AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

			Reference:	**CA18/2/3/10072**	
Aircraft Registration	ZU-EHW	**Date of Accident**	10 November 2021	**Time of Accident**	1735Z
Type of Aircraft	ELA-08 Gyrocopter		**Type of Operation**	Training (Part 141)	
Pilot-in-command Licence Type	Private Pilot Licence (PPL)	**Age**	46	**Licence Valid**	Yes
Pilot-in-command Flying Experience		**Total Flying Hours**	215	**Hours on Type**	20.9
Last Point of Departure	Overulate Airstrip, Musina, Limpopo Province				
Next Point of Intended Landing	Overulate Airstrip, Musina, Limpopo Province				
Damage to Aircraft	Destroyed				

Location of the accident site with reference to easily defined geographical points (GPS readings if possible)
Five hundred (500m) metres from Overulate Airstrip threshold at Global Positioning System (GPS) co-ordinates 22° 8'38.42" South, 029°38'20.14" East, and at a field elevation of 1623ft

Meteorological Information	Wind direction: East; Wind speed: mild; Air Temperature: 34°C; Visibility: Good

Number of People On-board	1+0	**Number of People Injured**	0	**Number of People Killed**	1	**Other (On Ground)**	0

Synopsis

On 10 November 2021, a pilot on-board the ELA 08 Gyrocopter with registration ZU-EHW was engaged in a solo training aircraft conversion flight when the accident occurred. The instructor was monitoring the pilot from the ground using a handheld radio. The pilot took off from Overulate Airstrip private farm in Musina, Limpopo province, with the intention to land back at the same airstrip. The flight was conducted under visual meteorological conditions (VMC) by day and under the provisions of Part 141 of the Civil Aviation Regulations (CAR) 2011 as amended.

According to the instructor, the pilot, who was also the owner of the gyrocopter and the private farm, executed the first demonstration circuit approach. During the second circuit (which consisted of tight turns) whilst on the downwind leg at approximately 350 feet (ft) above ground level (AGL), the pilot conducted his vital downwind checks. At this time, the gyrocopter suddenly yawed sharply and aggressively to the left and skidded as it side-slipped forward in the initial direction of travel (approach). The instructor stated that this action was indicative of a possible aggressive or sudden input on the left rudder pedal at full power setting. As a result, the gyrocopter tilted to the right and tumble-rolled whilst losing height before it disappeared in the nearby bush. The instructor ran to the location where he last had visual of the gyrocopter, and found it crashed approximately 500 metres from the runway threshold facing 248º south-west. The pilot was found helpless in the gyrocopter, his upper body and upper legs were on the ground. The pilot’s helmet was found near a thorn tree with the headset cable still connected to the audio jack in the cockpit. The instructor immediately called for assistance. The pilot, who was seriously injured, was airlifted to the hospital; however, he succumbed to his injuries four (4) days later. The gyrocopter was substantially damaged.

The gyrocopter had crashed following an abrupt aggressive yaw to the left which was caused by the pilot’s unintended left rudder pedal input at a high-power setting. The sudden left rudder pedal input was likely induced by the pilot when he tried to grab hold of his helmet that had fallen off of his head during the downwind vital checks. The gyrocopter lost stability due to inertia and it side-slipped and tumble-rolled before it crashed.

Probable Cause

The pilot’s helmet was not properly latched on his head, which caused him to unintentionally induce an aggressive left rudder pedal input when he tried to grab hold of it. As a result, the gyrocopter yawed to the left and the pilot lost control of it. The gyrocopter tumble-rolled before it impacted the ground.

SRP Date	14 February 2023	Publication Date	20 February 2023

OCCURRENCE DETAILS

Reference Number	**:** CA18/2/3/10072
Occurrence Category	**:** Category 1
Name of Owner/Operator	**:** Izak Johannes Pretorius
Manufacturer	**:** Ela Aviation
Model	**:** ELA -08
Nationality	**:** South African
Registration Marks	**:** ZU-EHW
Place	**:** Overulate Airstrip private farm
Date	**:** 10 November 2021
Time	**:** 1735Z

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 was notified to the Accident and Incident Investigations Division (AIID) on 10 November 2021 at about 1800Z. 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 Design/Manufacturer in accordance with CAR 2011 Part 12 and ICAO Annex 13 Chapter 4. The state of manufacturer, Bureau of Enquiry and Analysis (BEA) France had not appointed a non-travelling accredited representative and advisor. Investigators did not dispatch to the accident site for this investigation.

Notes:
1. Whenever the following words are mentioned in this report, they shall mean the following:

- *Accident — this investigated accident*
- *Aircraft — the Auto Gyrocopter ELA-08 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:

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

Table of Contents

Abbreviation	Description
AIID	Accident and Incident Investigations Division
º	Degree
ºC	Degree Celsius
'	Minutes
"	Seconds
AGL	Above Ground Level
AMSL	Above Mean Sea Level
AP	Approved Person
ATF	Authority to Fly
ATO	Aircraft Training Organisation
BEA	Bureau of Enquiry and Analysis
C of R	Certificate of Registration
CRS	Certificate of Release to Service
CVR	Cockpit Voice Recorder
CAR	Civil Aviation Regulations 2011
CPL	Commercial Pilot Licence
CRS	Certificate of Release to Service
CVR	Cockpit Voice Recorder
FDR	Flight Data Recorder
ft	Feet
GPS	Global Positioning System Co-ordinates
HCL	Horizontal Component of Lift
hPa	Hectopascal
Kts	Knots
LSA	Light Sport Aircraft
METAR	Meteorological Aerodrome Report
MHz	Megahertz
Mph	Miles per Hour
No.	Number
NPL	National Pilot Licence
PIC	Pilot-in-command
POH	Pilot’s Operating Handbook
SB	Service Bulletin
VFR	Visual Flight Rules
VNL	Medical restriction: Correction for defective near vision
VMC	Visual Meteorological Conditions
WCM	Weight Shift Microlight

1. FACTUAL INFORMATION

1.1. History of Flight

1.1.1 On 10 November 2021, a pilot on-board the ELA 08 Gyrocopter with registration ZU-EHW was engaged in a solo training aircraft conversion flight when the accident occurred. The instructor was monitoring the pilot from the ground. The pilot took off from Overulate Airstrip, which is a private farm in Musina, Limpopo province, with the intention to land back at the same airstrip. The pilot was the owner of both the gyrocopter and the private farm. The flight was conducted under visual meteorological conditions (VMC) by day and under the provisions of Part 141 of the Civil Aviation Regulations (CAR) 2011 as amended.

1.1.2 The instructor was positioned towards the centre of the runway and used a handheld radio to communicate with the pilot whilst he was monitoring his training circuit co-ordination. The pilot was conducting circuits which consisted of touch-and-go landings. The circuit training was the ninth (9^{th}) of the required 10-hour solo training for the pilot to be signed off (endorsed) on the aircraft type conversion rating. According to the instructor, the pilot had successfully executed the first demonstration circuit approach. During the second circuit (which consisted of tight turns) whilst on the downwind leg at approximately 350 feet (ft) above ground level (AGL), the pilot conducted his vital downwind checks. This is when the gyrocopter suddenly yawed sharply and aggressively to the left and skidded as it side-slipped forward in the initial direction of travel (approach). It then tilted to the right and tumble-rolled whilst losing height before it disappeared in the nearby bush. The instructor stated that this action was indicative of a possible aggressive input on the left rudder pedal at full power setting.

1.1.3 After witnessing the gyrocopter's disappearance in the nearby bush, the instructor ran in the direction of the gyrocopter's visual loss and found it crashed approximately 500 metres (m) from the runway threshold facing 248º south-west. He found the gyrocopter resting on its left-side. The pilot was found helpless in the gyrocopter, his upper body and upper legs were on the ground. The pilot's helmet was found near a thorn tree with the headset cable still connected to the audio jack in the cockpit. The instructor immediately called for assistance. The pilot was seriously injured in the accident. He was airlifted to the hospital; however, he succumbed to his injuries four (4) days later. The gyrocopter was substantially damaged.

1.1.4 The accident occurred during daytime on the private farm airstrip at Global Positioning System (GPS) co-ordinates reading S 22° 8' 38.42", E 029° 38' 20.14" and at a field elevation of 1623ft.

Figure 1: The view of the accident site. (Source: Google Maps)

1.2. Injuries to Persons

1.2.1 The pilot sustained serious injuries during the accident sequence. He later succumbed to his injuries four days after the accident.

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

Note: Other means people on the ground.

1.3. Damage to Aircraft

1.3.1 The gyrocopter was substantially damaged.

Figure 2: The damage sustained by the gyrocopter.

1.4. Other Damage

1.4.1 None.

1.5. Personnel Information

1.5.1 The instructor was initially issued a National Pilot Licence (NPL) by the Regulator (SACAA) on 23 October 1987. His renewed licence was issued on 24 February 2020 with an expiry date of 28 February 2021. He had a valid Class 4 medical certificate that was issued on 17 February 2020 with an expiry date of 31 March 2022.

Instructor

Nationality	South African	Gender	Male	Age	65
Licence Type	National Pilot Licence (NPL)				
Licence Valid	Yes	Type Endorsed	Yes		

Ratings	WCM Instructor Grade B, LSA Instructor Grade B, Gyro Instructor Grade A, AG Gyro
Medical Expiry Date	31 January 2022
Restrictions	VNL (Correction for defective near vision)
Previous Accidents	Not known

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

Flying Experience: Instructor

Total Hours	8317.8
Total Past 24 Hours	0
Total Past 7 Days	5.9
Total Past 90 Days	24.9
Total on Type Past 90 Days	12.8
Total on Type	500

1.5.2 The pilot was initially issued a Private Pilot Licence (PPL) (Aeroplane) as a fixed wing pilot on 8 February 2017. His licence renewal was issued by the Regulator on 23 May 2021 with an expiry date of 31 January 2022. The pilot's Class 2 medical certificate was issued on 27 January 2020 with an expiry date of 31 January 2022. The pilot began his auto-gyrocopter aircraft type conversion training after he had bought the gyrocopter.

Pilot

Nationality	South African	Gender	Male	Age	46
Licence Type	Private Pilot Licence (PPL) Aeroplane				
Licence Valid	Yes	Type Endorsed	No		
Ratings	None				
Medical Expiry Date	31 January 2022				
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	215.0
Total Past 24 Hours	0.3
Total Past 7 Days	0.3
Total Past 90 Days	20.9
Total on Type Past 90 Days	20.9
Total on Type	20.9

1.5.3 The instructor was the approved person (AP) who maintained the aircraft. The instructor had a National Pilot Licence with a Grade (A) Gyro Instructor rating that was issued by the Regulator on 25 January 2020 with an expiry date of 24 January 2022.

Approved Person Licence

Nationality	South African	Gender	Male	Age	65
Licence Type	Aircraft Maintenance Engineer (AME)				
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	• Normal aspired Piston Engines • Turbo-charged Piston Engines (Rotax Engine series: 912, 914, 503, 583) • Aeroplanes of Composite Construction MTOW 5700kg				

	• Aeroplanes of Tube & Fabric Construction MTOW 5700kg • Rotorcraft powered by Reciprocating Engines • Trikes (Sting, Challenger, Windlass)
Licence Issue Date	22 February 2021
Licence Expiry Date	21 February 2023
Restrictions	None

1.6. Aircraft Information

Figure 3: The picture of the gyrocopter. (Source: Pilot's Operator Handbook)

1.6.1 The information below is an extract from the ELA 07/08 Pilot's Operating Handbook.

The ELA-08 which is similar model to ELA-07 is a two-seater tandem-configured autogyro with double controls that is appropriately for giving flight instruction. The principal structure of the autogyro is made of TIG welded stainless steel tube which guarantees the absence of corrosion in the entire structure, without having to worry about the problems that this could cause inside the tubes. It is very important to ensure the whole structure is kept free from dust and grease to carry out the inspections with total guarantee. The steering system controls the front wheel, permitting the autogyro to be on the ground by pressing on the pedals from both pilot seats and the same pedals activate the steering shaft for flight control, and take-off and landing procedures. Its manoeuvring capacity is extremely high and since it is impossible for the autogyro to stall or enter a spin, it has unequalled safety in flight, and when taking off and landing, thanks to the fact that it is flown at a very low speed.

Gyrocopter Design, Operation:

Although gyrocopters are designed in a variety of configurations, for the most part the basic components are the same. The minimum components required for a functional gyrocopter are an airframe, a powerplant, a rotor system, tail surfaces, and landing gear. The airframe provides the structure to which all other components are attached. The powerplant provides the thrust necessary for forward flight and is independent of the rotor system while in flight. The rotor system provides lift and control for the gyrocopter. The fully articulated and semi-rigid teetering rotor systems are the most common. The tail surfaces provide stability and *control in the pitch and yaw axes. These tail surfaces are similar to an airplane empennage and may consist of a fin and rudder, stabiliser and elevator.*

Theory of Flight:

The information below is an extract from the Theory of Flight Handbook Syllabus prescribed by Director General of Civil Aviation, Govt. of India. First Edition of 2007

The primary control surface on an airplane includes the aileron, rudder and elevator. The aileron is utilised to provide lateral control of the aircraft which involves movements around longitudinal axis. The elevator controls provide movements along the lateral axis such as pitch (aircraft nose up and down/ diving) movements. The rudder controls the aircraft movement about the vertical axis. They provide directional controlled movements either to the left or to the right.

The information below is an extract from the Rotorcraft Flying Handbook: Gyrocopter Chapters 15,16 and 20.

Gyrocopter Flight Controls:

On a gyrocopter specifically has flight controls such as cyclic control, throttle, rudder, collective control and the horizontal tail surface.

- ***The cyclic control** provides the means whereby you are able to tilt the rotor system to provide the desired results. Tilting the rotor system provides all control for climbing, descending, and banking the Gyrocopter. As such there are no elevators and ailerons on a Gyrocopter. The most common method to transfer stick movement to the rotor head is through push-pull tubes or flex cables. This movements causes the Gyrocopter to rotate around two axes specifically the lateral for climbing and descending. And for banking and rolling during turns is a combination and coordination which rotate along both longitudinal and lateral axes.*

- ***The throttle** is conventional to most powerplants and provides the means for the pilot to increase or decrease engine power and thus, thrust.*

- ***The rudder** is operated by foot pedals in the cockpit and provides a means to control yaw movement of the aircraft which rotate around the vertical axes. Yaw movement is not the same as turning as this involves the aircraft fuselage rotation along the vertical axis. On a Gyrocopter, this control is achieved in a manner more similar to the rudder of an airplane than to the antitorque pedals of a helicopter. The rudder is also used to maintain coordinated flight, and at times may also require inputs to compensate for propeller torque.*

  Rudder sensitivity and effectiveness are directly proportional to the velocity of airflow over the rudder surface. Consequently, many Gyrocopter rudders are located in the propeller slipstream and provide excellent control while the engine is developing thrust. This type of rudder configuration, however, is less effective and requires greater deflection when the engine is idled or stopped.

How a Gyrocopter Turns

The information below is an extract from the ELA Gyrocopter Operating Handbook.

Flight Manoeuvres: Turns in level flight

According to the aircraft type Pilot Operating Handbook, when conducting a turn, select a reference, set turn with control stick, and maintain speed of the gyrocopter using the trim. To make turns at 15-degree angle, it would be necessary to increase the engine power in *order to keep height /speed and the rudder pedals to favour the turn. The maximum bank angle is 60 degrees.*

Airframe:

Manufacturer/Model	ELA Aviation/ ELA-08	
Serial Number	115	
Year of Manufacturer	2006	
Total Airframe Hours (At Time of Accident)	709	
Last MPI (Date & Hours)	699.1	21 September 2021
Hours Since Last MPI	9.9	
ATF (Issue Date)	21 September 2021	
C of ATF (Expiry Date)	30 September 2021	
C of R (Issue Date) (Present Owner)	13 July 2021	
Type of Fuel Used in the Aircraft	Avgas 100LL	
Operating Categories	Part 141	
Previous Accidents	None	

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

Engine:

Manufacturer/Model	Rotax 914 UL
Serial Number	4419344
Hours Since New	709
Hours Since Overhaul	TBO not yet reached

Propeller:

Manufacturer/Model	DUC/ Windspoon
Serial Number	2449
Hours Since New	709
Hours Since Overhaul	TBO not yet reached

1.6.2 The gyrocopter's maintenance records, including the logbooks, flight folio and the annual maintenance report were reviewed. The gyrocopter was maintained in accordance with both the airframe and engine manufacturers' prescribed maintenance manual procedures. All manufacturer's published Service Bulletins (SBs) and Service Instructions (SI) were adhered to by both the approved person (AP) who maintained the gyrocopter and the owner. There were no recorded defects in the maintenance records that would have adversely affected the airworthiness of the gyrocopter at the time of the flight.

1.6.3 The gyrocopter was issued an Authority to Fly (ATF) certificate by the Regulator on 18 October 2021 with an expiry date of 30 September 2022. The gyrocopter was issued a Certificate of Release to Service (CRS) by an AP following an annual maintenance inspection on 22 September 2021 with an expiry date of 21 September 2022 or at 784 airframe hours, whichever comes first unless the gyrocopter is involved in an accident or becomes unserviceable. There was sufficient fuel remaining in the gyrocopter's fuel tank post-accident.

1.7. Meteorological Information

1.7.1 The copy of the weather conditions report for 10 November 2021 was requested from the South African Weather Service (SAWS) on 14 December 2021. The meteorological aerodrome report (METAR) information was collected from Thohoyandou in Venda and covers the wider area including the accident site.

Wind Direction	070°	Wind Speed	03kt	Visibility	9999
Temperature	34°C	Cloud Cover	None	Cloud Base	None
Dew Point	None	QNH	1020		

1.8. Aids to Navigation

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

1.9. Communication

1.9.1 The gyrocopter was equipped with standard communication system as approved by the Regulator for the aircraft type. There were no recorded defects with the communication system prior to the flight. The instructor communicated with the pilot using a handheld radio on frequency 120.65-Megahertz (MHz). The pilot used the aircraft’s radio to communicate with the instructor at the time of the flight.

1.10. Aerodrome Information

1.10.1 The accident occurred 500m from the private farm’s airstrip runway threshold. The unregistered airstrip’s total measured length is 600m and the width is approximately 10m. The accident occurred at GPS co-ordinates S 22° 8'38.42", E 029°38'20.14" and at a field elevation of 1623ft.

1.11. Flight Recorders

1.11.1 The gyrocopter was neither equipped with a cockpit voice recorder (CVR) or a flight data recorder (FDR), nor was it required by regulation to be fitted to this aircraft type.

1.12. Wreckage and Impact Information

1.12.1 The gyrocopter accident occurred in a bush at a private farm, approximately 500m from the runway threshold. The gyrocopter was found facing 248º degrees south-west from the runway threshold. The gyrocopter impacted the ground on its left-side before it came to rest; it was found in the same position post-accident. The gyrocopter’s debris was fairly localised within a 20m radius.

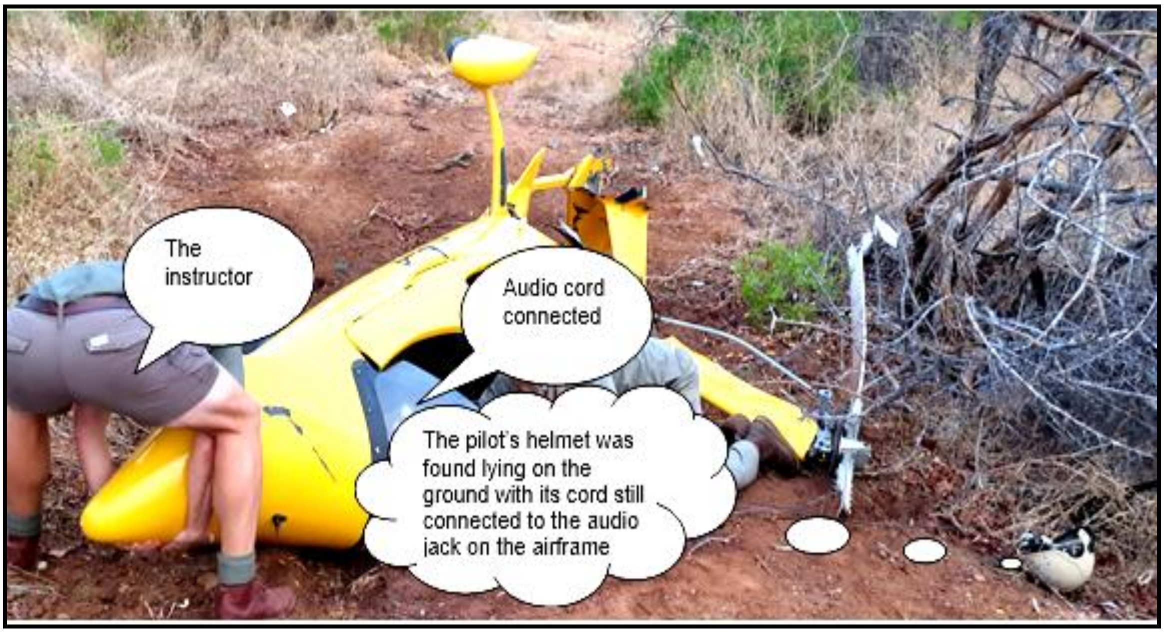


Figure 4: The aircraft immediately after the accident. (Source: Instructor)

The pilot's helmet was found about a metre from the gyrocopter, just above the main rotor head. Figure 4 picture was taken by the first responders, it shows the helmet's audio headset connecting cable (cord) still connected to the front cockpit audio jack instrument panel. The gyrocopter position was disturbed during an attempt to rescue the pilot from the wreckage (see Figure 4).

Figure 5: The damage sustained by the gyrocopter.

1.12.2 The left main landing gear had broken off, and the nose gear had folded under the bottom part of the fuselage. The left-side of the gyrocopter impacted the ground hard, resulting in multiple fuselage structure damage. The nose section was found slightly pointing towards the right, and had scratches sustained during impact. The engine mounting was found bent and facing left, which indicated inertia force at the time of impact. All engine control cables were still connected; they had continuity after being inspected. The engine turned without restrictions. The carbon fibre three-bladed propeller was still attached to the gyrocopter; all blades had sustained impact damage and were destroyed. The damage on the propeller indicated high-speed rotation under power at the time of impact or contact with the ground.

Figure 6: Damage on the main rotor hub.

1.12.3 The main rotor hub was found slightly bent; however, it was still intact. Both main rotor blades impacted the ground at high rotational speed. The first blade that impacted the ground disintegrated and broke off; it was flung approximately 20m from the main wreckage. The blade caused damage to some trees due to inertia. The second blade which was still attached to the rotor hub sustained damage to its outer section towards the tip; this is likely to be associated with the propeller and vertical stabiliser strike (impact). The two main rotor blade control links were found bent (see Figure 6).

Figure 7: The damage on the front cockpit instrument panel.

1.12.4 The front cockpit windshield was destroyed during the impact sequence. The front cockpit instrument panel was found bent; the damage was likely to have been caused by compression forces during the accident sequence. The cyclic control assembly unit had damage on the front attachment. The right-side rudder control paddle link was found detached and damaged.

Figure 8: The rear cockpit seat was configured securely for a solo flight.

1.12.5 The rear cockpit seat was safely secured for a solo configuration flight. The rear cockpit instrument panel was found still intact.

Figure 9: The severed vertical stabiliser.

1.12.6 The right-side winglet and the rudder were severed. It is likely that they were severed by the flapping main rotor blades during the accident sequence. The main vertical stabiliser fin rudder had detached during the impact sequence.

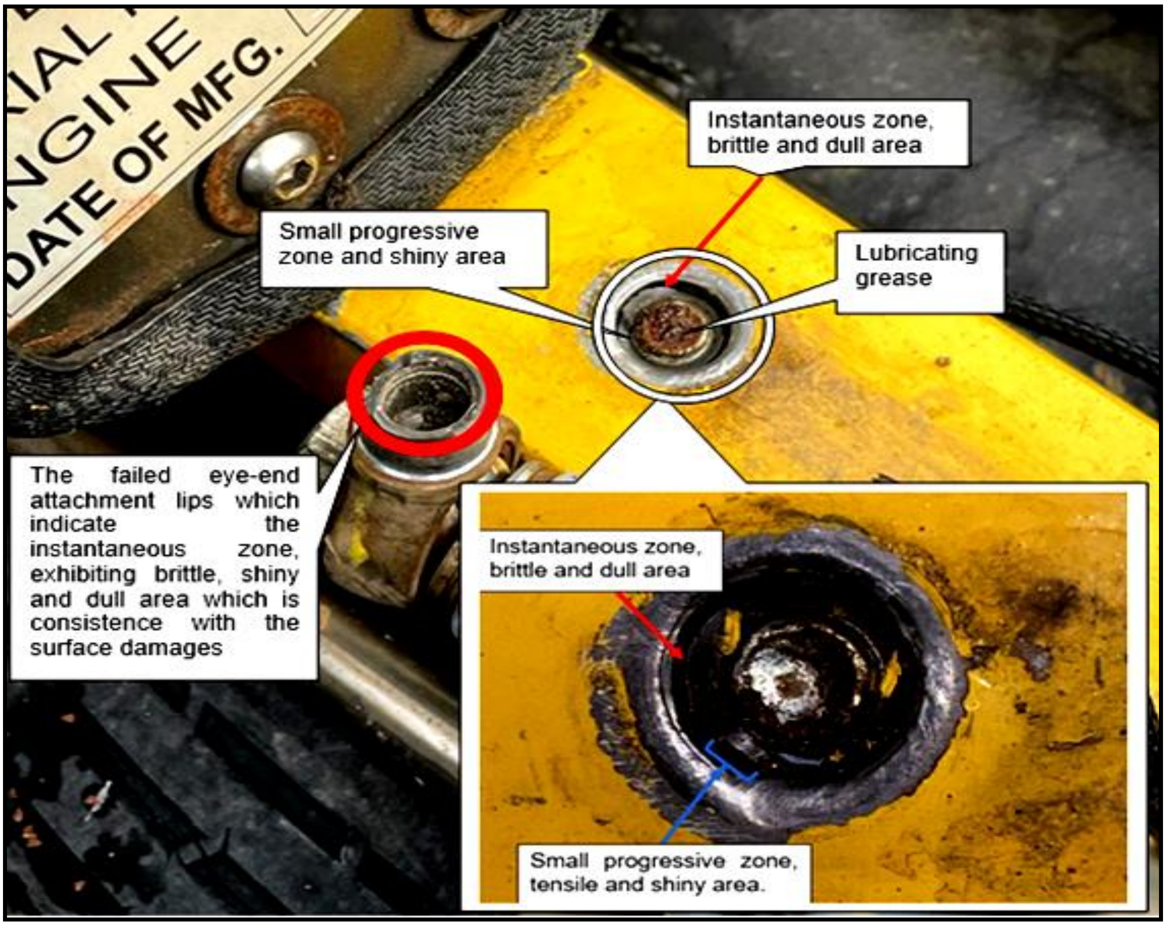


Figure 10: The failed attachment link. (Source: Instructor)

1.12.7 The control column mounting assembly sustained damage on the front eye-end attachment link bolt. The damage indicated a clear break (failure) caused by high load, which was likely to be acting sideways due to the main rotor flapping, resulting in great feedback forces on the control column during the accident sequence. The damage exhibits instantaneous zone, brittle and dull with a progressive zone with tensile and shiny area (refer to Annexure A for tests results).

Figure 11: The scratch marks left by the control column following the accident as it was tempered with by the recovery team. (Source: Recovery Team)

The recovery team tampered with (moved side) the control column, evidenced by scratch marks (see Figure 11).

Note: Figure 11 (photo) was taken at night-time by neighbours who came to assist with the recovery of the wreckage. A video was also captured which showed the control column being tampered with.

1.13. Medical and Pathological Information

1.13.1 The post-mortem report was not available at the time of finalising this report. Should any of the results have a bearing on the circumstances leading to the accident, they will be treated as new evidence and that will necessitate the reopening of this investigation. The pilot succumbed to his injuries while hospitalised a few days after the accident.

1.14. Fire

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

1.15. Survival Aspects

1.15.1 The accident was considered not survivable. The design structure of the gyrocopter partially covers the cockpit. Therefore, this compromised the pilot's survivability. Moreover, the pilot was exposed to an impact force due to the attitude at which the gyrocopter impacted the ground. The pilot had made use of the aircraft's safety harnesses.

1.15.2 The pilot's helmet was not safely secured during operation. It was found near the gyrocopter still connected to the airframe audio connecting jack. The helmet's mechanism was still in good condition and was working properly when tested.

1.16. Tests and Research

1.16.1 The eye-end bolt on the front mounting attachment of the rotor control system was found broken after the accident.

Rotor Control System:
The information below is an extract from the Gyrocopter ELA 07/07S Maintenance Manual.

The rotor control system is entirely made of stainless steel and mounted on a stainless-steel bearings rod end. The control columns are fixed at their lower ends to a toque bar that pivots on two bearings anchored to the main structure, joined at the top to a push-pull bar, which together with the former controls the control element. Two vertical bars emerge from this point that stop at two return devices, one at each side of the structure. The rotor control system has direct link resulting with feedback which can be felt on the control column from the rotor flapping. To lessen the excessive feedback inputs on the control column has been enhanced with trim mechanism which allows the easy and smooth operation. This trim mechanism also allows pilot to flight free hand. A demonstration on the feedback was conducted by the instructor to the investigating team.

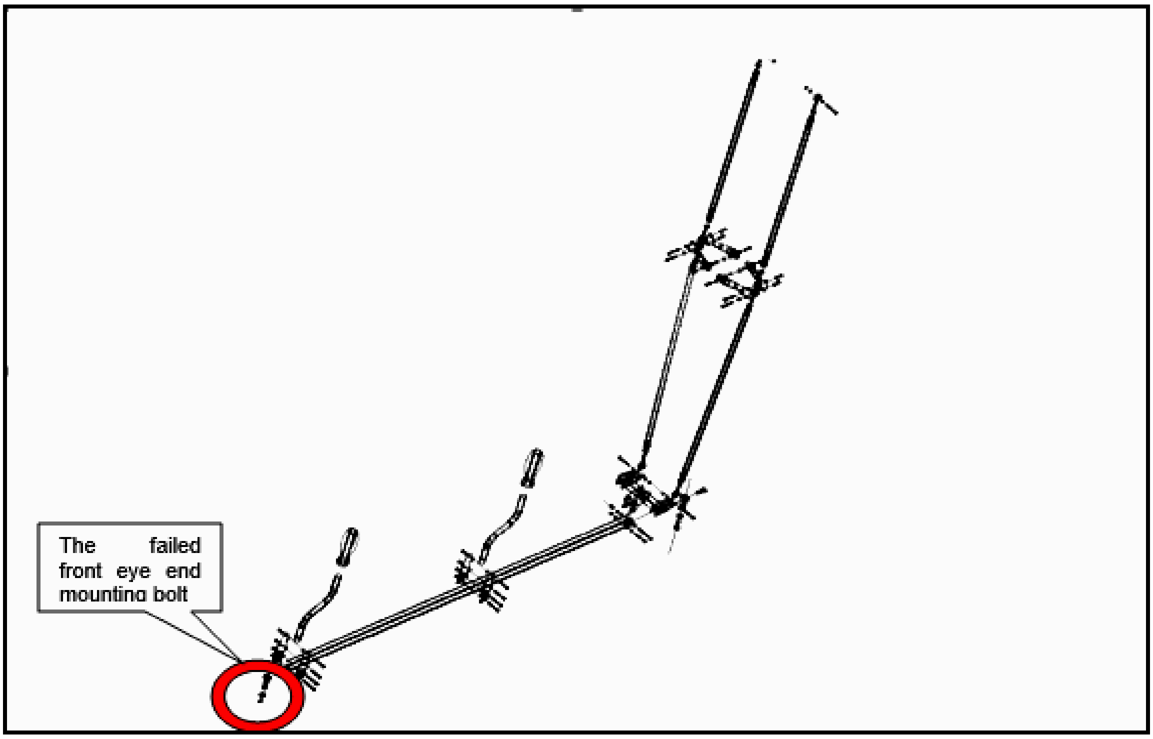


Diagram 1: The rotor control system. (Source: Gyrocopter Ela 07/07S Maintenance Manual)

In any case where there is aggressive manoeuvring which causes imbalance of the normal rotor flapping resulting with a severe abnormal rotor flapping, the feedback overrides the trim mechanism and act directly on the control column and cause it to move aggressively sideways (left to right) starting in most cases on the left-hand side. This uncontrolled movement of the control column during abnormal rotor flapping often cause injuries on the occupants (pilot) upper leg to an extend of breaking them. However, this could not be proven on this accident investigation as the post-mortem was not made available.

TESTS:
The failed eye-end bolt with female threads was tested by an independent qualified metallurgical consulting company commissioned by the instructor. (Refer to Appendix 1: Annexure A for the eye-end bolt failure test results report.)

Extract from the eye-end bolt failure test results report:
FAILURE MODE
Both failure surfaces were examined visually and with a stereo microscope at higher magnifications.
None of the failure surfaces examined contained any evidence of fatigue cracking.
An approximately 45° shear failure occurred along the entire circumference of the threaded hollow end portion of the rod end.

PROBABLE CAUSE OF THE FAILURE OF THE FRONT END
The rod end with its internal female thread clearly failed by abnormal bending, which introduced an overload induced shear failure. The failure of this rod end did not cause the accident. It failed during, and because of, the accident.

1.16.2 Research:

The information below is an extract from the Rotorcraft Handbook (Gyrocopter) by the Federal Aviation Administration (FAA).

Turns
Turns are made in Gyrocopter by banking the rotor disc with cyclic control. Once the area, in the direction of the turn, has been cleared for traffic, apply side ward pressure on the cyclic unit the desired bank angle is achieved. The speed at which the Gyrocopter enters the bank is dependent on how far the cyclic is displaced. When the desired bank angle is reached, return the cyclic to the neutral position. The rudder pedals are used to keep the Gyrocopter in longitudinal trim throughout the turn, but not to assist in establishing the turn. The bank angle used for the turn directly affect the rate of turn. As the bank is steepened, the turn rate increases, but more power is required to maintain altitude. A bank angle can be reached where all available power is required, with any further increase in bank resulting in a loss of airspeed or altitude. Turns during a climb should be made at the minimum angle of bank necessary, as higher bank angles would require more power that would otherwise be available for the climb. Turns while gliding increases the rate of descent and may be used as an effective way of losing excess altitude.

Skids

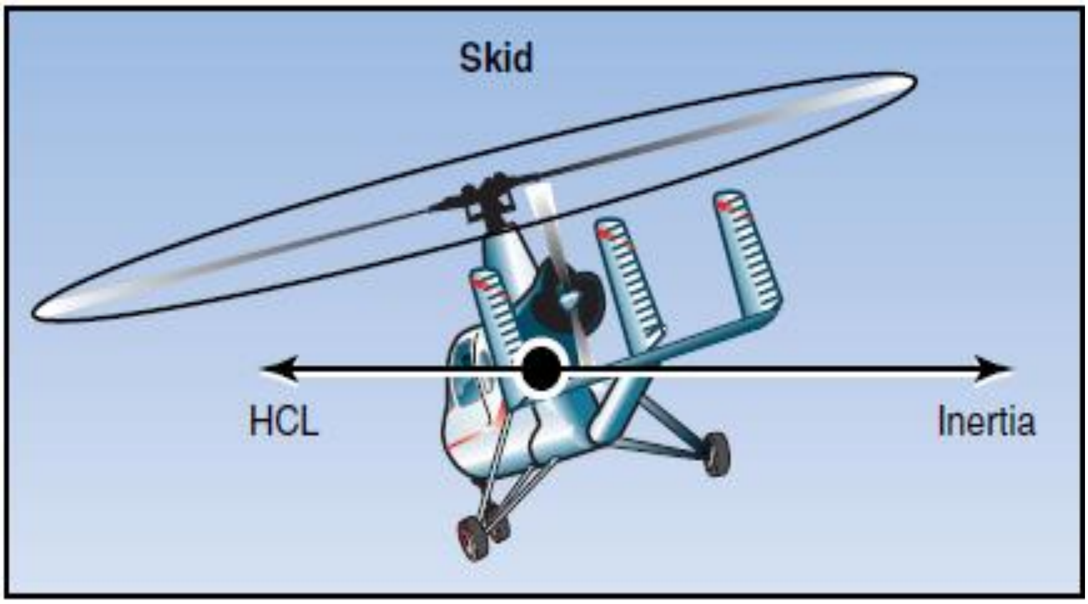


Diagram 2: Shows the effect of skid during a turn.

A skid occurs when the Gyrocopter slides sideways away from the center of the turn. [Diagram 2] It is caused by too much rudder pedal pressure in the direction of the turn, or by too little in the direction opposite the turn. If the Gyrocopter is forced to turn faster with increased pedal pressure instead of by increasing the degree of bank, it skids sideways away from the center of the turn instead of flying in its normal curved pattern. During a skid, *inertia exceeds the Horizontal Component of Lift (HCL). To reestablish equilibrium, increase the bank angle or reduce the rate of turn by applying rudder pedal. You may also use a combination of these two corrections.*

Common errors are caused by:

- *Improper coordination of flight controls*
- *Failure to cross-check and correctly interpret outside and instrument references.*
- *Using faulty trim technique.*

Thrust
Thrust in a Gyrocopter is defined as the component of total propeller force parallel to the relative wind. As with any force applied to an aircraft, thrust acts around the center of gravity (CG). Based upon where the thrust is applied in relation to the aircraft center of gravity, a relatively small component may be perpendicular to the relative wind and can be considered to be additive to lift or weight.

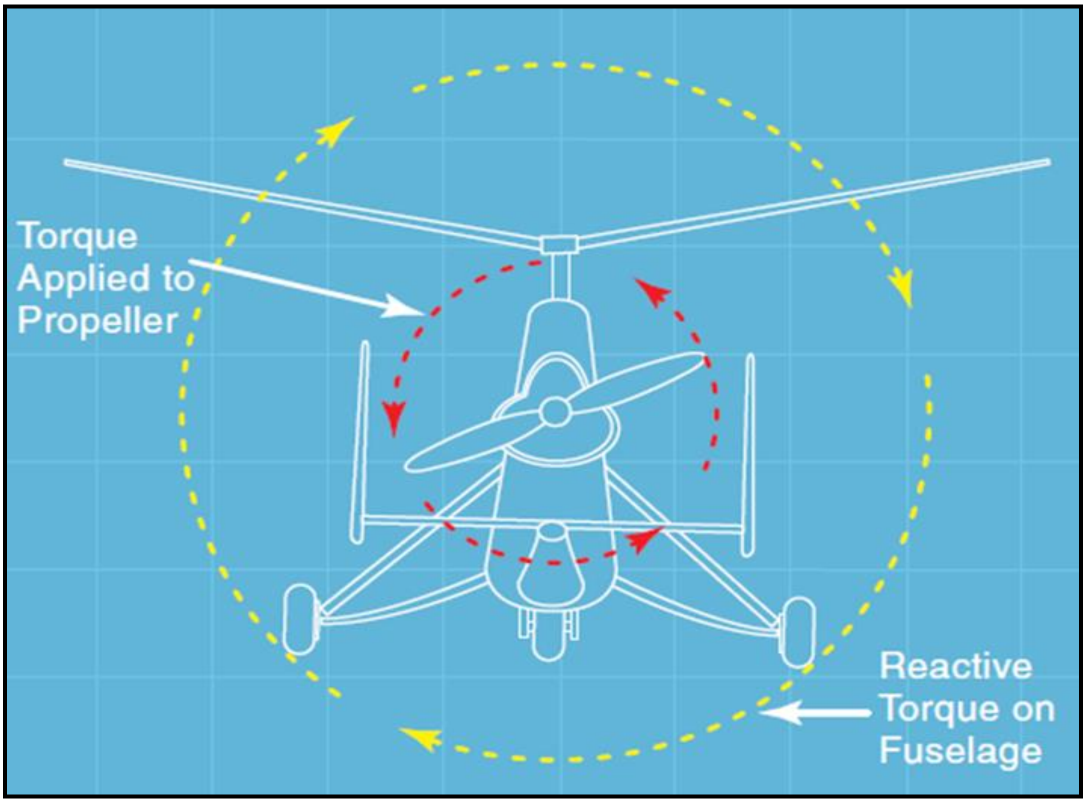


Illustration 1: Stability illustration with engine torque applied to the propeller opposing reaction

*In flight, the fuselage of a Gyrocopter essentially acts as a plumb suspended from the rotor, and as such, it is subject to **pendular action** in the same way as a helicopter. Unlike a helicopter, however, thrust is applied directly to the airframe of a Gyrocopter rather than being obtained through the rotor system. As a result, different forces act on a Gyrocopter in flight than on a helicopter. Engine torque, for example, tends to roll the fuselage in the direction opposite propeller rotation, causing it to be deflected a few degrees out of the vertical plane. This slight "out of vertical" condition is usually negligible and not considered relevant for most flight operations.*

Stability, Inertia and Instability

***Stability**: Is designed into aircraft to reduce pilot workload and increase safety. A stable aircraft, such as a typical general aviation training airplane, requires less attention from the pilot to maintain the desired flight attitude, and will even correct itself if disturbed by a gust of wind or other outside forces. Conversely, an unstable aircraft requires constant attention to maintain control of the aircraft. There are several factors that contribute to the stability of a Gyrocopter. One is the location of the horizontal stabilizer. Another is the location of the fuselage drag in relation to the center of gravity. A third is the **inertia** moment around the* *pitch axis, while a fourth is the relation of the propeller thrust line to the vertical location of the center of gravity (CG). However, the one that is probably the most critical is the relation of the rotor force line to the horizontal location of the center of gravity.*

Inertia: *Is the property of a moving or stationary physical object (an object having mass) to remain in that motion or remain stationary. The property of matter that causes it to resist any change of its motion in either direction or speed. Inertia energy is stored in the speed of on object, and must be exchanged or dissipated in order to change or stop the motion of that object,*

Instability: *The property of an (unstable) object or system that causes its motion or condition to diverge or oscillate once disturbed. An unstable object or system will not self-maintain equilibrium or self-restore to equilibrium once disturbed. External stabilization is required to maintain equilibrium of an unstable object or system.*

The following information is an extract from the Pilot Information Letter released by Auto-Gyro in January 2023. AG-PIL-2023-01-EN: Gyroplane yaw management and effects on controls.

Yaw as a result of an extreme pedal input*:*
It is important to remember that a gyroplane body hangs 'free' under the rotating wing or rotor disc. This freedom enables the body to be moved in all axes under and with respect to the rotor. A 90-degree yaw will place the body at 90 degrees to the oncoming airflow. This then means that the roll axis has effectively become the pitch axis. The rotor disc pitch angle in the direction of travel will tend to the nominal 10-degree aft orientation typical of forward flight at normal cruise speeds. However, in the roll axis the roll control stops will aim to limit the disc pitch angle to 8-9 degrees. In a light aeroplane or helicopter the wing or rotor disc would normally roll away from such sideslip. This characteristic on autogyros is very weak and easily overpowered, for example by the aerodynamic load induced on the gyroplane body in sideslip.

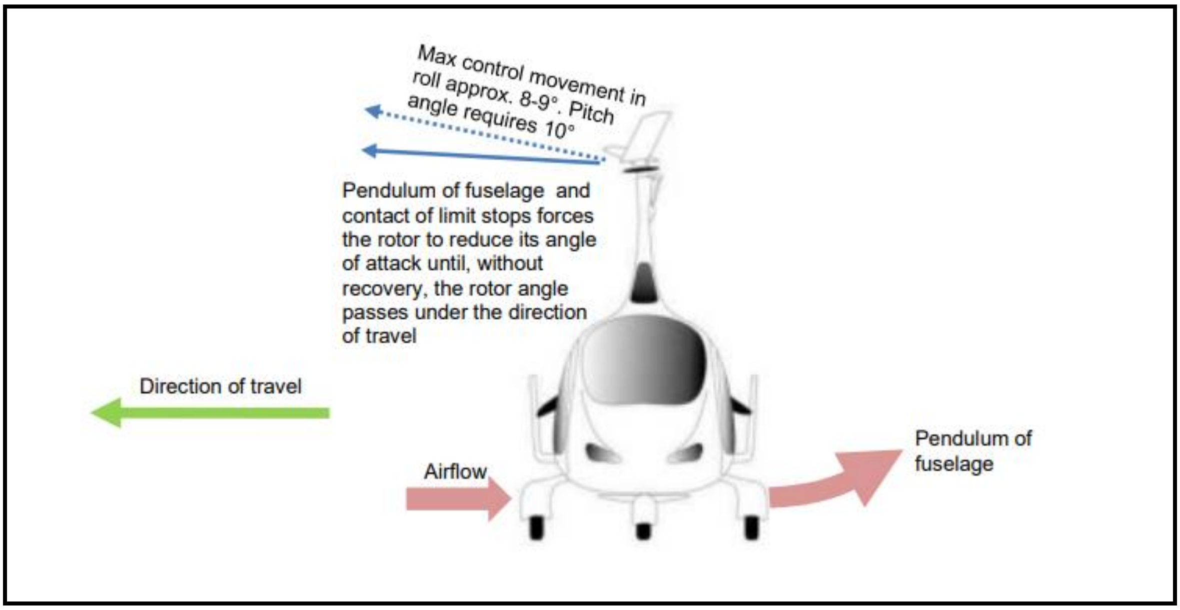


Diagram 3: This sketch assumes a full 90-degree yaw.

Consider then also that the aircraft is now flying sideways, and the side of the aircraft is facing the oncoming airflow. This airflow will create an increased drag force which will tend to swing the fuselage away from direction of flight. Because the rotor disc is already against the limit stops, and because the force from the body is considerable, the rotor disc is pitched down into the oncoming airflow. With the airflow now above rather than below the rotor disc the aircraft will rapidly roll over into the direction of flight, unless urgent corrective action is taken. Whilst this is an extreme example, Auto-Gyro is aware of a small number of such occurrences around the world.

***Side-slipping gyroplanes without careful control is inherently dangerous**.*
Recovery must be made promptly using pedal yaw input (effective provided there is propeller wash over the rudder), and lowering the nose to force the body into the direction of flight and maintain airflow through the rotor disc.

1.16.3 According to the pilot, who is also an instructor and an AP with more than 3000 flying hours on gyrocopter operation, all damage sustained by the gyrocopter was indicative of the rotor flapping, which could have been induced by any aggressive manoeuvre or unintended aircraft control input during flight. Any input which would induce flapping of the main rotor during flight could result in a fatal accident.

A rotor flapping demonstration was carried out for the investigating team. According to the expert, a gyrocopter is designed with a stable character which, when trimmed correctly, could be flown without touching the control column. In case where rotor flapping is induced by any abrupt manoeuvres, the feedback on the control column would become severely uncontrollable and would result in sideways movements. The sideways movements would also impair the strength of the forward attachment eye-end bolt as it would be subjected to high stress load with tensile forces to a point of breaking off. In many cases, the violent sideways movements of the control column could cause injuries to the pilot's upper leg. However, this scenario could not be verified for this accident as the post-mortem results were not made available at the time of completion of this report.

1.17. Organisational and Management Information

1.17.1 The gyrocopter was privately owned and operated by the pilot. His private farm was equipped with a private airstrip.

1.17.2 The AP who maintained the gyrocopter was licensed and approved by the Regulator. He had an AP certificate that was issued by the Regulator on 22 February 2021 with an expiry date of 21 February 2023. The gyrocopter was endorsed on his certificate. The Certificate of Release to Service (CRS) was issued by the AP on 22 September 2021 with an expiry date of 21 September 2022 or at 784 airframe hours, whichever comes first unless the gyrocopter is involved in an accident or becomes unserviceable.

1.17.3 The approved training organisation (ATO) which provided the pilot with training had a valid ATO certificate No: RAA/002 that was issued by the Regulator on 6 October 2021.

1.18. Additional Information

1.18.1 The pilot's helmet was found on the ground with its audio connecting cable attached to the airframe audio jack. According to the instructor, the pilot's helmet was not secured properly. The helmet provides a secure latching mechanism when engaged and worn correctly. The pilot's helmet was found latched without the strap feeding through the securing hook/lock.

The importance of wearing a helmet:

According to the Rotary Wing Forum, *"the least mishap that is likely to occur during gyrocopter operations is tipping over during take-off or landing. As such the helmet is worn when flying an open cockpit gyrocopter for obvious reasons of safety. Although it is not mandated but however optimal, it has been made exceptional as part of the safety practice and check list in case of any unforeseen situations to prevent occupants against head injuries from debris or during take-offs and landing with the possibility of aircraft tip-over. A precaution has been mandated based on the previous several occurrences whereby either the headset or the helmet coming off from the head during flight and going into the propeller causing worse damages or to stop them from moving around the pilot's head during flight. As such a helmet with latching mechanism is of preference to be worn during flight mostly on open cockpit gyrocopters. If the pilot uses a helmet, it is mandated that they* *secure it properly before starting the gyrocopter's engine. The same applies to when they are carrying passengers."*

Figure 12: (Left) A demontration of the helmet latching (securing) mechanism similar to that of the pilot in this accident. (Right) The manner in which the pilot's helmet was found post-accident.

According to the instructor, during the first five (5) hours of solo training, there was an occasion on which the pilot was observed with an unsecured helmet during the pre-start-up checks; he was duly corrected by the instructor. This was not endorsed on the student pilot's (pilot's) progress report. Apart from this occasion, the instructor does not recall the pilot making the same mistake. On the day of the accident flight, the instructor did not see if the pilot had secured the helmet correctly as he was positioned approximately 30m from the gyrocopter, observing and communicating with the pilot via a handheld radio.

1.18.2 According to the gyrocopter manufacturer's ELA technical and investigation team, "*in an accident of this type there are many factors to take into account. The human being is often the cause of the accident if the aircraft's maintenance care is up to date and is carried out by professionals. It could be a simple matter of having left the helmet unlatched. Due to the wind, the helmet would come lose and the pilot would attempt to fasten it quickly, neglecting the controls briefly. This would cause the gyrocopter to lose lift. If the helmet fell off the head, it would surely end up in the rear propeller, so the pilot would probably do everything possible to grab hold of it, not knowing that the consequence would be devastating. The controls could snap on impact.*

1.19. Useful or Effective Investigation Techniques

1.19.1 None.

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 particular organisation or individual.

2.2. Analysis

2.2.1 The pilot was initially issued a Private Pilot Licence (PPL) (Aeroplane) as a fixed wing pilot on 8 February 2017. His licence renewal was issued by the Regulator on 23 May 2021 with an expiry date of 31 January 2022. The pilot's Class 2 medical certificate was issued on 27 January 2020 with an expiry date of 31 January 2022. The pilot began his auto-gyrocopter aircraft type conversion training after he had bought the gyrocopter.

2.2.2 The instructor had a National Pilot Licence (NPL) with the Instructor Grade (A) gyrocopter rating. His licence was issued by the Regulator following a currency renewal on 25 January 2020 with an expiry date of 24 January 2022.

2.2.3 The approved training organisation (ATO) which was training the pilot for his conversion had a valid ATO certificate that was issued by the Regulator on 6 October 2021.

2.2.4 The gyrocopter was issued an Authority to Fly (ATF) certificate by the Regulator on 22 September 2021 with an expiry date of 30 September 2022. The gyrocopter was also issued a Certificate of Registration (C of R) by the Regulator on 13 July 2021. The approved person issued a Certificate of Release to Service (CRS) for the gyrocopter on 22 September 2021 with an expiry date of 21 September 2022 or at 784 airframe hours, whichever comes first unless the gyrocopter is involved in an accident or becomes unserviceable. There were no defects recorded in the gyrocopter maintenance records.

2.2.5 The AP who maintained the gyrocopter was also the instructor, he had an AP certificate issued by the Regulator on 22 February 2021 with an expiry date of 21 February 2023. He was certified to conduct maintenance on the gyrocopter type for both airframe and powerplant.

2.2.6 The gyrocopter was observed yawing sharply to the left-side at high power settings and skidded as it side-slipped. Subsequently, it tilted and tumble-rolled to the right whilst losing height and crashed into a nearby bush. This unusual manoeuvre is associated with a sudden unintended left rudder input which caused the gyrocopter to yaw aggressively to the left. During the yaw, the gyrocopter's fuselage rotated along the vertical axis to the left. Due to inertia at high engine power settings, the gyrocopter continued to move in the initial direction of travel as there was no turn co-ordination that took place. This resulted in the gyrocopter skidding as it side-slipped with inertia, exceeding the Horizontal Component of Lift. The gyrocopter then became unstable as the rotor disc induced further flapping in the direction of the skid, causing it to tilt. This further caused the central gravity (CG) to shift above the propeller thrust line, whereby more fuselage oscillation was induced. This resulted in the reactive fuselage torque becoming greater and induced oscillation sufficiently above the CG and completed a tumble.
The (above) induced tumbling of the gyrocopter supports the instructor's statement of account.

2.2.7 The pilot's helmet was found on the ground with its audio cable (cord) still connected to the audio jack in the airframe. It is likely that the pilot's helmet was not properly secured or latched. During the downwind vital checks, the helmet shifted or moved from the pilot's head due to relative wind or head movement. As a result, the pilot tried to grab hold of the helmet, stretching his body most likely to the right-side. He briefly neglected the controls and likely unintendedly gave a sudden left rudder pedal input, which resulted in the sudden aggressive left yaw. It is likely that the pilot's helmet came off during the flight as it was not properly latched.

2.2.8 It is also evident that an abnormal rotor flapping was induced due to gyroscopic rotor disk effect, which led to the subsequent tumble due to the sudden change in direction at a greater inertia during flight. Moreover, the rotor flapping contributed to the vertical stabiliser being severed during the accident sequence. The rotor flapping further weakened the eye-end mounting bolt due to excessive feedback during impact. The control column's front mounting eye-end sustained instantaneous failure damage.

2.2.9 The control column is designed with a trim function to allow the pilot to not put much effort during flight and is used to co-ordinate banking during a turn. The control column did not contribute to this accident.

2.2.10 The pilot's helmet was not properly latched, which caused him to unintentionally induce an aggressive left rudder pedal input. As a result, the gyrocopter yawed to the left and the pilot lost control; the gyrocopter tumble-rolled before it impacted the ground. The helmet was found on the ground with the audio connecting cable still connected to the audio jack. The instructor did not see if the pilot's helmet was secured properly prior to the flight as he was positioned a distance away from the aircraft during pre-flight; he was observing and communicating with the pilot via a handheld radio.

2.2.11 Fine weather conditions prevailed at the time of the flight. The weather conditions did not contribute to the accident.

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 particular 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

3.2.1 The pilot was initially issued a Private Pilot Licence (PPL) (Aeroplane) as a fixed wing pilot on 8 February 2017. His licence renewal was issued by the Regulator on 23 May 2021 with an expiry date of 31 January 2022. The pilot's Class 2 medical certificate was issued on 27 January 2020 with an expiry date of 31 January 2022. The pilot began his auto-gyrocopter aircraft type conversion training after he had bought the gyrocopter.

3.2.2 The pilot's gyrocopter type conversion training was in progress at the time of the accident. On the day of the accident, the pilot was conducting his solo flight test with the instructor observing him from the ground. Communication was established through a handheld radio on frequency 120.65MHz.

3.2.3 The ATO which was providing training to the pilot had a valid ATO certificate that was issued by the Regulator on 6 October 2021.

3.2.4 The instructor had a National Pilot Licence (NPL) with Instructor Grade (A) gyrocopter rating. His licence was issued by the Regulator following a currency renewal on 25 January 2020 with an expiry date of 24 January 2022.

3.2.5 The AP who maintained the gyrocopter was also the instructor to the pilot. He had an AP certificate that was issued by the Regulator on 22 February 2021 with an expiry date of 21 February 2023.

3.2.6 The gyrocopter was issued an ATF certificate by the Regulator on 22 September 2021 with an expiry date of 21 September 2022. The gyrocopter was also issued a Certificate of Registration (C of R) by the Regulator on 13 July 2021.

3.2.7 The gyrocopter was issued a CRS by the AP on 22 September 2021 following an annual maintenance inspection with an expiry date of 21 September 2022 or at 784 airframe hours, whichever comes first unless the gyrocopter is involved in an accident or becomes unserviceable.

3.2.8 The gyrocopter's control column mounting attachment eye-end link broke off from the airframe mounting during impact.

3.2.9 The gyrocopter was observed yawing sharply to the left-side at high power settings before it side-slipped and, subsequently, tumbled and crashed. This was consistent with the inadvertently left rudder input by the pilot as he tried to grab hold of his helmet.

3.2.10 The pilot's helmet was found on the ground just above the main rotor head with its cable still connected to the headset audio jack. Its securing latch was found engaged but the strap was not fed through the lock/hook.

3.2.11 The pilot succumbed to his injuries in hospital four days after the accident.

3.2.12 The gyrocopter sustained substantial damage to the fuselage structure, main rotor blades and three propeller blades. The left landing gear broke off and the right-side vertical stabiliser was severed by the main rotor during the accident sequence.

3.3. Probable Cause/s

3.3.1 It is likely that the pilot's helmet was not properly latched which distracted and caused him to make an aggressive input on the left rudder. This caused the gyrocopter to yaw to the left-side; the pilot lost control of the gyrocopter which subsequently tumble-rolled before it impacted the ground.

3.4. Contributory Factors

3.4.1 None.

4. SAFETY RECOMMENDATIONS

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.

4.1. Safety Recommendation/s

4.1.1 The Gyrocopter Operational Manual does not prescribe that a helmet should be worn during operation, but only the headset. Therefore, it is recommended that the manufacturer includes the wearing of the helmet during operation.

4.1.2 **Safety Message:** The Gyrocopter Operational Manual does not prescribe that a helmet should be worn during operation, but only the headset. Pilots are urged to wear and properly secure their helmets during operation to prevent or minimise the possibility of injuries should an accident occur.

5. APPENDICES

5.1 Annexure A: Failed eye-end bolt tests.

This report is issued by:

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

Appendix 1

Annexure A: The failed eye-end bolt tests

The following steps were considered during the process

Cleaning of the rod end with the bolt:

- *During a preliminary stereomicroscopic examination of the failure surfaces of the rod end with female thread1, substantial loose dirt was identified on the failure surfaces, which clearly deposited/accumulated after the failure of the rod end.*
- *The failed rod end and bolt with the other remnant of the failed rod end with the internal female thread were then separately cleaned in an ultrasonic bath in a degreaser at around 50°C.*
- *The components were then rinsed in water and cleaned/dried with methanol.*
- *During subsequent examination of the failure surfaces of the rod end, superficial brown rust (hydrated oxides and hydroxides of steel) was observed on relatively small portions of one failure surface. This rust clearly developed after the failure of the rod end. The rust was removed with an inhibited hydrochloric acid solution followed by water rinsing and final cleaning/drying with methanol.*

Macroscopic features of the failed rod end

The following macroscopic damage indicates that the rod end was subjected to severe bending during a single loading event:

- *A severe indentation on the one side of the hollow end portion of the rod end at its failure location.*
- *The morphology of the failure along the circumference of the rod end.*

The rod end with internal female thread failed at a substantial stiffness transition at the end of the bolt that was partially screwed into the rod end.

Annexure Figure 12 : Shows the failed eye-end bolt mounting section.

Photographs taken shortly after the accident and provided to the Writer. The arrows were added by the Writer. The red arrow in the bottom image shows a brownish substance on the bottom end of a bolt that was screwed into the rod end with its internal female screw thread. The rod end was at the bottom of the front control stick. The white arrow in the bottom image shows the fracture surface of the rod end. This fracture surface was not corroded and is therefore indicative of a fresh fracture surface. The matching fracture surface at the red arrow was also not corroded.

Annexure Figure13: Shows the failed eye-end bolt

Annexure Figure 14: Shows the failed part of the eye-end bolt

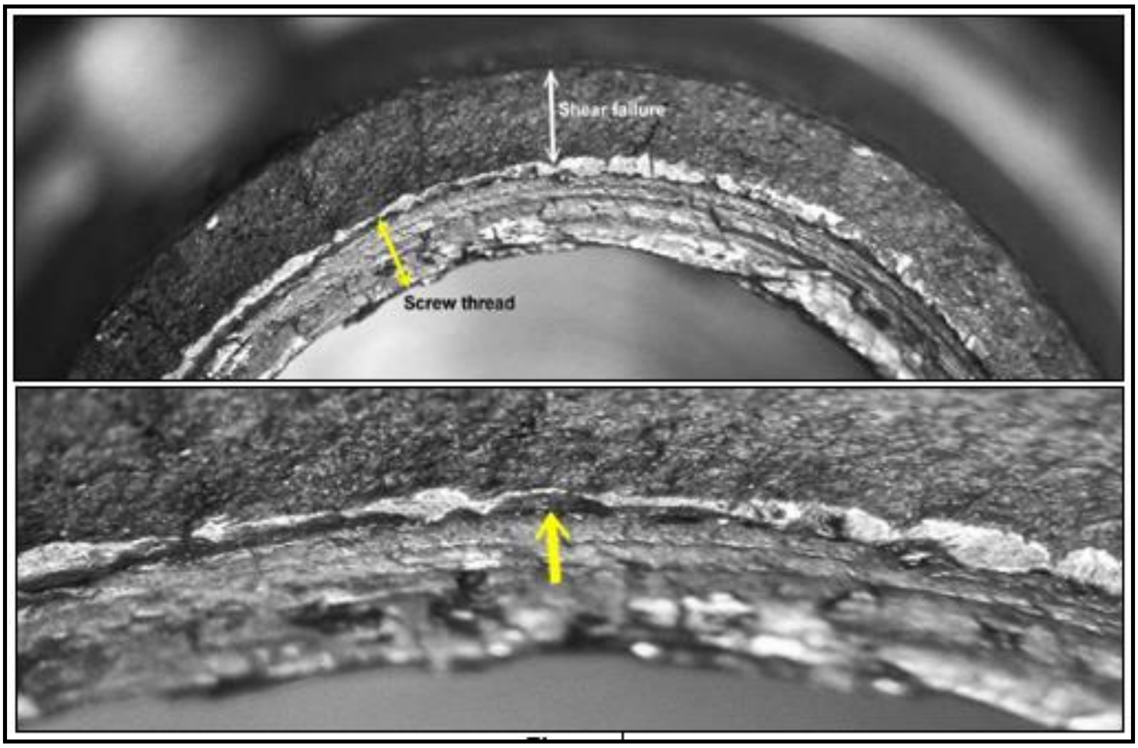
The indentation on the one side of the hollow end portion of the rod end, with female screw thread identified with the red arrow, and the morphology of the failure along the circumference of the rod end, especially along this side of the component, indicate that the rod end was subjected to abnormal bending. The side identified with the red arrow was subjected to compression. The opposite side was subjected to tension during the bending action. Also refer to the following figure.

Annexure Figure 15: Demonstration of forces that caused the bolt to fail

The rod end with internal female thread was subjected to bending, which produced an overload shear failure from the internal screw thread at the end of the bolt that was screwed into the threaded end portion of the rod end (following image)

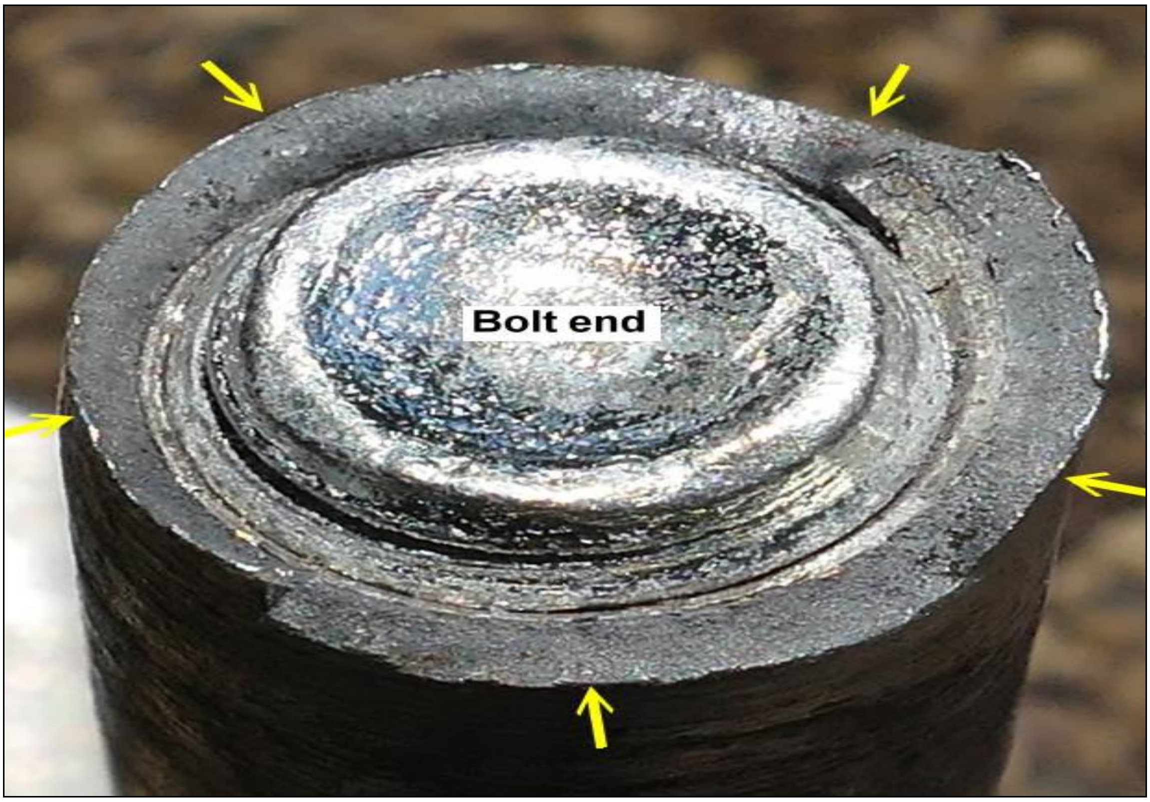
Annexure Figure 16: Demonstration of shear failure on the bolt circumference

The arrows identify an approximately 45° shear failure along the entire circumference of the threaded end portion of the rod end. This failure surface did not exhibit any evidence of fatigue cracking, i.e., the threaded end portion of the rod end failed during a single overload (bending).



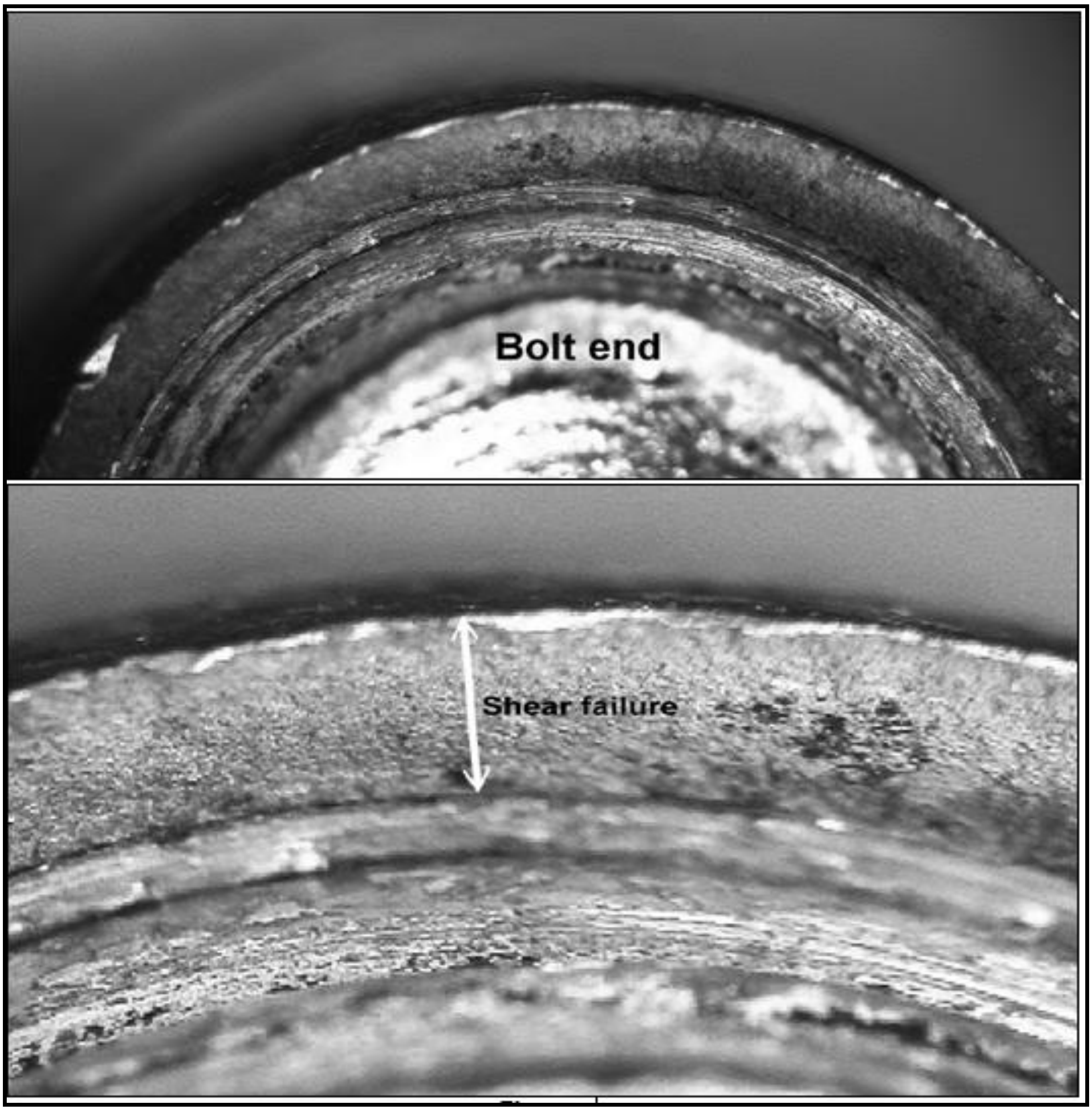
Annexure Figure 17: Shows the stereomicroscopic image of the failure portion

Stereomicroscopic images of a portion of the failure surface of the rod end in the previous figure. The arrow in the bottom image identifies the original position of the screw thread root. When a fatigue crack develops it usually develops from this location from inside the screw thread. The failure surface at the screw thread did not exhibit any evidence of even a shallow fatigue crack.



Annexure Figure 18: Shows the matching analysis of the failure surface

Matching failure surface of the rod end for the failure surface in Figure 3a. The threaded end portion of the rod end failed at a substantial stiffness transition, with the maximum bending stress in the rod end at the end of the bolt that was partially screwed into the rod end. The internal screw thread of the rod end offered a severe stress concentration, producing a shear failure along the entire circumference of the rod end. The unaffected electroplated end of the bolt indicates that the brownish substance observed on the bolt end immediately after the accident was dirt and not a corrosion product from the bolt



Annexure Figure 19: Stereomicroscopic image of the shear failure on the rod surface

Stereomicroscopic images of a portion of the failure surface of the rod end in the previous figure.

FAILURE MODE

Both failure surfaces were examined visually and with a stereo microscope at higher magnifications.

None of the failure surfaces examined contained any evidence of fatigue cracking.

An approximately 45° shear failure occurred along the entire circumference of the threaded hollow end portion of the rod end.

PROBABLE CAUSE OF THE FAILURE OF THE FRONT END

The rod end with its internal female thread clearly failed by abnormal bending, which introduced an overload induced shear failure.

The failure of this rod end did not cause the accident.

It failed during, and because of, the accident.