EXECUTIVE SUMMARY AND AIRCRAFT ACCIDENT REPORT

Reference:	CA18/2/3/8142

Aircraft Registration	ZU-DYF	**Date of Accident**	16 June 2006	**Time of Accident**	0935Z
Type of Aircraft	Dragonfly MK3		**Type of Operation**	Ferry Flight	
Pilot-in-command Licence Type	Airline Transport	**Age**	27	**Licence Valid**	Yes
Pilot-in-command Flying Experience	Total Flying Hours	3500.0		Hours on Type	2.0
Last point of departure	Virginia Aerodrome. (FAVG)				
Next point of intended landing	East London Aerodrome. (FAEL)				
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)					
In the Sawoti area approximately 35 nm south-west of Durban (GPS position: S30° 16'09'' E030° 31'31'').					
Meteorological Information	Surface wind: Light and Variable, Temperature: 19℃, Visibility: CAVOK				
Number of people on board	1 + 0	**No. of people injured**	1 + 0	**No. of people killed**	0

Synopsis

The pilot, as the sole occupant, departed from Virginia Aerodrome on a ferry flight to East London via Cato Ridge. The pilot avoided FADN Terminal Control Area (TMA) en-route to East London and climbed to 5500ft AMSL at an indicated air speed of 145kt. At that stage, the engine suddenly failed and his vision was impaired by engine oil which started emanating from the engine onto the windshield.
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During the subsequent forced landing in a harvested sugar cane field, the right-hand main landing gear and wing tip impacted a hill and thereafter a second hill.

The pilot suffered serious injuries.

The aircraft was destroyed during the impact sequence.

Probable Cause

Engine failure due to a con-rod failure in flight caused by incorrect fitment of the shim at the big-end Bearing, resulting in a forced landing.

Contributory Factor:

Pilot's impaired vision due to the windshield being covered by oil, resulting in the aircraft's landing speed being fairly high.

IARC Date		Release Date	

AIRCRAFT ACCIDENT REPORT

Name of Owner/Operator	: Mr. N.J. Cleator
Manufacturer	: Allan J Clarke
Model	: Dragonfly MK3
Nationality	: South African
Registration Marks	: ZU-DYF
Place	: Sawoti Area, 50nm South-West of Durban.
Date	: 16 June 2006
Time	: 0935Z

All incident times given in this report are indicated according to 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 (1997) this report was compiled in the interests of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and **not to establish legal liability**.*

Disclaimer:

This report is given without prejudice to the rights of the CAA, which are reserved.

SYNOPSYS:

1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 The aircraft was imported from the United States of America and was intended to be displayed as an advertisement in marketing the aircraft type. The aircraft was inspected and test-flown by the accident pilot. The intention was to ferry the aircraft to East London. On 15 June 2006, a special flight permit was requested by the owner for a ferry flight from FAVG to FAEL, which was approved on a Proving Flight Authority to Fly document issued on 15 June 2006, with an expiry date of 14 December 2006 or 135 airframe hours.

1.1.2 On 16 June 2006, the aircraft took off from FAVG at approximately 0825Z for a flight to La Mercy Aerodrome where he performed two (2) touch-and-go landings before returning to FAVG. The pilot then departed FAVG at 0902Z for the intended ferry flight to East London with 26 US Gallons of fuel on board. No flight plan was submitted. According to the pilot, he flew towards Cato Ridge in order to avoid the Durban Airspace Terminal Control Area (TMA).

1.1.3 After he successfully avoided entering the Durban controlled airspace (TMA), the pilot started to climb to 5500ft AMSL, at an Indicated Air Speed (IAS) of 145kt, but as he was about to report his position to the FADN Air Traffic Controller (ATC), the engine failed and oil started emanating from the engine onto the windshield. He then broadcasted a may-day call on VHF radio frequency 118.7MHz to FADN-ATC and notified the controller that he was committed to carry out a forced landing. The transmission was also overheard by a South African Airways aircraft in the FADN airspace which in turn, relayed the message to the FADN ATC.

1.1.4 The pilot attempted to carry out a forced landing in a harvested sugar cane field in the Sawoti area S/W of FADN, but the aircraft's speed was too fast and the right-hand main landing gear wheel and right-hand wingtip impacted with the ground on a hill. After the initial impact, the aircraft flew approximately 600 to 700m further on and impacted with another hill.

1.1.5 According to the pilot, his vision was restricted by engine oil emanating from the engine onto the cockpit windshield during the forced landing.

1.1.6 The pilot, who was the only occupant on board, sustained serious injuries during the impact sequence and was airlifted by a Search and Rescue 911 helicopter to the St. Augustine hospital in Durban.

1.1.7 The accident occurred during daylight conditions at 0935Z.

1.2 Injuries to Persons

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

1.3 Damage to Aircraft

1.3.1 The aircraft was destroyed on impact with the ground surface.

PHOTO 1: AERIAL VIEW OF WRECKAGE IN THE SUGAR CANE FIELD.

1.4 Other Damage

1.4.1 Damage was limited to the accident area around the wreckage.

1.5 Personnel Information

Nationality	South African	Gender	Male	Age	27
Licence No.	****************	Licence Type	Airline Transport		
Licence valid	Yes	Type Endorsed	No		
Ratings	Instructor Grade 3, Test Pilot class 2, Tug Pilot.				
Medical Expiry Date	05 December 2006				
Restrictions	None				
Previous Accidents	None				

1.5.1 According to the pilot, he was requested by the owner to fly the aircraft on a ferry flight from Virginia Aerodrome to East London. Although the owner had obtained authorization for the ferry flight from Virginia to East London, the pilot needed to be authorized to fly the aircraft type. No documentation was found on the pilot's SACAA file to the effect that the pilot had obtained an authorization to fly the aircraft type.

1.5.2 The pilot verbally stated that the owner of the aircraft had obtained a letter from the SACAA for him to fly the aircraft on the ferry flight from Virginia to East London. However, the letter was not recovered from the aircraft wreckage. A copy of the letter was also not found on the SACAA Pilot's file.

Flying Experience:

Total Hours	3500.0
Glider	850.0
Total Past 90 Days	60.0
Total on Type Past 90 Days	2.0
Total on Type	2.0

1.6 Aircraft Information

Airframe:

Type	Dragonfly MK3	
Serial Number	11796	
Manufacturer	Allan J Clarke	
Year of Manufacture	1997	
Total Airframe Hours (At time of Accident)	125.0	
Last Annual Inspection (Date & Hours)	12 June 2006	120.0
Hours since Last Annual Inspection	5.0	
*Authority to Fly (Issue Date)	15 June 2006	
Authority to Fly (Expiry Date)	14 December 2006 /or/ 135 hours	
C of R (Issue Date) (Present owner)	27 October 2005	
Operating Categories	Private	

1.6.1 A Proving Flight Authority to Fly for the aircraft was issued and approved on 15 June 2006 by the SACAA for a proving flight from Virginia to East London. The distance from Virginia to East London is approximately 480km. According to a written notification on the Proving Flight Authority to Fly document, one (1) flight from Virginia to East London via the shortest practical route was approved for the aircraft.

. **Engine:**

Type	Subaru EA82
Serial Number	0697/01
Hours since New	125.0
Hours since Overhaul	T.B.O. not yet reached

Propeller:

Type	Ivo- Prop Magnum
Serial Number	No available number
Hours since New	125.0
Hours since Overhaul	T.B.O.not yet reached

1.7 Meteorological Information

1.7.1 The Meteorological Information provided by the South African Weather Services stated that no official observations were available at the time and place of the accident. The most likely conditions at the place of the accident, south-west of Durban, were as follows:

1.7.1.1 Surface Analysis

A high pressure system was present east of the country as well as over the eastern part of the country. This caused an offshore flow over the KwaZulu-Natal coastal areas.

1.7.1.2 Upper Air Analysis

A high pressure system was present over the central interior.

1.7.1.3 Satellite Imagery

No satellite imagery was available.

1.7.1.4 Weather conditions in the vicinity of the accident

No official observations were available at the time and place of the accident. The most likely conditions at the place of the accident were:

Time: 0935Z
Temperature: 19˚C
Wind Direction: 250˚
Wind Speed: 03kt
Cloud: No low cloud.

1.8 Aids to Navigation

1.8.1 This was a Visual Flight Rules (VFR) flight. Aeronautical maps were found in the wreckage of the aircraft at the accident scene. A handheld Global Positioning System (GPS) was also found in the wreckage and appeared to have been used as an aid to navigation.

1.9 Communications

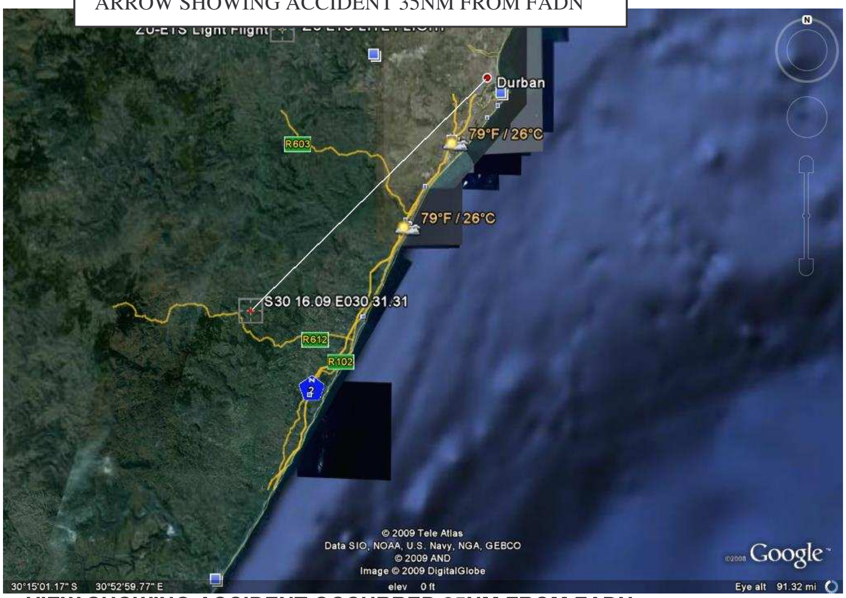
1.9.1 The pilot broadcasted a mayday call on the VHF frequency 118.7MHz to FADN-ATC which was subsequently also relayed by a South African Airways aircraft to the FADN-ATC.

1.9.2 The pilot advised FADN ATC that he was 217nm from FAEL and approximately 15 nm inland from the coast, and approximately 25 nm from Durban VOR.

1.10 Aerodrome Information

2.5.1 The accident did not occur at an aerodrome but in a harvested cane field, 35nm south-west of Durban at a GPS position S30˚16'09" E030˚31'31.

ARROW SHOWING ACCIDENT 35NM FROM FADN



VIEW SHOWING ACCIDENT OCCURRED 35NM FROM FADN

1.11 Flight Recorders

1.11.1 The aircraft was not fitted with a Cockpit Voice Recorder (CVR) or a Flight Data Recorder (FDR) and neither was required by regulations to be fitted to this type of aircraft.

1.12 Wreckage and Impact Information

1.12.1 During the forced landing in a harvested cane field, the aircraft's right-hand main landing gear wheel and right-hand wing-tip impacted a hill. After the initial impact, the aircraft still flew a further 600 to 700 metres and impacted with another hill. During the impact sequence, the firewall, forward of the instrument panel, canopy and the left- and right-hand wing were extensively damaged. The aircraft came to rest in an upright position following the impact.

PHOTO 2: VIEW OF AIRCRAFT WRECKAGE SHOWING DAMAGE TO WINGS & FUSELAGE.

PHOTO 3: FRONT VIEW OF WRECKAGE SHOWING EXTENSIVE DAMAGE TO AIRCRAFT.

1.12.2 During the on-site investigation it was noted that there was a hole in the crankcase of the engine. A failed connecting rod could be observed through the hole, near to the number 2 cylinder position. The hole in the crankcase caused the engine oil to escape from it and the cooling waterjacket in that area of the engine had also been penetrated, causing the cooling water to also escape from the cooling system. The outflow of the engine oil and cooling water spilled over the windshield and caused the vision of the pilot to be impaired.

1.12.3 It was also observed that a large counterweight which was bonded in the inside of the tail section had become dislodged as a result of the heavy impact with the ground surface.

1.13 Medical and Pathological Information

1.13.1 The pilot was airlifted by helicopter and admitted to hospital with serious injuries sustained during the accident sequence.

1.14 Fire

1.14.1 There was no evidence of a pre- or post-impact fire.

1.15 Survival Aspects

1.15.1 Although the pilot sustained serious injuries due to the destruction of the nose section and cockpit/cabin area on impact, he survived the accident. He was properly restrained by safety belts.

1.16 Tests and Research

1.16.1 The aircraft was recovered to the owner's property and the engine, still attached to the fire wall, was transported to the workshop of an Approved Person for further dismantling and inspection.

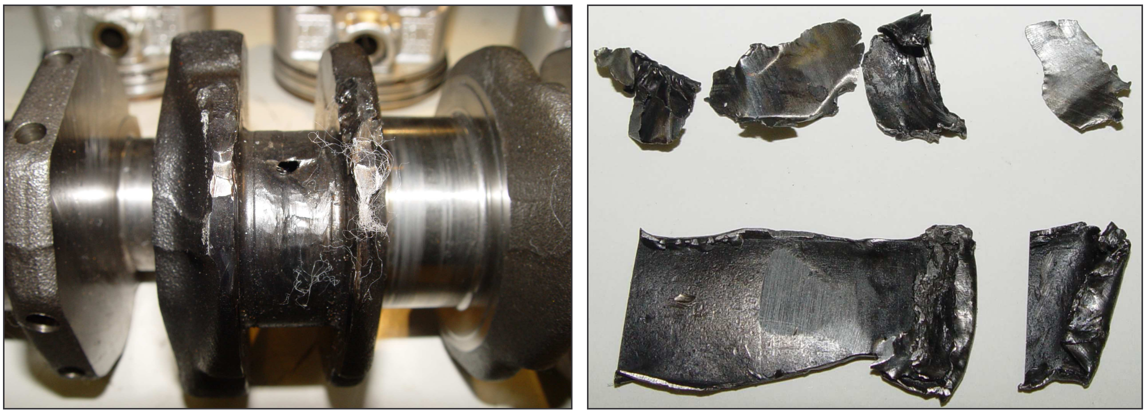
1.16.2 A general inspection of the engine revealed that damage was caused to the lower surfaces of the engine during the impact. The exhaust system, as well as the accessories mounted to the bottom of the engine suffered impact damage. It was noted that during the impact sequence the engine-mounting frame was deformed and caused the upper right-hand mounting point to impact a coolant receptacle welded to the intake manifold for that side. The failed welded joint appeared to be a poorly welded joint, as the aluminium welding material did not flow properly and had a porous appearance. A similar weld was noted on the left-hand side intake manifold.

1.16.3 The reduction gearbox was inspected and removed and no defects were identified with this assembly. It was noted that some of the oil tubes were severed from their attachment points.

1.16.4 The failed Subaru EA82 engine, serial no 0697/01, was submitted to an Approved Metallurgist, in order to determine the most likely reason for the engine failure. Annexure '1' & 2' is attached to this report. A brief summary of the Metallurgical Analysis Report is as follows

1.16.4.1 Visual and Stereo-microscope Investigation

The visual inspection revealed localized, but severe impact and heat damage at the position of failure. The remainder of the crankshaft, including contact surfaces, appeared to be in a serviceable condition. The serviceable big-end bearings showed only post-failure impregnation damage. Originally, the layered platelets that had impregnated the con-rod side of the big-end were considered to be the remains from a peel-type shim. Although this could not be ascertained beyond a doubt, it appears that the impregnated layered platelets originate from the extensively damaged upper half of the big-end bearing. No other remnants from the upper half (con-rod side) of the big-end bearing were retrieved. No clear explanation exists as to why the lower half (cap side) of the bearing was not damaged to the same extent. The softer aluminium layer from the lower half of the failed bearing was completely removed while the Scanning Electron Microscope (SEM) investigation showed some sub-surface diffusion due to the extreme temperatures. The SEM EDS analysis revealed that the material composition of the impregnated platelets compares to that of the base metal from the bearing. No obstructions were detected in the crankshaft oil feeding tubes.



PHOTOS 5 & 6: SHOWING CRANKSHAFT AT POSITION OF FAILURE & REMAINDER OF BIG-END BEARING.

1.16.4.2 The investigation of the remainder of the relevant engine confirmed that the failure had occurred over an undeterminable period of time and not catastrophically. Taking into account the condition of the remainder of the engine bearings as well as the localized nature of the heat damages, it can be derived that general oil starvation and/or other lubrication discrepancies cannot be considered as a primary cause of this failure. All evidence points to the breakdown of the con-rod bearing as the primary cause of the catastrophic failure of the engine during operation.

1.16.4.3 Under severe conditions, particularly in high performance engines, con-rods may bend and/or cause the elongation of the big-end, resulting in 'pinching' of the bearing.

1.17 Organisational and Management Information

1.17.1 This was a private flight. The pilot was requested by the aircraft owner to fly the aircraft from Virginia Aerodrome to East London Aerodrome.

1.17.2 The last Annual Inspection that was certified on the aircraft prior to the accident was on 12 June 2006 at 120.0 airframe hours by an Approved Person (AP) No. 41 of the Aero Club of South Africa.

1.17.3 A Proving Flight Authority to Fly for the Non Type Certified Aircraft (NTCA) was issued by the SA: CAA on 15 June 2006 with the expiry date being 14 December 2006 or 135 airframe hours. One (1) flight from FAVG to FAEL was approved via the shortest practical route from FAVG to FAEL.

1.18 Additional Information

1.18.1 According to the West-Can Equlties Ltd, Policies, Procedures Manual, Performance Data for the aircraft, the following aircraft information is applicable to the aircraft type:

Top Speed (Sea Level):	185 KIAS.
Cruise Speeds: 75% @ 8000ft:	180 KIAS.
: 65% @ 8000ft:	175 KIAS.
: 55% @ 8000ft:	165 KIAS.
Maximum Structural Cruise Speed:	175 KIAS.
Manoeuvring Speed:	140 KIAS.
Recommended Glide Speed (engine out):	85 KIAS.
Stall Speed:	58 KIAS.

1.18.2 Test pilot requirements:

Air Navigation Regulation (ANR) 1976 ,Test Pilot's Ratings
Regulation 3.16D states the following:

a) An applicant for a Class II test pilot's rating shall be the holder of a private pilot's or
higher grade licence.

b) Have completed not less than 500 hours' flight time of which not less than 300 hours were as pilot-in-command.

c) Be the holder of a appropriate aircraft category rating.

d) Be the holder of the appropriate aircraft class rating; and

e) Satisfy the Commissioner that he has adequate knowledge of test flying techniques.

Aeronautical Information Circular, (AIC) 30.6 03-03-15:
Air Navigation Regulation (ANR) 2.9D states the following:

- No person shall act as a test pilot of an aircraft unless he is the holder of a valid pilot's licence with a test pilot's rating. The requirements for a test pilot's rating are laid down in ANR 3.16D which clearly states that an applicant for a Test Pilot rating (class I or II) must be the holder of a valid Private Pilot or higher-grade licence with certain criteria.

- Test Flights will therefore be performed only by suitably rated pilots; this means **rated on type** and rated as a **Test Pilot**. A type rating is not applicable to a Class I Test Pilot Rating.

1.18.3 A pilot needs to complete training on the aircraft type until a qualified instructor finds the pilot competent to fly the aircraft type. In the case in which such an aircraft type is newly imported into the State and no qualified instructor exists in the State to complete such conversion training (as in the case of the accident aircraft), the SACAA may by application authorize a pilot with an instructor rating, to fly the aircraft to obtain experience on the aircraft type and in the future provide conversion training to other pilots. This authorization will be granted on the grounds of the pilot's qualifications and experience. Only when this authorization is obtained may the pilot fly the aircraft.

1.19 Useful or Effective Investigation Techniques

1.19.1 None

2. ANALYSIS

2.1 The pilot was tasked by the owner to ferry the aircraft from FAVG in Durban to FAEL when the accident occurred. The pilot first flew towards Cato Ridge en route to East London, in order to avoid the Durban Terminal Control Area (TMA). During the flight, he experienced an engine failure and was committed to carry out a forced landing in a harvested sugar cane field. During landing, the pilot's vision was restricted by oil and cooling fluid emanating from the engine onto the windscreen.

2.2 During the forced landing however, the aircraft speed was high and it impacted with a hill. The aircraft then flew a further estimated 600 to 700 metres and impacted with a second hill.

2.3 The pilot sustained serious injuries during the accident sequence and was airlifted by helicopter and admitted to hospital.

2.4 The Metallurgical Analysis Investigation on the Subaru engine concluded the following information:

2.4.1 Evidence points to the breakdown of the con-rod bearing as the primary cause for the catastrophic failure of the engine and that the failure occurred over an undetermined period of time and not catastrophically.

2.4.2 Taking into account the condition of the remainder of the engine bearings, as well as the localized nature of the heat damages, it can be derived that general oil starvation and/or other lubrication discrepancies cannot be considered as a primary cause of this failure.

2.4.3 Incorrect fitment of the assembly may lead to 'pinching' of the bearing, leading to higher wear rates and failure. Under severe conditions, particularly in high performance engines, con-rods may bend and/or cause the elongation of the big-end, resulting in 'pinching' of the bearing.

2.4.4 The available evidence points to the following sequence of events:

The breakdown of the shim seems to be the primary cause of the failure of the assembly. The causal factors for the failure of the shim can be oil starvation/breakdown and/or the mechanical breakdown of the shim itself, due to incorrect fitment. Although the former could not be determined conclusively due to the unavailability of oil samples, it is however, unlikely as the journal/bearing assemblies, downstream of the oil flow as well as others, seemed to be in relative good condition.

Following the breakdown of the shim, the sliding bearing was damaged, ensuing excessive wear that resulted in high temperature exposure of the assembly.

Following the total breakdown of the bearing, the con-rod was now in direct contact with the shim/crankshaft surfaces, resulting in seizure of the assembly. The con-rod became part of the crankshaft after seizure and subsequently fractured, and the con-rod was forced through the crankcase.

3. CONCLUSION

3.1 Findings

3.1.1 The pilot was the holder of a valid Airline Transport Pilot's Licence. He held an Instructor's Grade 3 rating and Test pilot class 2 Rating with an unrestricted Medical Certificate.

3.1.2 Although the pilot was the holder of a test pilot class 11 rating, he was not type rated on the non type certificated aircraft as required by ANR regulation 3.16D.

3.1.3 According to the pilot, he was requested by the owner to fly the aircraft on a ferry flight from FAVG to FAEL. There was however, no documentation found on the SACAA pilot's file to the effect that the pilot had obtained an authorization to fly the aircraft type at the time.

3.1.4 According to the pilot's questionnaire he had flown 2 hours on the aircraft prior to the ferry flight.

3.1.5 A Proving Flight Authority to Fly document for the aircraft was issued on 15 June 2006 for one (1) flight from Virginia aerodrome to East London via the shortest practical route from Virginia to East London. The actual distance from FAVG to FAEL is approximately 460km (256 nm).

3.1.6 No flight plan was submitted for the intended flight

3.1.7 According to SACAA records, the last Annual Inspection that was certified on the aircraft prior to the accident was on 12 June 2006, at 120 airframe hours.

3.1.8 The pilot experienced an engine failure during cruise at an IAS (Indicated Air Speed) of 145kt and was committed to execute a forced landing.

3.1.9 The engine failed during flight as a result of the con-rod failure which was primarily due to the incorrect fitment of the shim at the big-end bearing.

3.1.10 The pilot, who was the sole occupant on board the aircraft, sustained serious injuries in the accident.

3.1.11 The aircraft was destroyed in the accident.

3.1.12 The weather was fine and was not considered to be a factor in this accident.

3.2 Probable Cause/s

3.2.1 Engine failure due to con-rod failure in flight, due to incorrect fitment of the shim at the big-end bearing, resulting in a forced landing.

3.3 Contributory Factor:

3.3.1 Pilot's impaired vision, resulting in the aircraft's landing speed being fairly high.

4. SAFETY RECOMMENDATIONS

4.1 It is recommended in the interests of air safety, that the risk and/or compatibility of the use of engines such as the Subaru and Rotax engines in aircraft should be investigated further by the Airworthiness and Certification Departments of the SACAA.

4.2 With this investigation the failed components had no traceability. The certification process involved requires revision by the SACAA.

5. APPENDICES

5.1 Attachment: Metallurgical Analysis: Appendix 1
Attachment: Metallurgical Analysis: Appendix 2

-END-

Report reviewed and amended by the Advisory Safety Panel
26 May 2009

ITEM: **DRAGONFLY CON-ROD FAILURE, ZU-DYF**

1. INTRODUCTION

1.1. The failed Subaru Stratus EA-81 con-rod from the Dragonfly aircraft (Photo 1), number ZU-DYF, was submitted to determine the possible reason/s for failure during operation.

Photo 1: Failed con-rod from Subaru engine (courtesy CAA)

1.2. Con-rod Failures: The following are typical con-rod failure modes in combustion engines:

- Fracture: Under highly stressed conditions, high rpm, etc., cracks may initiate in prone areas.
- Distortion: Under certain conditions the big-end may be distorted causing the housing to become oval. This causes the bearing to lose clearance at the narrow point, leading to bearing seizure and the rod then becoming part of the crank and carving a path for itself through the crankcase.
- Bending: Boosted engines tend to get pushed to the limits of peak cylinder pressure rather than rpm, so a popular con-rod failure mode for them is buckling the rod in compression due to detonation. This is usually not catastrophic.
- Bearing failure: This is commonly caused by oil starvation or breakdown due to oil feeding hole obstruction or other. This may lead to the seizure of the bearing onto the crankshaft and the con-rod becoming part of it, leading catastrophic failure. Incorrect fitment may cause the bearing to spin that will lead to heat build-up causing oil breakdown and subsequent seizure.

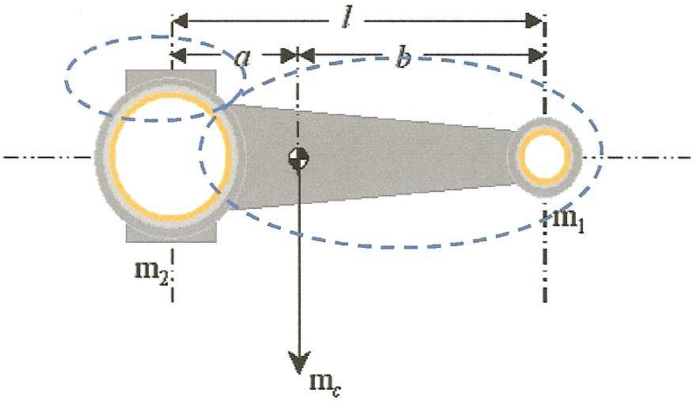


Diagram 1: Con-rod construction, only sections encircled in blue was retrieved for investigation purposes.

1.3. This report is divided into the following sections:

2. APPLICABLE DOCUMENTS

None.

3. DEFINITIONS

(a) SEM Scanning Electron Microscope
(b) EDS Energy Disperse X-ray Analysis
(c) OEM Original Equipment Manufacturer
(d) CAA Civil Aviation Authority

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), Radiation Protection Officer (RPO) registered with the National Nuclear Regulator (NNR) and Aircraft Accident Investigator (SCSI).

5. APPARATUS AND METHODOLOGY

(a) The apparatus employed for this investigation are Scanning Electron-, Stereo Microscopes and Digital Camera.

(b) The methodology included a visual investigation of supplied parts followed by a Scanning Electron- and a Stereoscopic investigation.

6. INVESTIGATION

6.1. **Visual and Stereo-microscope Investigation.** The visual inspection revealed high temperature exposure on the crankshaft in the relative position (Photo 2). Extensive impact damage in the relevant areas is also evident (Photo 2). The impact damages resulted in the bending damages to the con-rod (Photo 3). The bottom area of the con-rod (Photo 4) showed signs of extensive impact damages, ductile extrusion, damaged fracture surfaces and deformed remains from what appeared to be a shim as well as high temperature induced discoloring. The con-rod fracture surfaces A and B (Photo 5) revealed some discoloring and foreign material deposit. The remainder of the cap fastener (Photo 5) showed signs of impact damages and two fracture surfaces C and D (Photo 7). The cap fastener bolt revealed signs of bending damages (Photo 6). Fracture surfaces C and D revealed no clear signs of pre-failure crack formation (Photo 7) but high temperature induced discoloring. The contact faces between the fastening bolt and nut and the remainder of the cap fastener (Photo 7) showed signs of multiple mechanically induced impact marks. This is most probably due to the disintegrating of the opposite fastener first leaving the remainder of the assembly exposed to some movement for an amount of cycles before final failure. The contact faces between the cap and con-rod (Photo 8) revealed extensive fretting wear that may be attributed to this movement. The remainder of the shims (Photo 9) for the sliding bearing showed signs of impact and severe sliding wear damages and evidence of carbon flake deposits formed under conditions of high temperatures. This is an indication that the assembly did not fail catastrophically but over a period of time. This amount of high temperature discoloring (Photo's 2, 4, 7, 8, 9 and 12) of the relevant components close to the bearing/journal contact area correlates with this notion.

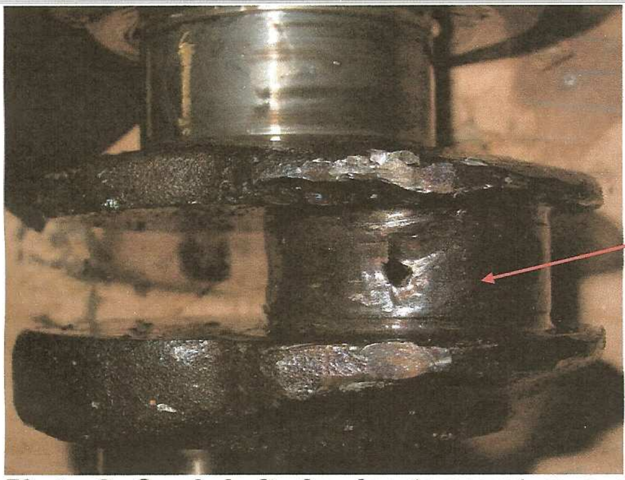


Photo 2: Crankshaft showing temperature exposure and severe damages (courtesy CAA)

Photo 3: Con-rod showing bending and surface damages (digital)

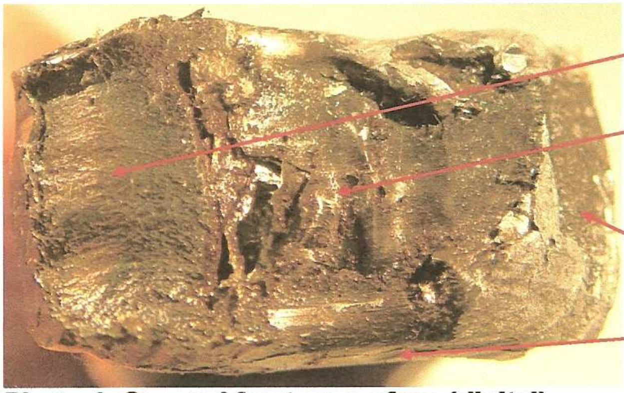


Photo 4: Con-rod fracture surface (digital)

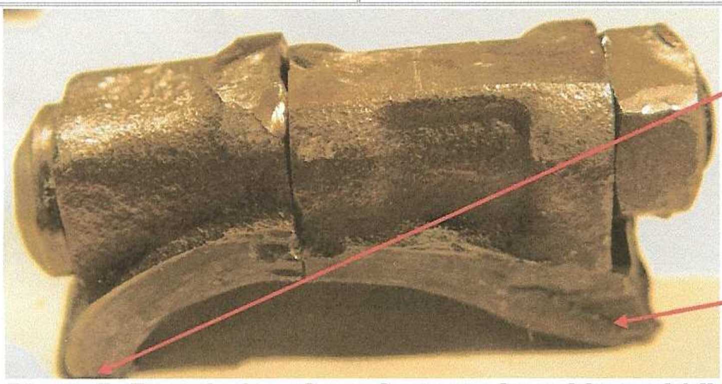


Photo 5: Remainder of cap fastener from big-end (digital)

Photo 6: Big-end cap fastener bolt showing some bending damages (digital)

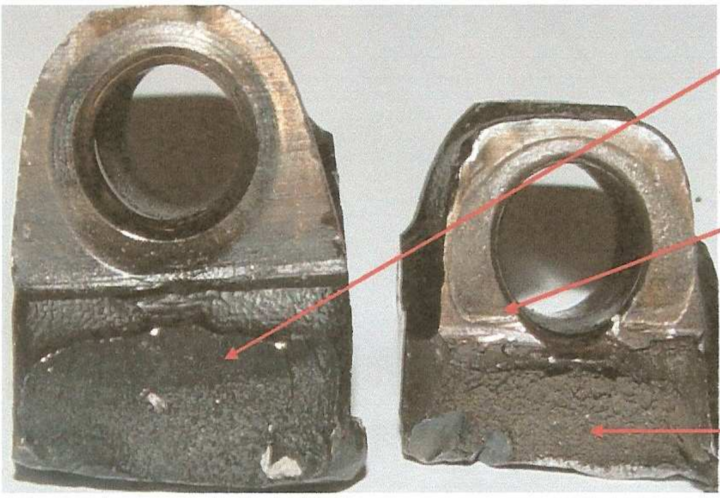


Photo 7: Fracture surfaces from cap fastener (digital)

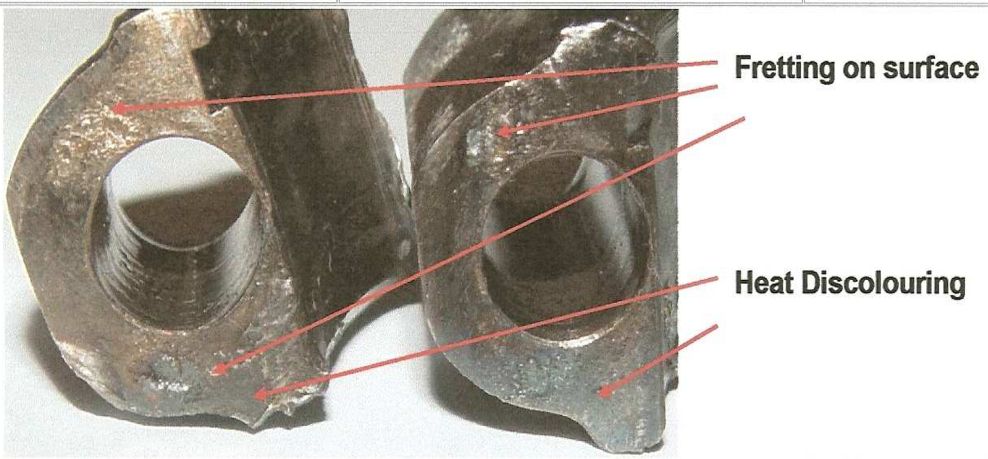


Photo 8: Contact face areas from cap fastener showing fretting and discoloring (digital)

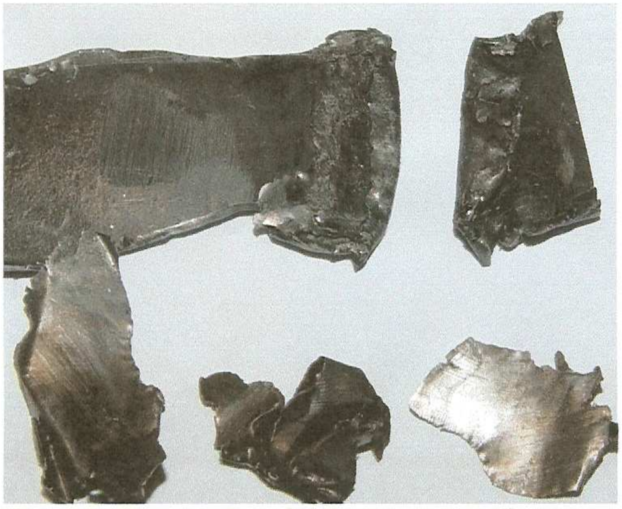


Photo 9: Remainder of the shim (digital)

6.2. Microscopic Investigation. The SEM investigation at higher magnifications revealed extensive damages to most of the fracture surfaces. Fracture surface B also showed some signs of deposits (Photo 10) from a foreign metal (Table 2) with some traces of aluminium. This can be attributed to the impact with the aluminium based crankcase. Fracture surface A (Photo 11) exposed signs of a ductile fracture combined with high temperature exposure. The surface geometry (Photo 12) corroborate with the high temperature exposure showing some surface cracking.

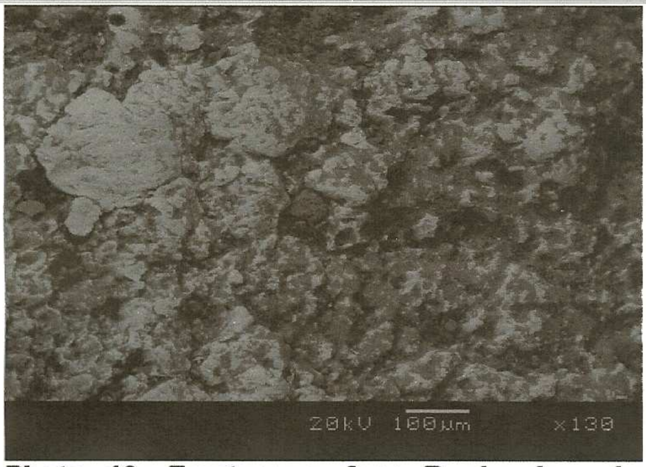


Photo 10: Fracture surface B showing signs of foreign deposits (x130, SEM, backscatter image)

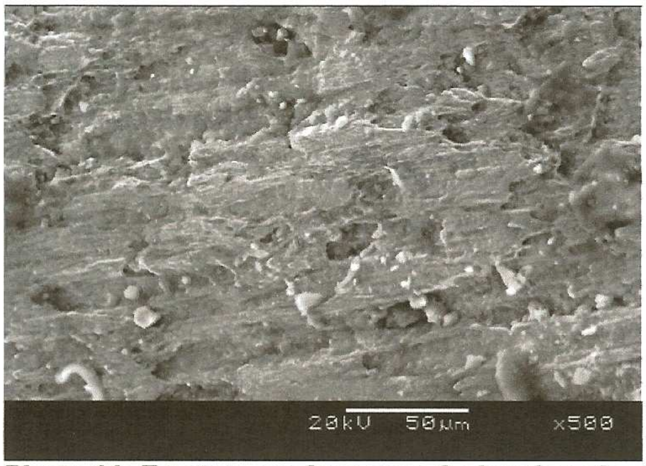


Photo 11: Fracture surface area A showing shear type failure geometry (x500, SEM)

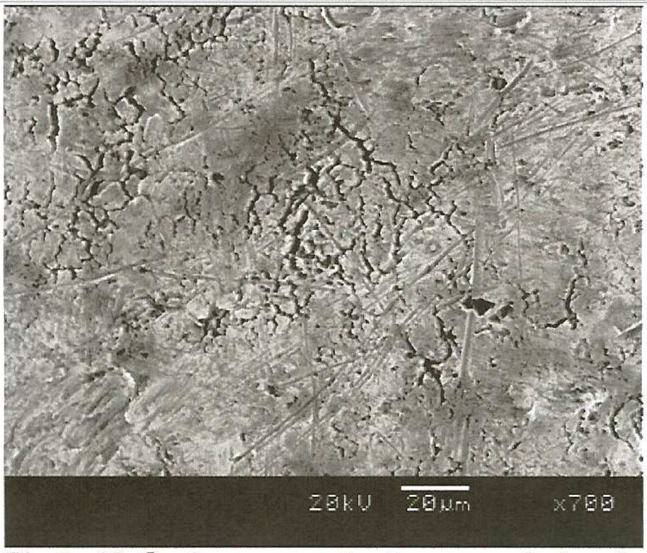


Photo 12: Surface geometry from remainder of shim (x700, SEM)

Quantitative Analysis

SHIM CLEAN AREA 1

ZAF Correction Acc.Volt.= 20 kV Take-off Angle=37.72 deg
Number of Iterations = 3

Element	k-ratio (calc.)	ZAF	Atom %	Element Wt %	Wt % Err. (1-Sigma)
Al-L	0.0092	2.210	1.43	2.04	+/- 0.06
Si-K	0.0009	1.861	0.33	0.16	+/- 0.02
P -K	0.0009	1.590	0.27	0.15	+/- 0.03
Sn-L	0.0040	1.095	0.21	0.44	+/- 0.08
Ca-K	0.0014	0.960	0.19	0.13	+/- 0.03
Mn-K	0.0045	1.027	0.47	0.46	+/- 0.08
Fe-K	0.9662	1.000	97.11	96.61	+/- 0.48
Total			100.00	100.00	

Table 1: EDS analysis of remainder of shim (EDS, SEM)

Quantitative Analysis

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FRACTURE SURFACE DEPOSIT 1

ZAF Correction Acc.Volt.= 20 kV Take-off Angle=42.61 deg
Number of Iterations = 3

Element	k-ratio (calc.)	ZAF	Atom %	Element Wt %	Wt % Err. (1-Sigma)
Al-K	0.0047	2.309	2.20	1.08	+/- 0.06
Si-K	0.0034	1.764	1.18	0.60	+/- 0.05
S -K	0.0025	1.282	0.55	0.32	+/- 0.03
Mn-K	0.0161	1.028	1.64	1.65	+/- 0.19
Fe-K	0.9613	1.002	94.44	96.34	+/- 0.53
Total			100.00	100.00	

Table 2: EDS analysis of fracture surface B deposits (EDS, SEM)

7. DISCUSSION AND CONCLUSIONS

7.1 The evidence of high temperature exposure to the parts supplied for this investigation corroborate that the assembly failed over an undeterminable period of time and not catastrophically.

7.2. No clear evidence of fatigue crack forming in any of the supplied parts could be established.

7.3. The supplied parts contained the remainder of what appears to be a peel-shim. Although not supplied for this investigation, it appears from photographs courtesy of CAA that the remainder of the con-rods from the same engine (Photo 13) is fitted with the same peel-shims. Generally peel-shims are utilized to enhance the clearances conformation during assembly between the con-rod and sliding bearing contact surfaces. This practice may increase the risk for failure of the assembly if not correctly installed.

7.4. The available evidence points to the following sequence of failure:

7.4.1. The breakdown of the shim seems to be the primary cause for failure of the assembly. The causable factors for the failure of the shim can be oil starvation/breakdown and/or the mechanical breakdown of the shim itself due to incorrect fitment. Although the former could not be determined inconclusively due to the unavailability of oil samples, it is unlikely as the journal/bearing assemblies, downstream from the oil flow as well as others, seems to in relative good condition (determined from photographs courtesy CAA). The latter is the most probable cause for failure of the shim.

7.4.2. Following the breakdown of the shim, the sliding bearing was damaged ensuing excessive wear that resulted in the high temperature exposure of the assembly.

7.4.3. Following the total breakdown of the bearing the con-rod was not in direct contact with the shim/crankshaft surfaces resulting in seizure of the assembly.

7.4.4. The con-rod became art of the crankshaft after seizure and fractured at point A. Fractures B, C and D followed with more in between. Subsequently the con-rod was forced through the crankcase.

Photo 13: Intact con-rod from same engine (courtesy CAA)

8. RECOMMENDATIONS

8.1. It is strongly recommended that before final conclusions are formulated with regard to this case, the remainder of the relevant engine and propeller assembly undergo a detailed investigation. During this investigation the fitment of shims, wear patterns of the remainder of the journal/bearing/con-rod assemblies as well as signs of excessive vibration could be determined.

9. DECLARATION

9.1. All digital images has been acquired by the author and displayed in an un-tampered manner.

ITEM: **DRAGONFLY CON-ROD FAILURE, ZU-DYF**

1. INTRODUCTION

1.1. The Investigation Report, **MET-002-11-06 Issue 1** dated 2006-11-24, has reference. The remainder of the relevant Subaru Stratus EA-81 engine from the Dragonfly aircraft (Photo 1), number ZU-DYF, was submitted to determine the possible reason/s for failure during operation.

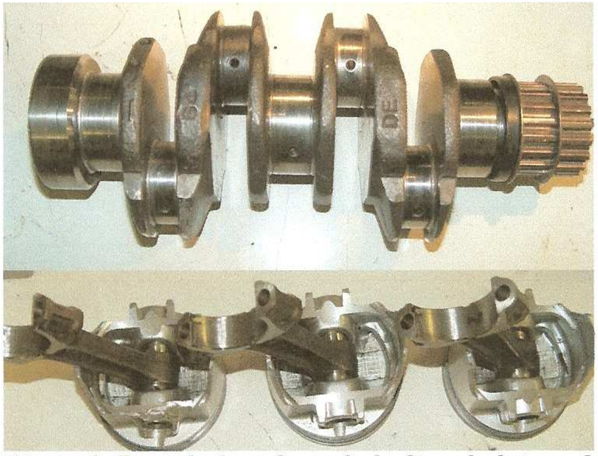

Photo 1: Remainder of crankshaft and pistons from Subaru engine (digital)

1.3. This report is divided into the following sections:

2. APPLICABLE DOCUMENTS

(a) Investigation Report: MET-002-11-06

3. DEFINITIONS

(a) SEM Scanning Electron Microscope

(b) EDS Energy Disperse X-ray Analysis
(c) OEM Original Equipment Manufacturer
(d) CAA Civil Aviation Authority

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), Radiation Protection Officer (RPO) registered with the National Nuclear Regulator (NNR) and Aircraft Accident Investigator (SCSI).

5. APPARATUS AND METHODOLOGY

(a) The apparatus employed for this investigation are Scanning Electron-, Stereo Microscopes and Digital Camera.

(b) The methodology included a visual investigation of supplied parts followed by a Scanning Electron- and a Stereoscopic investigation.

6. INVESTIGATION

6.1. **Visual and Stereo-microscope Investigation.** The visual inspection revealed localized but severe impact and heat damages to the position of failure (Photo 2). The remainder of the crankshaft including contact surfaces, appeared to be in serviceable condition. The serviceable big-end bearings showed only post-failure impregnation damages (Photo 4). Originally the layered platelets impregnated onto the con-rod side of the big-end (Photo 5), was considered to be the remains from a peel-type shim. Although this could not be ascertained beyond doubt, it appears that the impregnated layered platelets (Photo's 5 and 6) originate from the extensively damaged upper half of the big-end bearing. No other remnants from the upper half (con-rod side) of the big-end bearing was retrieved. No clear explanation exist why the lower half (cap side) of the bearing (Photo 3) was not damaged to the same extend. The softer aluminium layer (Photo 7) from the lower half of the failed bearing (Photo 8) was completely removed while the SEM investigation showed some sub-surface diffusion due to the extreme temperatures. The SEM EDS analysis revealed that the material composition of the impregnated platelets compares to that of the base metal from the bearing. No obstructions in the crankshaft oil feeding tubes were detected.

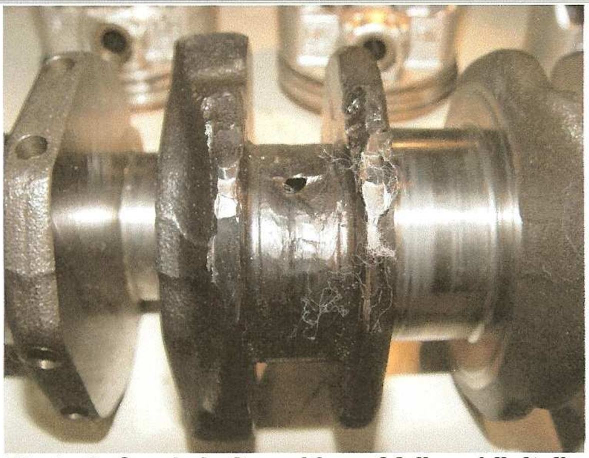

Photo 2: Crankshaft position of failure (digital)

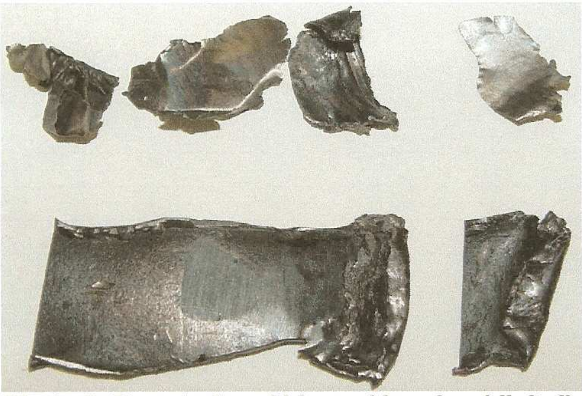

Photo 3: Remainder of big-end bearing (digital)

Photo 4: No 4 big-end bearing showing impregnation (digital)

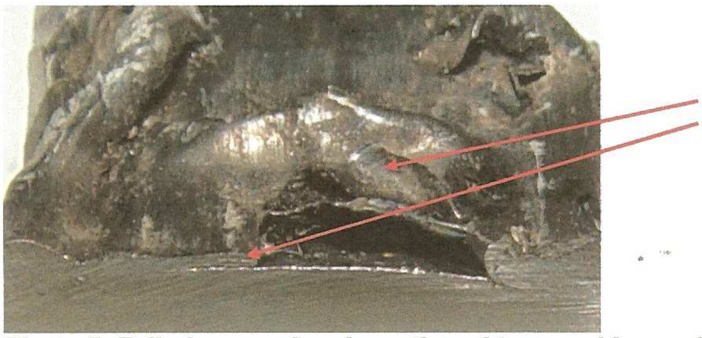

Photo 5: Failed con-rod end, sectioned to reveal layered bearing (digital)

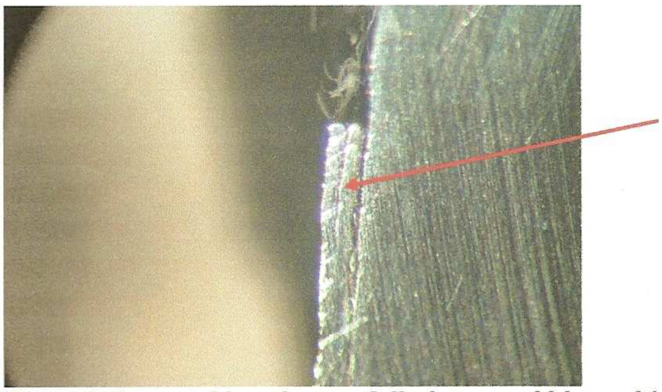

Photo 6: Layered bearing on failed con-rod big end (stereo)

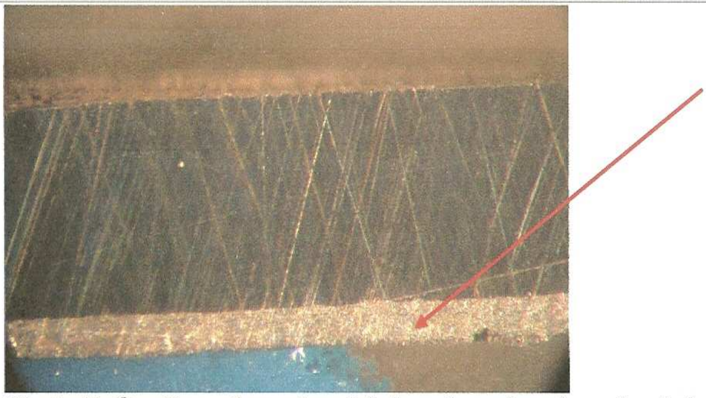

Photo 7: Section of serviceable bearing showing aluminium layer (stereo)

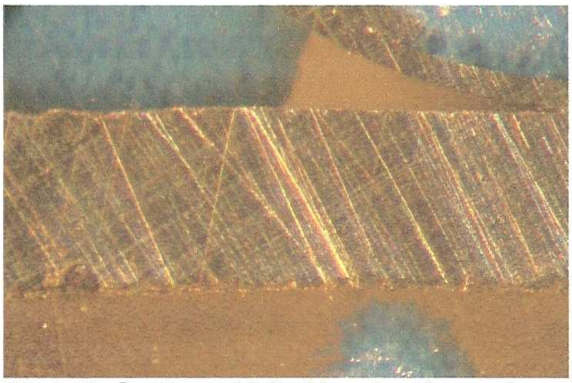

Photo 8: Section of failed bearing (stereo)

7. DISCUSSION AND CONCLUSIONS

7.1 Investigation of the remainder of the relevant engine confirms that assembly failed over an undeterminable period of time and not catastrophically.

7.2. Taking into account the condition of the remainder of the engine bearings as well as the localized nature of the heat damages it can be derived that general oil starvation and/or other lubrication discrepancies can not be considered a primary cause to this failure. All evidence point to the breakdown of the con-rod bearing as the primary cause for the catastrophic failure of the engine during operation.

7.3. Taking into account the severe damages inflicted to the relevant bearing and con-rod the failure of the aluminium con-rod big-end bearings may be due to one or more of the following:

7.3.1. Aluminium has little embedability. Consequently, any hard abrasive particles that find their way between the bearing and journal may become trapped and score the surface leading to flaking and scoring resulting in excessive wear and ultimately failure.

7.3.2. Aluminum is a hard material that withstands wear better than copper/lead bearings but is less tolerant to incorrect fitment and is very reliant to good oil circulation. Aluminium bearings fitted to remanufactured engines (it is unknown if this engine underwent any remanufacturing process) may be exposed to incorrect tolerances leading to premature failure.

7.3.3. Incorrect fitment of the assembly may lead to 'pinching' of the bearing leading to higher wear rates and failure.

7.3.4. Under severe conditions, particularly in high performance engines, con-rods may bend and/or cause the elongation of the big-end resulting in 'pinching' of the bearing.

8. RECOMMENDATIONS

8.1. None.

9. DECLARATION

9.1. All digital images has been acquired by the author and displayed in an un-tampered manner.