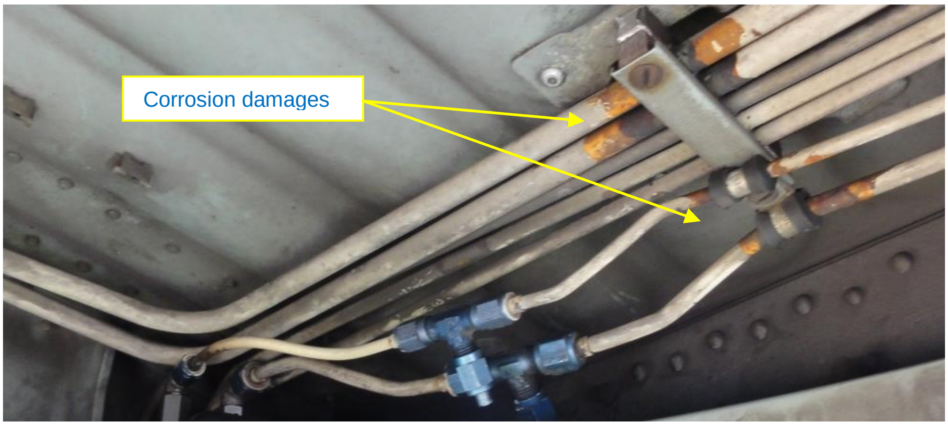


Figure 13. Area in the aircraft's tubing where corrosion was found.

The tube connection for total air pressure at the inlet for both engines (PT2) was damaged. The pipe to the left engine was severed and provisionally repaired with a piece of rubber tubing. The tube to the right engine was leaking at one connection. When the connection was loosened, the tube burst as a result of corrosion, see Figures 14 and 15.

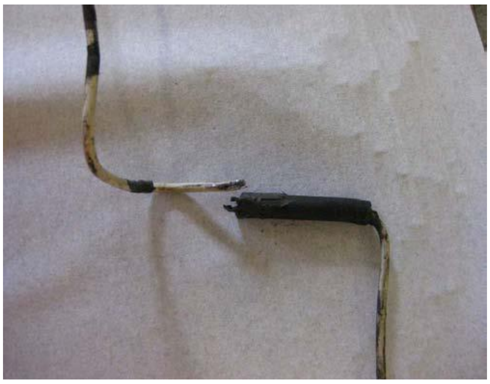


Figure 14. PT2 tube to the left engine.

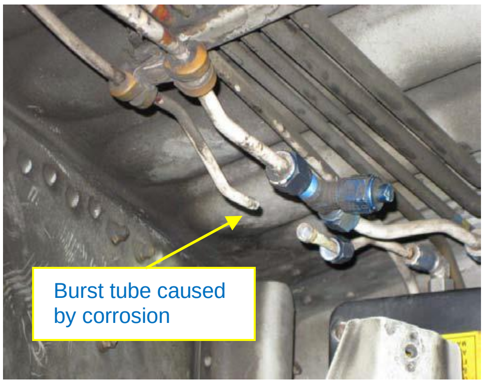


Figure 15. PT2 tube to the right engine.

It was also established that the pipe connections for the static air pressure at both engines' outlets (PS5) were leaky and that the tube contained a certain amount of water. No other defects were established at the time.

SHK has analysed the damage and their potential effect on the event. The analysis is reported in section 1.16.10.

1.16.2 Analysis of engine noise

The sequence of events and the landing were filmed by a passenger who sat in a window seat by the left engine. The take-off sequence comprises the aircraft's positioning on the runway for take-off and the initial take-off sequence until the oscillations in RPM begin. The landing includes the final landing itself as well as engines shutdown.

The footage also contains a clear recording of the engine/propeller noise. With the intention of gaining information on the engines' RPM, SHK has analysed the recorded engine noise at a sound lab. The analysis reveals that the noise has a key note (main frequency) which is largely attributable to the pulses of airflow that occur when the propeller blade tips (four per engine) pass the aircraft body.

The key note is measured in Hertz (Hz). Via the key note of the recorded sounded, the actual propeller RPM can be calculated using the formula: RPM = (Hz/4)*60. An RPM of 1591 corresponds to 100% RPM on the engine instruments in the cockpit.

The below spectrogram (Figure 16) shows the fundamental tone of the recorded propeller sound during 100 seconds of the take-off sequence.

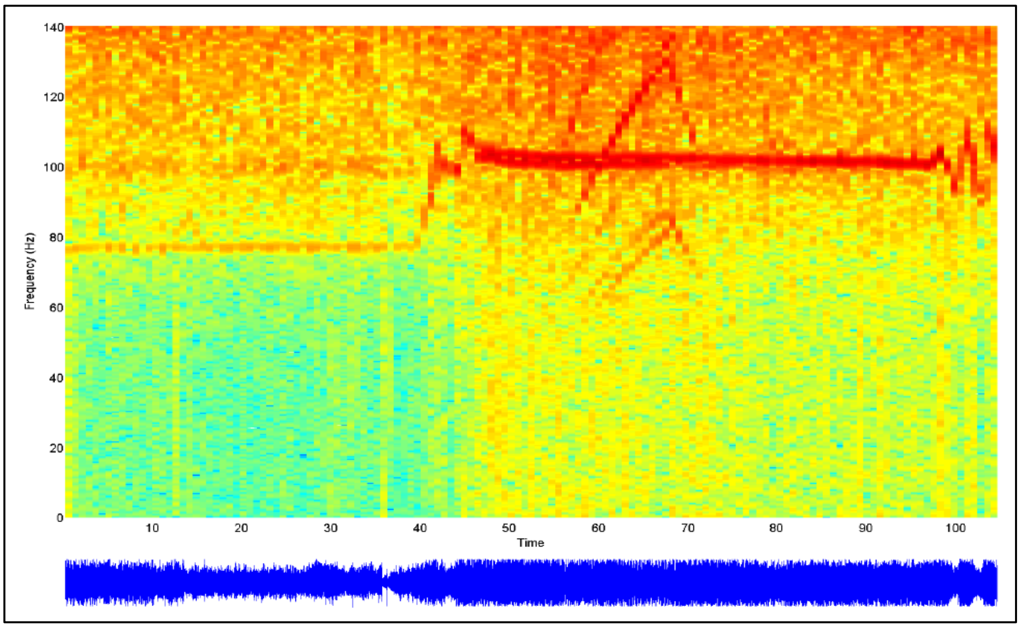


Figure 16. Spectrogram of the propeller noise during the take-off sequence.

The spectrogram shows a key note (or two almost simultaneous key notes) whose frequency increased at around 40 seconds in, from approx. 77 Hz (1155 RPM, 73 %) to approx. 109 Hz (1635 RPM, 103 %) at around 46 seconds and after two seconds decrease to 102 Hz (1530 RPM, 96 %) There after continue until 97 seconds and then gradually decrease to approx. 100 Hz (1500 RPM, 94 %). At a time of around 100 seconds, the frequency began to oscillate with increasing amplitude.

The below spectrogram (Figure 17) shows the key note of the recorded propeller sound during landing.

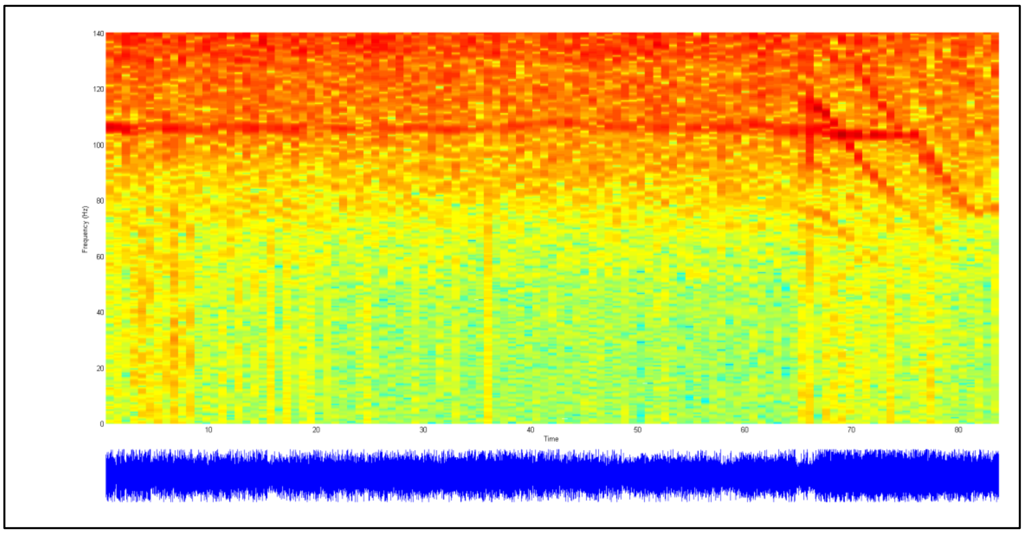


Figure 17. Spectrogram of the propeller noise during landing.

The spectrogram reveals a relatively even and stable key note of 106 Hz (1590 RPM, ~100%) which towards the end decreases quickly.

1.16.3 Correction of FDR data

The correction-polynomial FDR data used in this investigation has, in summary, been developed in accordance with the following:

The FDR unit in question was mounted back into the aircraft. Thereafter, the engines were run on the ground in accordance with a specially developed programme. The schedule for running the engines included a number of performance points within normal RPM and power ranges. In parallel with the recordings made by the FDR, a manual reading and documentation of the values displayed on the instruments in the cockpit was carried out for each performance parameter.

Following the engine run, these two recordings were compared and correction factors could be calculated for each performance parameter. These enabled a correction-polynomial for the entire operating range to be drawn up. By using this table to correct the FDR data downloaded from the flight in question, useful information on the engines' RPM and Tq has been obtained.

SHK is aware that this “practical” method of compensating for the missing documentation of the FDR system may have some errors, which has been taken into consideration in the analysis in section 2.

1.16.4 Fuel and oil analyses

Fuel from the aircraft's fuel tanks has been analysed in terms of the applicable specification for Jet A1. Oil from both engines has been analysed. The engines' oil and fuel filter has been removed and investigated. The work has been carried out by a material lab. Their final report is summarised below:

- All fuel samples fulfil the applicable specification for Jet A1 apart from the fact that the number of solid particles of both metallic and non-metallic material is somewhat higher than the applicable specification in three of the samples.
- Oil samples from both engines fulfil the normal specification for this type of aviation engine oil.
- Fuel filters from the engines show the presence of solid particles of both metallic and non-metallic material. The quantity of particles is deemed not to be so great that the fuel flow was limited, or that there was a serious loss of pressure across the filter.
- Oil filters from the engines show the presence of solid particles of both metallic and non-metallic material. The quantity of particles is deemed not to be so great that the oil flow was limited, or that there was a serious loss of pressure across the filter.

1.16.5 Previous cases with oscillations of RPM and Tq during take-off

When investigating an accident (NTSB report AAR-88/06) involving a Jetstream 31, which occurred on 26 May 1987 in New Orleans in the USA, it was established that during take-off the aircraft experienced severe oscillations in the engines' RPM and Tq. The pilots reduced power on both engines to idle and attempted to land on the remaining runway. The aircraft over ran the runway and left the confines of the airport with serious consequences.

In connection with the investigation of the incident, the engine manufacturer Garret (now Honeywell) and the aircraft manufacturer BAe performed an extensive analysis of the potential consequences if the take-off is performed with an RPM which is too low.

It was then clear that an imbalance can occur between the FCU and the Propeller Governor if the RPM is not sufficiently high when a high engine power is set. The results may include severe oscillations in RPM and the propeller setting and thereby in the engine's thrust (Tq).

As mentioned in section 1.6.9, the acceleration schedule allows a certain maximum fuel flow (FF) to the engine during acceleration at a given engine RPM. Under normal operating conditions, with the engine stable at a constant RPM, the FF is set by the Main Metering Valve (MMV) via the Power Lever. At 100% RPM there is a margin between the FF demanded by the Power Lever schedule and the maximum FF limit available from the acceleration schedule (the vertical dashed line at 100% RPM in Figure 18 below). The engine is operating in a stable mode in terms of engine power.

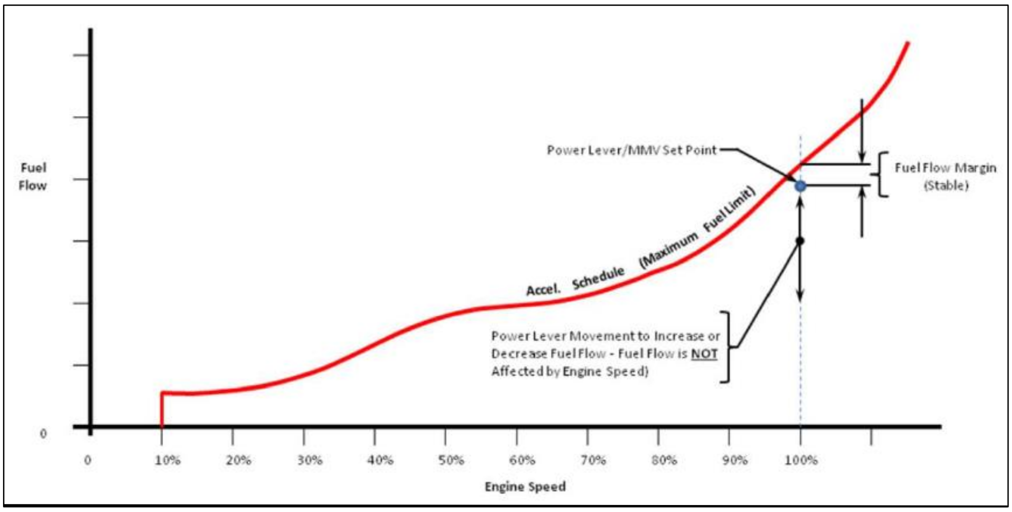


Figure 18. Stable operating mode. Photo: Honeywell.

If the RPM Lever is set to a position lower than 100% RPM the engine will have a stable operation as long as the Power Lever is advanced in a low or mid-power range. The MMV set point than is below the acceleration schedule, as illustrated as Point 1 in Figure 19 below. In this position there is space for the Propeller Governor to adjust for any variation of RPM away from the set point speed by adjustment of propeller blade angle.

If the Power Lever, at the same RPM, is advanced to take off power, as Point 3, the MMV set point will intersect the acceleration schedule as depicted by Point 2 and the FF will be reduced. Since the acceleration schedule is a function of RPM, any variation in RPM caused by the Propeller Governor will cause a variation in FF due to the acceleration schedule. As both the Propeller Governor and acceleration schedule compete to control the engine, via RPM or FF, an unstable operation, with oscillations in RPM and Tq, will occur.

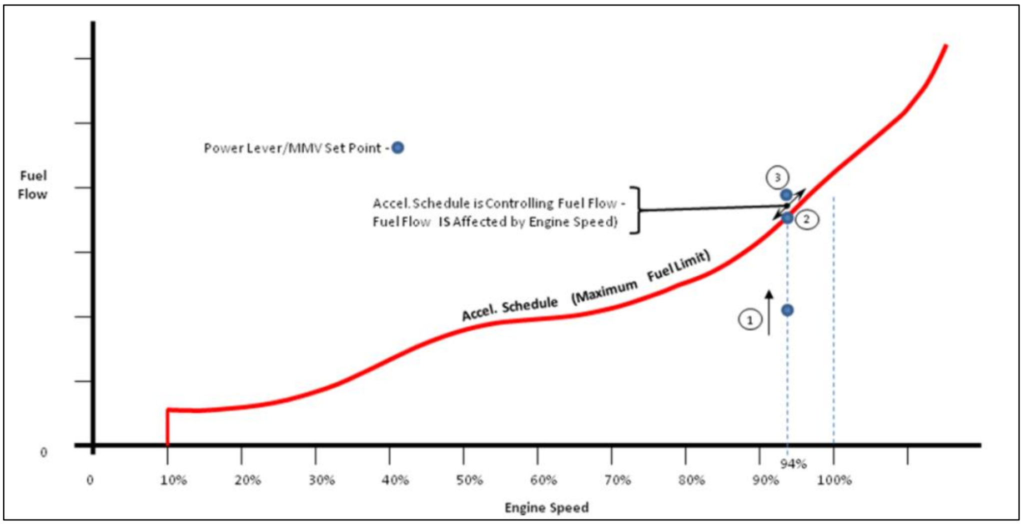


Figure 19. Unstable operating mode. Photo: Honeywell.

It is possible to re-establish a stable operating mode under the acceleration schedule if the RPM is set higher using the RPM Lever or if the engine power is set lower using the Power Lever.

If no changes are made, the oscillations continue and can activate the TTL system if the maximum permitted EGT or Tq values will be exceeded (see section 1.6.9). The TTL system will then more or less restrict the flow of fuel to the engine, which is thereby a contributing factor to the unstable operating mode.

The fact that this situation can occur has been verified in practical tests carried out by the engine manufacturer. It has then been established that such oscillations can in certain modes diverge and result in very severe oscillations in the engine's thrust.

As a result of these investigations the engine manufacturer has raised the lowest permitted RPM setting in Propeller Governing Mode during flight, from 94.5% - 95.5% to 95.5% - 96.0%.

1.16.6 Measures taken by the type certificate holder

Several cases of incidents of this type have been reported to the manufacturers over the years, who have clarified the operation of the RPM Lever as follows:

Manufacturers Operating Manual (MOM) – Normal Procedures Section:

- “Advance both RPM levers to the fully forward position. Observe the RPM increase to between 96% and 97%; 100% RPM will not be achieved until POWER levers are advanced. Verify RPM at 100%”.

Flight Manual - Limitations Section Take-off RPM:

- “Take-off with less than 100% RPM is not permitted”.

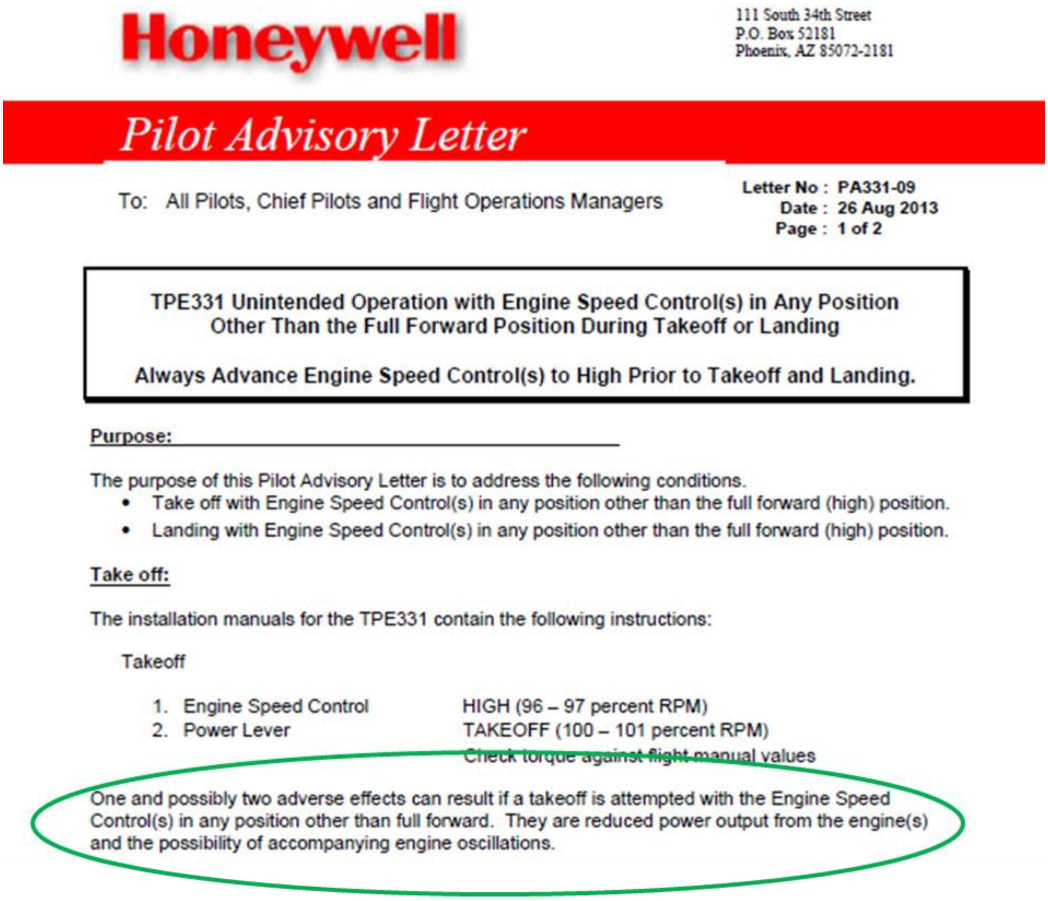
Flight Manual – Normal Procedures Section:

- “RPM levers…………………………… Fully advanced”.

TPE331 Engine Installation Manual:

- “CAUTION: ENGINE SPEED CONTROL LEVER MUST BE IN HIGH POSITION OR TORQUE FLUCTUATIONS MAY OCCUR”.

Following the incident in question, Honeywell has published Pilot Advisory letter No PA331-09 (Figure 20). The circled text is particularly important to note.



Honeywell

111 South 34th Street
P.O. Box 52181
Phoenix, AZ 85072-2181

Pilot Advisory Letter

To: All Pilots, Chief Pilots and Flight Operations Managers

Letter No : PA331-09
Date : 26 Aug 2013
Page : 1 of 2

TPE331 Unintended Operation with Engine Speed Control(s) in Any Position Other Than the Full Forward Position During Takeoff or Landing

Always Advance Engine Speed Control(s) to High Prior to Takeoff and Landing.

Purpose:

The purpose of this Pilot Advisory Letter is to address the following conditions.

- Take off with Engine Speed Control(s) in any position other than the full forward (high) position.
- Landing with Engine Speed Control(s) in any position other than the full forward (high) position.

Take off:

The installation manuals for the TPE331 contain the following instructions:

Takeoff

1.	Engine Speed Control	HIGH (96 – 97 percent RPM)
2.	Power Lever	TAKEOFF (100 – 101 percent RPM)
		Check torque against flight manual values

One and possibly two adverse effects can result if a takeoff is attempted with the Engine Speed Control(s) in any position other than full forward. They are reduced power output from the engine(s) and the possibility of accompanying engine oscillations.

Figure 20. Passage from Pilot Advisory Letter No PA331-09. Photo: Honeywell.

After the incident, the type certificate holder BAe Systems, sent out an information letter to all Jetstream operators in which they emphasized the information mentioned above.

1.16.7 *Spontaneous movement of the RPM Lever without the pilots knowledge*

When questioned by SHK, BAe has stated that it does not know of any cases in which the engine levers were reported to have moved spontaneously in any direction without the pilots' knowledge as a result of vibrations, low friction or similar. As the engines' levers have no mechanical connection with one another, BAe considers it unlikely that such a movement could occur at the same time on both levers.

1.16.8 *Incorrect engine configuration at take-off*

Besides the possibility for the pilots to read the engine instruments and physically check the setting of the levers, the aircraft type has no warning system which displays any configuration error during take-off. When questioned by SHK, BAe has stated that the possibility for the pilots to “notice” during the initial take-off sequence if the RPM Lever is not fully advanced is limited. The acceleration on the runway and the perception of this can of course be somewhat lower, but this is influenced by several other factors such as the aircraft's take-off mass, runway conditions, wind component in the take-off direction, etc.

According to the European certification rules, (CS 23), for small transport aircraft, there are no requirements regarding warning systems for incorrect configuration in take off. In the category large transport aircraft, (CS 25), these systems are mandatory. Jetstream 31/32 are certified according to CS 23.

1.16.9 Propeller Synchronizing System

When asked by SHK, BAe has stated that it is unaware of any cases in which the engines' Propeller Synchronizing System is said to have caused oscillations in the engines' thrust that affected the flight. The system can only affect the engines' RPM by a maximum ± 0.5%, which is considered too low to have any impact in this respect.

1.16.10 Potential consequences of defective PT2 and PS5 tubing

On SHK's commission, Honeywell has performed an extensive impact analysis regarding whether the established leaks in the PT2 and PS5 tubes and the presence of water in the PS5 tube to the engines may have had an impact on the sequence of events. The analysis, which was verified by the aircraft manufacturer and SHK, has produced the following results:

- The effect of the leakage in the PT2 and PS5 tube on the function of the TPE331 SRL System and SRL-EGT during the circumstances in question was non-existent or negligible.
- The effect of the leakage in the PT2 and PS5 tubes on the function of the TTL System during the circumstances in question was non-existent or negligible.
- No other functions in the engines are deemed to have been affected by the defective PT2 and PS5 piping and thereby contributed to the engine disruptions.
- In summary, the defects in the PT2 and PD5 tubes are deemed not to have affected the sequence of events.

1.16.11 Interviews with the crew

The interviews SHK has held with the crew are the basis of the sequence of events presented in section 1.1. Both pilots considered themselves to be well rested prior to the flight and did not feel any fatigue when their flight duty began.

Both the commander and the co-pilot have stated that procedures and measures during take-off were followed and carried out in accordance with the S.O.P, and that the RPM Levers were in the correct position, i.e. HIGH.

The crew has also explained that they have not observed anything abnormal or that any malfunctions were noted before or during the take-off itself. The rotation and initial climb had been carried out in accordance with prescribed routines and no deviations regarding the engines' function - or the aircraft in general - had been observed.

The engine disruptions had therefore come as a complete surprise for both pilots. Due to the critical flight phase when the incident occurred - low altitude and low speed - the commander deemed it inappropriate to use any checklists. He considers the measures he took to be based on experience.

Due to the layout of the surrounding terrain, the commander made the assessment that there was no other alternative than to attempt to return to the field for landing. Despite the serious situation, both pilots felt that the cooperation in the cockpit was good during the engine disruptions, and that calmness could be maintained in the cockpit for the duration of the six minute-long flight.

1.16.12 Simulator tests

SHK has carried out operative tests in a Jetstream simulator. The purpose was to test different scenarios, with similar circumstances, which could have affected the sequence of events. The tests also gave SHK the possibility to gain greater insight into the aircraft type in general and its performance in various situations. Furthermore, they provided a picture of how the crew may have perceived the event and the difficulties that arose.

There is no guarantee that a simulator will perform like a real aircraft in all situations. Nor is it possible to recreate all of the scenarios or establish with any certainty that the malfunctions tested in a simulator would produce the same results in reality.

A large number of take-offs were performed, all with external factors as similar as possible to those in the event in question. In the simulator, take-off with a correctly rigged engine could be carried out even if the RPM levers were in the *taxi* position, i.e. producing a minimum 96% as soon as the throttles are put into *flight idle*. The test for this showed no appreciable or negative effect on take-off. The software in the simulator did not allow for the occurrence described in section 1.16.5, with oscillations during take-off with an RPM which was too low, to be programmed in for a test flight.

The scenario which was close to identical with the event in question was when the signal from the SRL system to the EGT indicator failed. The oscillations in RPM and torque which then occurred corresponded to the crew's description of the event in question. The yawing, directional changes, reduced acceleration and difficulties maintaining altitude that arose could be likened to what happened to the aircraft on 3 May in Sveg. No faults or malfunctions have been established in the SRL system on the aircraft in question, however.

For natural reasons it was not possible to perform a check to determine the likelihood of any spontaneous movements of the RPM levers.

1.17 Organisational and management information

1.17.1 General

AS Avies is an Estonian airline whose registered office is in Tallinn. The company was founded in 1991 and conducts flight operations of both regular and non-regular nature. The non-regular traffic consists mainly of charter flights and air taxi and is operated using smaller jet aircraft of the types Hawker and Learjet.

The regular traffic consists of scheduled services in various countries and is operated using aircraft of the type Jetstream 31/32. In Sweden, the company operates a number of routes, including Sveg – Stockholm/Arlanda, for the Swedish company Avies Sverige AB, which acquired the traffic rights on these routes following a tender procedure.

1.17.2 Public tender of air traffic

The basic principle within the EU is that all Community air carriers are entitled to freely exercise traffic rights on all air routes within the Union. The principle is established in article 15(1) of *Regulation (EC) No. 1008/2008 of the European Parliament and of the Council of 24 September 2008 on common rules for the operation of air services in the Community (Recast).*

A departure from the principle of the right to freely operate air traffic concerns routes being considered vital for the economic development of a particular region and which are not possible to operate solely on the basis of usual commercial interests. For such routes, as provided for in Article 16 of the same Regulation, a public service obligation may instead be imposed. This means, in so far as is relevant in this case, that a single air carrier is awarded the exclusive right to operate air traffic on the route in question. An exclusive right of this kind must be offered through a public tender procedure (Articles 16 and 17 in the Regulation).

Air traffic on the route in question between Sveg and Stockholm/Arlanda is not operated on the usual commercial basis. Instead, a public service obligation applies on the route. The airline *Avies Sverige AB* has been awarded the exclusive right to air traffic following a public tender procedure. The authority responsible for the tender is the Swedish Transport Administration. Avies Sverige AB has in turn engaged the Estonian operator *AS Avies* to conduct air traffic as a subcontractor.

1.17.3 Operational prerequisites

A prerequisite for a company to be allowed to operate air traffic within the EU is that it holds an operating licence. Under Article 4 of Regulation 1008/2008, the company is entitled to obtain an operating licence if it holds a valid AOC[15]. An issued AOC certifies that the company has the professional ability and organisation to ensure the safety of operations. In order to obtain the operative licence, it is furthermore required that the company demonstrates that it has access to aircraft and that the company, and the persons behind it, meet certain requirements with regard to insurance and good repute, including not having been declared bankrupt, and other financial conditions.

An operating licence is issued by the competent authority of the EU country in which the company is registered. From Article 15(2) of the Regulation follows that a Member State may not subject a Community air carrier that holds an operating licence and an AOC to any further licensing requirements to be allowed to exercise air traffic within the Union. Under Article 6 of *Council Regulation (EEC) No 3922/91 of 16 December 1991 on the harmonization of technical requirements and administrative procedures in the field of civil aviation,* Member States shall recognise such certifications issued by another Member State in respect of legal and natural persons engaged in, among other things, the operation of aircraft.

At the time of the Swedish Transport Administration's tender procedure for air traffic on the route in question, AS Avies held a valid operating licence and AOC issued in accordance with EU law. Thus there was no basis for the Swedish Transport Administration to undertake additional controls or place other demands on the company from a safety perspective.

1.18 Additional information

1.18.1 Provisions concerning FDR and CVR

Commission Regulation (EC) No 859/2008, also known as EU-OPS, states in OPS 1.160 – Preservation, production and use of flight recorder recordings – that

> *When a flight data recorder is required to be carried aboard an aeroplane, the operator of that aeroplane shall:*
>
> *[---]*
>
> *ii) keep a document which presents the information necessary to retrieve and convert the stored data into engineering units.*

In Annex 6 of the Chicago Convention, attachment D. Flight recorders, the following is stated under point 1.3.4:

> *Documentation concerning parameterallocation, conversation equations, periodic calibration and other*

[15] AOC (Air Operator Certificate).

serviceability/maintenance information should be maintained by the operator. The documentation must be sufficient to ensure that accident investigation authorities have the necessary information to read out the data in engineering units.

1.18.2 Measures taken

Owing to the shortcomings established to exist on the operator's end in this investigation - see section 1.16.1 - as well as shortcomings established in another SHK investigation concerning the same operator (see SHK's report RL 2014:01, File number L-38/13), the authority has made the decision to call attention to these shortcomings via a letter to the Estonian and Swedish civil aviation supervisory authorities respectively.

The letter contained a safety recommendation to both supervisory authorities; to conduct a complete operational and technical audit of the operator in question, whether individually or in collaboration. In this context, it should be mentioned that it is the Estonian authority – as the body responsible for issuing the operator's AOC – which has supervisory responsibility for the company. The Swedish Transport Agency has no supervision responsibilities but is able to check parts of the safety and quality of operations via, e.g. SAFA[16] inspections.

The concerned supervisory authorities' response to SHK can be summarised as followed:

The Estonian supervisory authority has instructed the operator to improve its safety programme and to appoint a Flight Safety Programme Manager for the company's flight operations. Together with a representative of the Swedish Transport Agency, the authority's technical division has also carried out an audit on one of the operator's technical bases in Sweden. In addition to this, the authority has also stated that the operator is being watched more closely and that the development of the prescribed safety programme will be followed carefully.

The Swedish Transport Agency has initiated a dialogue with the Estonian supervisory authority owing to the safety recommendation issued by SHK, and has also called attention to the shortcomings in a meeting with the European Commission's ASC[17]. As mentioned, the Swedish Transport Agency has also participated in a technical audit at one of the operator's technical bases in Sweden. The authority has also stated that in 2012 it carried out a number of SAFA inspections on the operator, which resulted in high load factors.

[16] SAFA (Safety Assessment of Foreign Aircraft).
[17] ASC (Air Safety Committee).

1.19 Special methods of investigation

Not applicable.

2. ANALYSIS

2.1 Operational

2.1.1 Flight conditions

The external conditions were good, with a clear and cold morning with no precipitation or contamination of the manoeuvre area. The aircraft had been parked in a hangar overnight, meaning de-icing was unnecessary. According to the crew, there was also nothing else out of the ordinary or that could have disrupted their procedures to such an extent that it would constitute a risk of impairment to their attention.

There were no technical remarks noted in the aircraft's logbook. The aircraft had been fuelled prior to take-off, but the oil and fuel analysis carried out does not indicate any contamination or anything else which could have affected the functioning of the engines.

The commander stated that he had carried out an external inspection of the aircraft prior to take-off and did not notice anything abnormal. SHK therefore assumes that the commander assessed the aircraft to be airworthy from a technical viewpoint for the flight in question.

2.1.2 The pilots' situation

The crew were at the end of a long period of service. Both pilots had carried out flight duties for a number of consecutive days prior to the event but felt, according to their statements, well rested on the day in question.

The commander, also an instructor for the airline, with over 3 000 hours on this aircraft type, can be said to have had a great deal of experience on this aircraft type. The co-pilot, who was fairly recently employed by the company, had less experience on this type. As this aircraft type is normally used for shorter flights, the pilots perform many take-offs and landings.

The interviews revealed that the cooperation between the pilots worked well and that there were no deviations from the company's operational routines, neither at this time nor during previous flights together.

Overall, SHK believes that the pilots' ability to carry out this flight were good.

2.1.3 The flight

Based on the facts that arose in section 1.16.5, SHK establishes that the RPM was most likely too low during take-off. Whether or not this was caused by the RPM Lever not being set at max level for take-off, or by a spontaneous backward movement of the lever of its own accord, cannot be established. The information provided by the manufacturer concerning spontaneous movements (see section 1.15.6) indicates, however, that this scenario is unlikely.

As previously mentioned, the J31/32 does not feature a warning system that could have prevented this situation at an early stage. According to the procedure, the pilots are intended to ensure the correct RPM and torque values are obtained, but they have limited opportunity to detect deviations such as if the RPM lever was not in the correct position. This limitation has also been highlighted by the aircraft manufacturer. SHK comes back to this matter in section 2.4.1.

The crew have stated that the standardised procedures in S.O.P. have been followed. The investigation has not had the necessary facts to assess this information.

2.1.4 The incident

Assessing the degree of severity of an incident is always subjective to some extent. Pilots in commercial aviation are always trained in handling engine failure during their regular competency checks. This training normally focuses on the most critical phases of a flight – take-off and initial climb. Training in failure of and oscillations in *both* engines is however not normally included in the training, as the likelihood of such situations is extremely low.

The commander stated that there were great difficulties controlling the aircraft and keeping it in the air during the minute in which the oscillations took place. Both pilots also explained during the interviews that during certain stages, they believed they would have to perform an emergency landing on the underlying terrain. SHK can establish that the physical stress on the crew at this moment was likely very high.

A situation involving an aircraft which is difficult to control, with oscillations on both engines, which the pilots are not specifically trained for, is a situation which can easily lead to the wrong decision and rash actions. According to concordant information obtained in the interviews, however, calmness was maintained in the cockpit during the incident and the decision to attempt a turnaround to head back to the airport to land may be considered to have been well motivated, considering the circumstances.

The commander took certain measures when the oscillations occurred, including a reduction of the power and disconnection of the TTL system. It has however not been possible to evaluate whether these had any effect on the rest of the sequence. Once the oscillations ceased, a normal landing could be performed.

2.2 Recording of sound and flight data

2.2.1 Flight Data Recorder – FDR

According to the provisions of EU-OPS, an operator of aircraft - where a Flight Data Recorder is required - must also be able to provide documentation concerning the conversion of information stored in the FDR into engineering units. These requirements have come about so as to enable the investigating authorities to examine and analyse incidents and accidents in commercial aviation in a suitable format, with the purpose of improving flight safety.

The requirement must be considered to entail that the operator is responsible for ensuring the recorders featured in the operated aircraft are continuously maintained and calibrated so that the investigative authorities are able to read off correct information at any time.

As described in section 1.10.1, SHK was able to establish that mandatory documentation, necessary to convert the digitally recorded information to engineering units, was missing by the operator.

In investigations which include different types of system failures, it is of the utmost importance that SHK is allowed access to correct data in order to perform a reliable analysis of the sequence of events and malfunctions. The present case involving engine failure is an example of an incident in which data from the FDR can be considered the single most important fact to the investigation.

SHK has however been able to correct selected FDR data manually since the FDR unit was mounted back into the aircraft. The reference values which were obtained in this manner have since been used in the investigation in order to correct the initial values read. The analysis of these values cannot be guaranteed to constitute a factual basis which is precise in every way, but has a high degree of reliability so that it can be used in the investigation.

It should also be noted that in order to perform corrections of the obtained values, the FDR unit and aircraft must be intact. In the event that the aircraft is destroyed, this measure would not have been possible, or would at least have been made considerably more complex. In summary, SHK deems the lack of documentation to enable the reading of correct FDR data to be a major shortcoming on the part of the operator.

2.2.2 Cockpit Voice Recorder – CVR

It has been established that the Cockpit Voice Recorder on the aircraft in question was fully functional at the time of the event. It has not been possible, however, to obtain information from the time of the incident due to the unit not being shut off and the information thus being recorded over.

SHK considers it to be a major shortcoming on the part of the operator that existing routines for shutting off the unit – thereby securing the content – were not followed in connection with this incident. The information stored on this unit is normally an essential means of support for the investigation, partly in order to verify the crew's statements. It would be beneficial to include instructions to the crew in suitable manuals and documents to shut off the unit immediately after landing in the event of an incident.

2.3 Technical

2.3.1 General

In connection with the incident, SHK has carried out only a limited investigation of certain parts and systems on the aircraft in question. The discovery of corrosion and prohibited service actions discovered during this limited inspection – combined with other established shortcomings – have constituted grounds for the recommendation sent by SHK to the concerned supervisory authorities; see section 1.18.2.

2.3.2 The incident

In connection with take-off, severe oscillations of the power occurred in both engines at low altitude, which entailed a serious flight safety risk.

No technical fault which could explain the engine oscillations has been found. Neither the defects established in some of the piping (see section 1.16.1) nor the pollutants found in the fuel and oil filter are deemed by SHK to have had any significance in this context. It is unlikely that there would have been temporary external conditions of some sort that affected the function of the engines during take-off. According to SHK's experience, both engines have also functioned after the incident, with no remarks.

SHK establishes that the sequence of events and the similar oscillations in both engines is very much in line with what has occurred in previous incidents with this aircraft type when a high engine power is set whilst the engine RPM is too low; see Figure 21. This is supported by the fact that the amplitude of the oscillations increased drastically after a certain time; this indicates that the engines' TTL system was activated. This “characteristic” of the engine/propeller installation has been verified and is well known by engine and aircraft manufacturers.

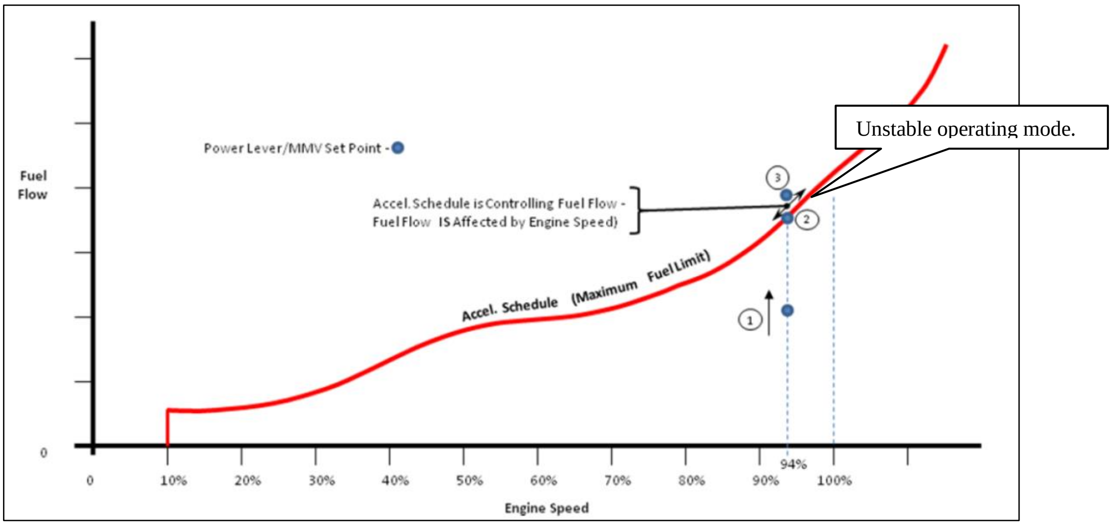


Figure. 21. Unstable operating mode. Photo: Honeywell.

Everything thus points to the oscillations on both engines being caused by their RPM being too low for the high power output during the take-off.

Information emphasizing the matter has been published in documents like the aircrafts Installation Manual as well as in an NTSB's report NTSB/AAR-88/06.

Despite the fact that information on this "characteristic" had previously been published, it was not known to the pilots at the time of the incident. There is therefore cause to consider complementary information measures which could ensure that all pilots of this aircraft type, and aircraft types with a similar type of engine and propeller system, have full knowledge of the potential risks.

2.3.3 FDR and sound analysis

The lack of correct information from the aircraft's flight recorders was unfortunate as this reduced the possibility to find likely explanations for why the RPM was too low during take-off. SHK's analysis of the sequence of events prior to the engine disruptions is therefore based on the pilots' memories, the corrected FDR recordings and an analysis of the sound picked up in the video recording.

As previously mentioned, the pilots stated that during take-off the RPM Levers were in their fully forward position, which corresponds to over 100% RPM, and that the position of the friction control knob was checked and that the lever was not moved thereafter.

The corrected FDR recording and sound analysis reveals a somewhat different sequence of events. Whilst the sound analyses and the corrected recordings cannot be expected to be completely accurate, they constitute two independent sources which clearly show that the RPM of both engines prior to take-off first quickly increased, from around 72% (idle) to around 100%, but thereafter immediately reduced to around 95%. For a period of around 50 seconds, the RPM then continued to decrease slowly to around 94%, when the severe oscillations began on both engines. According to the FDR recording, the oscillations first began with a low amplitude on the left engine, whose RPM was at that point lower than that of the right engine.

The fact that both the FDR recording and the sound analysis reveal that the RPM on both engines following the incident and during approach were normal, i.e. around 100%, indicates that these values are representative.

2.3.4 RPM Levers

A possible explanation for the sequence of events could be that the RPM Levers were pushed forward to their maximal position but that the friction control knob was not tightened enough. The lever could then suddenly have come back somewhat without the pilots noticing. When the RPM thereby decreased, approaching 94%, the engine oscillations began.

As the levers are not mechanically interlinked, however, it is unlikely that the levers would so promptly - and simultaneously - move back. Over the years this aircraft type has been in operated, no cases of any such spontaneous movement of these levers have been reported to the aircraft manufacturer.

Another explanation could be that the RPM Levers were pushed forward quickly, but not to the maximal position. The recorded “max RPM” of just over 100% could very well have been an “overshoot” before the RPM slowly stabilised thereafter at around 94%. Against this scenario, however, is the pilots' recollection that both levers were pushed forward to max, in accordance with the procedures prescribed in S.O.P.

It has not been possible with the available information to say with certainty which of the two alternatives caused the oscillations. The most likely cause, however, is that the levers were not pushed all the way forward, and that the lack of a warning system meant that the pilots did not notice the incorrect configuration.

2.3.5 Conclusions from the technical analysis

SHK establishes that the specific characteristics of this aircraft type - i.e. that severe oscillations in the engine power can occur if the RPM is too low when the power output is high - can entail a serious flight safety risk if the pilots do not have full knowledge of the phenomenon.

2.4 Operational safety

2.4.1 Warning system

It can with a high degree of certainty be established that the cause to the power oscillations was a too low RPM and that this is a known characteristic of the engine type in this model of aircraft.

As this incident can be categorised as very serious, SHK believes that a certain amount of attention should be paid to the aircraft model's warning system. At the time of this report there are however no requirements for a warning system to be installed on this class of aircraft.

From a flight safety viewpoint, it cannot be considered satisfactory that a system in which the consequences of a malfunction or mismanagement can be so serious that oscillations occur on both engines simultaneously does not feature a safety system which warns the pilots.

The aircraft type in question, J31/32, is not equipped with a “take-off configuration warning”, which provides a warning in the event of an incorrect configuration for take-off. Checking that the RPM Levers are in the correct position for take-off can only be achieved via manual verification by one of the pilots.

SHK therefore believes it may be necessary to evaluate the conditions for equipping the aircraft type with a warning system which makes the pilots aware of any incorrect engine configuration during take-off.

2.4.2 Emergency checklists

The malfunction which occurred during the incident in question was likely caused by an incorrect engine configuration for take-off. The consequences - serious engine oscillations just after take-off - occurred in a critical phase of the flight when the aircraft was at low altitude during acceleration from a low speed area. During this phase of the flight, the crew's focus must be on the flight continuing in a safe manner.

In such a situation, the crew cannot be expected to take out an emergency checklist in order to look up the most appropriate measures. Such measures should be included in memory items. The fact that the commander still carried out virtually all of the prescribed measures at the time is likely attributable to his long experience – including his service as an instructor – on the aircraft type. Recently trained pilots, or pilots with low experience on the type, cannot be expected to possess the equivalent knowledge.

SHK considers this incident to be so serious that the conditions for the crew's handling of this problem need to be revised. The pilots' initial training should therefore be conducted in a manner which highlights the problem, whilst prescribed measures are trained as memory items during initial and recurrent flight training on the type.

2.5 Other observations

2.5.1 Operational

SHK has found shortcomings in the airline's manuals. The terms for the levers and their position during take-off vary in different manuals. This is undesirable and makes the crew's conditions during both training and flying more difficult. It can also entail a greater risk of prescribed measures being interpreted differently in certain situations.

One example is the different terms used for procedures in the checklist (see 1.6.11) which are intended to ensure the RPM Levers are in the correct position for take-off, i.e. fully forward. The operator alternately uses the terms HIGH and FLIGHT. Some of these different terms are also found in the TC holder’s manuals.

2.5.2 Technical

During the technical investigation carried out under SHK's supervision, defects in the aircraft were established in the form of PT2/PS5 tubing and corrosion damages (see Figures 13, 14, 15). Whether or not this had an effect on the sequence of events, these discoveries indicate an insufficient technical standard on behalf of the operator.

2.5.3 Technical/operational

SHK can establish that the operator did not follow applicable provisions concerning the keeping of flight log and following up technical remarks on the aircraft.

The existing regulations are meant to ensure that the technical log system describes all technical faults which have arisen during operation. If this system is handled in another manner, the risk of noted errors and malfunctions will be unknown to, e.g. a new crew which commences a crew change on the aircraft in question.

The system created by the operator (which thus lies outside of the regulations) with the express purpose of reducing the risk of the aircraft remaining on the ground is remarkable from a safety perspective. It is also somewhat surprising that the supervisory authorities have not noted or called attention to this during audits of their operations.

3. CONCLUSIONS

3.1 Findings

a) The pilots were qualified to perform the flight.
b) The aircraft had had a Certificate of Airworthiness and valid ARC.
c) Oscillations to both engines occurred soon after take-off.
d) Corrosion was found when inspecting the aircraft in question.
e) During the inspection, technical remarks were found that were not noted in the aircraft's log book.
f) Power to the Cockpit Voice Recorder (CVR) was not cut, which means that no sound recordings were available for the investigation.
g) The operator was missing mandatory documentation necessary to convert the digitally saved FDR-information into engineering units.
h) Take-off and initial climb were carried out at an RPM which was too low.
i) It is known that engine oscillations can occur during take-off in connection with a too low RPM.
j) The pilots were not aware of the risks of a too low RPM during take-off.
k) Some information in the company's – and TC holder's – operations manuals was not concordant.
l) This aircraft type has no warning system for take-off with an incorrect engine configuration.

3.2 Causes/Contributing Factors

The incident was likely caused by a too low RPM during take-off. A contributing factor was that the aircraft type has no warning system for take-off with an incorrect engine configuration.

4. SAFETY RECOMMENDATIONS

EASA is recommended to:

- Investigate the conditions for installation of a warning system on the aircraft type in question which notifies the pilots of an incorrect engine configuration in connection with take-off. *(RL 2014:07 R1)*
- Endeavour to revise the emergency checklist for this aircraft type so that measures in the event of engine oscillations in connection with take-off are changed so as to be included as “memory items”. *(RL 2014:07 R2)*
- Take measures to ensure that initial and recurrent training on this aircraft type are supplemented with information and training regarding the risks of incorrect engine configurations during take-off. *(RL 2014:07 R3)*

The Swedish Accident Investigation Authority respectfully requests to receive, **by September 15 2014** at the latest, information regarding measures taken in response to the recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Mikael Karanikas Stefan Christensen