AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:		CA18/2/3/10147	
Aircraft Registration	ZU-CIA	**Date of Accident**		27 April 2022		**Time of Accident**	0748Z
Type of Aircraft	Jabiru SP			**Type of Operation**		Private NTCA (Part 94)	
Pilot-in-command Licence Type	National Pilot Licence			**Age**	44	**Licence Valid**	Yes
Pilot-in-command Flying Experience		**Total Flying Hours**			116.3	**Hours on Type**	47.7
Last Point of Departure	Rhino Park Aerodrome, Gauteng Province						
Next Point of Intended Landing	Witbank Aerodrome (FAWI), Mpumalanga Province						
Damage to Aircraft	Substantial						

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

On R104 provincial road (GPS co-ordinates: 25°51’45.54” South 028°55’06.24” East)

Meteorological Information	Surface wind, 090°/8 knots; temperature, 13°C; scattered clouds at 6 500 feet						
Number of People On-board	1 + 1	**Number of People Injured**	0	**Number of People Killed**	0	**Other (On Ground)**	0

Synopsis

On Wednesday morning, 27 April 2022 at approximately 0724Z, a pilot and a passenger on-board a Jabiru SP aircraft with registration ZU-CIA took off on a private flight from Rhino Park Aerodrome in Gauteng province with the intention to land at Witbank Aerodrome (FAWI) in Mpumalanga province. Whilst en route to FAWI, flying at 6 500 feet (ft) the engine suddenly splattered and eventually stopped. The pilot attempted to restart the engine, but it was in vain. The pilot elected to execute a forced landing on the R104 provincial road. During the landing roll, the outer section of the left wing collided with a road sign pole, which caused the aircraft to veer off the road before it came to rest in a right-wing low attitude. The aircraft sustained substantial damage. No person on-board the aircraft was injured.

During the engine teardown inspection, it was found that the crankshaft gear had failed; and the component was subjected to a laboratory examination. The engine stoppage was attributed to the failure of the crankshaft gear which was determined to have been caused by hydrogen embrittlement (HE) that most probably manifested during the manufacturing process of the gear assembly. The exact cause/s of the hydrogen induced cracking (HIC) could not be determined.

Probable Cause

An engine stoppage occurred in-flight due to the failure of the crankshaft gear. The pilot executed a forced landing on a provincial road (R104), and shortly after touchdown, the left wing collided with a road sign pole which caused the aircraft to ground-loop and veer off the road.

Contributory Factor:

The engine stoppage was attributed to the failure of the crankshaft gear, which was determined to have been caused by hydrogen embrittlement that most probably manifested during the manufacturing process of the gear assembly.

SRP date	8 November 2022	Publication date	10 November 2022

Occurrence Details

Reference Number	**:** CA18/2/3/10147
Occurrence Category	**:** Accident (Category 1)
Type of Operation	**:** Operation of None-type Certified Aircraft (Part 94)
Name of Operator	**:** Private (Hire and Fly)
Aircraft Registration	**:** ZU-CIA
Aircraft Make and Model	**:** Jabiru SP
Nationality	**:** South African
Place	**:** Provincial Road R104, 10nm west of Witbank Aerodrome
Date and Time	**:** 27 April 2022, 0748Z
Injuries	**:** None
Damage	**:** Substantial

Purpose of the Investigation

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

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.

Investigation Process

The Accident and Incident Investigations Division (AIID) of the South African Civil Aviation Authority (SACAA) was notified of the occurrence on 27 April 2022. The occurrence was classified as an accident according to the CAR 2011 Part 12 and ICAO STD Annex 13 definitions. Notification was sent to the State of Registry, Operator, Design, Manufacturer in accordance with CAR 2011 Part 12 and ICAO Annex 13 Chapter 4. The State of Manufacturer and Design did not appoint an accredited representative but appointed an advisor. The AIID did not dispatch an investigator to the accident scene.

Notes:

1. *Whenever the following words are mentioned in this report, they shall mean the following:*
   Accident — this investigated accident
   Aircraft — the Jabiru SP involved in this accident
   Investigation — the investigation into the circumstances of this accident
   Pilot — the pilot involved in this accident
   Report — this accident report

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

Disclaimer

Table of Content

Abbreviation	Description
°	Degrees
°C	Degrees Celsius
AFM	Aircraft Flight Manual
AGL	Above Ground Level
AIID	Accident and Incident Investigations Division
AMO	Aircraft Maintenance Organisation
AMSL	Above Mean Sea Level
AP	Approved Person
ATF	Authority to Fly
CAR	Civil Aviation Regulations
C of R	Certificate of Registration
CRS	Certificate of Release to Service
ft	Feet
FAWI	Witbank Aerodrome
GPS	Global Positioning System
hPa	Hectopascal
ICAO	International Civil Aviation Organisation
km/h	Kilometres per hour
kt	Knots
kW	Kilowatt
m	Metre(s)
METAR	Meteorological Aerodrome Report
MTOW	Maximum Take-off Weight
nm	Nautical Miles
NPL	National Pilot Licence
NTCA	Non-type Certified Aircraft
PIC	Pilot-in-command
QNH	Barometric Pressure Adjusted to Sea Level
SACAA	South African Civil Aviation Authority
SAWS	South African Weather Service
TBO	Time Between Overhaul
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
VHF	Very High Frequency
Z	Zulu (Term for Universal Co-ordinated Time - Zero Hours Greenwich)

1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 On Wednesday morning, 27 April 2022 at 0724Z, a Jabiru SP aircraft with registration ZU-CIA took off from Rhino Park Aerodrome in Gauteng province. On-board the aircraft were the pilot and the passenger who intended to land at Witbank Aerodrome (FAWI) for breakfast, and then return to Rhino Park Aerodrome. Visual meteorological conditions by day prevailed at the time of the flight, which was conducted under the provisions of Part 94 of the Civil Aviation Regulations (CAR) 2011 as amended.

1.1.2 The pilot stated that after take-off, he climbed overhead the aerodrome to assess the weather conditions towards the east. Thereafter, he continued with the flight and climbed to 6 500 feet (ft) and opted to route towards the north of Bronkhorstspruit town. While flying between the N4 highway and the R104 roadway, approximately abeam the Kusile Power Station, the engine suddenly splattered and eventually stopped. The pilot then cycled the carburettor heat knob, switched on the auxiliary fuel pump and attempted an engine restart, but to no avail.

1.1.3 The pilot briefed his passenger that he would be conducting a forced landing on the R104 roadway as there was too much traffic on the N4 highway. At the time, there was no traffic on the section of the R104 he had elected to land on. He selected full wing flaps for landing, and after touchdown on the road, he immediately applied foot brakes to bring the aircraft to a stop as his biggest concern was that the aircraft might collide with a vehicle or a truck. During landing, the outer section of the left wing struck a road sign pole and the aircraft yawed to the left and veered off the roadway. The pilot stated that he did not see the road sign pole before he landed the aircraft. As the aircraft skidded to the right on the gravel, parallel to the roadway, the right main landing gear support strut broke off before the aircraft came to rest in a right-wing low attitude. The pilot secured the aircraft before disembarking with his passenger unassisted. They were both not injured during the accident sequence. The aircraft was substantially damaged. The pilot stated that it took approximately 2 minutes from the time the engine failed until the aircraft came to rest on the side of the road.

1.1.4 The accident occurred during daytime at Global Positioning System (GPS) co-ordinates determined to be 25°51’45.54” South 028°55’06.24” East, at an elevation of 4 913ft.

Figure 1: The position of the ZU-CIA aircraft in relation to the N4 highway. (Source: Google Earth)

1.2 Injuries to Persons

Injuries	Pilot	Crew	Pass.	Total On-board	Other
Fatal	-	-	-	-	-
Serious	-	-	-	-	-
Minor	-	-	-	-	-
None	1	-	1	2	-
Total	**1**	**-**	**1**	**2**	**-**

Note: Other means people on the ground.

1.3 Damage to Aircraft

1.3.1 The aircraft sustained substantial damage during the accident sequence.

Figure 2: The aircraft as it came to rest next to the R104 roadway.

1.4 Other Damage

1.4.1 None.

1.5 Personnel Information

1.5.1 Pilot-in-command (PIC)

Nationality	South African	Gender	Male	Age	44
Licence Type	National Pilot Licence (NPL)				
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	None				
Medical Expiry Date	31 January 2025 (Class 4)				
Restrictions	None				
Previous Accidents	None				

Note: Previous accidents refer to past accidents the pilot was involved in, when relevant to this accident.

Flying Experience:

Total Hours	116.3
Total Past 24 Hours	3.1
Total on Type Past 90 Days	3.1
Total on Type	47.4

1.6 Aircraft Information

1.6.1 Jabiru SP

Figure 3: The file picture of the ZU-CIA aircraft. (Source: Flight Zone Aviation Photography)

Airframe:

Manufacturer/Model	Shadow Lite CC / Jabiru SP	
Serial Number	434	
Year of Manufacture	2000	
Total Airframe Hours (at time of accident)	7 671.4	
Last Annual Inspection (hours & date)	7 636.0	8 March 2022
Hours Since Last Inspection	35.4	
ATF (issue date & expiry date)	23 March 2016	31 March 2023
C of R (issue date) (Present Owner)	12 November 2018	
Maximum Take-off Weight (MTOW)	490kg	
Type of Fuel Used	Avgas	
Operating Category	Part 94 and 96	
Previous Accidents/Incidents	27 June 2005, engine failure in-flight, forced landing at Swartkops Air Force Base. 4 February 2006, the nose gear collapsed during landing at Witbank Aerodrome. 28 August 2010, the nose gear collapsed during landing at Rhino Park Aerodrome. 1 February 2011, pilot lost directional control during landing at Kitty Hawk Aerodrome and the aircraft veered off the runway. 7 December 2014, the propeller struck the ground	

	following a precautionary landing by the pilot due to high cylinder head temperature (CHT). 26 June 2016, engine failure in-flight; pilot executed a forced landing with damage limited to the engine and propeller. Inlet valve on the No. 4 cylinder failed. 12 January 2018, pilot lost directional control during landing at Middelburg Aerodrome and the aircraft veered off the runway into a ditch and came to rest in an inverted attitude approximately 50m from the runway. 21 January 2021, engine failure in-flight; the pilot executed a forced landing on an open field near Brits.

Note: Previous accidents refer to past accidents the aircraft was involved in, when relevant to this accident.

The duration of the accident flight was 20 minutes; these hours were added to the information in this report.

Engine:

Manufacturer/Model	Jabiru 2200
Serial Number	22A3244
Hours Since New	1 916.8
Hours Since Overhaul	412.7

According to the engine installation record on page 26 of the aircraft logbook (the aircraft has only one logbook for airframe, engine, and the propeller), the engine was installed on 25 January 2021 with zero hours entered after overhaul.

Propeller:

Manufacturer/Model	P-Prop
Serial Number	N3268
Hours Since New	308.9
Hours Since Overhaul	TBO not yet reached

1.7 Meteorological Information

1.7.1 The weather information entered in the table below was obtained from the pilot questionnaire.

Wind Direction	090°	Wind Speed	8 kt	Visibility	5 000 m
Temperature	13°C	Cloud Cover	Scattered	Cloud Base	6 500 ft
Dew Point	7°C	QNH	1028 hPa		

1.8 Aids to Navigation

1.8.1 The aircraft was equipped with standard navigational equipment as approved by the Regulator (SACAA). There were no records indicating that the navigation system was unserviceable prior to the accident flight.

1.9 Communication

1.9.1 The aircraft was equipped with a standard communication system as approved by the Regulator. There were no recorded defects with the communication system prior to the accident flight.

1.10 Aerodrome Information

1.10.1 The accident did not occur at an aerodrome.

1.11 Flight Recorders

1.11.1 The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), and neither was required by regulation to be fitted to the aircraft type.

1.12 Wreckage and Impact Information

1.12.1 The pilot landed on the R104 roadway in an easterly direction. During the landing roll, the outer section of the left wing collided with a road sign pole (see Figure 4), causing the aircraft to veer off to the left-side and depart the roadway. As the aircraft left the asphalt surface, the right main landing gear strut broke off approximately midspan, which caused the right wing to make contact with the ground. The aircraft came to rest in a right-wing low attitude.

Figure 4: The road sign pole with which the aircraft's left wing collided, leaving a mark on it (see yellow block).

Figure 5: The tyre markings of the main wheels (both sides) as the aircraft veered off the roadway.

Figure 6: The right main gear strut broke off approximately midspan.

Figure 7: The damage to the left wing following impact with the road sign pole.

1.13 Medical and Pathological Information

1.13.1 Not applicable.

1.14 Fire

1.14.1 There was no pre- or post-impact fire.

1.15 Survival Aspects

1.15.1 The accident was survivable.

1.16 Tests and Research

1.16.1 Engine Teardown

The Jabiru 2200 engine with serial number 22A3244 was removed from the wreckage and was later subjected to a teardown inspection. It was found that the crankshaft gear assembly with part number 4643084 had failed in operation. The failed component was subjected to a metallurgical analysis. The metallurgical report is attached to this report as Appendix A.

Conclusion from the laboratory report:

The investigation results revealed the primary contributing factor towards the failure of the crankshaft gear was hydrogen embrittlement. The exact cause/s towards the hydrogen induced cracking (HIC) could not be determined by this investigation – the original equipment manufacturer's (OEM's) manufacturing process is proprietary information.

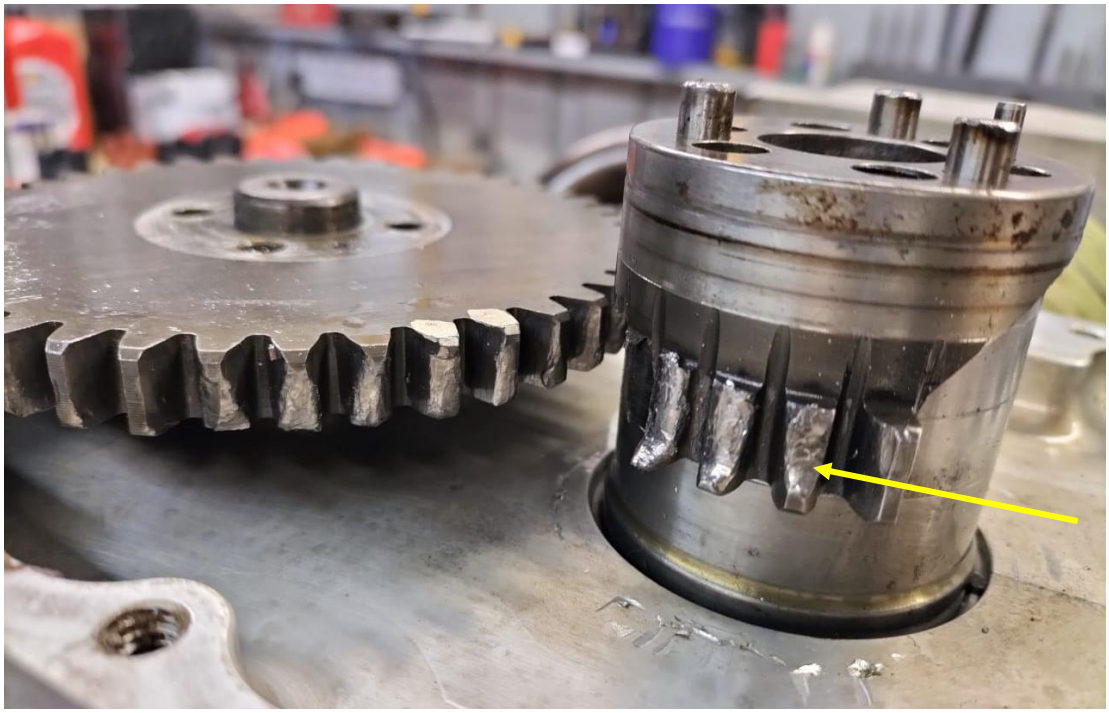


Figure 8: The crankshaft gear assembly that failed, indicated by the yellow arrow.

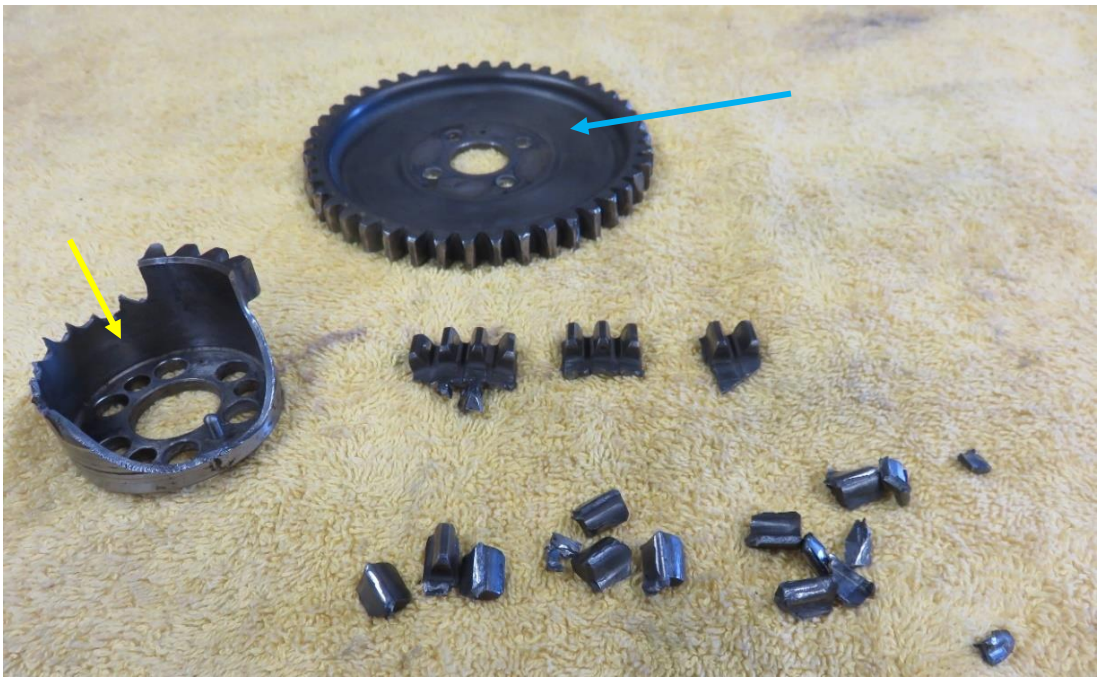


Figure 9: Fractured pieces from the crankshaft gear assembly and the flywheel (blue arrow).

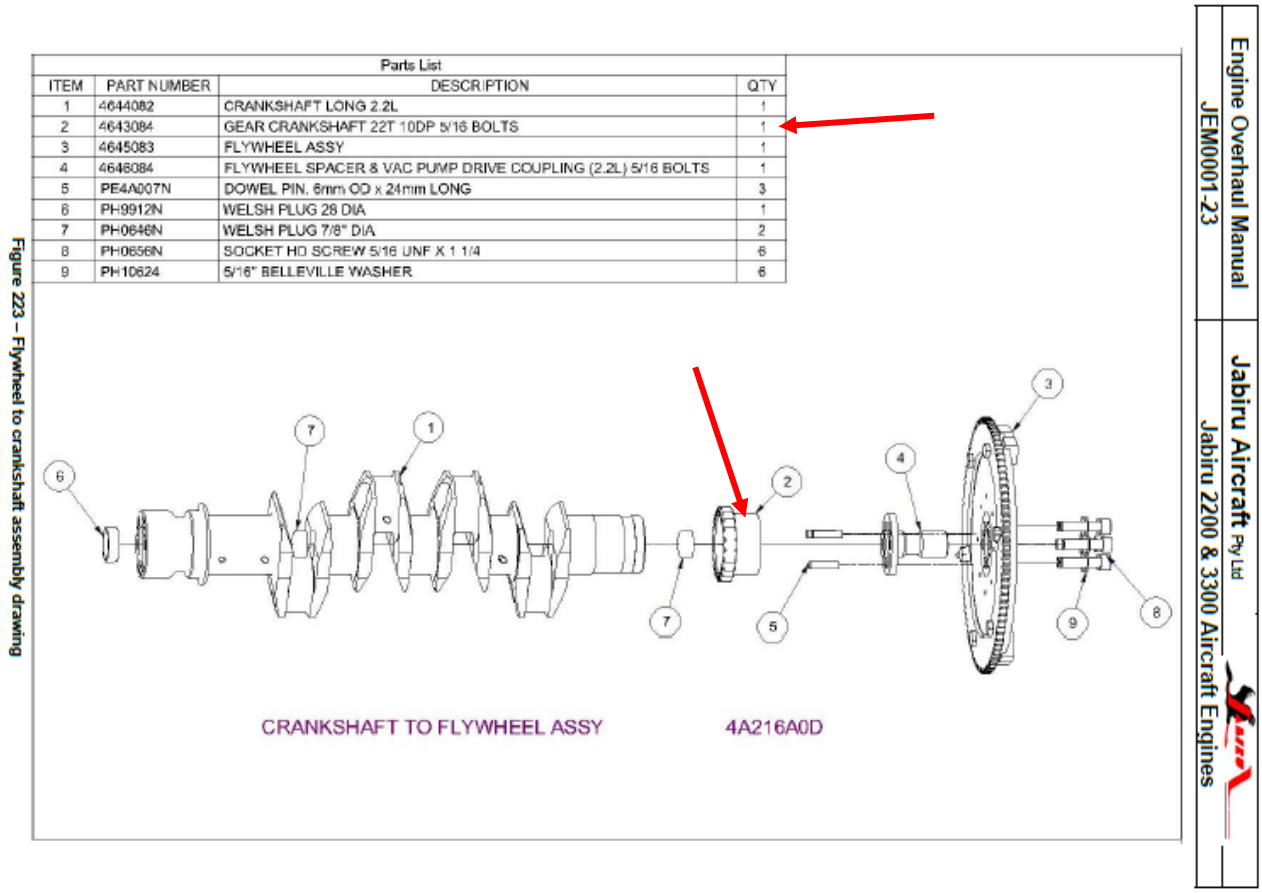


Illustration 1: Crankshaft to Flywheel assembly.

1.17 Organisational and Management Information

1.17.1 This was a private flight conducted under the provisions of Part 94 of the Civil Aviation Regulations 2011 as amended.

1.17.2 The last annual inspection that was carried out prior to the accident flight was certified on 22 March 2022 at 7 636.0 airframe hours. The inspection was carried out by an aircraft maintenance organisation (AMO) that had a valid AMO approval certificate, issued on 6 September 2021 with an expiry date of 31 August 2022.

1.18 Additional Information

1.18.1 Hydrogen Embrittlement (HE)

(Source: Fundamentals of Aircraft Material Factors, 2nd Edition, Charles E. Dole, Page 151/2)

"Hydrogen embrittlement can either be discussed under the categories of Fatigue, Corrosion, or in a category of its own. It does include such factors as stress concentrations, foreign

substances, and progressive failure. Although cycle stress speeds up the process, the cycles are not necessary for failure.

Hydrogen embrittlement is a very complex phenomenon. We will simply the discussion by limiting it to electroplated ferrous materials. Steel aircraft parts such as bolts, landing gear parts, and drive shafts are often electroplated with cadmium to improve the surface wear properties. We will discuss the tree parts of the hydrogen embrittlement process.

1. *Origin of Hydrogen*

   In the electroplating process, hydrogen is released from the electrolyte and some hydrogen atoms enter the steel material being plated. Once the plating process has been completed, the hydrogen is trapped in the steel. The atomic spacing of the plating cadmium is much smaller than that of the steel. So, the hydrogen atoms can move through the steel but cannot escape to the atmosphere through the plating.

2. *Transport of Hydrogen*

   If the hydrogen influences the fracture behaviour of a structure, it must be at the same critical location. It can either be at this location before the metal was stressed or it must be transported to this region during the deformation process. In the plating process the hydrogen is disbursed throughout the metal, thus the method of transportation is of interest. When hydrogen originates in the metal lattice the primary transport reaction is called lattice diffusion. The hydrogen atoms are so small that they can move (diffuse) through the steel atoms though the metal is in the solid state. The transport of hydrogen from its equilibrium position to some critical stress location is caused by a general kinetic reaction. The hydrogen thus is concentrated at stress raisers such as crack ends.

3. *Hydrogen Embrittlement Interaction*

   Hydrogen has been observed to influence the fracture of all metals investigated to date. In steel, the hydrogen concentration at a region of high stress concentration results in precipitation of molecular (as contrasted to atomic) hydrogen.

   Molecular hydrogen, (H2), causes a pressure build-up at internal defects, thus it can cause failure even without applied loads. With externally applied loads the pressure build-up is much higher and failure is accelerated.

   Standard procedure to protect plated aircraft parts is to bake them for about 28 hours. The higher temperature allows the hydrogen to work its way out through the plating material and escape to the atmosphere."

1.19 Useful or Effective Investigation Techniques

1.19.1 No new methods were used.

2. ANALYSIS

2.1 General

From the available evidence, the following analysis was made with respect to this accident. This shall not be read as apportioning blame or liability to any organisation or individual.

2.2 Analysis

2.2.1 Man (Pilot)

The pilot had a National Pilot Licence (NPL) and was accordingly rated on the aircraft type. Following the engine failure, the pilot made the decision to execute a forced landing on the R104 roadway, as there was no traffic on the road at the time. The initial phase of the landing roll was uneventful, but later, the left-wing outer section (see Figure 7) struck the road sign pole which caused the pilot to lose control of the aircraft. The aircraft ground-looped and veered off the road. Neither of the two occupants was injured, nor was damage caused to property on the ground.

2.2.2 Machine (Aircraft)

The aircraft was manufactured in 2000 and was one of the first Jabiru aircraft to fly in South Africa. With reference to the content in sub-heading 1.6 *Aircraft Information* of this report, it is evident that the aircraft was involved in several accidents and incidents in the past. The crankshaft gear failure which caused the engine to fail, resulted in the aircraft's damage during the landing roll. The crankshaft gear failure was attributed to a manufacturing process – known as hydrogen embrittlement. It is a process that is used to provide protective coating to some components that have been manufactured from a certain type of material. If this process is not performed meticulously, there is a potential that the component would not reach its service life without failure. It should be noted that the engine had operated for 1 916.8 hours since new, and 412.7 hours since overhaul. According to the Service Bulletin JSB-001-01 that was issued on 11 May 2004 by Jabiru Aircraft (Pty) Ltd, the time for a full overhaul on this engine type is 2 000 hours should a top overhaul been carried out at 1 000 hours.

The AIID was informed by the local aircraft agent/OEM that there was a revision issued regarding the crankshaft gear where the diameter had been changed from 50mm to 52mm. The reason for this change was not stated, but it could have been that this type of failure was not an isolated case. The difference between the 50mm and 52mm crankshaft gear was not made available to the AIID even though it was requested to better understand the rationale behind it. The fundamental matter is that there is no benefit in increasing the diameter of the crankshaft gear if the manufacturing process has the potential of being flawed with a possibility of the failure of the gear before it reaches its full service life, as have been witnessed by the investigation team.

During the engine teardown inspection, it was found that the crankshaft gear had failed, and was subjected to a laboratory examination. The engine stoppage was attributed to the failure of the crankshaft gear that was determined to have been caused by hydrogen embrittlement (HE) which most probably manifested during the manufacturing process of the gear assembly. The exact cause/s to the hydrogen induced cracking (HIC) could not be determined.

2.2.3 Environment

Fine weather conditions prevailed at the time of the forced landing; the weather had no bearing to this accident.

The roadway on which the pilot had selected to conduct a forced landing was in good condition, and there was no traffic on the road at the time that posed a threat or a hazard to the aircraft. The outer section of the left wing struck the road sign pole that was located next to the road.

3. CONCLUSION

3.1 General

From the available evidence, the following findings, causes and contributing factors were made with respect to this accident. These shall not be read as apportioning blame or liability to any organisation or individual.

To serve the objective of this investigation, the following sections are included in the conclusion heading:

- **Findings —** are statements of all significant conditions, events, or circumstances in this accident. The findings are significant steps in this accident sequence, but they are not always causal or indicate deficiencies.
- **Causes —** are actions, omissions, events, conditions, or a combination thereof, which led to this accident.
- **Contributing factors —** are actions, omissions, events, conditions or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the accident occurring, or would have mitigated the severity of the consequences of the accident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil, or criminal liability.

3.2 Findings

The Pilot

3.2.1 The pilot was issued a National Pilot Licence (NPL). According to his logbook, he had flown a total of 116.3 hours of which 47.4 hours were on the aircraft type.

3.2.2 The pilot was issued a valid Class 4 aviation medical certificate on 7 January 2022 with an expiry date of 31 January 2025.

3.2.3 The pilot attempted an engine restart, but it was in vain.

3.2.4 Whilst flying at a height of 6 500 feet, the engine suddenly splattered and eventually stopped. During the landing roll on the R104 roadway, the outer section of the left wing collided with a road sign pole which caused the aircraft to veer off the roadway before it came to rest in a right-wing low attitude.

The aircraft ZU-CIA

3.2.5 The aircraft was issued an Authority to Fly on 23 March 2016 with an expiry date of 31 March 2023.

3.2.6 The aircraft was issued a Certificate of Release to Service (CoA) on 23 March 2022 with an expiry date of 31 March 2023 or at 7 736.0 airframe hours, whichever comes first.

3.2.7 The aircraft was issued a Certificate of Registration (CoR) on 12 November 2018.

3.2.8 The last annual inspection carried out on the aircraft prior to the accident flight was certified on 22 March 2022 at 7 636.0 airframe hours. The aircraft had accumulated a further 35.4 airframe hours since the said inspection.

3.2.9 The engine had accumulated a total of 1 916.8 hours since new and 412.7 hours since its last overhaul. The engine time before overhaul (TBO) was 2 000 hours.

3.2.10 The engine was installed on the aircraft on 25 January 2021.

3.2.11 The failure of the crankshaft gear was attributed to hydrogen embrittlement.

Environment

3.2.12 Fine weather conditions prevailed at the time of the flight, with the wind blowing from the east at 8 knots. The pilot landed into wind.

3.2.13 The pilot opted to execute a forced landing on a provincial road, where there was no traffic.

3.2.14 During the engine teardown inspection, it was found that the crankshaft gear had failed, and the component was subjected to a laboratory examination. The engine stoppage was attributed to the failure of the crankshaft gear that was determined to have been caused by hydrogen embrittlement (HE) which most probably manifested during the manufacturing process of the gear assembly. The exact cause/s to the hydrogen induced cracking (HIC) could not be determined.

3.3 Probable Cause

3.3.1 An engine stoppage occurred in-flight due to the failure of the crankshaft gear. The pilot executed a forced landing on a provincial road (R104), and shortly after touchdown, the left wing collided with a road sign pole which caused the aircraft to ground-loop and veer off the road.

3.4 Contributory Factor

3.4.1 The engine stoppage was attributed to the failure of the crankshaft gear. The gear failure was determined to have been caused by hydrogen embrittlement (HE) which most probably manifested during the manufacturing process of the gear assembly.

4. SAFETY RECOMMENDATIONS

4.1 General

The safety recommendations listed in this report are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation and are based on the conclusions listed in heading 3 of this report. The AIID expects that all safety issues identified by the investigation are addressed by the receiving States and organisations.

4.2 Safety Recommendation/s

4.2.1 None.

5. APPENDICES

5.1 Appendix A (Metallurgical report on the Crankshaft gear assembly failure)

This report is issued by:
Accident and Incident Investigations Division
South African Civil Aviation Authority
Republic of South Africa

Appendix A

COMPILED BY:	UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA LABORATORY FOR MICROSCOPY & MICROANALYSIS	PAGE 1 OF 7
	FAILURE ANALYSIS REPORT: CRANK GEAR ASSEMBLY, JABIRU SP, AIRCRAFT ZU-CIA	DOCUMENT NUMBER FA-008-06-22
COMPILED FOR: SACAA (AIID)		DATE 2022-06-15 / ISSUE 1

ITEM: **CRANKSHAFT GEAR ASSEMBLY, JABIRU 2200 ENGINE, JABIRU SP, AIRCRAFT ZU-CIA**

1. BACKGROUND INFORMATION

1.1. The fractured Crankshaft Gear assembly (Diagram 1, no 2; Part No 4643084; Photo 2) from a Jabiru 2200 Engine, serial no 22A3244, originating from a Jabiru SP (Photo 1) aircraft with registration ZU-CIA, was submitted to determine the most probable contributary cause/s towards failure during operation.

1.2. The TTSN of the relevant engine is **1916.8 hours** with **412.7 hours** since Overhaul (TSO).

1.3. The OEM certified AMO revealed that the as found 50mm diameter part was not correct as per OEM specifications[1].

1.4. The relevant aircraft was involved in a number of incidents and accidents that involved the engine itself and/or possible impact loading to the engine, the latest involving a landing accident during on 12 January 2018 (Extract 1).

Photo 1: File photo, ZU-CIA[2]

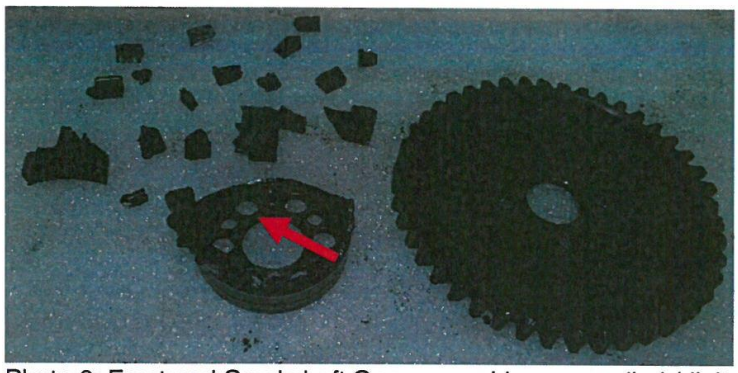


Photo 2: Fractured Crankshaft Gear assembly, as supplied (digital)

[1] SACAA/AIID
[2] Courtesy AIRPORTDATA.com

Extract 1: ZU-CIA accident, 12 January 2018[3]

1.5. This report is divided into the following sections:

2. APPLICABLE DOCUMENTS

(a) Jabiru Engine Parts Book

3. DEFINITIONS

AAI	Aircraft Accident Investigation	NDI	Non-Destructive Inspection
AC	Advisory Circular	NDT	Non-Destructive Testing
AISI	American Iron and Streel Institute	OEM	Original Equipment Manufacturer
AME	Aircraft Maintenance Engineer	OHSA	Occupational Health and Safety Act
AMO	Aircraft Maintenance Organization	POD	Probability of Detection
ASI	Air-Speed Indication/or	QMS	Quality Management System
ASTM	American Society for Testing and Materials	RC	Rockwell C-scale
EBSD	Electron Back-Scatter Diffraction	RoD	Rate of Descend
ECSA	Engineering Counsel of SA	RT	Radiographic Testing
EDS	Energy-Dispersive X-ray Spectroscopy	SABS	South African Bureau of Standards
FAA	Federal Aviation Authority	SACAA	South African Civil Aviation Authority
HSS	High-Strength Steels	SB	Service Bulletin
ICAO	International Civil Aviation Authority	SEM	Scanning Electron Microscope
IG	Inter-Granular	TG	Trans-Granular
IR	Infra-Red or Thermal Testing	UT	Ultra-Sonic Testing

[3] Courtesy Aviation Safety Network.com

MAUW	Maximum All-Up Weight	VSI	Vertical Speed Indication/or
NDE	Non-Destructive Evaluation	MPI	Mandatory Parts Inspection
TTSN	Total Time Since New	TBO	Time Before Overhaul
BE	Big End	SE	Small End
TSO	Time Since Overhaul	HE	Hydrogen Embrittlement
HIC	Hydrogen Induced Cracking	SCC	Stress Corrosion Cracking

4. PERSONNEL

(a) The investigative member and compiler of this report is Mr C.J.C. Snyman. Mr Snyman is a qualified Physical Metallurgist (Metallurgical Engineering, 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

Note 1: *Only the supplied parts were considered.*

The visual inspection revealed extensive damages to the flywheel gear teeth (Photo 3, red arrow). This can be attributed as collateral damages following the failure of the Crankshaft Gear.

The visual inspection revealed multiple fractures surrounding the gear teeth section of the Crankshaft Gear (Photo 4, blue arrow).

Higher magnification revealed multiple outer surface fractures suggesting a high hardness condition at the primary fracture locations (Photo 4, blue arrow; Fractograph 1).

The corresponding fracture surface morphology revealed a clear outer surface layered effect (Fractograph 2). Within this layer indications of primary intergranular fracture progression were noted (Fractograph 3) which is indicative of Hydrogen Embrittlement (HE), a form of Hydrogen Induced Cracking (HIC). HIC can be attributed to the manufacturing processes and/or environmental exposure/s (corrosion).

No clear signs of fatigue, corrosion and/or other metallurgical discrepancies were noted.

Final, fast fracture morphology (Fractograph 4) consistent with a more ductile behaviour.

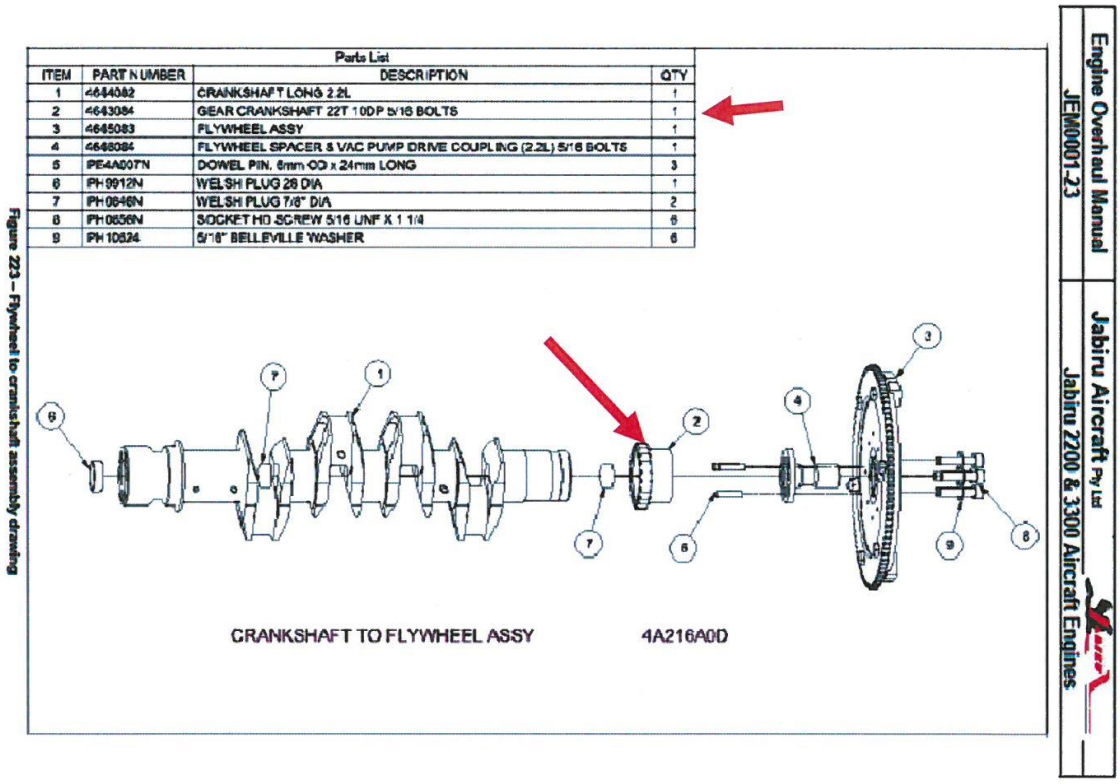


Diagram 1: Jabiru 2200 crankshaft layout[4]

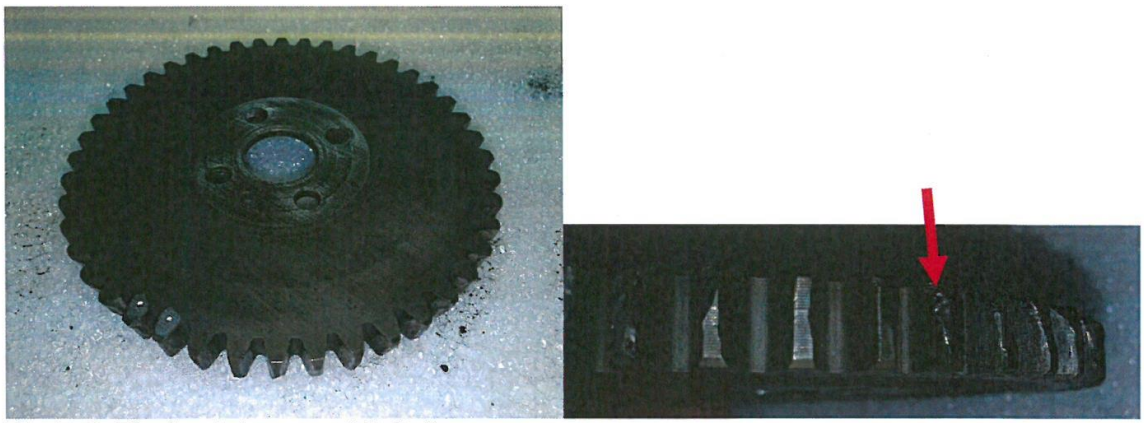


Photo 3: Flywheel damages (Digital)

[4] Courtesy Jabiru

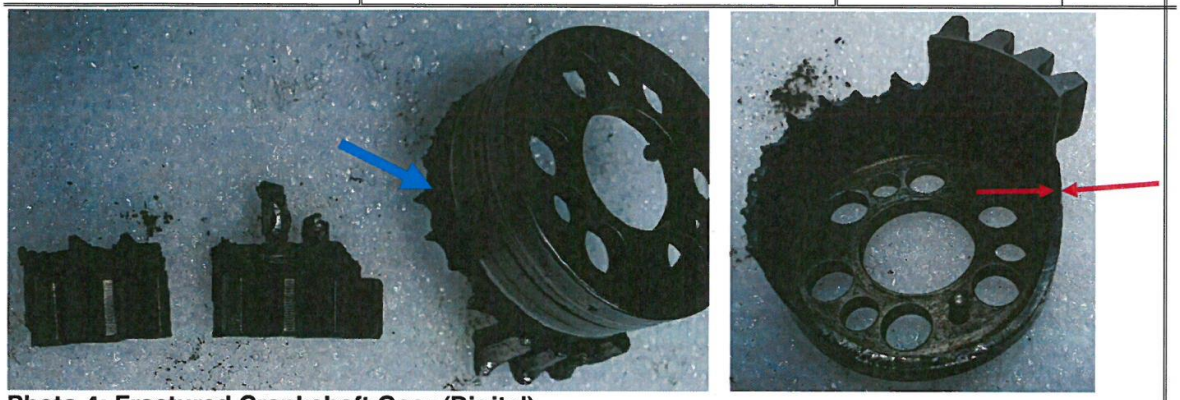
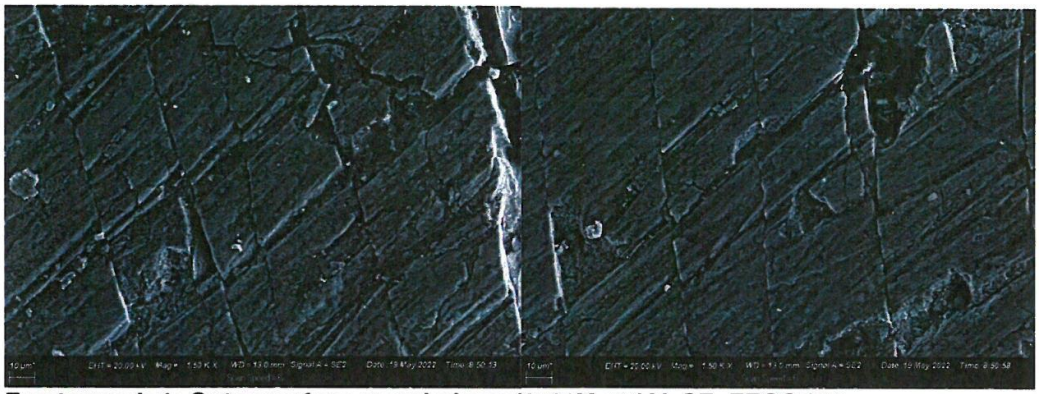
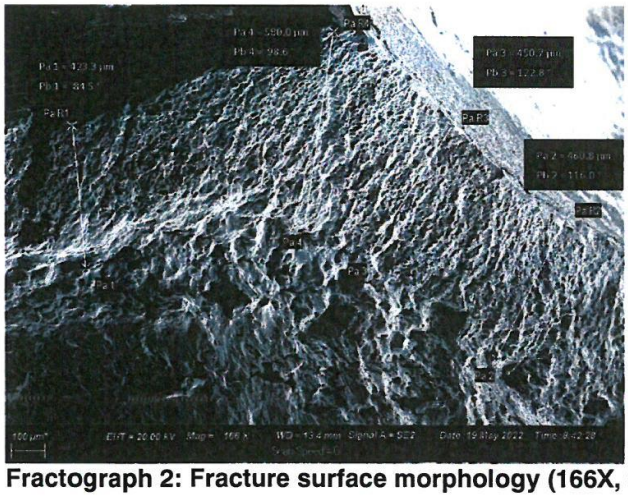


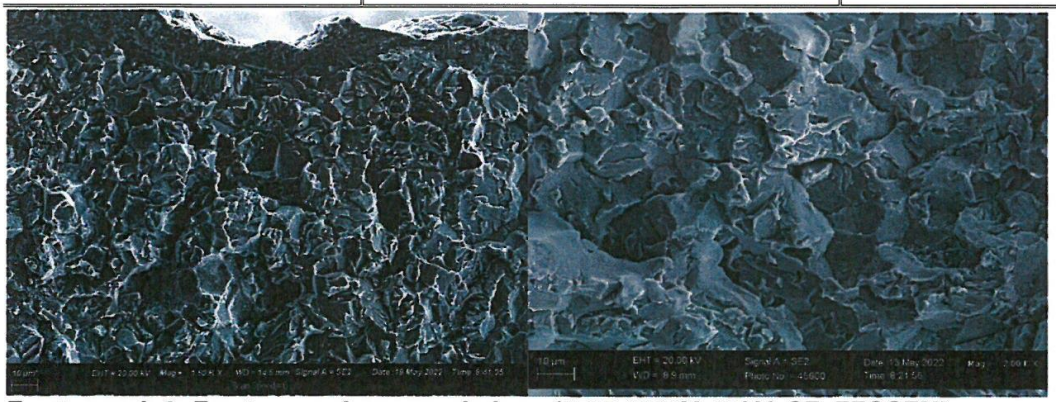
Photo 4: Fractured Crankshaft Gear (Digital)



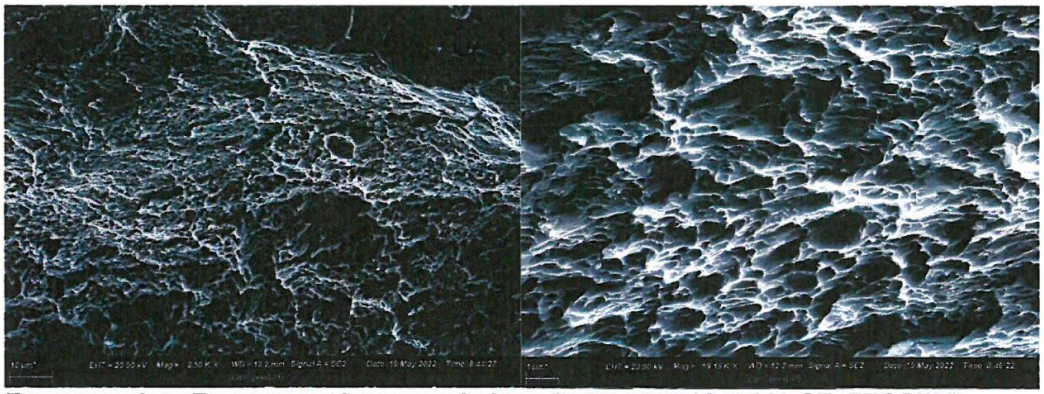
Fractograph 1: Outer surface morphology (1500X, 20kV, SE, FEGSEM)



Fractograph 2: Fracture surface morphology (166X, 20kV, SE, FEGSEM)



Fractograph 3: Fracture surface morphology (1500-2000X, 20kV, SE, FEGSEM)



Fractograph 4: Fracture surface morphology (2500-19190X, 20kV, SE, FEGSEM)

7. DISCUSSION AND CONCLUSION/S

Note 2: *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 investigation results revealed the primary contributing factor towards the failure of the Crankshaft Gear is Hydrogen Embrittlement. The exact cause/s towards the HIC could not be determined by this investigation – *the OEM manufacturing process is proprietary information*.

7.2. HIC is predominantly introduced by the manufacturing processes, particularly during plating/hardening where the component surface might be exposed to higher-than-normal ionised hydrogen (H+) concentration/s. Failing to remove the absorbed hydrogen by proper heat treatment, will result in HE and a loss in ductility with subsequent brittle behaviour of the metal. *However, HIC usually manifests itself within a relative short period of time (not operational time) following the exposure while in this case the part remained intact for an extended period. It can be hypothesized that the HIC was magnified during the engine impact loading/s (ref.p.1.4.) thus contributing to the timing of the final fracture.*

7.3. The exact reasoning behind the alleged OEM's requirement regarding the replacement of the Ø 50mm part with a Ø 52mm was not made known to this investigation. However, even if an increase in wall-thickness of the part is envisaged (Photo 4, red arrows), eliminating HIC should remain the primary focus during the manufacturing processes.

8. RECOMMENDATIONS

8.1. It is strongly recommended that the AIID investigation team determine if the manufacturing processes applicable to the relevant part, and parts already in service, conforms to the elimination of HIC.

9. DECLARATION

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