AIRCRAFT ACCIDENT SHORT REPORT

CA18/2/3/9789: Unsuccessful forced landing following an engine failure in-flight.

Date and time	: 23 May 2019 at 0722Z
Location	: Hans Merensky Golf Course, Phalaborwa
Aircraft registration	: ZU-FFB
Aircraft manufacturer and model	: Micro Aviation New Zealand Ltd, Bantam B22J
Last point of departure	: Phalaborwa Aerodrome (FAPH)
Next point of intended landing	: Skukuza Aerodrome (FASZ)
Location of accident site with reference to easily defined geographical points (GPS readings if possible)	: 18th Fairway at the Hans Merensky Golf Course, Phalaborwa 23°57'52.47" South 031°10'03.31" East
Meteorological information	: Surface wind: 045°/2 kt, temperature: 15°C, CAVOK
Type of operation	: Private (Part 94)
Persons on board	: 1
Injuries	: None
Damage to aircraft	: Substantial

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 (CARs) (2011), this report was compiled in the interests of the promotion of aviation safety and the reduction of the risk of aviation accidents and incidents and **not to apportion blame or liability**.*

Disclaimer:

This report is produced without prejudice to the rights of the South African Civil Aviation (SACAA), which are reserved.

1. SYNOPSIS

1.1 On Thursday morning 23 May 2019, at approximately 0710Z, the pilot being the sole occupant on-board the microlight aircraft took off from Phalaborwa Aerodrome (FAPH) for an intended flight to Skukuza Aerodrome (FASZ). Approximately six minutes after take-off while flying at a height of about 1 500 feet above ground level (AGL), the engine started running rough and the pilot decided to turn back to FAPH. The engine's revolutions per minute (RPM) then started to decay and, a short while later, the engine stopped. The pilot performed a forced landing on the 18th fairway of a nearby golf course. The aircraft touched down hard.

1.2 The pilot did not sustain any injuries. The aircraft sustained substantial structural damage during the accident sequence.

1.3 The investigation revealed that the aircraft experienced an unsuccessful forced landing following an engine failure in-flight which was attributed to a mechanical failure.

2. FACTUAL INFORMATION

2.1 History of flight

2.1.1 The microlight aircraft was hangared at Phalaborwa Aerodrome (FAPH). On Thursday morning 23 May 2019, the pilot pushed the aircraft out of the hangar, whereafter it was refuelled with 70 litres of AVGAS. He then conducted his pre-flight inspection and took off from Runway 19 at 0710Z for a flight along the Kruger National Park (KNP) boundary with the intention to land at Skukuza Aerodrome (FASZ). Fine weather conditions prevailed at the time of the flight and the wind was light and variable.

2.1.2 The pilot stated that he climbed to a height of approximately 1 500 feet (ft) above ground level (AGL). Approximately six minutes into the flight, the engine started running rough and the pilot decided to turn back to FAPH with the intention to land there and assess the problem. After completing the turn, the engine's revolutions per minute (RPM) started to decay from 2 600 RPM (cruise setting) to 1 800 RPM with the engine running very rough. The pilot could hear the strange noise which sounded like metallic clanking. A few seconds later, the engine stopped, which was associated with a load clunking sound.

2.1.3 At that stage, the pilot realised that he was not going to make it back to the aerodrome (FAPH) and decided to execute a forced landing on the 18th fairway of the Hans Merensky Golf Course, which was to the south of FAPH and within gliding distance of the aircraft. There were no golfers, any other people or animals at the 18th fairway at the time. He then broadcast a Mayday call on the VHF frequency 124.80 MHz, switched off the master switch and selected 20° flaperon for the landing. At a height of approximately 4 to 5ft above the fairway, the pilot stalled the aircraft, which resulted in a hard landing, causing the nose landing gear as well as the left main gear to collapse. This caused the aircraft to pitch violently forward. The engine cradle could not withstand the impact forces, therefore, the engine collapsed onto the pod and windscreen. The pilot was not injured in the accident. Several people who were at the Hans Merensky Golf Course at the time rushed to the scene to assist the pilot.

2.1.4 The accident occurred during daylight conditions at a geographical position that was determined to be 23°57'52.47" South 031°10'03.31" East at an elevation of 1312ft above mean sea level (AMSL).

2.1.5 The aircraft touched down in a northerly direction on the 18th fairway of the Hans Merensky Golf Course. As can be seen in Figures 1 and 2, the aircraft came to an abrupt stop following the hard landing, which cause the landing gear as well as the engine cradle to collapse onto the canopy.

Figure 1: The microlight aircraft as it came to rest on the fairway

Figure 2: The front view of the microlight aircraft on the fairway

Figure 3: The front view of the aircraft with the boom structure bent to the right (post recovery)

2.1.6 The engine, a Jabiru 3300A, with serial No. 33A2061 (Figure 4) was removed from the wreckage and was taken to a maintenance facility where a teardown inspection was conducted on Wednesday, 12 June 2019.

The teardown inspection determined that the catastrophic engine failure was due to a broken exhaust valve on the number 4 cylinder. It was found that the top section of the valve stem, just below the split collet, as well as at the valve neck, had failed as can be seen in Figure 7. The failure mode of the valve is discussed in the laboratory report which can be found attached to this report as Annexure A.

The relevant components were retrieved from the engine and were sent for metallurgical examination. The failure analysis report can be found attached to this report as Annexure A.

In Figure 5, debris from the piston is visible in the number 4 cylinder after the head assembly was removed.

Figure 4: The engine prior to the teardown examination

Figure 5: Visible fragments within the No. 4 cylinder are fragments of the piston and a deformed conrod

Figure 6: Visible fragments of the piston in the engine after the sump was removed

Figure 7: The 3 pieces of the fracture exhaust valve (bottom) and a used valve (right side)

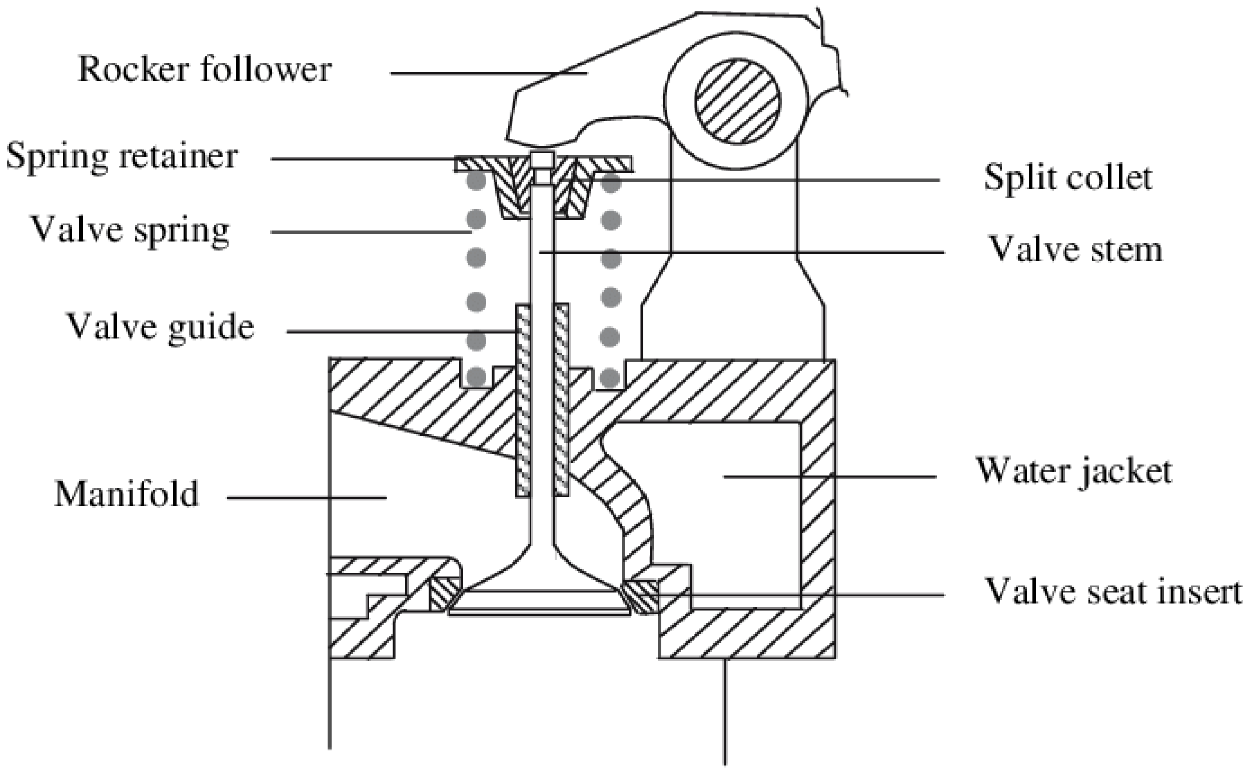


Figure 8: Schematic illustration of the valve system (Image from internet, Google search)

3. FINDINGS

3.1 The pilot was the holder of a valid national pilot's licence (NPL), which had been issued on 3 September 2013. He had the microlight aircraft type endorsed on his licence.

3.2 The pilot was the holder of a valid aviation medical certificate (Class 4), which was issued on 25 September 2018 and with an expiry date of 30 November 2021.

3.3 The pilot had accumulated a total of 458.9 flying hours at the time of the accident. The hours were on the Bantam B22J aircraft type.

3.4 The pilot had conducted his conversion onto the Bantam B22J type microlight aircraft on 3 September 2013.

3.5 The aircraft was issued with a valid Authority to Fly on 5 March 2019, with an expiry date of 4 March 2020.

3.6 The certificate of release to service of this microlight aircraft was issued on 5 March 2019 and would have lapsed on 4 March 2020 or at 535.0 airframe hours, whichever came first.

3.7 The last annual inspection carried out on the aircraft prior to the accident flight was certified on 5 March 2019 at 435.6 airframe hours by an approved aircraft maintenance organisation (AMO). A further 22.6 hours had been flown with the aircraft since the inspection.

3.8 The pilot stated that a strange noise, like clanking metal, came from the engine before it stopped.

3.9 The engine was subjected to a teardown examination and it was found that the exhaust valve on the number 4 cylinder had failed due to fatigue, which resulted in a catastrophic engine failure with extensive internal engine damage.

3.10 Nobody was injured in the accident sequence.

3.11 The prevailing wind at the time of the flight was from the north-east at 2 kt, and the temperature was 15°C. There was no METAR available for FAPH.

4. PROBABLE CAUSE

4.1 Unsuccessful forced landing following an engine failure in-flight, which was attributed to a fatigue failure of the number 4 cylinder exhaust valve.

5. CONTRIBUTING FACTOR

5.1 From the laboratory report, it was evident that the cylinder head was exposed to very high temperatures during operation. The same observation was made on the area where the valve head failed.

6. REFERENCES USED IN THE REPORT

6.1 Engine teardown examination, which was done in the presence of the investigator.

6.2 Laboratory report (Exhaust valve failure on Jabiru A3300 engine).

7. SAFETY RECOMMENDATION

7.1 AIID had investigated three accidents involving Bantam B22J aircraft that were fitted with Jabiru engines which suffered valve failures over an eight-month period. These three accidents were as follows:

(i) 24 September 2018, ZU-EGU, Bantam B22J (Engine model A2200, No. 4 cylinder exhaust valve failed, engine hours were 555.6)

(ii) 8 February 2019, ZU-DOG, Bantam B22J (Engine model A2200, No. 4 cylinder inlet valve failed, engine hours were 898.0)

(iii) 23 May 2019, ZU-FFB, Bantam B22J (Engine model A3300, No. 4 cylinder exhaust valve failed, engine hours were 459.2)

In the interest of aviation safety, it is recommended that the South African Civil Aviation Authority (SACAA) Aviation Safety Operations division in co-operation with the engine original equipment manufacturer (OEM) conduct a safety study into the cause of these valve failures and how to mitigate this from continuing as this is out of the norm. Consideration should be given to the following:

It is further recommended that the material composition of the valves, especially the exhaust valves, be looked at in detail as it would appear that excessive heat, or a lack of adequate cooling had a significant effect on the integrity of the exhaust valves that failed.

It is worth noting that all three failures occurred on the number 4 cylinder.
The Jabiru A2200 is a four-cylinder engine and A3300 a six-cylinder engine.

The two exhaust valves that failed had been in operation for 555.6 and 459.2 hours respectively, which was less than 100 hours between the two of them.

8. ORGANISATION

8.1 This was a private flight, which was conducted under the provisions of Part 94 of the Civil Aviation Regulations (CAR) of 2011 as amended. The pilot was also the owner of the aircraft.

9. APPENDICES

9.1 Annexure A (Exhaust valve failure report on Jabiru A3300 engine)

COMPILED BY:	LABORATORY FOR MICROSCOPY & MICROANALYSIS (Universiteit van Pretoria / University of Pretoria / Yunibesithi ya Pretoria)	PAGE 1 OF 13	
	FAILURE ANALYSIS REPORT: BANTAM B22J ENGINE COMPONENT, AIRCRAFT No ZU-FFB	DOCUMENT NUMBER FA-004-07-19	
COMPILED FOR: SACAA (AIID)		DATE 2019-07-11	ISSUE 1

ITEM: **EXHAUST VALVE ASSEMBLY, JABIRU 3300 ENGINE, BANTAM B22J AIRCRAFT, No ZU-FFB**

1. BACKGROUND INFORMATION

1.1. Selected components from a failed Jabiru 3300 engine (Photo 2), originating from a Bantam B22J aircraft no ZU-FFB (Photo 1), were submitted to determine the most probable contributary cause/s towards the failure of the exhaust valve (Photo 3, red arrow; cylinder head assembly serial no 153-232-33A) during operation.

Photo 1: ZU-FFB[1]

Photo 2: Supplied components (digital)

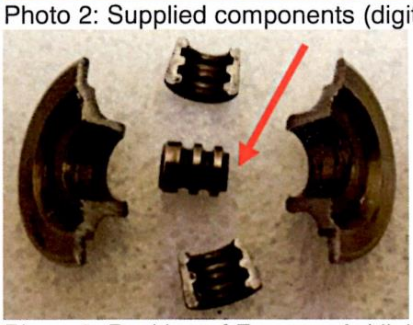


Photo 3: Position of Fracture A (digital)

1.2. This report is divided into the following sections:

[1] Courtesy Flight Zone

2. APPLICABLE DOCUMENTS

(a) SACAA Report CA12-L-002/220119
(b) Jabiru Service Letter JSL014-2 and JSL008-2
(c) CASA Report No 141118-1-70

3. DEFINITIONS

(a) OEM Original Equipment Manufacturer
(b) FEGSEM Field Emission Gun Scanning Electron Microscope
(c) FOD Foreign Object Damage
(d) EDS Energy Dispersive X-ray Analysis
(e) rpm Revolutions per Minute
(f) SACAA South African Civil Aviation Authority
(g) AIID Accident and Incident Investigation Division

4. PERSONNEL

(a) The investigative member and compiler of this report is Mr C.J.C. Snyman, ID number 6406105057080. Mr Snyman is a qualified Physical Metallurgist (H.N.Dip. Metallurgical Engineering, Tech. PTA, ECSA Registration: Prof. Eng. Tech. No 201670194), Radiation Protection Officer (RPO, NNR, No 281) and Aircraft Accident Investigator (SCSI).

5. APPARATUS AND METHODOLOGY

(a) The methodology included visual inspection of the affected part/s, sample preparation and Light-, Stereo- and FEGSEM/EDS analysis.

6. INVESTIGATION RESULTS

6.1. Visual Inspection

Note 1: *Due to the unavailability of the remainder of the complete engine for this investigation, only the supplied parts were considered.*

The visual inspection revealed two distinct fractures within the supplied exhaust valve, Fracture A (Photo 6) and B (Photo 7). Fracture A initiated within the bottom (valve head end) serration (Diagram 1, red arrow) and fracture B adjacent to the valve head (green arrow).

The visual inspection of the supplied cylinder head (Photo 4) revealed clear indications of high temperature exposure (red dashed circle) but no clear indications of incorrect valve spring installation (red arrow) that might have contributed to fracture A.

The valve stem/guide interface revealed no clear indications towards wear patterns that might suggest improper clearance/s and/or excessive guide wear (Photo 7).

The bottom section of the exhaust valve stem revealed clear indications of temperature induced transverse stress fracture initiations (Photo 7, red dashed circle; Photo 8).

The opposing fracture surfaces at Fracture B (Photo 7, yellow dashed square) revealed extensive post-failure damages with no detectable fracture mode indications.

The top valve spring washer revealed some indications of wear while the remaining thickness ±1.6mm (Diagram 2) proved to be within the allowable OEM limits.

6.2. High Magnification Inspection

Note 2: The exhaust valve was sectioned for microscopy analysis purposes.

The Stereo-microscope analysis of Fracture A revealed indications of a fatigue fracture initiation (Photo 9, yellow dashed squares). Considering that the valve rotates during operation, no other clear indications towards possible secondary fatigue initiation/s could be detected due to extensive post-failure, impact induced smearing marks (Photo 9).

The collet (Diagram 1; valve lock) revealed no clear indications of excessive wear and/or possible seizure/binding unto the valve stem during operation (Fractographs 1 and 2).

Secondary fracture initiations were noted in adjacent serrations (Fractograph 3, red arrow) suggesting a possible homogeneous over-stress exposure/material deficiency during operation.

The normal collet/valve stem load contact interfaces revealed indications of extensive material flaking (Fractograph 4, yellow dashed circles). This can be attributed to the noted corrosion induced pitting.

The exhaust valve stem hard surfaced layer revealed significant variations in thickness (Fractographs 6 and 7) with the average layer thickness at the position of the noted fatigue fracture (Fractograph 8) initiation point (Fractograph 6, yellow dashed line) only 41% of the remainder.

Post-failure smearing marks and secondary cracking were noted (Fractograph 9). The former suggest that Fracture A was exposed to impact/s induced by the bottom section of the exhaust valve being forced upward during the final number of engine rotation/s.

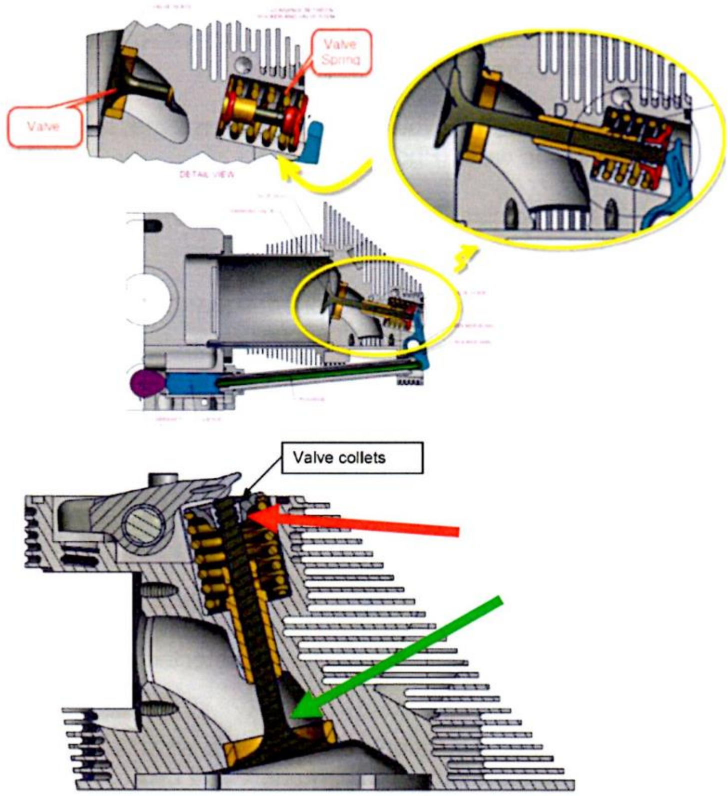


Diagram 1: Jabiru 2200 Valve assembly layout[2]

Diagram 2: Top valve spring washer measurement[3]

[2] Courtesy CASA Report No 141118-1-70 & JSL008-2
[3] Courtesy JSL008-2

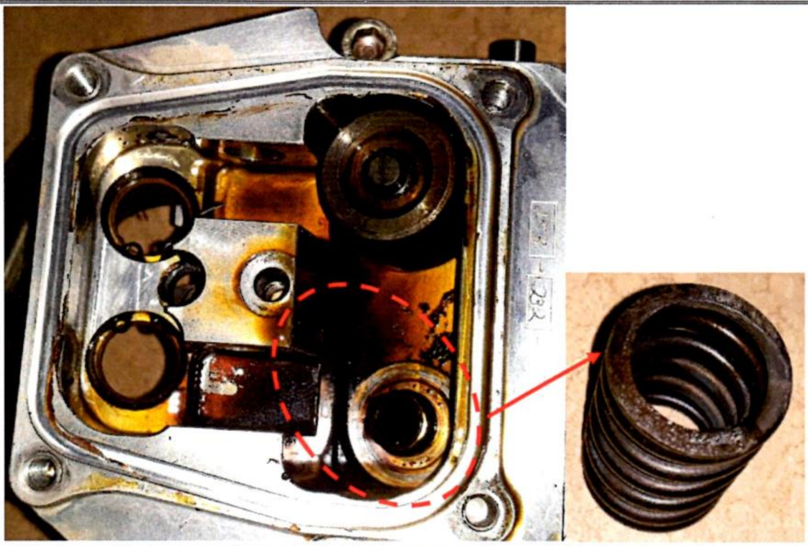


Photo 4: Valve spring seat area, indications of high temperature exposure (digital)

Photo 5: Evhaust valve seat, piston- and head conditions (digital)

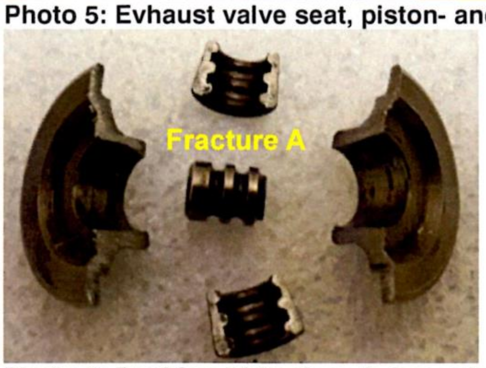


Photo 6: Position of fracture A, top valve spring washer condition (digital)

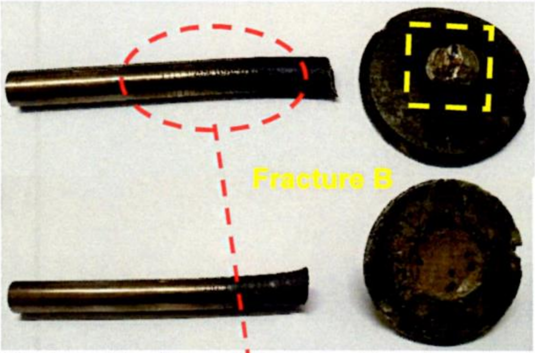


Photo 7: Position of Fracture B, exhaust valve stem condition (digital)

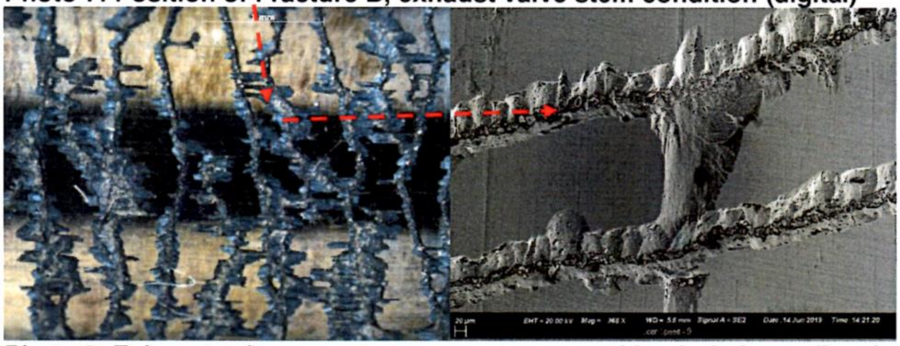


Photo 8: Exhaust valve stem, transvere stress cracking intiations, discoloring (Stereo/FEGSEM)

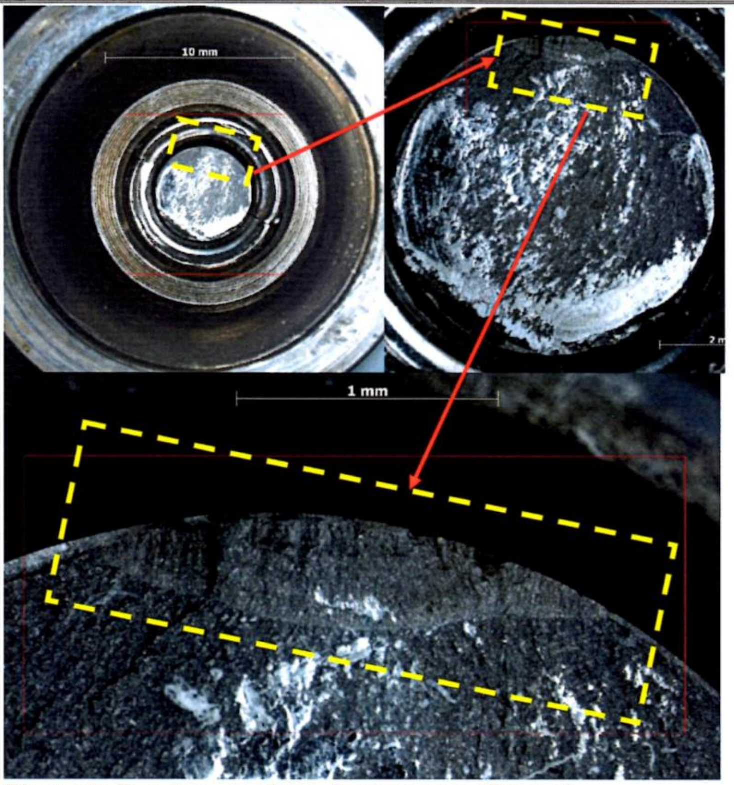
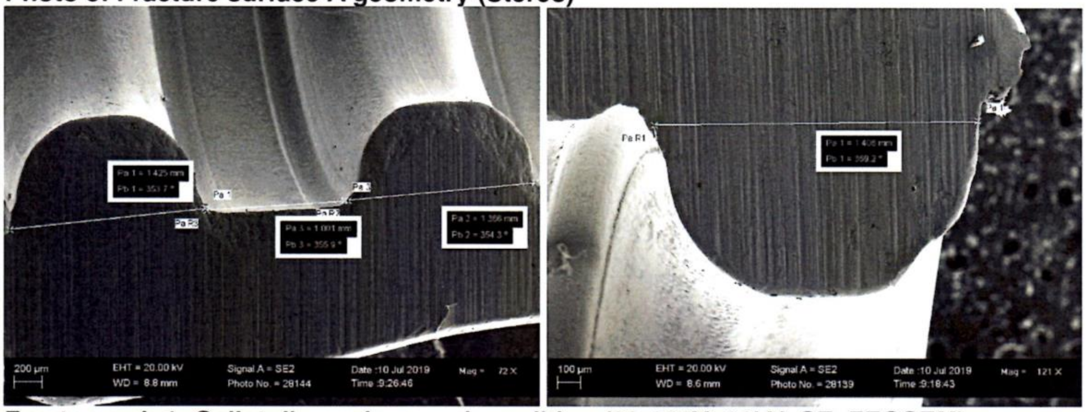
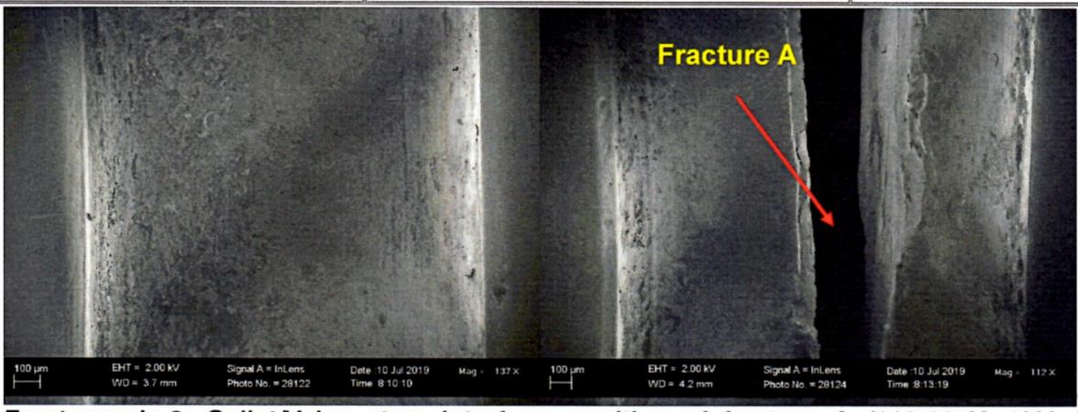


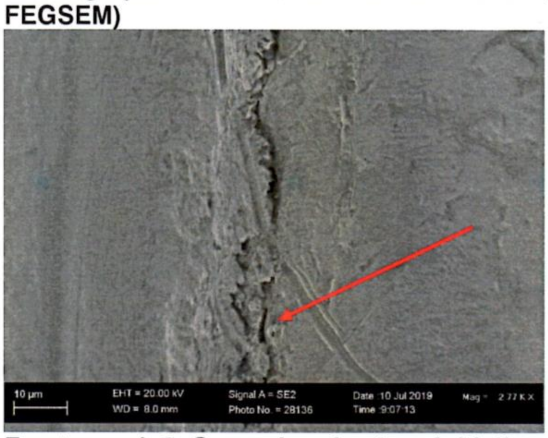
Photo 9: Fracture surface A geometry (Stereo)



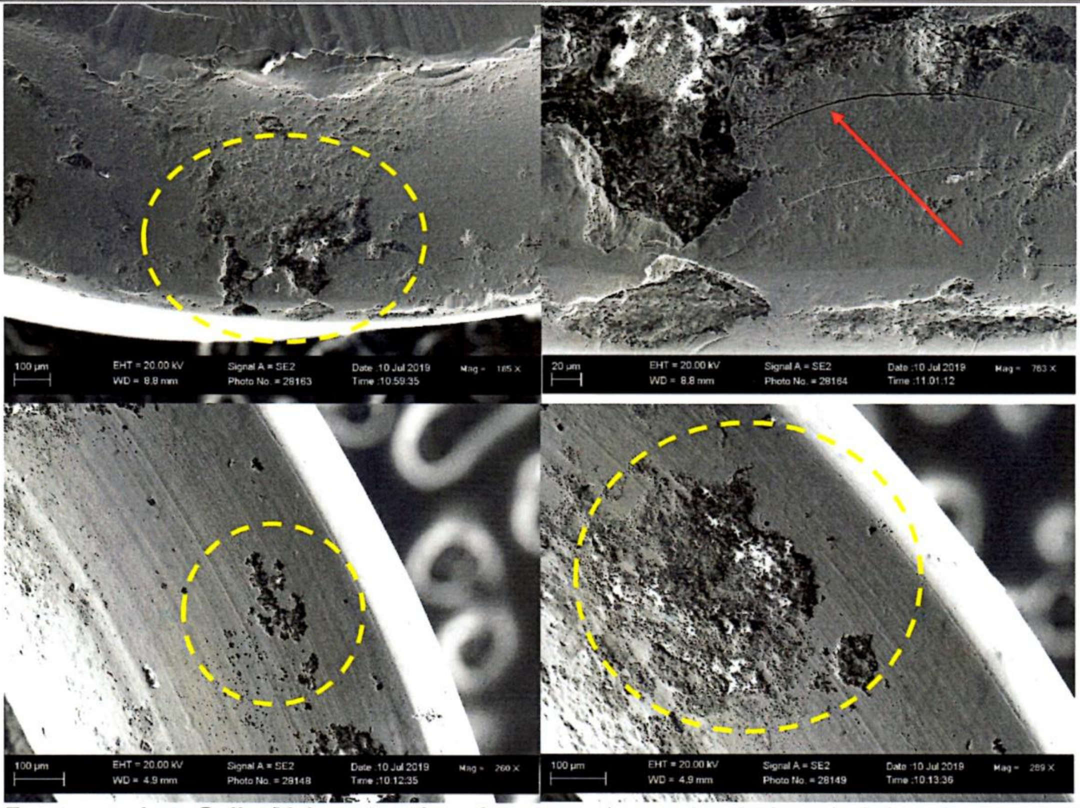
Fractograph 1: Collet dimensions and condition (32-121X, 20kV, SE, FEGSEM)



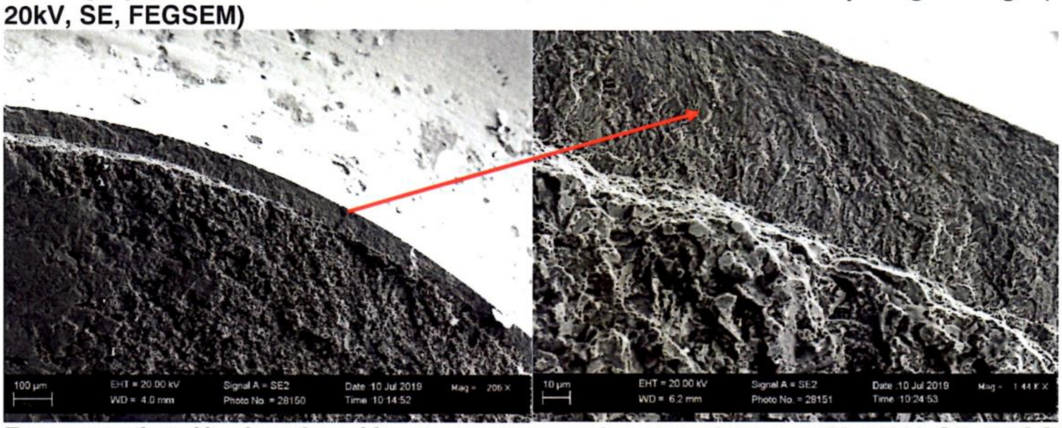
Fractograph 2: Collet/Valve stem interface, position of fracture A (112-137X, 2kV, InLens, FEGSEM)



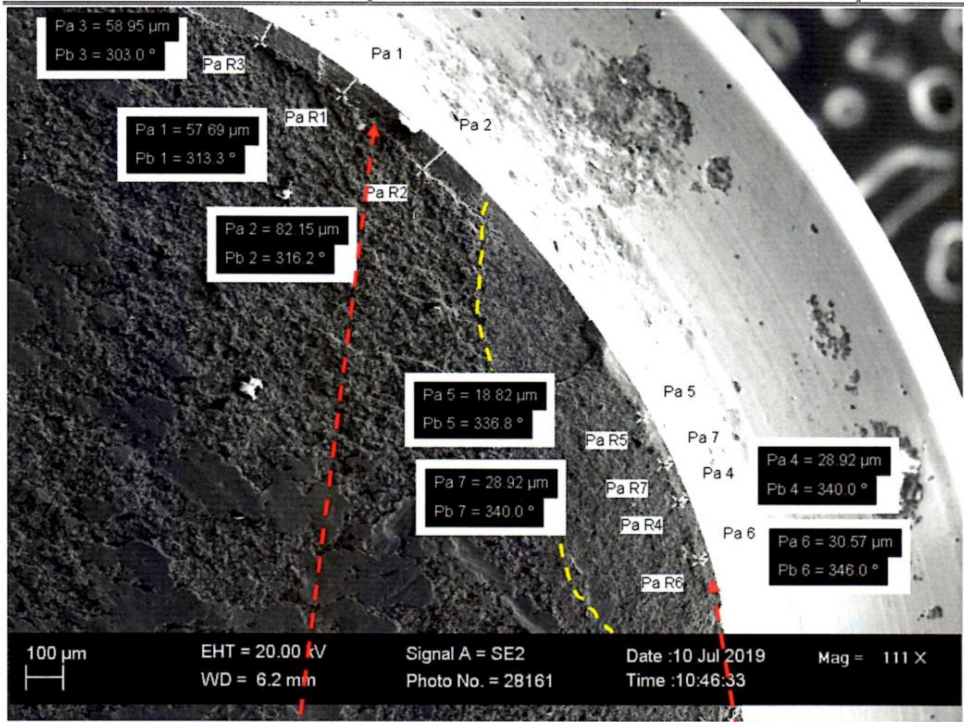
Fractograph 3: Secondary fracture initiation (2770X, 20kV, SE, FEGSEM)



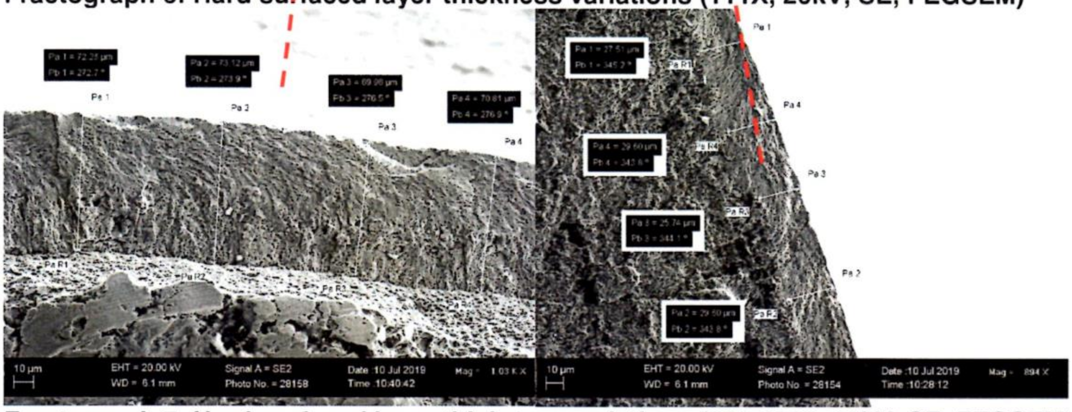
Fractograph 4: Collet/Valve stem interface, wear/corrosion induced pitting damage (185-383X, 20kV, SE, FEGSEM)



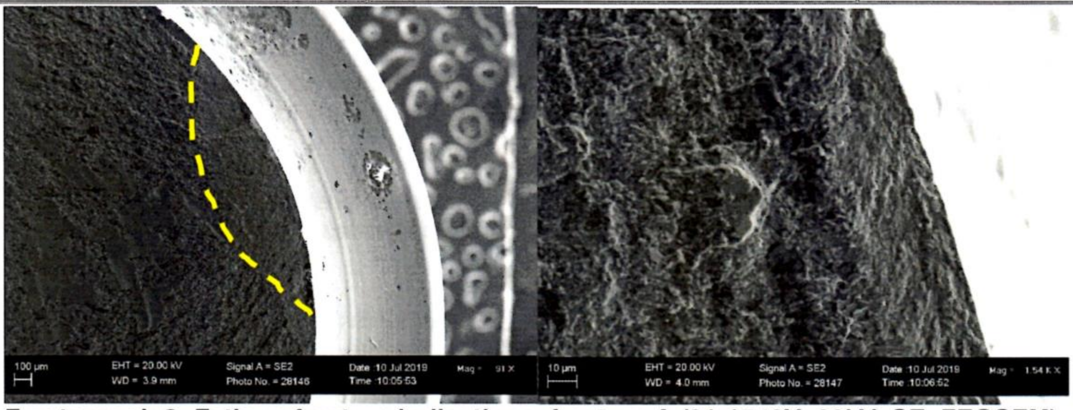
Fractograph 5: Hard surfaced layer geometry, valve stem (206-1440X, 20kV, SE, FEGSEM)



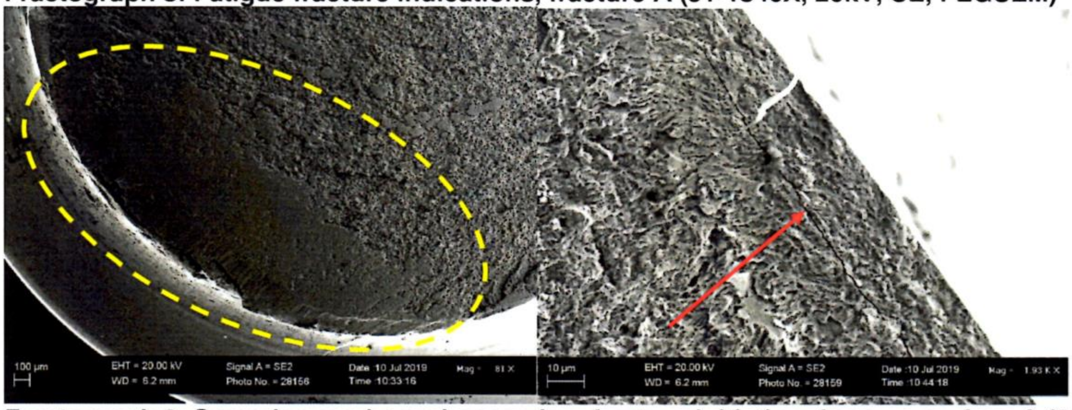
Fractograph 6: Hard surfaced layer thickness variations (111X, 20kV, SE, FEGSEM)



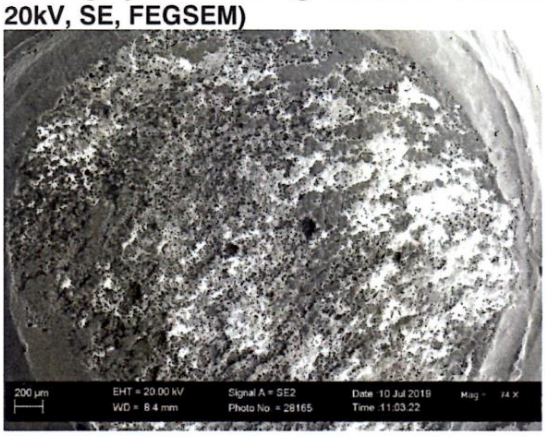
Fractograph 7: Hard surfaced layer thickness variations (894-1030, 20kV, SE, FEGSEM)



Fractograph 8: Fatigue fracture indications, fracture A (91-1540X, 20kV, SE, FEGSEM)



Fractograph 9: Smearing marks and secondary fracture initiation, fracture surface A (81-1930X, 20kV, SE, FEGSEM)



Fractograph 10: Opposing fracture surface damages, valve stem, fracture surface A (74X, 20kV, SE, FEGSEM)

7. DISCUSSION AND CONCLUSIONS

Note 3: *The conclusions are based on the investigation results obtained from the supplied parts/components and information only. All information supplied to this investigation from other parties are considered factual.*

7.1. The visual inspection revealed clear indications of high temperature exposure within the cylinder head area in proximity of the exhaust valve assembly. This correlates with OEM inspection requirements (Extract 1).

The visual and high-magnification inspection of the exhaust valve stem revealed clear indication of high temperature exposure/s during operation and corelates with OEM inspection requirements (Extract 1).

The indications above suggest that the exhaust valve assembly was exposed to excessively high temperatures during operation. *The exact cause thereto could not be determined by this investigation – see Note 1.*

7.2. The high magnification inspection of Fracture A revealed inconsistent hard surface layer thicknesses in the vicinity of the initiation point of the noted fatigue fracture within the serrated area (collet/valve stem interface). This could have contributed to the noted *secondary* surface cracks and most probably led cause to the initiation of the *primary* fatigue fracture.

7.3. The results ascertained from the supplied parts (see Note 3) suggest that both fractures, **A and B,** had clear cause towards initiation.

Fracture A due to fatigue fracture initiation/s brought about by hard-surfaced layer inconsistencies and/or operational forces induced as a secondary effect due to the interjected movement of the exhaust valve during operation. The latter possibly due to resistance of movement at the guide/stem interface because of the high temperature induced lubrication failure.

The indications at the position of **Fracture B** suggest failure due to excessively high operational temperature exposure/s.

However, due to the extensive post-failure damages, it could not be derived which of **Fractures A or B** initiated first in the sequence of events, and, whether both conditions for failure was present simultaneously. The only indication that **Fracture A** most probably initiated first is the presence of the time-dependant fatigue fracture, thus suggesting that **Fracture B** was imminent.

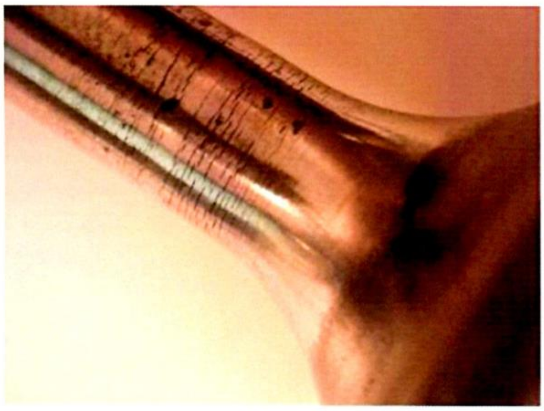
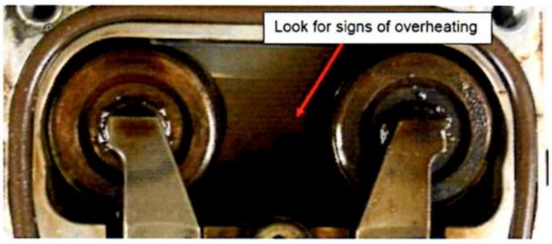


Figure 2: Valve with extensive stress cracks.



Extract 1: High temperature indications[4]

8. RECOMMENDATIONS

8.1. Considering the detrimental effects on Flight Safety of an engine failure during operation, it is recommended that the remainder of the engine to be inspected.

9. DECLARATION

9.1. All digital images have been acquired by the author, unless otherwise stated, and displayed in an un-tampered manner.

[4] Courtesy JSL-014-2