AIRCRAFT ACCIDENT INVESTIGATION REPORT

INVESTIGATION REPORT ON AN ACCIDENT INVOLVING GIPPSLAND AEROSPACE (GA 8 - AIRVAN) AIRCRAFT WITH REGISTRATION A2 – AJZ THAT OCCURRED AT SUMELO SETTLEMENT, SOUTH OF MAUN AIRPORT, ON THE 1st JULY 2023.

REFERENCE MTPW/AIG/15/23

Name of Operator	MACK AIR (PTY) LTD
Aircraft Manufacturer	GIPPSLAND AEROSAPCE (MAHINDRA)
Aircraft Name and Serial Number	GA – 8 AIRVAN / GA8-04-059
Investigating Authority	DIRECTORATE OF ACCIDENT INVESTIGATION REPUBLIC OF BOTSWANA

AERIAL VIEW OF THE FORCED LANDED AIRCRAFT AT SUMELO SETTLEMENT

Contents

PURPOSE OF THE INVESTIGATION

This investigation was conducted in accordance with **Civil Aviation (Accident and Incident Investigation) Regulations of 2022** of the Republic of Botswana, which is aligned with ICAO Annex 13 for the principal purpose of determining the circumstances and causes of the accident with a view to the preservation of life and avoidance of similar accidents in future and not to ascribe blame to any persons.

The **Civil Aviation Act of 2011** at **Section 75** stipulates that:

"*The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents and not to apportion liability or blame.*"

Disclaimer

This report is circulated without prejudice to the rights of the investigating authority, which are reserved.

The Directorate of Accident Investigation (DAI) categorised this occurrence as an accident that warrants a full investigation. An Investigator-in-Charge (IIC) was appointed to conduct the investigation. DAI allocated the investigation a file reference number MTPW/AIG/15/23.

The Republic of Botswana as the State of Occurrence, as well as the State of Registry and the State of Operator informed all the relevant stakeholders, mainly State of Design and the victim's (passengers') State of origin about the accident.

Finally, in the event any party comes across new information/evidence that they would like to share with the investigation Authority, kindly contact the IIC at jsebineng@gov.bw or (+267) 73005766.

Directorate of Accident Investigation
Private Bag 007
Gaborone
Botswana

GLOSSARY OF ABBREVIATION

AOC:	Aircraft Operator Certificate
ATC:	Air Traffic Control
ATPL:	Airline Transport Pilot's License
ATC:	Air Traffic Control
ATS:	Air Traffic Services
AWOC:	Aerial Work Operator Certificate
BPS:	Botswana Police Services
CAAB:	Civil Aviation Authority of Botswana
CPL:	Commercial Pilot Licence
CoA:	Certificate of Airworthiness
CoR:	Certificate of Registration
CRMA:	Certificate Relating to Maintenance of Aircraft
DATCO:	Duty Air Traffic Controller
ETA:	Estimated Time of Arrival
GA – 8:	Gippsland Aerospace GA 8 Airvan aircraft
GPS:	Global Positioning System
ICAO:	International Civil Aviation Organisation
METAR:	Meteorological Aerodrome Report
NM:	Nautical Mile
PIC:	Pilot-In-Command
PPL:	Private Pilot Licence
RCC:	Rescue Control Centre
TTSN:	Total Time Since New
UTC:	Universal Time Coordinated (i.e. Local time minus 2 hours) or Zulu time

SYNOPSIS

On the 1st July 2023 at around 0930hrs Zulu, a Gippsland Aerospace GA – 8 Airvan registered A2 – AJZ forced landed at a settlement named Sumelo. The Mack Air (Pty) owned aircraft was flying inbound to Maun airport from Dinaka airstrip. The anticipated flight duration was forty – five (45) minutes.

A2 – AJZ was on its final leg of a three-legged scheduled flight that started off from Maun airport to Jack's camp, then from Jack's camp to Dinaka airstrip. The aircraft was now heading back to base, Maun airport, as the last leg of that flight schedule.

Mack Air (Pty) Ltd holds an Aircraft Operator Certificate issued by the Civil Aviation Authority of Botswana (CAAB). In addition, Mack Air (Pty) Ltd holds an Aerial Work Operator approval and both certificates are numbered (049). Furthermore, it is issued with an Air Transport Service Licence (domestic and international non – scheduled), by the same aviation regulatory body. The ATSL is issued under the number (009/2022).

Leading to the accident, A2 - AJZ had earlier departed from Dinaka airstrip where it had picked up two (2) passengers on the way to Maun, in total there were five (5) persons onboard being one (1) crew and four (4) passengers. After take-off, the aircraft climbed up to flight level 075 (7500 feet). A2 – AJZ had fuel endurance enough for a one (1) hour forty – five (45) minutes flight. Maun Air Traffic Control (ATC) had instructed A2 – AJZ to report once it attained top of the climb.

At approximately thirteen (13) minutes into the flight, the ATC contacted A2 – AJZ on two occasions but there was no response from the aircraft. Within a short period of time a distress call sign was received by ATC:

"Mayday…Mayday…Mayday..ah..Green Tail 125..and we are 27 miles and to the field…we are picking the field 27 miles going down."

That was the last communication between ATC and A2 - AJZ. The aircraft experienced loss of engine oil pressure and subsequent raise in

engine oil temperature. As the engine oil temperature rose above 100°C (hundred degrees - Celsius), the aircraft engine consequently shut down due to overheating. The pilot-in-command was forced to initiate a forced landing in a difficult terrain next to a settlement called Sumelo.

The pilot glided A2 – AJZ to a chosen field and ended up bringing it to land on trees and shrubs as it could not make it to a cleared space ahead, which apparently was a small piece of ploughing field.

The passengers did not suffer any injuries during the landing of the aircraft on the trees. Though there were damages to the aircraft, they were not that extensive as they were restricted only to small dents on the wings and destruction of protruding elements such as pitot tube, pilot door – step, taxi light lenses, etc.

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1. Factual Information

1.1 History of Flight

1.1.1 On the 1st July 2023 at 0905hrs Zulu, A2 – AJZ took-off from Dinaka airstrip to Maun airport with one (1) crew and four (4) passengers. The aircraft had fuel duration of one (1) hour and forty-five (45) minutes whereas the expected flight time to the intended destination was approximately forty – five (45) minutes.

1.1.2 The purpose of the flight was to pick clients (fare paying passengers/tourists) and bring them back to Maun. The aircraft had left Maun earlier to Jacks' camp where it dropped off one (1) passenger and picked two (2) passengers. From Jack's camp, A2 – AJZ flew to Dinaka where it picked up 2 more passengers to end with a total of 4 passengers onboard.

1.1.3 A2 – AJZ contacted Maun airport approach control inbound from Dinaka at 0910 UTC. At that point the aircraft was still climbing to its cruise altitude of flight level 075. ATC had instructed A2 – AJZ to report once it reached the top of the climb.

1.1.4 At 0924 Z Maun ATC initiated contact with A2 – AJZ on two occasions but to no avail. By then the pilot was engrossed by a developing situation where the engine oil pressure indicator has shown a drastic drop. This happened just after A2 – AJZ reached top of the climb and was cruising with 32 nautical miles inbound Maun.

1.1.5 The loss of engine oil pressure led to increasing engine oil temperature. The temperature increased to a point where it exceeded 100 °C and this called for the pilot to apply emergency procedures. The aircraft engine subsequently failed due to raise in engine oil temperature and forced landing procedures were applied as mitigating measures.

1.1.6 A2 – AJZ ended up landing on a bush of small trees and shrubs at a settlement named Sumelo. There were no injuries nor fatalities to all persons onboard the aircraft. Sumelo settlement is twenty – seven nautical miles (27 Nm) south of Maun. The actual point where the aircraft ended up landing is S 20° 26´ 00" E 023° 19´ 07".

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	0	0	Nil
Serious	0	0	Nil
Minor/None	0	0	

1.3 Damage to aircraft

1.3.1 A2 – AJZ sustained very minor damages due to impact with small trees and shrubs. The aircraft suffered dents on the leading edges of both wings, as well as the leading edge of the horizontal stabilizer and the main landing gear fairings. Both taxi lights on the right and left broke. Top and bottom engine leading edge cowlings were slightly broken. The pitot tube got bent and the door step on the pilot side broke.

1.4 Other damage

1.4.1 The other damage was only limited to shrubs and small trees that had their branches and leaves clipped off by the aircraft as it came to land.

1.5 Personal information

Nationality	Kenya	Gender	Female	Age	37 years
License #	CA 2102917	Date issued	7th Jan 2022	Endorsement	CPL (A)
			Cessna		

Ratings	Single & Multi (Land)	A/C Type	172; Cessna 206; Cessna 208 GA 8 Airvan	English Proficiency level	6
Medicals	CAAB issued 9th Dec 22 till 31st Dec 23	Limitations	Nil	Previous accident	Nil
Total flying time	3769.4 hrs	Total flying time on type	2488.9hrs	Total flying time in command	3330.4hrs
Total flying time past 28 days	98.5hrs	Total flying time past 24hrs	6.6hrs		

1.6 Aircraft Information

1.6.1 A2 – AJZ was issued with a current certificate of airworthiness on the 4th August 2022 that was valid until 3rd August 2023. A2 – AJZ recently completed a 100-hour inspection in accordance with approved maintenance program (B/AMP/577A MAC05 Issue 2, Revision 0). It was issued with a certificate relating to maintenance of an aircraft on the 28th June 2023.

1.6.2 Upon arrival at the accident site, engine oil capacity was checked through an oil dipstick in order to determine whether the engine had adequate oil. The oil level showed satisfactory quantities as it was found to be above the minimum safe limit of 2.8 quarts as per the GA – 8 Airvan operating handbook.

Manufacturer and model	Gippsland Aerospace Airvan GA 8	Serial Number	GA8-04-059	Year of Manufacture	May 2004
Registration	21/04/2021	Certificate of Reg #.	972/1	Category	Commercial
		C of M		Time since	<3hrs (less

Total hours	8371	issue date	26/07/2023	C of M issue	than 3hrs)
Engine Constructor	Lycoming Engine	Engine Type	IO-540-K1A5	Constructor #	L-28756-48A
Engine date of Construction	6th June 2014	Engine total time since new	7700	Engine total time since overhaul	1500hrs
Propeller type	Hartzell (metal constant speed)	Propeller constructor	Hartzell Propeller Inc.	Propeller number & Serial #	HC-C2YR-1BF/F8475 R NS6795B
Number of blades	2	Propeller total time since new	649.1hrs	Prop total time since overhaul	new
ELT make and model	Artex & ME 406	Emission class & Frequency	6K00A3E & 121.5 – 406 MHz	License #	BOCRA-ASL-RCL-2031-2022-2

1.7 Meteorological information

1.7.1 The obtaining weather conditions on the fateful day were as reported by METAR; FBMN 010800HRS 10010KT CAVOK 19/M01 Q1028.

1.8 Aids to navigation

1.8.1 Aids to navigation had no bearing in this accident.

1.9 Communications

1.9.1 Communications between the aircraft and the ATC was normal at all times until the moment the pilot started to focus on the emergency at hand. The pilot contacted ATC signalling distress and later managed to communicate with traffic that was nearby appraising them of her location as well as status of the passengers.

1.10 Aerodrome information

1.10.1 The terminal aerodrome was Maun airport whereas the Dinaka airstrip was the last point of departure. Neither aerodrome has got anything to do with the accident.

1.11 Flight recorders

1.11.1 Not applicable to this accident.

1.12 Wreckage and impact information

1.12.1 The aircraft wreckage was found positioned by the trees. The wreckage was intact and free from fire. The damage sustained by the aircraft was mainly due to the impact with the tree branches.

1.12.2 The aircraft though it had no engine power, appeared to have glided towards its final landing position at a smooth angle. On closer examination of the surrounding bush, it was observed that the aircraft started clipping tree tops from a distance of 100 meters. As the distance increased the aircraft further lost height and started coming into contact with tree branches and tree stems. These thick branches prevented the forward motion and cushioned the aircraft as it touched down to its rest position.

1.13 Medical and pathological information

1.13.1 Not applicable as no injuries nor fatalities were incurred.

1.14 Fire

1.14.1 Not applicable as no fire ensued pre or post-accident.

1.15 Survival aspects

1.15.1 The forced landing was survivable, after touch down on the ground, the pilot was able to communicate with the close by traffic. The message from the A2 – AJZ was being relayed to the Maun ATC as well as the Mack Air base at Maun. Mack Air base managed to despatch a helicopter with a medical doctor to the scene of accident immediately. Another helicopter soon followed to ferry both the crew and passengers back to Maun.

1.16 Tests and research

1.16.1 The aircraft engine was taken for an observed laboratory stripping and test analysis. The engine showed signs of discolouration at the cylinder fins surrounding the spark-plugs. The engine oil filter was the first component to be tested. At the time the oil filter was removed from the engine, it was found to be dry with very little oil presence within. **(see figure 2a).**

1.16.2 The metal canister containing the engine oil filter was cut open in order to inspect the filter component for debris. The paper filtering component was found dry and littered with shiny particles plastered all over the can. The shiny particles were very fine and minute, more like magnetic iron fillings. **(see figure 2b and 2bb).**

1.16.3 The next component to be tested was the suction oil filter/screen resident within the oil sump. The suction oil filter/screen was found clogged with black rubber like material. In addition, small particles of copper like material were found inside the filter as a second layer of debris clogging the mesh filter. **(see figure 2c).**

1.16.4 Inspection of the oil sump revealed the presence of metal chips. There were fine to large metal pieces found within the oil sump. A sample from the oil found in the sump was taken for testing and analysis. **(see figure 2d).**

1.16.5 The engine stripping and inspection was done on internal components, the disassembled engine enabled inspection of the pistons, crankcase, bearings and oil seals.

1.16.6 The number 5 piston connecting rod was found broken inside the crankcase. The uncontained movement of connecting rods for pistons 5 and 6 had punched holes at the bottom of the crankcase. A broken piece of a connecting rod cap was found in the oil sump. The nut and bolt used to secure the connecting rod big end were found to be intact on the broken piece. **(see figure 3a, b, c, d, e)**

1.17 Organisational and management information

1.17.1 Mack Air (Pty) Ltd is the organisation approved by the CAAB and is issued with an Aircraft Operator Certificate. In addition, Mack Air (Pty) Ltd holds an Aerial Work Operator approval and both certificates are numbered (049). Furthermore, it is issued with an Air Transport Service License (domestic and international non – scheduled), by the same aviation regulatory body. The ATSL is issued under the number (009/2022).

1.18 Additional information

1.18.1 The survivability of the accident was largely to the manner in which the Pilot in Command handled the emergency. It was observed that the PIC was very alert and did not panic. She was in contact with her base at all times, updating them of the unfolding events. A decision was taken at the base that she must shut down the engine, unfortunately at that point the engine failed on its own. The manner in which she piloted the powerless aircraft to its final rest position, saved passengers from serious injuries and the aircraft from extensive damage.

1.19 Useful or effective investigation techniques

1.19.1 Not applicable.

2. Analysis

2.1.1 All the accessory assembly components were found to be serviceable. The oil impeller drive assembly, fuel pump assembly and vacuum pump assembly, etc, were moving freely without any disturbance.

2.1.2 The aircraft records (engine logbook) reveals that the aircraft was not flown for an extended period from 21st March 2019 until 18th February 2022. The engine records showed that prior to coming into operation the aircraft engine was overhauled. Following its return into service on the 18/02/2022 after overhaul, the first engine oil change was conducted twice at 25 hours intervals. The oil change intervals were then extended and carried out once at 50 hours. Afterwards, the engine oil change interval happened at 100 hours until the accident.

2.1.3 The engine oil quantity check was one of the two initial examinations to be done on A2 – AJZ at the scene of accident. The engine oil dipstick showed between 7- and 8-quarts level of oil in the engine. According to the technical log report, the last oil uplift was of 1- quart on the morning of 1st July 2023. This was a top up to the 7-quarts that was already inside the engine from the previous day. The tech log revealed that A2 - AJZ embarked on a number of flight operations on the day that lasted five (5) hours before the engine failure. Upon inspection, the engine could not rotate and appeared to have ceased.

2.1.4 From the oil filter analysis results it was determined that the rate of component wear within the engine were high. The wearing off of the bronze bush occurred at an alarming rate that it reached a critical level. The analysis of debris in the filter revealed plain carbon steel as a major constituent within the

debris. There were also traces of brass/bronze flakes. **(See appendix 1).**

2.1.5 The suction oil screen/filter was found to be clogged with chips of bronze as well as rubber like black material. The rubber like black material appeared to be remnants of a crankcase main bearing oil seal. Upon closer inspection of the crankcase main bearing, it was discovered that the bearings had signs of heat spots/marks and chaffing from metal to metal contact. The oil seal was also affected by this metal pounding leading to its chipping off. Further, there were nicks or scratches on the thrust face due to metal-on-metal contact. Small rubber like particles from a pounded seal were also evident in the front oil drain annuls. **(see figure 4a, b)**

2.1.6 The main bearings also showed signs of wear and tear due to friction with the crankshaft. The resultant chaffed metal particles became trapped between the front crankshaft slinger and the crankcase lower oil drain cavity. It was observed that a considerable amount of metal sludge was still within the crankcase and has not made its way to the engine oil sump. **(see figure 5a, b)**

2.1.7 Connecting rod bearings for piston 5 was worn due to lack of lubricant. The connecting rod big end bearing cap of piston 5 failed and ended up being dislodged from the crankshaft. The connecting rod punched through the wall of the crankcase as it was now in an uncontained movement. Hence the crankcase was breached and large metal debris fell into the oil sump below. The 2 failed connecting rods damaged the bottom of both halves of the crankcase causing open holes on the housing. **(see figure 3b, c, d)**

3 Conclusions

3.1 Findings

3.1.1 A2 – AJZ engine experienced low engine oil pressure and a very high engine oil temperature during the fateful flight from Dinaka airstrip. This was largely due to oil starvation since the oil flow passage was blocked. Though the oil pump was functioning properly, it was not able to deliver the necessary oil to the engine for cooling, lubricating and sealing purposes due to blockage of the suction filter.

3.1.2 The clogged suction oil screen did not allow oil passage to the oil filter leading to the detected low oil pressure. The presence of metal particles in the engine oil filter is testament to the fact that initially oil was able to pass through the suction oil screen before there was total blockage of the suction oil screen due to the increased size and number of the metal debris.

3.1.3 Low oil pressure automatically led to rise in the engine oil temperature due to lack of sufficient oil supply. The most affected components were the main bearing and cylinder 5 and 6 journal bearings.

3.1.4 The resultant heat on the journals led to big end connecting rod disintegrating and the piston connecting rod punched holes in the crankcase and the engine ceased.

3.1.5 Considering that the engine was recently overhauled, a question that come to the fore relates to the type of oil used to "break-in" the engine. The engine failure bears similar traits to the previous engines where the use of oil additive was recommended.

3.2 Probable cause

3.2.1 The probable cause of the accident is deemed to be engine failure due to oil starvation leading to raise in engine operating temperature. The engine oil distribution was disrupted by blockage of filters (suction screen and the main oil filter). The main bearings and connecting rods bearings showed signs of heat stress which led to their subsequent separation (failure). The separation of the big end connecting rod cap led to an uncontained movement of the connecting rod which ended up with the connecting rod breaching the crankcase by punching holes that completely destroyed the crankcase housing.

3.3 Contributing factors

3.3.1 The crankshaft oil seal subsequent deterioration due to crankshaft pounding led to its breaking into small pieces that blocked the suction oil screen. This process appears to have been gradual over a period of time. Ultimately, the suction oil screen prevented oil passage to the main oil filter and the engine oil pressure was reduced hence the rise in engine oil temperature.

3.3.2 The obvious impact of oil starvation was crankshaft bearings failure due to excessive heat generated. The main bearing was one of the most affected to the point of wearing off (chaffing) resulting in its fine metal chips clogging not only the engine oil drain annuls but the oil suction screen as well. As more bearings failed the connecting rods caps disintegrated due to excessive heat and breached the crankcase.

3.3.3 According to the engine teardown investigation report by the manufacturer (Lycoming Engine), there are similarities between this accident and other engine failures post COVID – 19 as a result of aircraft inactivity during the lockdown.

"*The mode of failure is consistent with the engine being operated in a dry start condition – whereby the engine oil has drained from the bearings and galleries during prolonged inactivity. Subsequent engine starts in a dry condition has led to front bearing oil starvation and subsequent metal pick up between the crankshaft main journal and breakup of the front bearing journal. The crankshaft thrust face has also been heavily damaged. In this case the metal particles (metal sludge) has become trapped between the front crankshaft slinger and the crankcase lower oil drain cavity. [ref Fig 4 expanded] In this example, the bulk of the metal sludge has not found its way into the engine sump. There was no apparent warning of impending engine failure, as there were no known reports of metal detected in scheduled filter inspections prior to the engine seizure."*[1]

4 Safety recommendations

4.1 It is recommended that the storage of engines during an extended period of inactivity or during transporting to client after shop overhaul must adopt measures aimed at ensuring that the oil film between the main bearings and the crankshaft is not displaced. The loss of lubrication is detrimental to the crankshaft main bearings and the crankshaft as it will lead to metal on metal contact, resulting in engine failure due to excessive heat generation.

4.2 It is recommended that oil suction screen inspection must be amongst one of the checks that are carried out frequently after the engine has been subjected to long periods of inactivity. This must also apply to new or recently overhauled engines that are just brought into operation. The results of both main oil filter and the suction screen must be documented for future reference.

[1] Source: Botswana engine teardown report by Lycoming Engine

4.3 It is recommended that the aircraft operators (pilots and mechanics) be sensitized on the characteristics of lubricating oils used specifically for engine "break-in" of new, rebuilt or overhauled engines.

4.4 A documented record of oil used during every oil-uplifts must be kept by both pilots and mechanics for future reference. The record must capture details like the type of oil used, brand and the weight of the oil. This must apply at all times whether the aircraft is at base or out of base.

4.5 The engine manufacturer – Lycoming Engine, must consider including the subject engine IO – 540 – K1A5 amongst those that the oil additive part number LW – 16702 can be applied on.

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Figures of images

Figure 1a: Aerial view of A2 – AJZ after forced landing at Sumelo settlement

Figure 1b: A2 – AJZ forced landed on the bush

Figure 2a: Main oil filter removed from the canister during lab testing

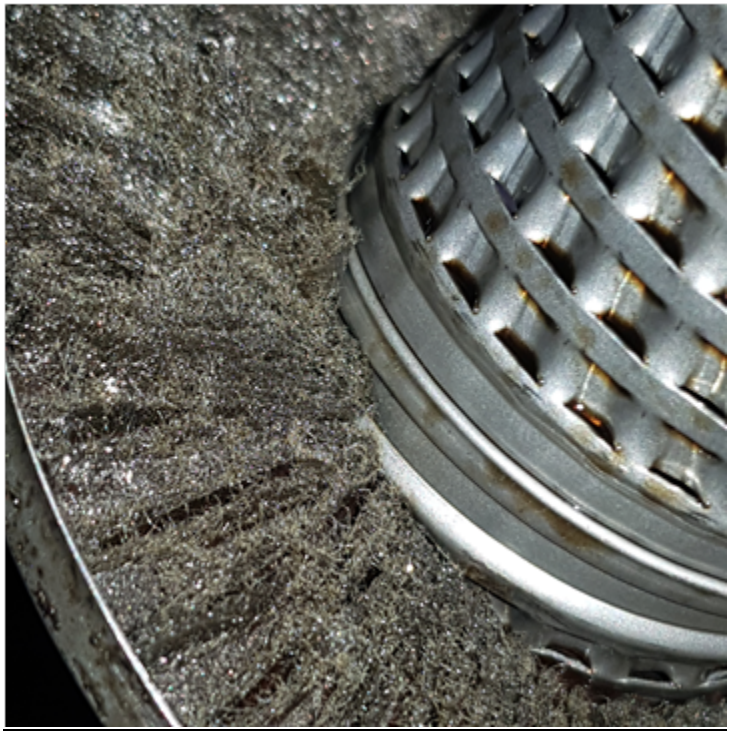


Figure 2b: Cut open oil filtering component littered with shiny metal debris

Figure 2bb: Main oil filter canister cut open and exhibiting dried up sludge of oil and some metal debris

Figure 2c: Debris clogging the suction filter

Figure 2d: Oil sump with metal debris of all sizes

Figure 3a: Broken off connecting rod big end cap

Figure 3b: Broken off big end connecting rod cap (Note that the connecting rod bolt and nut are still intact)

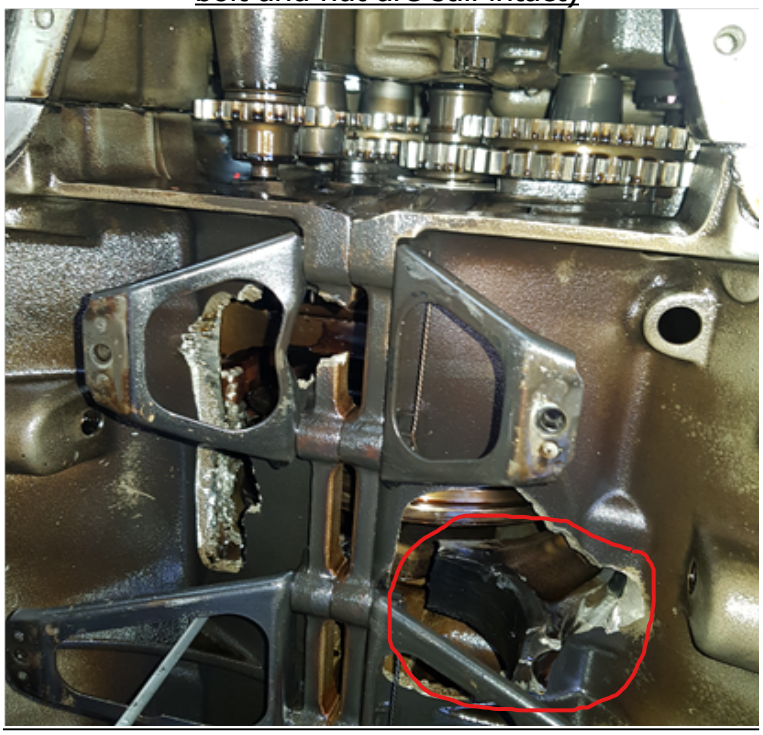


Figure 3c: Broken big end connecting rod #5 piston

Figure 3d: Crankcase bottom side punched out by uncontained connecting rod

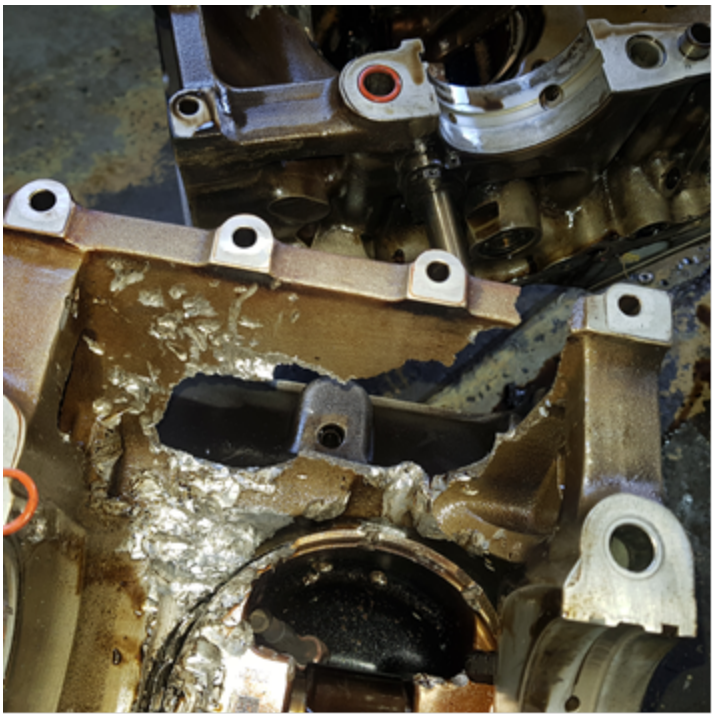


Figure 3e: Separated crankcase revealing the internal damage caused by uncontained motion of the connecting rod

Figure 4a: Sludge made up of metal debris and rubber material collected in the annul

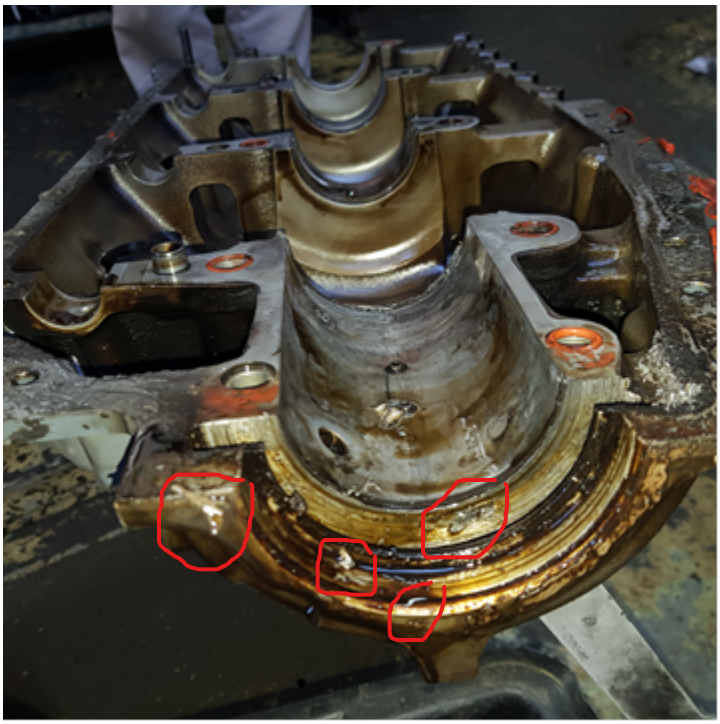


Figure 4b: Damaged thrust face (nicks showing)

Figure 5a: Main bearing with broken metal pieces due to metal on metal contact (chafing)

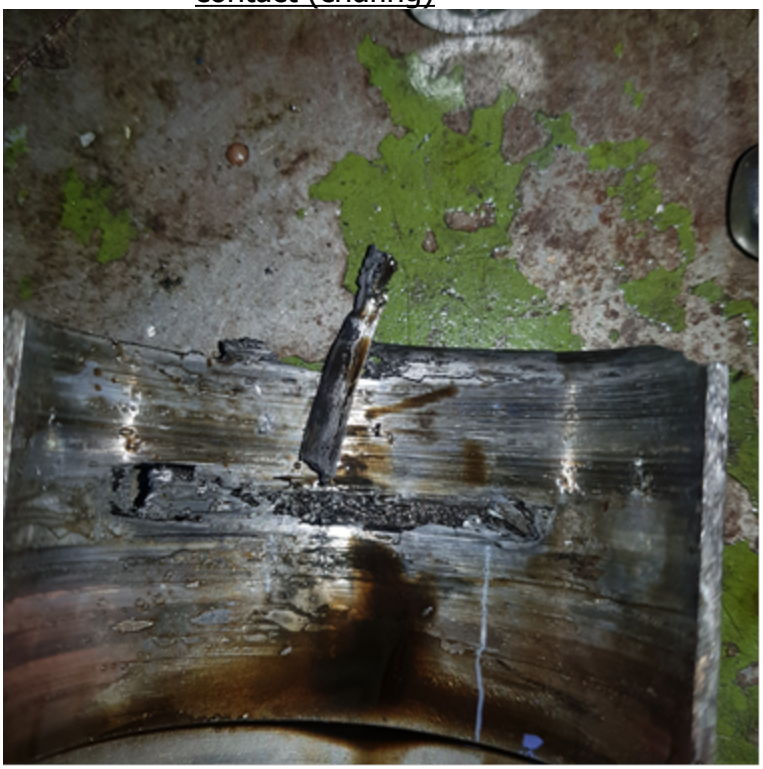
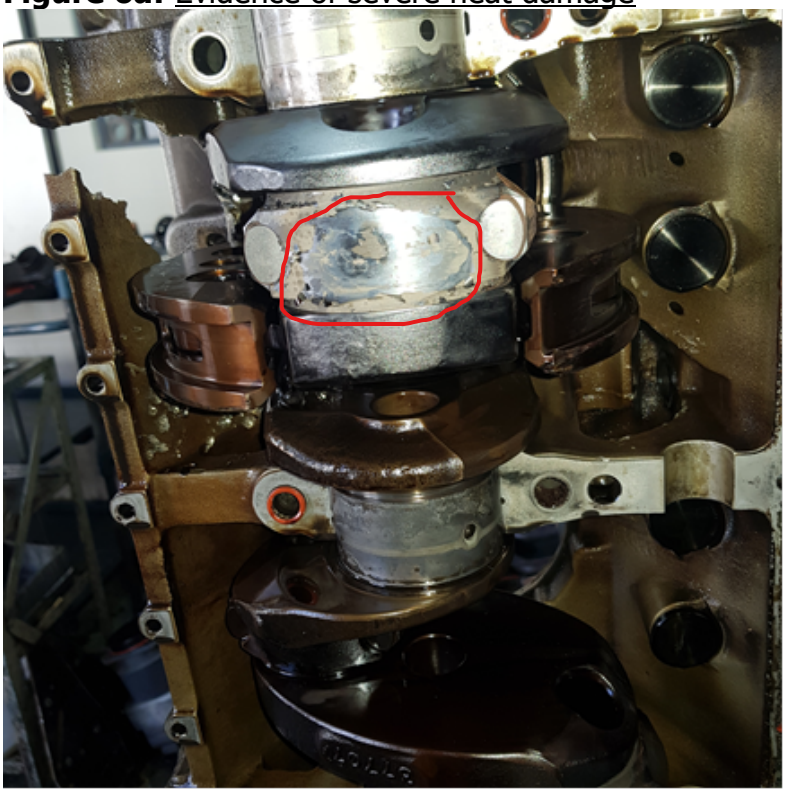


Figure 5b: Metal debris of broken main bearing

Figure 6a: Evidence of severe heat damage



APPENDIX 1

WEAR® CHECK
Condition Monitoring Specialists

AIRCRAFT

KWAZULU-NA
P.O. BOX
WESTMEA
TEL: (031) 70
FAX: (031) 70

GAUTE
P.O. B
ISAND
TEL: (011) 39
FAX: (011) 39

Ms S Earle [Sharlene]

Absolute Aviation
P O Box 42
Lanseria
1748

Registration	: A2-AJZ	Code	: 8CSP
Aircraft type	: "GA8 AIRVAN"	Job No.	:
Component	: SINGLE ENGINE	Location	: LANS

Registration: A2-AJZ - SINGLE ENGINE - S

	SAMPLE NUMBER	DATE SAMPLED	LAB DATE	COMPONENT TIME	PERIOD FILTER IN USE	TIME S OVER
1	FG231601	30.08.23	31.08.23			

STEEL ALLOY WEAR PARTICLES

OTHER WEAR PARTICLE

Sample	Plain Carbon Steel	alloy steel 4340	alloy steel 9310	tool steel M50	stainless steel 400 series	stainless steel 300 series	ppt hardened steel 17-4	Silver	Aluminium	Magnesium	Copper	Lead
1	3	0	0	0	0	0	0	0	1	0	1	0

Major = 3 Minor = 2 Trace = 1 Not detected = 0

TOTAL FILTER DEBRIS ANALYSIS

Too few values to plot mass (mg) filt

Sample	mass (mg) filter patch	pqi filter patch	pqi oil
1	782	21797	43

0 = none 1 = very few 2 = few 3 = some 4 = moderate 5 = heavy

GRAPHICAL REPRESENTATION OF PARTICLE SHAPE A

Too few values to plot cutting

Too few values to plot sliding

Too few values

-END-