AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

Reference:	CA18/2/3/9767

Aircraft Registration	ZS-OOB	**Date of Accident**	29 January 2019	**Time of Accident**	0552Z

Type of Aircraft	Pitts Special S-2B	**Type of Operation**	Private (Part 91)

Pilot-in-Command Licence Type	Commercial Pilot Licence	**Age**	71	**Licence Valid**	Yes
Pilot-in-Command Flying Experience	**Total Flying Hours**	6497.7	**Hours on Type**	1012.8	

Last Point of Departure	Rand Aerodrome (FAGM), Gauteng Province
Next Point of Intended Landing	Rand Aerodrome (FAGM), Gauteng Province

Location of the accident site with reference to easily defined geographical points (GPS readings if possible)

Kliprivier area in Gauteng Province at GPS co-ordinates: 26° 26' 12.50" South 028° 7' 16.31" East and at a field elevation of 4922ft AMSL

Meteorological Information	Wind: 326° at 14kts, Temperature: 27 °C, Dew Point: 12 °C, Visibility: 9999m and QNH: 1027 hPa.

Number of People On-board	1+0	**No. of People Injured**	1	**No. of People Killed**	0

Synopsis

On Tuesday, 29 January 2019, a pilot on-board a Pitts Special S-2B aircraft with registration mark ZS-OOB experienced an engine failure while returning to the Rand Aerodrome (FAGM) in Johannesburg after an aerobatic formation practise session in Kliprivier, Gauteng province. When the pilot was at about 500 feet (ft) above ground level (AGL), he heard a loud bang and saw smoke coming from the engine compartment. According to the pilot, oil splashed on the windshield before the engine stopped. The pilot carried out an emergency landing. The aircraft was landed hard and came to rest in a nose-down and left-wing low position. The aircraft was destroyed during the accident sequence as it landed hard on an uneven terrain, while the pilot sustained serious injuries.

The investigation revealed that there was no evidence of an oil change or screen cleaning every 25 hours as required by Mandatory Service Bulletin (MSB) No. 480F, mandated by the engine manufacturer on aircraft engaged in aerobatic manoeuvres. There was also no evidence of engine oil upliftment during operation. These two findings have led to the reduction in oil quantity, which resulted in the connecting rods and bearings overheating before failing and, thus, causing engine failure.

Probable cause/s and/or contributory factors

An unsuccessful forced landing following an in-flight engine failure caused by the failure of the No. 3 and No. 6 cylinder connecting rods as a result of overheating due to insufficient lubrication.

SRP Date	19 January 2021	Publication Date	4 February 2021

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Abbreviation	Description
°	Degrees
ºC	Celsius
AD	Airworthiness Directive
AIC	Aeronautical Information Circular
AMO	Aircraft Maintenance Organisation
AMSL	Above Mean Sea Level
AW	Airworthiness
CAR	Civil Aviation Regulations
C of A	Certificate of Airworthiness
C of R	Certificate of Registration
CPL	Commercial Pilot Licence
CRS	Certificate of Release to Service
CVR	Cockpit Voice Recorder
E	East
FAGM	Johannesburg/Rand Aerodrome
FCU	Fuel Control Unit
FDR	Flight Data Recorder
ft.	Feet
GPS	Global Positioning System Co-ordinates
hPa	Hectopascal
Kg	Kilogram
Km	Kilometre
Kts	Knots
L	Litres
L/hr	Litres per Hour
METAR	Meteorological Terminal Aviation Routine Weather Report
MHz	Megahertz
Mph	Miles Per Hour
MPI	Mandatory Periodic Inspection
MSB	Mandatory Service Bulletin
No.	Number
PIC	Pilot-in-command
POH	Pilot's Operating Handbook
QNH	Query Nautical Height
Qt.	Quarts
RPM	Revolutions per Minute
RSA	Republic of South Africa
SACAA	South African Civil Aviation Authority
SB	Service Bulletin
SI	Service Instruction
SL	Service Letter
TBO	Time between overhaul
TT	Total Time
TSO	Time Since Overhaul
UTC	Co-ordinated Universal Time
VHF	Very High Frequency
Z	South African Standard Time is UTC plus 2 hours

DESCRIPTION OF ACCIDENT

Reference Number	**:** CA18/2/3/9767
Name of Owner/Operator	**:** Spamair (Pty) Ltd
Manufacturer	**:** Aviat Aircraft Inc.
Model	**:** Pitts Special S-2B
Nationality	**:** South African
Registration Marks	**:** ZS-OOB
Place	**:** Kliprivier, Gauteng Province
Date	**:** 29 January 2019
Time	**:** 0552Z

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

*In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011, this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and **not to establish blame or liability**.*

Investigations process:

The accident was notified to the Accident and Incident Investigations Division (AIID) on 29 January 2019 at about 0730Z. The investigator/s dispatched to the accident site at Kliprivier on 29 January 2019. The investigator/s co-ordinated with all authorities on site by initiating the accident investigation process according to Civil Aviation Regulations Part 12 and investigation procedures. The AIID of the South African Civil Aviation Authority (SACAA) is leading the investigation as the Republic of South Africa (RSA) is the State of Occurrence.

Notes:

1. *Whenever the following words are mentioned in this report, they shall mean the following:*
   - *Accident – this investigated accident*
   - *Aircraft – the Pitts Special S-2B involved in this accident*
   - *Investigation – the investigation into the circumstances of this accident*
   - *Pilot – the pilot involved in this accident*
   - *Report – this accident report*

2. *Photos and figures used in this report were taken from different sources and may be adjusted from the original for the sole purpose of improving clarity of the report. Modifications to images used in this report were limited to cropping, magnification, file compression; or enhancement of colour, brightness, contrast; or addition of text boxes, arrows or lines.*

Disclaimer:
This report is produced without prejudice to the rights of the AIID, which are reserved.

1. FACTUAL INFORMATION

1.1. History of Flight

1.1.1 On Tuesday, 29 January 2019, four aerobatic aircraft departed the Rand Aerodrome (FAGM) in Johannesburg for an aerobatic practise in Kliprivier in Gauteng province. Upon successful completion of the practise session and while on their return flight to FAGM, the pilot flying a Pitts Special S-2B aircraft with registration mark ZS-OOB experienced an engine failure. The aircraft was operated under the provisions of Part 91 of the Civil Aviation Regulations (CAR) 2011 as amended.

Figure 1: A view of the accident site. (Source: Google Earth)

1.1.2 When the pilot was at about 500 feet (ft) above ground level (AGL), he heard a loud bang and saw smoke coming from the engine compartment. Thereafter, he saw oil splash on the windshield before the engine stopped. The pilot then prepared for an emergency landing by first looking for a suitable field to land the aircraft. Thereafter, he landed the aircraft; but it was a hard landing. The aircraft came to rest in a nose-down and left-wing low position.

1.1.3 The aircraft was destroyed during the accident sequence with damages to the propeller, the engine cowlings, engine, both left wings, the bottom right wing and the fuselage. The pilot sustained serious injuries during the accident sequence and was transported to a local hospital in an ambulance.

1.1.4 The accident occurred during daylight with fine weather conditions prevailing at Global Positioning System (GPS) co-ordinates: S 26° 26' 12.5", E 028° 7' 16.31" and at a field elevation of 4922 feet (ft) above mean sea level (AMSL).

1.2. Injuries to Persons

Injuries	Pilot	Crew	Pass.	Other
Fatal	-	-	-	-
Serious	1	-	-	-
Minor	-	-	-	-
None	-	-	-	-
Total	1	0	0	0

1.3. Damage to Aircraft

1.3.1. The aircraft was destroyed during the accident sequence.

Figure 2: The damaged aircraft post-accident.

1.4. Other Damage

1.4.1 None.

1.5. Personnel Information

Nationality	South African	Gender	Male	Age	71
Licence Number	0270087265	Licence Type	Commercial Pilot Licence		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instrument, Night, Safety pilot, Aerobatics, Tug				
Medical Class & Expiry Date	Class 1, 31 May 2019				
Restrictions	Corrective Lenses, Hypertension protocol				

Flying Experience:

Total Hours	6497.7
Total Past 90 Days	73.5
Total on Type Past 90 Days	24.5
Total on Type	1012.8

Aircraft Maintenance Personnel:

Nationality	South African	Gender	Male	Age	80
Licence Number	0272006461	Licence Type	Aircraft Maintenance Engineer		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Textron Lycoming series, HO-360/ HIO-360 series and Teledyne Continental Engines group				
Restrictions	Corrective lenses, hypertension protocol				

The aircraft maintenance engineer (AME) who certified the maintenance performed on the landing gear prior to the accident flight had an AME Licence, which was initially issued on 5 October 1974. The licence was reissued on 8 December 2017 with an expiry date of 31 December 2019. The AME had the aircraft type Textron LYC HO-360 HIO-360 Series and Teledyne Continental Engines Group endorsed on his licence.

1.6. Aircraft Information

1.6.1. A Pitts Special S-2B is a high-performance aircraft type recommended by the manufacturer for aerobatics. It is a two-seater in tandem cockpits (one behind the other), with dual symmetrical controls; and is flown from the rear seat when flying solo. The aircraft is a biplane (two pairs of wings, one above the other) with the auxiliary tank in the upper wing and the main fuel tank in the forward bay of the fuselage. The aircraft has a fixed landing gear and is fitted with a flat six-side oppose Lycoming AEIO-540-D4A5 engine type.

Airframe:

Type	Pitts S-2B Special	
Serial Number	5030	
Manufacturer	Aviat	
Date of Manufacture	1983	
Total Airframe Hours (At time of Accident)	2733.90	
Last MPI (Date & Hours)	04 May 2018	2675.8
Hours Since Last MPI	58.1	
C of A (Original Date of Issue & Expiry Date)	12 August 2014	12 August 2019
C of R (Issue Date) (Present owner)	05 March 2009	
Operating Category	Standard Part 135	
Recommended Fuel used	Avgas LL100	

1.6.2 A review of all aircraft maintenance records such as logbooks, Mandatory Periodic Inspection (MPI) records and flight folios was conducted. All published manufacturer Service Bulletins (SBs), Service Letters (SLs) and Service Instructions (SIs) were checked for compliance for both the airframe and engine. According to the Pitts Special S-2B Maintenance Manual, servicing, inspection and/or testing are required at 50-, 100- and 1000-hour intervals or annually, whichever occurs first. The aircraft's maintenance history, according to the airframe logbook, was as follows:

- The ZS-OOB aircraft was issued a Certificate of Release to Service (CRS) on 4 May 2018 at 2675.8 hours with an expiry date of 3 May 2019 or at 2775.8 hours of flight time, whichever occurs first.
- According to the aircraft documentation flight folio and defect report, the duration of the flight conducted on 23 January 2019 was 1.20 hours, which were added to 2732.70 airframe hours; on that date, the airframe hours equated to 2733.90 and not 2733.26 as stated in the owner/operator questionnaire.

1.6.3 According to the pilot's questionnaire, the aircraft had 60 litres of AVGAS 100LL remaining at the time of the accident.

Engine:

Type	Lycoming AEIO-540-D4A5
Serial Number	L-22308-48A
Hours since New	2733.90
Hours since Overhaul	1352.12

1.6.4 The engine's maintenance history according to the engine logbook was as follows:

- The last engine overhaul was at 1381.78 hours on 22 February 1999. During the last inspection carried out at 2675.8 total airframe hours on 4 May 2018, it was recorded that a 12-year engine inspection had been carried out.

- The investigation team did not receive evidence of oil replenishment records as they were never recorded in the aircraft's flight folios. The oil register was requested from the operator to determine the last time the oil level was replenished after the last maintenance and/or any oil replenishing that occurred prior to the accident. Upon request, the Aircraft Maintenance Organisation's (AMO's) representative indicated that the oil register for the ZS-OOB aircraft was lost or misplaced and had submitted a sworn statement to the effect.

According to CAR 2011 Part 91.03.6(2) and (3) as amended requires the following:

(2) The PIC of the aircraft shall enter the fuel and oil records referred to in sub-regulation (1) in the flight folio.

(3) The owner or operator shall maintain oil records to enable the Director to ascertain that trends for oil consumption are such that an aircraft has sufficient oil to complete each flight.

1.6.4.5 SA-CATS Part 91.03.5(1)(1)(o) as amended requires the following:

FLIGHT FOLIO

1. Information to be contained in a flight folio

(1) An owner or operator must retain the following information for each flight in the form of a flight folio –

(o) fuel and oil used

1.6.5 According to available information in the engine maintenance records, the only registered recordings were engine oil and oil filter changes. There was no evidence of any oil upliftment during operation. Also, there were no recordings of the information relating to the engine total time (TT) or engine time since overhaul (TSO) for both entries:

- 13 December 2011: The logbook indicated that the engine oil and filter changes were recorded between 2180.7 hours MPI on 14 April 2011 and 2276.9 hours MPI on 11 April 2012 (96.2 hours).

- 2 December 2013: The logbook indicated that the engine oil and filter changes were recorded between 2372.5 hours MPI on 16 April 2013 and 2471.5 hours MPI on 7 March 2014 (99.0 hours).

1.6.6 The engine manufacturer had published the Mandatory Service Bulletin (MSB) No.480F on 25 May 2017 relating to oil servicing, metal solids identification after oil servicing and associated corrective action. The SB was mandatory on all Lycoming direct drive and TIGO-541 piston engines. According to MSB No. 480F, *for correct operation, an engine must have clean filtered oil of the correct grade and viscosity for in-flight ambient temperatures to lubricate all its moving parts. Oil must be changed at regular intervals.*

While compliance with the oil change schedule and inspections in Table 1 of this SB is mandatory, in special circumstances, the oil change intervals given can be extended by not more than 5 hours while en route to a place where the oil change can be done. (Refer to Table 1 below)

[Source: https://www.lycoming.com/sites/default/files/SB480F%20Oil%20ServicingMetallic%20Solids%20Identification%20After%20Oil%20Servicing%20and%20Associated%20Corrective%20Action.pdf]

Table 1 Oil Service Schedule

Task	*Frequency*
*Oil suction screen cleaning on the inverted oil system on any aerobatic engine****	*After the first 25 hours of operation after initial start-up or in 4 months (whichever occurs first*)*
Routing oil change and oil pressure screen cleaning/ inspection	*After every 25hours of operation or every 4 months (whichever occurs first**)*
	After replacement of any engine cylinder
***Oil change intervals must not exceed 4 months if the aircraft has not been flown for at least 25 hours in a 4-month period. More frequent oil changes are recommended if weather conditions, or salt spray in coastal environments.*	

There were no records in the logbook or flight folios that indicated compliance with the Textron Lycoming MSB No. 480F, revised on 25 May 2017, which prescribes a schedule and instructions for oil and oil filter changes, as well as oil pressure screen and oil suction screen cleaning, which is applicable to all Lycoming engines.

1.6.7 The engine manufacturer also published a Service Instruction (SI) No. 1009AS, dated 25 May 2006, which addressed the recommended time between overhaul periods for all Lycoming aircraft engines. (Source: https://flymall.org/aircraft/docs/Lycoming-Recommended-Overhaul%20Times.pdf)

All engines that do not accumulate the hourly period of time between overhaul (TBO) specified in this publication are recommended to be overhauled in the 12th year.
The manufacturer further explained that engines that do not accumulate at least 25 hours in four months (which is an indication that they have periods of inactivity in their life) puts the onus on the operator to determine a suitable TBO period.

The manufacturer's requirement indicated that operators who fly aerobatics should calculate 5% of the hours they fly in 12 years to determine their TBO, which would be different from the normal TBO of 1400 hours. The operator indicated that if they fly 100 hours a year, thus, in 12 years, they would have flown 1200 hours and 5% of that would be 60 hours. Therefore, 1400 hours minus 60 hours totals 1340-hour TBO. According to the Regulator's Aeronautical Information Circular (AIC) 18.19, private operators are not mandated to comply with the calendar requirements for overhaul.

The current engine TBO is set at 1400 hours, however, taking into consideration Note 6 of the Lycoming SI No. 1009, since the engine is exposed to 5% aerobatic flying, it will have a maximum TBO of 1330 hours (1400 hours × 0.05).

Propeller:

Type	Hartzell HC-C2YR-4CF
Serial Number	AU11695B
Hours Since New	900.39
Hours Since Overhaul	63.05

1.6.8 According to the propeller logbook compliance record, all applicable SBs/SLs/SIs as well as the required scheduled maintenance of the propeller were complied with prior to the accident. There were no recorded defects with the carburettor and engine recorded in the flight folio and defect logs prior to the accident.

1.7. Meteorological Information

1.7.1. Meteorological information obtained from the South African Weather Service (SAWS) website Meteorological Terminal Aviation Routine Weather Report (METAR) for FAGM on 29 January 2019 at 0800Z was:

Wind direction	326 °	Wind speed	14 kts	Visibility	9999 m
Temperature	27 °C	Cloud cover	Nil	Cloud base	Nil
Dew point	12 °C	QNH	1027 hPa		

1.8. Aids to Navigation

1.8.1. The aircraft was equipped with standard navigational equipment as approved by the Regulator (SACAA) for the aircraft type. There were no recorded defects with the navigational equipment prior to the accident.

1.9. Communication

1.9.1. The aircraft was equipped with standard communication equipment as approved by the Regulator for the aircraft type. There were no recorded defects with the communication equipment prior to the accident. The pilot had communicated with his fellow pilots (other pilots on the other aircraft) whom he was practising aerobatics with at radio frequency special rules Johannesburg South 125.8 Megahertz (MHz).

1.10. Aerodrome Information

1.10.1. The aircraft accident did not occur near an aerodrome. It occurred at Kliprivier area, Gauteng province, on an open field in a residential area at GPS co-ordinates: 26° 26' 12.50" South 028° 7' 16.31" East and at a field elevation of 4922ft AMSL.

1.11. Flight Recorders

1.11.1. The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder CVR), nor was it required by regulation for either to be fitted to the aircraft type.

1.12. Wreckage and Impact Information

1.12.1. The aircraft crashed on an open grass terrain in a private farm at Kliprivier area. According to the on-site observation, the aircraft approached from a north-west direction, which was consistent with the direction of the initial impact marks. Following the unsuccessful forced landing, the aircraft ground-looped and came to rest facing 180° (south east).

Figure 3: Damages on the aircraft's left side, engine compartment and propeller spinner.

1.12.2. Wreckage observation revealed that the aircraft impacted the ground in a left-wing attitude, consistent with a left-wing sideslip, followed by the engine and the right wing. The aircraft debris at the accident site was consistent with the described accident sequence.

1.12.3. Both the left-side wings and the right-side bottom wing were destroyed during the accident sequence. The engine propeller and nacelle sustained substantial damages. The propeller sustained damage on one of its blades, which is an indication that the engine was not under power prior to impact. The propeller spinner was damaged during the accident sequence. The aircraft's canopy was found on the right-side of the aircraft near the tail, with the Perspex damaged.

1.12.4. The aircraft was flown from the rear seat (this was indicated by evidence of the front cockpit being configured for rear flight control).

Figure 4: The detached left main landing gear wheel fairings covers.

1.12.5. The main landing gears were damaged, and the left main wheel fairing detached.

1.12.6. The engine had two holes on the top cover near cylinder No.3 and No.6 assembly positions, with the connecting rods protruding.

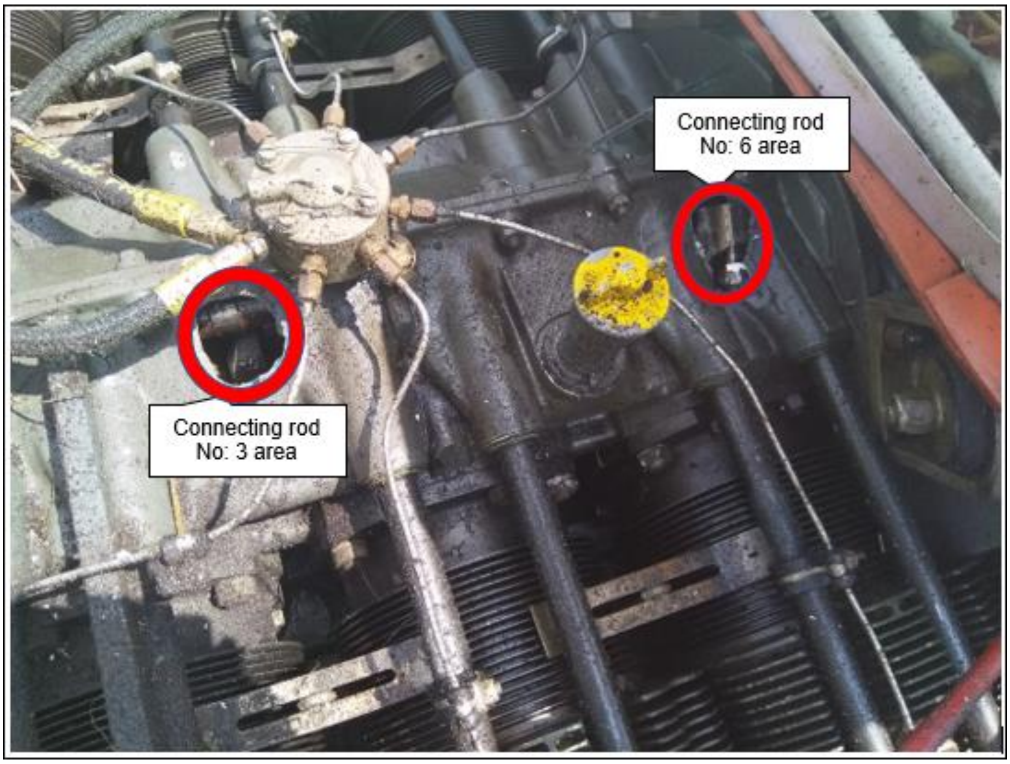

Figure 5: Orange circles show holes in the engine crankcase in the No.3 and No.6 cylinders.

1.12.7. Although the pilot had stated that oil had splashed on the windshield, there was no evidence of oil at the accident site and on the aircraft's windshield during the on-site investigation. Oil residue was confined to the engine compartment as shown in Figure 5.

1.13. Medical and Pathological Information

1.13.1. None.

1.14. Fire

1.14.1. The pilot reported that smoke emanated from the engine prior to impact; however, there was no evidence of a pre- or post-impact fire. The smoke was caused by the oil coming into contact with the hot engine surface.

1.15. Survival Aspects

1.15.1. The accident was considered survivable as the pilot flew the aircraft from the rear pilot seat, which was not severely affected by the impact forces. Severe impact damage was on the front part of the aircraft. Additionally, the use of the fitted lap belt and upper torso restraints had increased the pilot's chances of survivability.

1.16. Tests and Research

1.16.1. Dismantling of the engine for inspection

The wreckage was recovered to the operator's Hangar 34 at the Rand Aerodrome by the AMO responsible for ZS-OOB's maintenance. Due to the two holes observed on the crankcase around the No.3 and No.6 piston cylinder areas, it was required that the engine be dismantled for further examination. The engine was dismantled by the AMO responsible for the aircraft's maintenance.

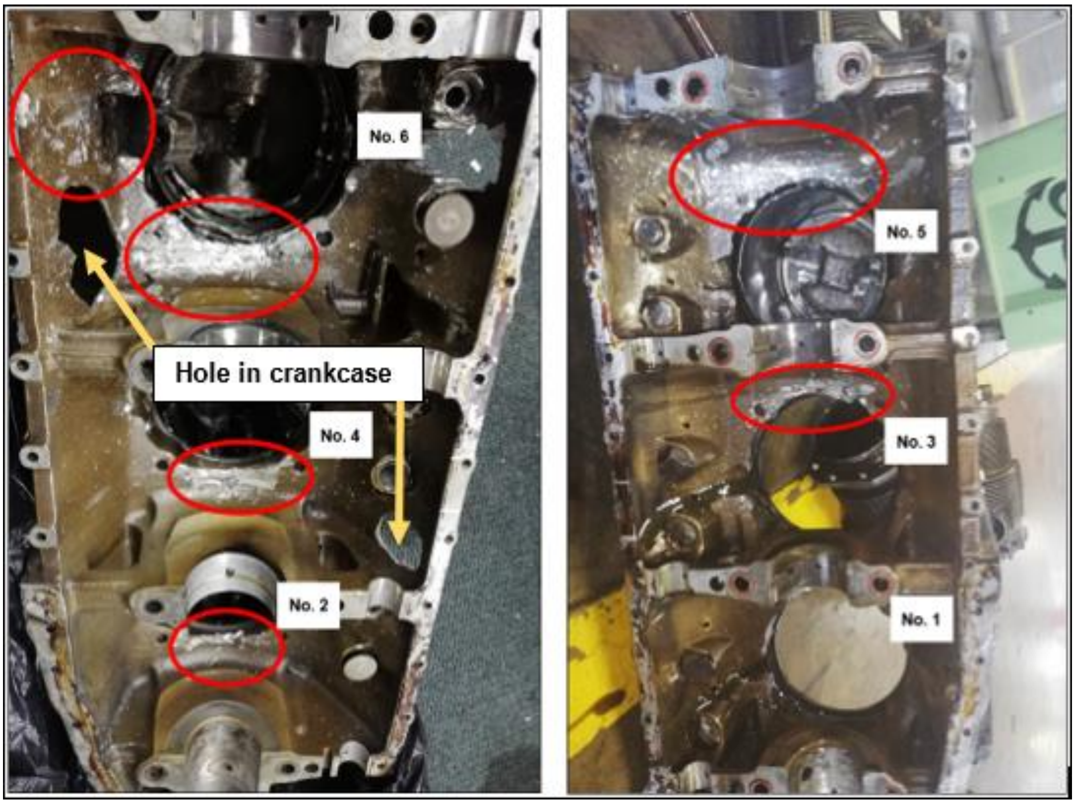

Figure 6: Severe impact marks and dents (circled in red) inside the crankcase from ricocheting debris from the No.6 connecting rod after failure. The yellow arrows show the holes in the crankcase caused by the No.3 and No.6 connecting rods.

On 17 July 2019, the complete engine disassembly was carried out and a visual inspection was undertaken on all engine components. However, on arrival of the investigating team, some of the engine components, including the oil filter, were already removed from the aircraft and the AMO did not make these available to the investigating team. The following observations were made:

<u>Crankcase Visual Inspection (Figure 6)</u>

- After separating the crankcase, severe multiple sites of impact marks and dents were observed throughout the internal crankcase and other components caused by ricocheting debris of the No.6 connecting rod following its fracture while the crankshaft was still rotating. The marks and dents were more pronounced around the No.6 and No.5 piston areas, while the severity of the marks decreases around the No.4, No.3, No.2 and No.1 piston areas, respectively (see Figure 7). This was an indication that the No.6 connecting rod had failed first, followed by the No.3 connecting rod.

- Figure 7 shows that the No.5 and No.6 piston cylinders were jammed in the crankcase; these could not be removed due to distortion from impact, making it difficult for the dismantling team to separate the two halves of the crankcase. A destructive method was used to separate the crankcase.
- There was evidence of oil in the engine. Also, debris from the crankcase was found in the oil sump.

Cylinder and Piston Visual Inspection

- The cylinder head valves of the No.1, No.2, No.3 and No.4 cylinders were easily removed from their assemblies and did not show signs of excessive build-up of carbon.
- The cylinder head valves of the No.5 and No.6 cylinders could not be removed from their assemblies due to impact distortion of the pistons which could not be removed from the cylinders.
- There was no evidence of overheating on the cylinders, pistons or valve assemblies.

Connecting Rod Visual Inspection (Figure 7 & 8)

- Connecting rods of the No.3 and No.6 pistons had failed and had punctured holes in the upper crankcase while cracks were observed on the bottom crankcase caused by the impact of the crankshaft jamming adjacent to the No.3 and No.6 piston areas.
- The No.6 connecting rod was jammed in the crankcase. Remnants of the No.6 piston connecting rod big-end housing were damaged extensively, and the rest of the housing was recovered from the oil sump.
- The nature of the failure of the No.6 connecting rod indicated that the big-end housing had been destroyed during operation before disintegrating due to the impact forces and before it got stuck in the crankcase hole.
- The No.6 connecting rod was discoloured, which indicated a prevalence of heat build-up during operation prior to its failure. The presence of excessive heat in the region had caused a drop in the yield strength, ultimately leading to micro crack formation that spread rapidly through the big-end housing.
- The bearing material had been forced out of the bearing caps, leaving the connecting rod running on the steel housing. This was indicated by the reduced thickness of the bearing inserts. (Figure 7 shows an illustration and a picture of the intact connecting rod compared to the failed connecting rod from the failed engine.)

- The No.6 connecting rod and bearing cap had broken into four parts and the remnants of the recovered bolt exhibited failure on overload, which is characterised by necking (elongation).

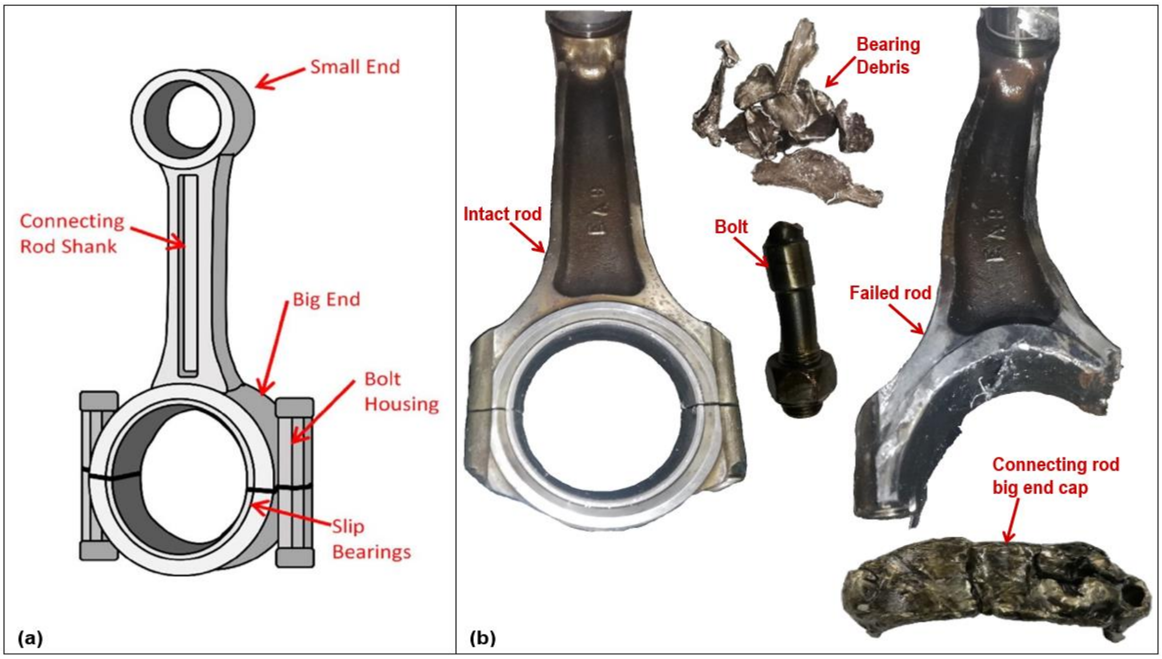

Figure 7: (a) For reference, the key parts of a generic connecting rod assembly; (b) the intact No.5 connecting rod and the failed No.6 connecting rod with failed components.

Evidence of heat tinting was observed, suggesting the existence of thermal hotspots in the material which contributed to the connecting rod failure. (Figure 8b shows the fractured surface; the red block indicates the suggested region of crack initiation.)

- Sections of the slip bearing had melted onto the inner control rod big-end of the connecting rod (all referred to as galling) because of substantial amount of heat that was generated by friction between the bearing and the connecting rod big-end, primarily due to oil starvation.

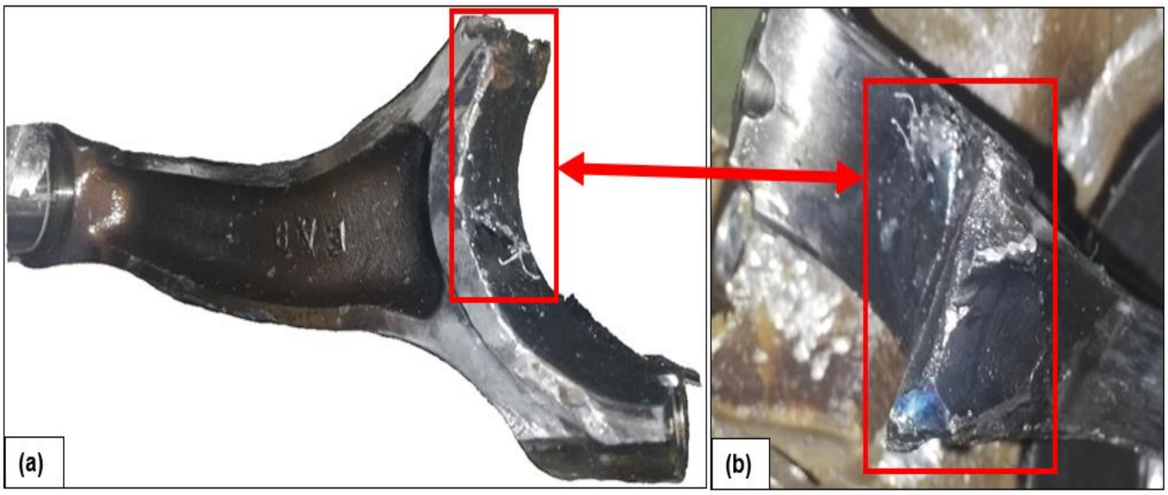

Figure 8: The failed connecting rod; (a) fractured and blackened big-end rod and melted bearing; (b) a closer view of the fractured point showing heat tinting.

Crankshaft Journal Visual Inspection (Figure 9)

- The crankshaft counterweights were intact. The No.6 crankshaft journal was discoloured, an evidence of overheating.

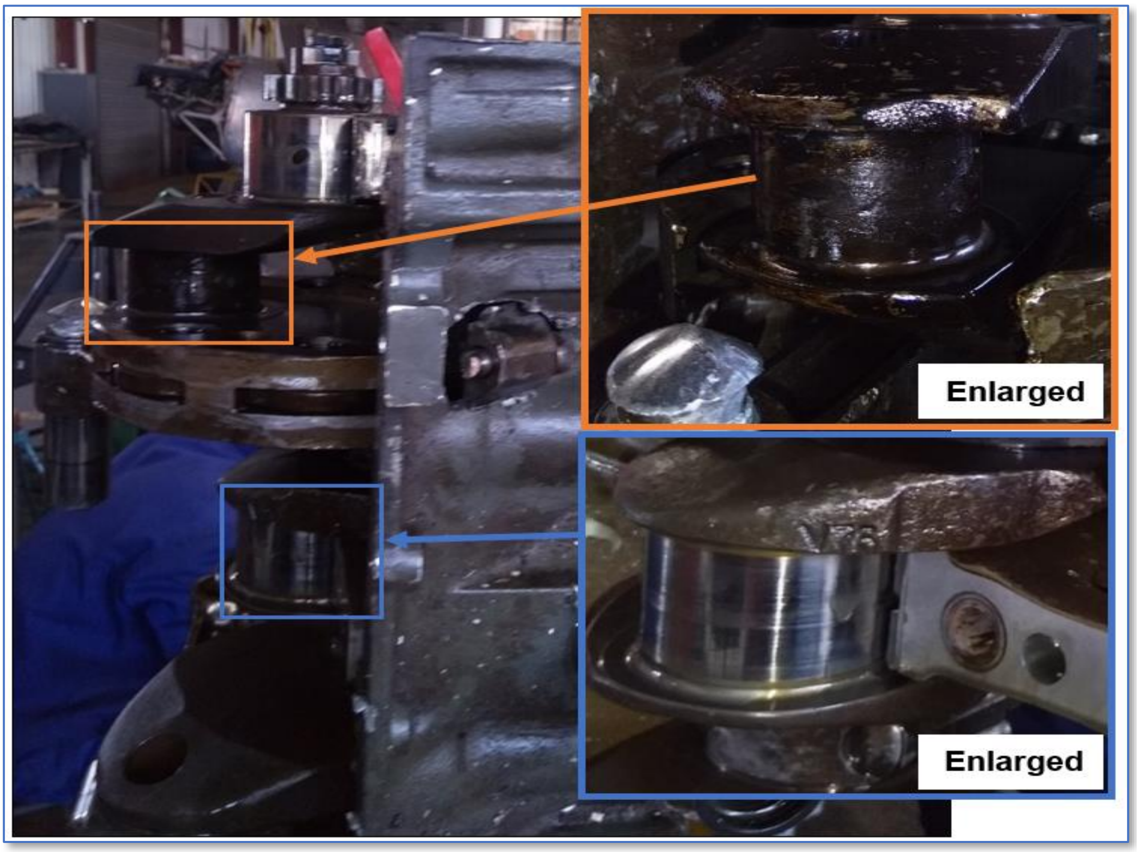

Figure 9: The orange block and arrow show the discoloured No.6 crankshaft journal. The blue block and arrow show the No.5 crankshaft journal without discolouration.

1.17. Organisational and Management Information

1.17.1. The pilot-in-command (PIC) is both the owner and operator of the aircraft. The PIC is also the owner of the AMO that carried out the last MPI on the aircraft prior to the accident flight. The aircraft was operated under the provisions of Part 91 of the Civil Aviation Regulations (CAR) 2011 as amended.

1.17.2. The AMO which carried out the last maintenance inspection on ZS-OOB aircraft prior to the accident flight had an approved AMO certificate that was issued by the SACAA in line with the provisions of Part 145 of the CAR 2011.

During the investigation, details were revealed of how the latest Certificate of Airworthiness (C of A) for the ZS-OOB aircraft was approved for a 24-month period, issued on 6 June 2017 with an expiry date of 12 August 2019 by the signing Airworthiness (AW) inspector. The evidence of the previously issued certificates indicated that they were issued in accordance with CAR 2011, Subpart 21.08.12 (1). Following the interview, it was determined that the currency fee officer made an error during the issuance of the C of A.

According to CAR 2011, Subpart 21.08.12 (1): *A certificate of airworthiness shall, subject to sub-regulation (2), be valid for a period of 12 months or until it is surrendered by the holder thereof, or is suspended by an authorised officer, inspector or authorised person, or cancelled by the Director*.

1.17.3. The operator and the AMO had no records of engine oil consumption monitoring and all oil upliftment done by the AMO and the operator were not recorded in the aircraft's flight folio; this was in contravention of the Civil Aviation Regulations Part 91.03.6(2),(3) and Part 91.03.5 read together with SA-CATS 91.03.5.

1.17.4. The operator was issued a Part 96 and Part 135 Air Operator Certificate (AOC) on 20 April 2018 with an expiry date of 31 March 2019. The ZS-OOB aircraft had been duly authorised under the AOC in line with the provisions of Part 135 of the CAR 2011. However, at the time of the accident, the aircraft was operated under the provisions of Part 91 of the Civil Aviation Regulations (CAR) 2011 as amended.

1.18. Additional Information

1.18.1 Australian Transport Safety Board (ATSB) had previously conducted an aviation safety research and analysis report- B20070191. The research focused on aircraft reciprocating engine failures. *[Source: https://www.atsb.gov.au/media/29980/b20070191.pdf, pg. 63-69]*

In the research, ATSB investigated three occurrences involving connecting rod big-end fractures of Lycoming IO-540, Lycoming TIO-540-J2B and Lycoming IO-540-E135, which were reported between the years 2000 and 2003. The failures occurred at random time since overhaul of 1300-, 1035- and 157-hours.

The failure analysis of the three connecting rod big-end fractures showed similarities based on the following findings:

- *The big-end housing fractures were a result of fatigue crack growth from the outer surface to the inner surface of the housing.*
- *The sites of fatigue crack initiation are associated with regions of reduced cross-section created by the counterbore at the transition between the housing and the connecting rod 'I' beam, indicated by white arrows in Figure 10.*
- *The big-end bearings had been destroyed prior to the fracture of the big-end housing, evident from galling of the bearing to the inner housing.*

- *The aluminium-tin/lead-tin bearing alloy of the big-end connecting rods were determined to have had separated from the steel back of the housing and the bearing inserts had uniformly reduced in thickness and forced out through the gap between the big-end housing and the crankshaft journal. (See figure 9, top-right image of bearing remnants.)*

Figure 10: The recovered fragments of the big-end housing (top left), some of the larger fragments of the bearing inserts (top right), detailed view of both housing fractures at the transition to the rod "I" beam (bottom). The sites of fatigue initiation are arrowed. [Source: ATSB's Analysis of Aircraft Reciprocating-Engine Failure, pg.63]

The ATSB's analysis further identified that galling (adhesive wear) occurs in regions when the bearing gets attached to the steel inner surface of a rod's housing. The surface damage created by galling is known to be a potent initiator of fatigue cracking. According to ATSB's analysis of engine failures, "evidence of overheating of the big-end bearing is associated with a loss of lubrication".

Following the findings made from the big-end connecting rod failures, the ATSB conducted a further study of the characteristics of the bearing material when exposed to changes in the oil viscosity that occurs in operation. The extent of oil film stability is commonly shown by the relationship between the coefficient of friction of the bearing and the bearing characteristic parameter, μN/P (μ –viscosity, N – rotational speed, P – load per unit of projected bearing area), as shown in Figure 11.

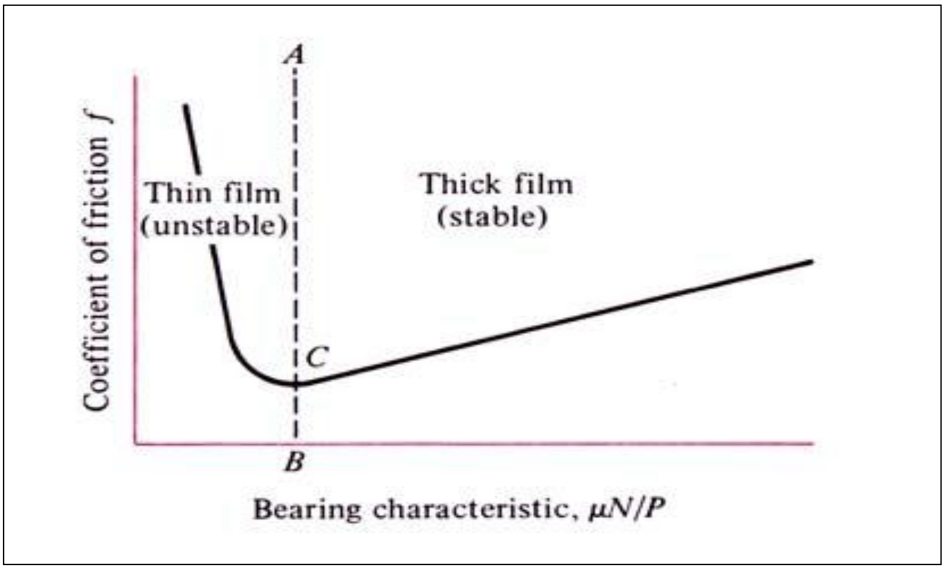

Figure 11: Variation of the coefficient of friction with bearing characteristic parameter. (Source: https://www.atsb.gov.au/media/29980/b20070191.pdf, p 124)

From the study, the ATSB arrived at the following conclusions pertaining to engine bearing failures, which is applicable to all engine types:

- *The critical features for successful bearing operation are the dimensions and geometry of the shaft and bearing, the surface roughness of the shaft and bearing, the rotational speed of the shaft in the bearing, and oil viscosity.*

- *If the bearing operating parameters are to the right of the line BA and there is a change in viscosity, speed or loading pressure that decreases the bearing characteristic parameter, then the reduction in friction results in a reduction in heat in the lubricant and an increase in viscosity.*

- *If the bearing parameters lie to the left of the line BA, then a decrease in viscosity would increase friction, a temperature rise would occur, and the viscosity would be reduced further, resulting in unstable lubrication and the increasing possibility of metal to metal contact.*

1.18.2 Following the accident, visual examination of the engine found that the No.6 connecting rod little-end had fractured and separated from the piston. The separated end of the connecting rod had collided with the underside of the piston, driving the piston into the cylinder head and fracturing the cylinder attachment fasteners. The force of the collision and the failing of the connecting rod fractured the camshaft and extensively fractured the crankcase. Both upper engine mounts separated from the crankcase during that sequence.

Examination of the fracture surfaces in the connecting rod little-end housing revealed that fracture initiated from a region of fatigue cracking. Fatigue cracking initiated on the inner surface of the housing. Examination of both the housing inner surface and the No.6 piston pin found that galling had occurred between the pin and the housing inner surface.

Figure 12 and 13 show similar failures from ATSB. An overview of the rear of the left engine after being removed from the aircraft; and the fractured small end of the No. 6 connecting rod.

For galling to occur between the piston pin and the inner surface of the housing, the bronze bush normally fitted to the housing must not be present. It is evident in this case that the bronze bush had been destroyed during engine operation. An examination of other connecting rods from the engine revealed that the bushes were in various states of destruction. Subsequent examination of a connecting rod from the right engine of the aircraft (following engine overhaul after the occurrence involving the left engine) found that the little-end bush was progressively being destroyed.

1.19. Useful or Effective Investigation Techniques

1.19.1. None.

2. ANALYSIS

2.1.1. The pilot was licensed and qualified to conduct the aerobatic practise flight. The pilot also had a Commercial Pilot Licence (CPL). The pilot's last validation was on 30 May 2018 with an expiry date of 31 May 2019. The pilot was issued a Class 1 medical certificate on 3 May 2018 with an expiry date of 31 May 2019, with limitations requiring him to have hypertension under control and correction for defective near vision.

2.1.2. The pilot's experience and knowledge on the aircraft type limitation was appropriate.

2.1.3. The aircraft had an airworthiness certificate which was validated for 24 months by the Regulator from the date of issue on 6 June 2017 with an expiry date of 12 August 2019. The Regulator had issued an airworthiness certificated for a period of 24 months, which was in contravention of CAR 2011, Subpart 21.08.12 (1). The investigation determined that the action taken by the AW inspector during the renewal of the C of A was not in line with the existing regulatory requirements and internal SACAA procedures. Additionally, the currency fee officer made an error in the dates on the certificate, which was issued for 24 months and not 12 months.

2.1.4. The last inspection carried out on 4 May 2018 was a 50-hour scheduled inspection at 2675.8 airframe hours. There were no pre-existing mechanical faults with either engine or the fuel system recorded in the flight folio and defect logs prior to the accident. Despite the airworthiness certificate, which was valid for 24 months, the aircraft mandatory periodic inspection maintenance for 100 hours was carried as per schedule calendar time. The aircraft was issued a Certificate of Release to Service (CRS) on 4 May 2018 with an expiry date of 3 May 2019 or at 2775.8 hours, whichever occurs first. At the time of the accident, the aircraft had operated for 58.1 hours since its last MPI.

2.1.5. There were no records in the logbook or flight folios that indicated compliance with the Textron Lycoming Mandatory Service Bulletin (MSB) No. 480F, revised on 25 May 2017, which prescribe a maintenance schedule and instructions for oil and oil filter changes, as well as oil pressure screen and oil suction screen cleaning, which is applicable to all Lycoming engines at 25 hours of operation or every four months, whichever occurs first. This was a non-compliance with provisions of Part 43.02.5, Subpart 2 of the CAR which relates to *Overhaul: General requirements*. However, according to the Regulator's AIC 18.19, private operators are not mandated to comply with the SB unless they are mandatory as stated.

2.1.6. The engine manufacturer's published SI No: 1009 advised operators in Note 6 that they must determine the percentage of time the engine is used for aerobatics and establish their own TBO. According to the operator, the aircraft and, thus, the engine were exposed to 5% aerobatics in a 1400-hour period and that the current engine's TBO was 1400 hours for the ZS-OOB. According to the calculations directed by Textron Lycoming's SI No. 1009, the operator should have calculated the TBO for the ZS-OOB's engine which was exposed to 5% aerobatic flying to a maximum TBO of 1330 hours (1400 hours - (70× 0.05) = 1330 TBO hours). At the time of the accident, the engine had a TSO of 1352.12 hours. Therefore, based on its normal operation for aerobatics, the engine had exceeded its maximum tolerable TBO by 22.12 hours. Although this procedure could have help to enhance the safe and durability of an engine operation, neither the operator nor the AMO complied with the SI as published.

2.1.7. Visual examination of the No.3 and No. 6 connecting rods revealed evidence of blackening, heat tinting and sections of the slip bearing that had melted onto the big-end of the connecting rod. Heat tinting observed suggested that the thermal hotspots in the material contributed to the connecting rod failure; this was because of the substantial amount of heat generated by friction between the bearing and connecting rod's big-end, primarily leading to adhesive wear.

According to the ATSB research and analysis on the failure of Lycoming engines on three occurrences in Australia, the investigation revealed that the three occurrences with regards to the failed engines had similar characteristics to the ZS-OOB's connecting rod big-end failure. The ATSB concluded that the failure was attributed to fatigue cracking of the connecting rod housing as a result of galling of the bearing to the big-end connecting rod's housing inner surface associated with loss of lubrication.

2.1.8. The investigation revealed that there was no evidence of an oil change or screen cleaning every 25 hours as required by MSB No. 480F, which is mandated by the engine manufacturer on aircraft engaged in aerobatic manoeuvres. There was also no evidence of engine oil upliftment during operation. The two may have led to the reduction in the oil quantity, which led to overheating of the connecting rods and bearings before failing and subsequently causing engine failure. The aircraft was forced landed hard on an uneven terrain, which resulted in its destruction.

3. CONCLUSIONS

3.1. Findings

3.1.1 The pilot was licensed and qualified to conduct the flight in accordance with International Civil Aviation Organisation (ICAO) and the provisions of Part 61 of the CAR 2011. The pilot was medically fit with a valid medical certificate to operate the flight in accordance with the provisions of Part 67 of the CAR 2011. The pilot's actions and statements about the occurrence indicated that he had adequate knowledge and understanding of the aircraft and its systems.

3.1.2 The maintenance records indicated that the aircraft engine was not maintained in accordance with existing manufacturer's maintenance requirements.

The aircraft had an airworthiness certificate which was validated by the Regulator for 24 months from the date of issue on 6 June 2017 with an expiry date of 12 August 2019. The Regulator had issued an airworthiness certificated for a period of 24 months, which was in contravention of CAR 2011, Subpart 21.08.12 (1).

3.1.3 The last inspection carried out on 4 May 2018 was a 50-hour scheduled inspection at 2675.8 airframe hours. There were no pre-existing mechanical faults with the engine, or the fuel system recorded in the flight folio and defect logs prior to the accident. The aircraft was issued a Certificate of Release to Service (CRS) on 4 May 2018 with an expiry date of 3 May 2019 or at 2775.8 hours, whichever occurs first. At the time of the accident, the aircraft had operated for 58.1 hours since its last MPI.

3.1.4 The manufacturer (Textron Lycoming) Mandatory Service Bulletin (MSB) No. 480F, revised on 25 May 2017, prescribes a maintenance schedule and instructions for oil and oil filter changes as well as oil pressure screen and oil suction screen cleaning, which is applicable to all Lycoming engines at every 25 hours of operation or every four months, whichever occurs first. The operator had not incorporated this MSB and this was in contravention of Part 43 of the CAR 2011.

3.1.5 The investigation revealed that there was no evidence of an oil change or screen cleaning every 25 hours as required by MSB No. 480F, which is mandated by the engine manufacturer on aircraft engaged in aerobatic manoeuvres. There was also no evidence of engine oil upliftment during operation. The two may have led to the reduction in oil quantity, which resulted in the connecting rods and bearings overheating before failing and, thus, causing engine failure. The aircraft was forced landed hard on an uneven terrain, resulting in its destruction.

3.1.6 No evidence of splashed oil on aircraft's windshield was found during an on-site investigation.

3.2 Probable Cause

3.2.1 An unsuccessful forced landing following an in-flight engine failure caused by the failure of the No. 3 and No. 6 cylinder connecting rods as a result of overheating due to insufficient lubrication.

3.3 Contributory Factors

3.3.1 None compliance with the manufacturer's issued MSB.
3.3.2 Poor maintenance practises.

4 SAFETY RECOMMENDATIONS

4.1.1. It is recommended to the Director of Civil Aviation that in the conduct of safety oversight, the SACAA ensures that operators and aircraft maintenance organisations comply with the manufacturer's maintenance instructions for safe operation of aircraft. The operator and the AMO were not recording and monitoring the oil consumption of the engines.

4.1.2. **Safety message:** The operator and the aircraft maintenance organisation must ensure that they adhere to the Civil Aviation Regulations requirements and the manufacturer's maintenance requirements.

4.1.3. It is recommended to the Director of Civil Aviation to review Circular (AIC) 18.19, which states that private operators (need) not comply with the manufacturer's calendar requirements for engine overhaul. The review should determine if the AIC 18.19 is still relevant considering the revised manufacturer's mandatory service bulletin for engine overhauls.

5. APPENDICES

5.1 Appendix A – Engine components inspection observations.
5.2 Appendix B – Last Certificate of Airworthiness for ZS-OOB aircraft.

This Report is issued by:

Accident and Incident Investigations Division
South African Civil Aviation Authority
Republic of South Africa

APPENDIX A

Engine components inspection observations

Some components were already removed from the engine prior to the investigators arriving and following observations were made:

- The ignition system with harnesses (L/H and R/H Magnetos and harnesses): appeared to be in good condition and appearance of minor chafing of the ignition harnesses was noted.
- Spark plugs: the spark plugs were not numbered during removal to identify specific location they were installed on the engine. Eight of the twelve plugs had carbon build-up on them.
- Fuel pump and fuel divider valve: appeared to be in good condition.
- Oil sump: contained debris from the failed components (i.e. parts of a connecting rod, springs, part of the connecting rod bolt) and small metal particles (i.e. flakes, chafing).
- Alternator: had some impact on the fins and were not rotating and had a mounting that was broken off, however the casing appeared to be in good condition.
- Propeller and Propeller Governor: Governor shaft turning freely. 1 blade of the propeller distorted with scratch marks on the forward face.
- Oil filter: the oil filter was not examined.

APPENDIX B

Last Certificate of Airworthiness for ZS-OOB.

SOUTH AFRICAN CIVIL AVIATION AUTHORITY

Section/division: Airworthiness

Form Number: CA 91-11

APPROVAL FOR ISSUE OR RE-ISSUE OR AMMENDMENT OR DUPLICATE OF CERTIFICATE OF AIRWORTHINESS

Aircraft registration marks							Z	S	–	O O	B
Airframe hours	2624.4					AMO No:					
Engine hours	1. 2624.4		2.			3.			4.		
Propeller	1.		2.			3.			4.		
Copy of release to service	Folio No.					Copy of inspection report			Folio No.		
Fees	Folio No.					Project no AO			Folio No.		
Airworthiness category	Standard	✓				Restricted			Experimental		
Operational Part	91		121	127	133	135 ✓	136		137	138	141
Original date of issue	✓	Date of re-issue				Duplicate			Amendment		
Date	2014/08/13					Expiry Date			2019/08/12		
Grounding register amended / checked						YES			NO		N/A

Additional information or instructions:

[redacted]

SIGNATURE OF INSPECTOR	NAME IN BLOCK LETTERS	DATE
[redacted]	[redacted]	2017-05-08

SIGNATURE OF CURRENCY OFFICER	NAME IN BLOCK LETTERS	DATE
[redacted]	[redacted] South African Civil Aviation Authority	2017-05-05

Verifying certificate of airworthiness issued correctly:

SIGNATURE OF MANAGER	NAME IN BLOCK LETTERS	DATE
[redacted]	[redacted]	06 JUN 2017

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SOUTH AFRICAN CIVIL AVIATION AUTHORITY
REPUBLIC OF SOUTH AFRICA

AW 21757
CERTIFICATE NO: CA 21-C-0

CERTIFICATE OF AIRWORTHINESS

REV NO:356/ZS-OOB/14

1 Nationality and registration marks	2 Manufacturer and manufacturer's designation of aircraft	3 Aircraft serial number
ZS-OOB	PITTS S-2B	5030

4 Categories **STANDARD Part 135**

5 This certificate of airworthiness is issued, pursuant to the Convention on International Civil Aviation, dated 7 December 1944, the Civil Aviation Act, 2009 (Act 13 of 2009), as amended and the Civil Aviation Regulations, 2011 as amended, in respect of the above-mentioned aircraft which is considered to be airworthy when maintained and operated in accordance with the foregoing and the pertinent operating limitations.

6 Special conditions: None

7 Original date of issue: 2014/08/13

8 **Expiry date:** **2019/08/12**

Jurie F. Gouws
Manager: Aircraft Registration & Inspection
SA Civil Aviation Authority

DIR [redacted]