AIRCRAFT SERIOUS INCIDENT SHORT REPORT

CA18/3/2/1294: The propeller separated from the crank shaft flange in-flight and the pilot executed a forced landing on a farm.

Date and time	: 20 November 2019, 0510Z
Aircraft registration	: ZU-CUN
Aircraft manufacturer and model	: Zenith Air, Zodiac CH-601 XL
Last point of departure	: Kimberley Aerodrome (FAKM), Northern Cape Province
Next point of intended landing	: Vryburg Aerodrome (FAVB), North West Province
Location of incident site with reference to easily defined geographical points (GPS readings if possible)	: Farm Vergelegen near Spitskop Dam, North West GPS position: 28°12'16.72" South 024°30'04.83" East
Meteorological information	: Surface wind: 235°/10kt; temperature: 25°C; CAVOK
Type of operation	: Private (Part 94)
Persons on-board	: 1 + 0
Injuries	: None
Damage to aircraft	: Minor

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

*In terms of Regulation 12.03.1 of the Civil Aviation Regulations (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.***

Disclaimer:

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SRP Date: 11 August 2020 **Publication Date:** 12 August 2020

1. SYNOPSIS

1.1 On Wednesday, 20 November 2019 at 0510Z, the pilot who was the sole occupant on-board the aircraft executed a forced landing on a farm after an in-flight separation of the propeller from the crankshaft flange. The aircraft, with registration marks ZU-CUN, had departed Kimberley Aerodrome (FAKM) approximately 40 minutes earlier and it was en route to Vryburg Aerodrome (FAVB). Visual meteorological conditions (VMC) had prevailed at the time and the pilot had filed a flight plan prior to take-off. He was flying at flight level (FL) 075 or 7 500 feet above mean sea level (AMSL) when the serious incident happened. The pilot declared an emergency by broadcasting a Mayday on the Johannesburg radar west frequency, stating that he was going to execute a forced landing on an open field near Spitskop Dam. The pilot was not injured during the incident, but the aircraft sustained minor damage. The flight was a private flight conducted under the provisions of Part 94 of the Civil Aviation Regulations (CAR) 2011 as amended.

1.2 The investigation revealed that it was probable that the separation of the propeller in-flight was a result of wear and tear of the propeller attachment bolts and the drive bushes due to failure to comply with the propeller maintenance manual inspection requirements.

2. FACTUAL INFORMATION

2.1 History of flight

2.1.1 On Wednesday, 20 November 2019, the pilot who was the sole occupant on-board the aircraft took off from Kimberley Aerodrome (FAKM) to Vryburg Aerodrome (FAVB) on a private flight. After take-off, the pilot was instructed by air traffic control (ATC) to remain below the terminal control area (TMA) at 5000 feet (ft). Once he was outbound from the TMA, he was cleared to climb to flight level (FL) 075 or 7 500 feet (ft) above mean sea level (AMSL) as per his flight plan.

2.1.2 The pilot stated that approximately 40 minutes after take-off from FAKM, flying towards north-west of FAKM and whilst on cruise phase of the flight, he could see Spitskop Dam straight ahead. Soon after, he experienced a sudden shudder throughout the aircraft whereafter he lost control of the aircraft for approximately 10 seconds. After he had managed to recover the aircraft, he noted that the propeller had separated from the crankshaft flange and the engine was over speeding. He then switched off the engine and set the aircraft up for the best glide speed, which was 75 miles per hour (mph) and trimmed the aircraft as he was committed to the forced landing straight ahead.

2.1.3 He then declared an emergency by broadcasting a Mayday three times on the Johannesburg radar west frequency, stating that he was going to execute a forced landing in an open field near Spitskop Dam. After the aircraft was brought to a stop, he again broadcast on the same frequency that he was safe on the ground. His message was relayed to the Johannesburg radar by the crew of another aircraft — ZS-SST, a Cessna T206H — which was flying in the Kimberley area at the time. The pilot was not injured during the forced landing, but the aircraft sustained minor damage when the left wing impacted a perimeter fence post (see Figure 2).

2.1.4 Being a remote area, there were no persons on the farmstead at the time of the serious incident. The pilot decided to walk towards the main road (R370), which was approximately 1.5 kilometres (km) from his location at the time. Once at the roadside, he was able to identify his location and he then called for assistance via his cellular phone.

2.1.5 The accident occurred during daylight at Global Positioning System (GPS) determined to be 28°12’16.72” South 024°30’04.83” East, at an elevation of 3 526ft AMSL.

Figure 1: The aircraft at the incident site. (Photograph was taken on-site by the pilot)

2.1.6 According to available maintenance records, a new P-Prop 66" x 48" (right-hand rotation) which is a two-bladed wooden, fixed-pitch propeller with serial number N2767 was fitted to the aircraft on 13 December 2007 at 178.9 airframe hours. The propeller had been in operation for 203.7 hours since it was fitted 12 years prior to the serious incident flight. The last annual inspection carried out on the aircraft prior to the serious incident flight was certified on 6 June 2019 at 360.9 airframe hours. Attached to this report as Annexure B is the maintenance inspection form with reference to the propeller for this aircraft as documented in the aircraft manufacturer maintenance manual. From the time the propeller was installed on the aircraft until the serious incident flight, which was nearly a period of 12 years, only 202.8 hours were flown with the aircraft.

2.1.7 The propeller maintenance manual requires the removal and inspection of the propeller at 1 000 hours of operation or 5 years in service, whichever occurs first. No evidence in the maintenance records of the removal of the propeller for inspection as called for by the manufacturer was found by investigators during the review of the aircraft maintenance documents or records after its installation on 13 December 2007 (see Annexure B).

2.1.8 The table below provides an indication of the aircraft maintenance history as documented in the airframe logbook, which was opened on 25 November 2004; and the flight folio, which was opened on 29 September 2006.

Type of maintenance	Date	Total time	Person approving AI
Annual Inspection (AI)	15 February 2005	61.9	Approved Person
Annual Inspection	30 July 2006	95.2	Approved Person
Change of Ownership Annual Inspection	17 December 2006	126.8	Approved Person
Annual Inspection and Propeller Change	13 December 2007	178.9	Approved Person
No evidence of any maintenance inspection for the year 2008			
Annual Inspection	7 January 2009	214.1	Approved Person
Annual Inspection	6 January 2010	252.8	Approved Person
Annual Inspection	4 January 2011	297.0	Approved Person
Annual Inspection	8 January 2012	323.2	Approved Person
Annual Inspection	14 January 2013	340.9	Approved Person
(Re-done) Annual Inspection	11 March 2013	340.9	Approved Person
No evidence of any maintenance inspection for the year 2014			
No evidence of any maintenance inspection for the year 2015			
Annual Inspection	15 February 2016	349.2	Approved Person
Annual Inspection	11 May 2017	349.2	Approved Person
Annual Inspection	3 November 2017	360.9	Approved Person
No evidence of any maintenance inspection for the year 2018			
Annual Inspection	6 June 2019	360.9	Approved Person
Intentionally left blank			
Serious Incident	**20 November 2019**	**382.6**	**21.7 hours were flown**

Note: Airframe logbook maintenance history table.

2.1.9 The six drive bushes as well as the flywheel/ring gear depicted in Figure 3 were taken to a laboratory for microscopy and microanalysis examination, which concluded the following:

(i) *"Considering the noted elongation damages at all 6 flywheel holes, it can be derived that **under-torque** of the attachment bolts allowed for movement of the drive bushes in the rotational plane while under an applied load (engine).*

(ii) *The extent of the elongation damages at the locating drive bush location again suggest **under-torque** as the primary contributing factor while the damages at the remaining 5 positions suggest a combination of **under-torque and bush/flywheel hole dimensional variations***. The reason for the latter discrepancy could not be ascertained by this investigation.

(iii) *Contributing to the above is the use of a singular locating drive bush thus allowing for radial movement of the remaining 5 bushes within the rotational plane under load.*

(iv) *The resultant detrimental influence on propeller vibration due to the loosened attachment bolt and drive bush movement undoubtedly enhanced the fatigue fracture initiation and progression rate."*

The laboratory report is attached to this report as Annexure C.

Figure 2: Damage to the left wing caused by impact with a fence post. (Photograph was taken on-site by the pilot)

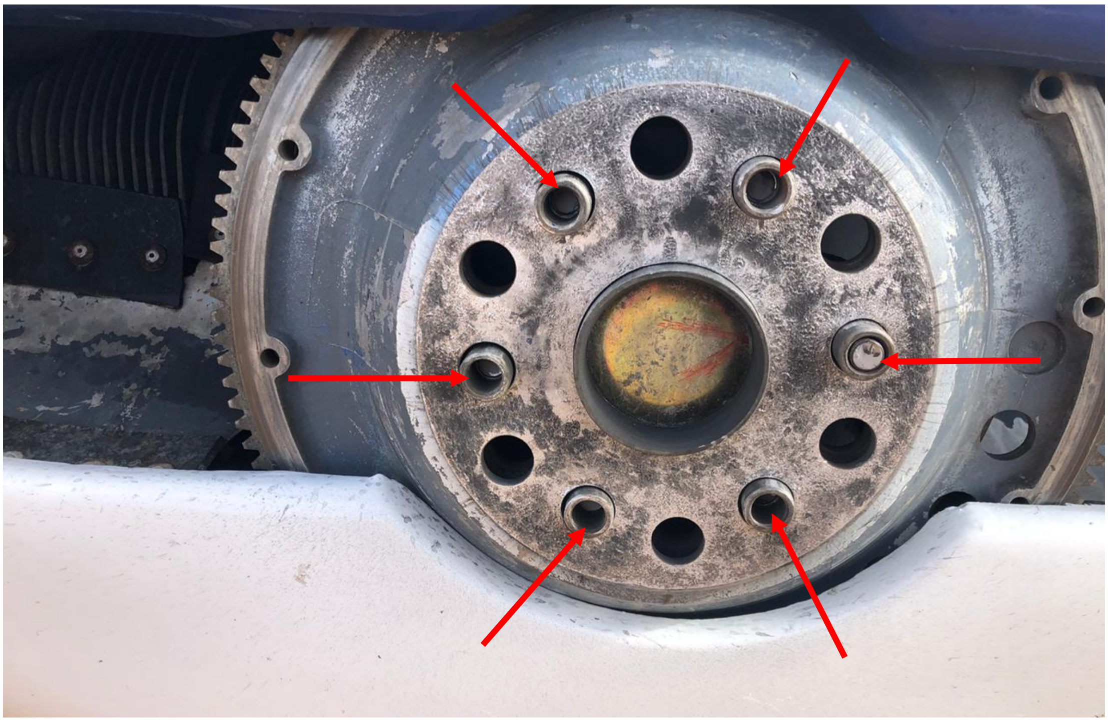

Figure 3: The six drive bushes protruding through the flywheel/ring gear. (Photograph was taken on-site by the pilot)

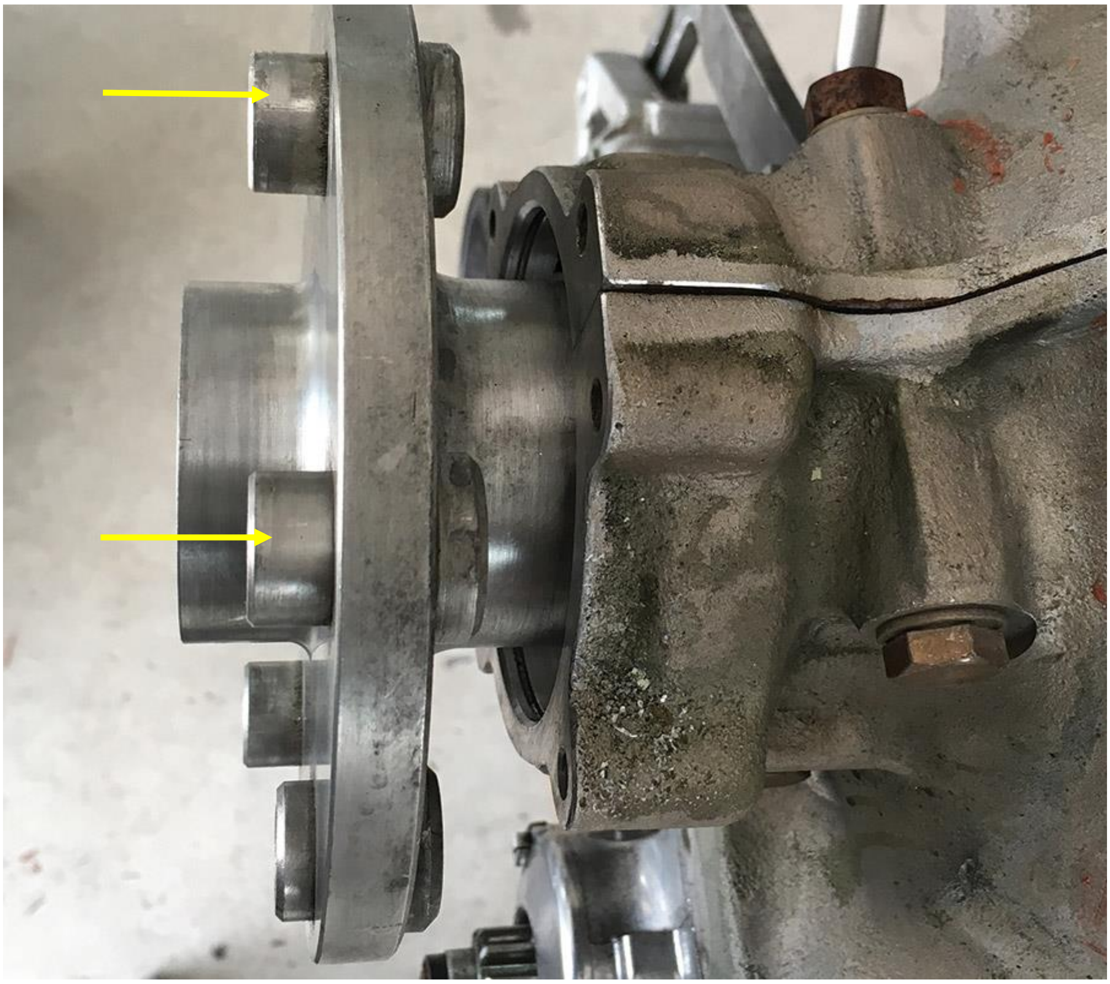

Figure 4: A view of the crankshaft flange with some of the drive bushes indicated by yellow arrows.

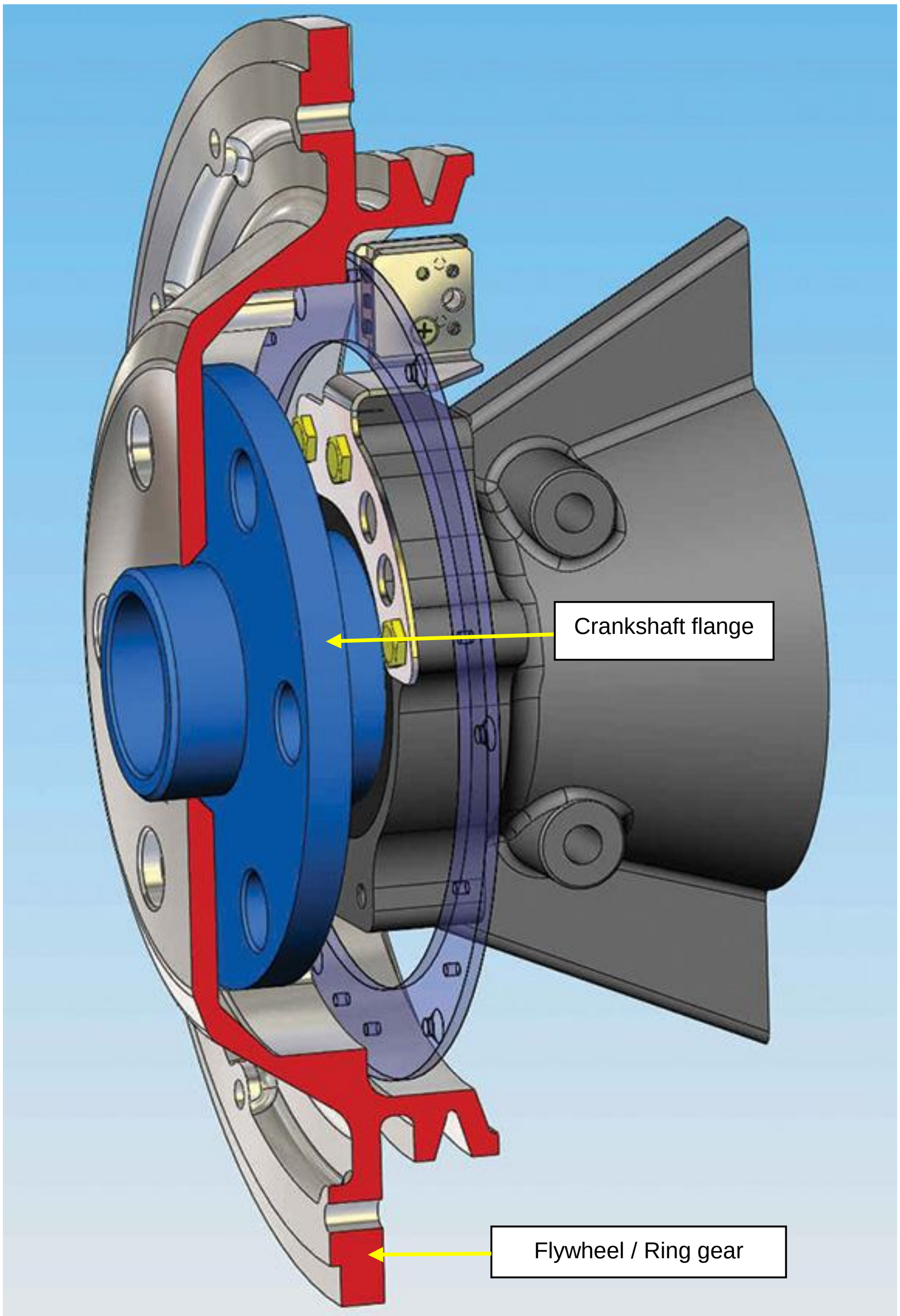

Figure 5: A cutaway drawing of the crankshaft flange and the flywheel/ring gear.
(Source: www.kitplanes.com)

2.1.10 The propeller was not found after it had separated from the crankshaft flange and, therefore, it was not possible to determine its condition after the serious incident.

3. FINDINGS

3.1 The pilot was issued a Private Pilot Licence on 16 October 2019 with an expiry date of 31 October 2020.

3.2 The pilot was issued an aviation medical certificate (Class 2) on 14 August 2018 with an expiry date of 31 August 2023.

3.3 This flight was a private flight conducted under Part 94 of the Civil Aviation Regulations (CAR) 2011 as amended.

3.4 The aircraft was issued an Authority to Fly on 25 October 2019 with an expiry date of 31 October 2020.

3.5 The last annual inspection carried out on the aircraft prior to the serious incident flight was certified on 6 June 2019 at 360.9 airframe hours. A further 21.7 hours were flown with the aircraft since its last inspection.

3.6 A new propeller (P-Prop 66” x 48”), with serial number N2767 was installed on the aircraft on 8 December 2007 at 179.8 airframe hours by an Approved Person (AP). Since the installation of the new propeller, the aircraft had flown a total of 203.7 hours over a 12-year period without any removal and inspection as required by the propeller maintenance manual.

3.7 The propeller maintenance manual requires removal and inspection of a propeller at 1000 flight hours or every five years, whichever comes first; and this requirement was never complied with. It was probable that the separation of the propeller in-flight was a result of wear and tear of the propeller attachment bolts and the drive bushes due to failure to comply with the propeller maintenance manual inspection requirements.

3.8 The propeller was not found after it had separated in-flight and, therefore, it was not possible to determine its condition.

3.9 The aircraft was registered in the South African Register as a non-type certified aircraft (NTCA).

3.10 According to available evidence obtained from the airframe logbook, which was opened on 25 November 2004, there were several annual inspections that were not performed over the years until the serious incident flight. This had a direct effect on the continuous airworthiness status of the aircraft.

3.11 The aircraft was not maintained in accordance with Part 44.01.6 (Annual Inspections), as well as Part 44.02.01 (Acceptance of maintenance schedule) of the Civil Aviation Regulations (CAR) 2011 as amended.

3.12 The pilot was not injured during the forced landing on an open piece of farmland, but the aircraft sustained damage.

3.13 The prevailing wind at the time of the flight was from south-west at 10 knots, and the temperature was 25°C, according to the pilot.

3.14 The METAR for FAKM at 0500Z was as follows: 200500Z 11007KT CAVOK 21/02 Q1014=. Fine weather conditions prevailed during the flight on the day of the serious incident.

4. PROBABLE CAUSE

4.1 It was probable that the separation of the propeller in-flight was a result of wear and tear of the propeller attachment bolts and the drive bushes due to failure to comply with the propeller maintenance manual inspection requirements.

4.2. CONTRIBUTING FACTOR

4.2.1 Lack of proper maintenance practises as stipulated on the aircraft maintenance manual as well as Part 44.01.6 and Part 44.02.01 of the Civil Aviation Regulations of 2011 as amended. Lack of proper maintenance in line with the maintenance manual.

5. REFERENCES USED IN THE REPORT

5.1 Pilot questionnaire (form CA 12-03)
5.2 Owner questionnaire (form CA 12-04)
5.3 Aircraft maintenance documents (airframe logbook)
5.4 Failure Analysis report from the Laboratory for Microscopy and Microanalysis, University of Pretoria.
5.5 Zodiac 601XL, Maintenance Manual, Propeller Inspection
5.6 Propeller (P-Prop), Care, Handling and Maintenance Manual
5.7 Australian Government, Civil Aviation Safety Authority (Airworthiness Bulletin, Wooden Propeller Maintenance, AWB 61-007, dated 11 March 2008)

6. SAFETY RECOMMENDATION

6.1 Safety Message: Owners and operators to ensure at all times that aircraft maintenance manual instructions are complied with. Had the owner complied with propeller maintenance manual instruction requirements, this serious incident could have been avoided.

6.2 Safety Message: The SACAA to ensure that aircraft comply with manufacturers' maintenance instructions during safety oversight. This aircraft was not in compliance for more than 7 (seven) years prior to the serious incident flight and yet the SACAA renewed its Authority to Fly annually.

7. ORGANISATION

7.1 This was a private flight and the pilot was also the owner of the aircraft.

8. Appendices

8.1 Annexure A (Abstract from CASA Airworthiness Bulletin No. 61-007, dated 11 March 2008, Wooden Propeller Maintenance)
8.2 Annexure B (Propeller Inspection, Zodiac 601XL, Maintenance Manual, pg. 12, 50)
8.3 Annexure C (Laboratory report from the University of Pretoria)

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

ANNEXURE A

1, Abstract from CASA Airworthiness Bulletin No. 61-007, dated 11 March 2008, Wooden Propeller Maintenance.

"Wooden propellers have a natural tendency to 'work loose' over time.

a. *Despite protection of the propeller by multiple coats of lacquer, the wood due to its nature is very susceptible to changes in humidity, which can adversely affect the compression load applied by the attaching bolt tension.*

b. *When an aircraft is operated in an area of high humidity or during the wet months of the year, the timber in the propeller swells, and as the expansion area of the hub between the two flanges is limited by the hub bolts, some of the wood fibres are crushed. As the propeller dries out during dry weather and shrinks, the timber no longer fills the space between the two flanges. Accordingly, the hub bolt nuts become loose; the propeller is then allowed to slip and causes charring and possible sheering of the wood adjacent to the bolt holes, this sheering could eventually lead to cracking and possible propeller failure.*

One method of overcoming this problem is to check the tension of the attachment bolts whenever there is a significant increase in ambient humidity in either direction, or when there is a change in seasons or a change in aircraft locality. In addition, the bolt tension should be checked after the first flight following fitment of the propeller and at each periodic inspection, or prior to flight after the aircraft has been idle for an extended period of time (for instance two changes of season).

Most wooden propellers have no fixed overhaul period so consequently may remain in service as an 'on condition' item, as long as the responsible AME is satisfied that *it meets all of the appropriate standard. They are normally only removed when the engine is removed for maintenance. Wooden propellers should be carefully inspected when they are removed, for damage, security of leading-edge strips, screws and rivets. Careful attention should be paid to the area around the bolt holes for cracking and crushing."*

2. Abstract from P-Prop Handling, Care and Maintenance of Propellers Manual. Pg. 7

"VERY IMPORTANT PLEASE, CHECK YOUR PROPELLER REGULARLY FIXED PITCH WOOD PROPELLERS.

1. Due to the nature of wood itself, it is necessary that wood propellers and blades be frequently inspected to assure continued airworthiness. Inspect for such defects as cracks, bruises, scars, warpage, evidence of glue failure and separated laminations, sections broken off and defects in the finish.

2. Irrespective of the make, propellers of wooden construction shall be removed and carefully inspected every 1 000 hours of operation or 5 years in service, whichever is the shorter, AND when engines are overhauled, also if the plane has been standing for a while, for conditions such as the following:

2.1 Elongated bolt holes

2.2 Out of track condition

2.3 Cracks in the shaft hole, bolt holes or blades

2.4 Oversize shaft hole

2.5 Broken lag screws which attach the metal leading edge sleeve to the blade

2.6 Separated laminations

2.7 Cracked internal laminations

2.8 Split blades

2.9 Cracks or deep cuts across the grain of the wood even on the paint

2.10 Loose lag screws or rivets

2.11 Appreciable warp of blades

2.12 Appreciable portions of wood missing

2.13 Inspect for damaged hub flanges caused by over tightening (the recommended torque values usually range from 15 to 24 foot-pounds)

3. The propeller shall be re-varnished, and the balance checked and corrected.

4. Any repairs required shall be carried out according to the provision made of AC43-13-1A, or as the manufacturers prescribe.

5. Refer doubtful cases to the manufacturer."

ANNEXURE B

TABLE 1 – ZODIAC INSPECTION FORM

Make / Model	Serial No.	Airframe Hours	Type of Inspection (Circle One)
	Registration No:	Engine Hours:	50 100 500 1000

Symbols: + Indicates perform task, - Indicates do not perform task

Task	Refer to	Intervals (Flight Hours) 50	100	500	1000	Initials
Propeller Group	First bolt torque is at 5 hours.					
1. Check propeller bolts for torque and safeties.	Sensenich Continued Airworthiness	+	+	+	+	
2. Inspect blades and hub for cracks, corrosion, damage, etc.	Requirements. Also see Appendix 1 of this manual.	+	+	+	+	
3. Inspect spinner and backing plate.		+	+	+	+	
Engine Group **Danger**	See Engine Operators Manual.					
Ground magneto primary circuit before working on engine.						
1. Check for oil/fuel leaks.		+	+	+	+	
2. Check for particles on oil suction screen and sump drain plug.		-	+	+	+	
3. Drain oil and refill. Safety plug.		+	+	+	+	
4. Perform cylinder compression test.		-	+	+	+	
5. Clean the spark plugs. Adjust gap	Section 6.5	-	+	+	+	
6. Check and set magneto timing. See 29.		-	+	+	+	
7. Check magneto breaker points and lubricate breaker point felt.		-	-	-	+	
8. Clean oil suction and oil pressure screens		-	+	+	+	
9. Inspect the wet type foam air filer.		-	+	+	+	
10. Inspect the exhaust manifold for cracks (carb and cabin heat shroud removed).		-	+	+	+	
11. Inspect the heat shrouds for cracks, etc.		-	+	+	+	
12. Inspect the motor mount fuselage and engine attachment points and braces.		+	+	+	+	
13. Inspect the rubber engine vibration isolating mounts for cracks damage, etc.		+	+	+	+	

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3.3
Inspection page 1 of 8

SECTION XII

PROPELLER SYSTEM

5. WOOD PROPELLER INSPECTION.

Follow the manufactures instructions for maintenance an operations. For the Sensenich wood propellers, Doc# WOOD_CF_REV_A 5-20-04 may be helpful.

If instructions are not available from the propeller manufacturer, the following may be used:

Inspection of a wood propeller. Inspect to ensure the following:
(1) The drain holes are open on metal edged blade tips
(2) The metal/composite leading edge is secured and serviceable
(3) The blades, hub, and leading edge have no scars or bruises
(4) The mounting bolt torque and safety wire or cotter pins are secure
(5) There are no cracks on the propeller spinner (if applicable), and the safety wire is secure
(6) There are no small cracks in the protective coating on the propeller, which are caused by UV radiation
(7) The charring around the mating surface of the prop and the engine flange -- both indications of a loose propeller

Torque: A new, wooden propeller should have the mounting bolts checked for proper torque within the first hour of flight.
(1) After 10 hours, check the bolt torque every 50 hours thereafter. The mounting bolt torque also should be checked prior to flight if the aircraft has been in storage for a long period of time (3 to 6 months).
(2) If the bolts need to be torqued, it is suggested all the bolts be loosened for an hour to allow the wood to relax. ''Finger tighten'' the bolts until snug and tighten the attaching bolts in small increments, moving diagonally across the bolt circle. It is good practice to check the propeller track) as the bolts are torqued down. The torqued bolts should be safety wired in pairs.
(3) If nylon/fiber insert type nuts are used, they should be changed every time the propeller bolts are re-torqued. They should never be used with a bolt with a cotter key hole in the threaded area because the sharp edges around the hole will cut the nylon/fiber insert and reduce the fasteners effectiveness. All self-locking nuts should have at least two bolt threads visible pass the nylon/fiber insert after torquing.
(4) If any of the following damage is found, a wood propeller should be removed from the aircraft and sent back to the manufacturer / repair station for repair. If the propeller cannot be saved, it should be marked unserviceable.
(i) Any cracks in the blades or hub
(ii) Deep cuts across the wood grain
(iii) Blade track that exceeds 1/16" limits after attempts to repair
(iv) Any warpage or obvious defect
(v) Extreme wear (leading edge erosion, bolt hole elongation)
(vi) Any separation

NOTE: When parking the aircraft, always leave the wood propeller in the horizontal position. This position will allow the wood to absorb small amounts of moisture evenly across it's entire span rather than concentrating the moisture (weight) in the low blade and creating a vibration problem.

ANNEXURE C

COMPILED BY:	UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA **LABORATORY FOR MICROSCOPY & MICROANALYSIS**	**PAGE 1 OF 9**
	FAILURE ANALYSIS REPORT: PROPELLER ASSEMBLY, ZODIAC CH601, AIRCRAFT No ZU-CUN	**DOCUMENT NUMBER** FA-003-04-20
COMPILED FOR: SACAA (AIID)		**DATE** 2020-04-01 / **ISSUE** 1

ITEM: **PROPELLER ASSEMBLY, ZODIAC CH601, AIRCRAFT No ZU-CUN**

1. BACKGROUND INFORMATION

1.1. Selected components from a failed propeller assembly (Photo's 2 and 3) originating from a Zodiac CH601 XL aircraft (Photo 1), registration no ZU-CUN, were submitted to determine the most probable contributary cause/s towards failure during operation.

Photo 1: Accident site, ZU-CUN[1]


Photo 2: Supplied components, as found (digital)

1.2. This report is divided into the following sections:

2. APPLICABLE DOCUMENTS

(a) SACAA Standard Letter No CA 12-L-002/130418

[1] Courtesy SACAA/AIID

3. DEFINITIONS

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

4. PERSONNEL

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

5. APPARATUS AND METHODOLOGY

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

6. INVESTIGATION RESULTS

6.1. Visual Inspection

Note 1: Only the supplied parts were considered.

The visual inspection revealed 6x fractured propeller attachment bolts with failures initiated within the threaded sections (Photo's 2, 3 and 4) in proximity of the flywheel/starter ring assembly (Diagram 1).

Notwithstanding corrosion damages inflicted post-failure, selected bolt fracture surfaces revealed indications towards a **fatigue failure mode** (Photo's 4 and 7).

Indications of extensive mechanical wear were noted on all 6 bushes at the drive bush/flywheel hole interfaces (Photo 4, yellow square).

Inspection of the No 1 locating drive bush revealed extensive elongation damages to the flywheel hole (Photo 5, blue arrow) with corresponding damages to the remaining 5 positions.

The noted plastic deformation on the propeller side of the No 1 locating bush flywheel hole (Photo 6, red arrow) suggest an applied operational load in the direction as indicated (Photo 5, red arrows).

The locating drive bush bolt fracture surface revealed indications of a **fatigue mode of failure** initiating at the thread root area and progressing as indicated (Photo 7, red dashed arrow).
A dimensional inspection revealed a **2.5%** clearance between the flywheel hole and the locating drive bush (Table 1). This clearance can be attributed to the extensive elongation damages noted at this position.

Clearances between **7.9%** and **8.3%** were noted at the remaining 5 drive bush positions. This can be attributed to both the noted elongation damages and drive bush outside diameter.

6.2. High Magnification Inspection

The threaded sections revealed no clear indications of over-torque induced damages (Fractograph 1).

The drive bush/flywheel hole contact surface revealed extensive mechanical smearing damages (Fractograph 2).

The SEM analysis of the bolt fracture surfaces revealed **fatigue** fracture initiations thus confirming the **failure mode** (Fractograph 3).

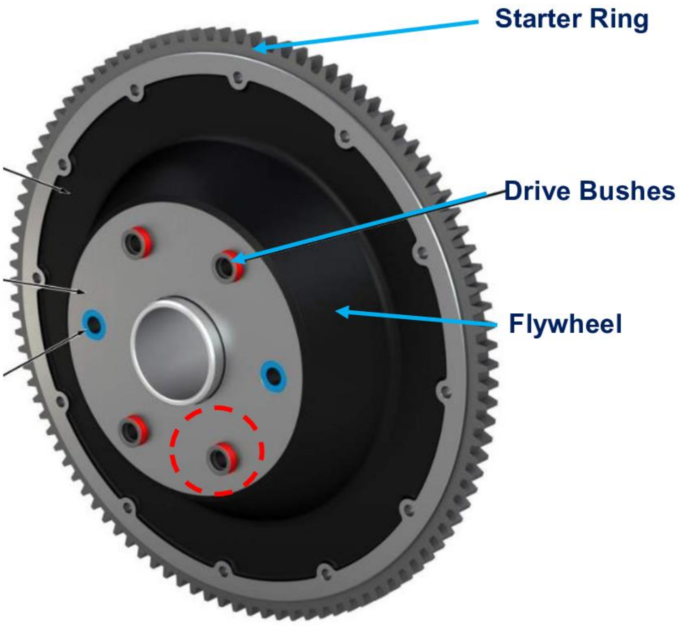


Diagram 1: Typical Flywheel assembly

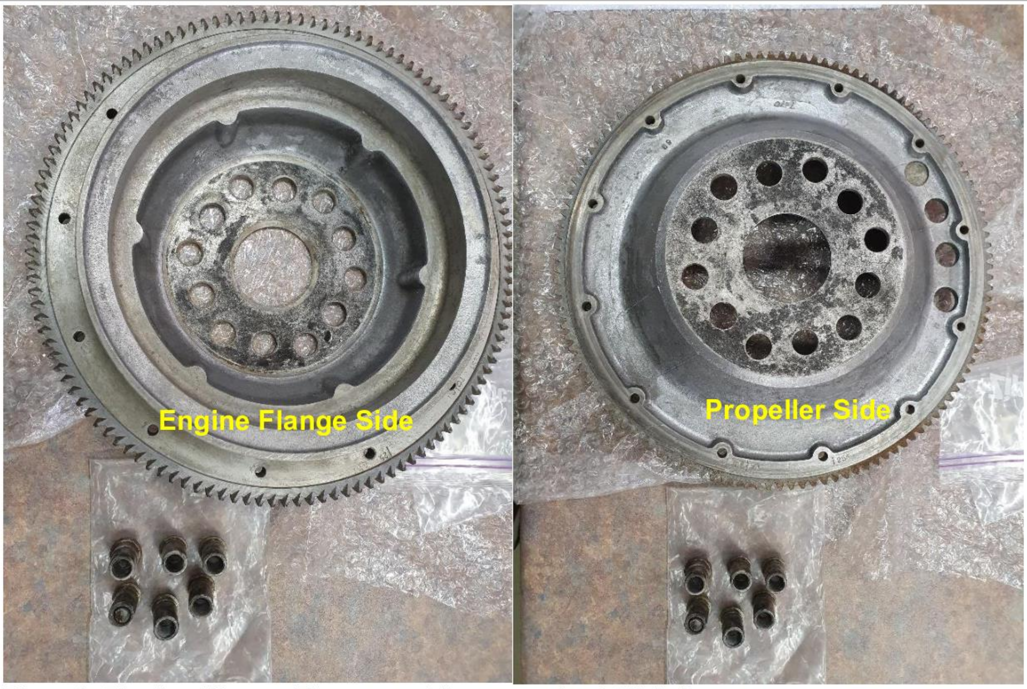


Photo 3: Flywheel/Starter Ring assembly, as received (digital)

Photo 4: DriveBushes, surface conditions and geometries (digital)

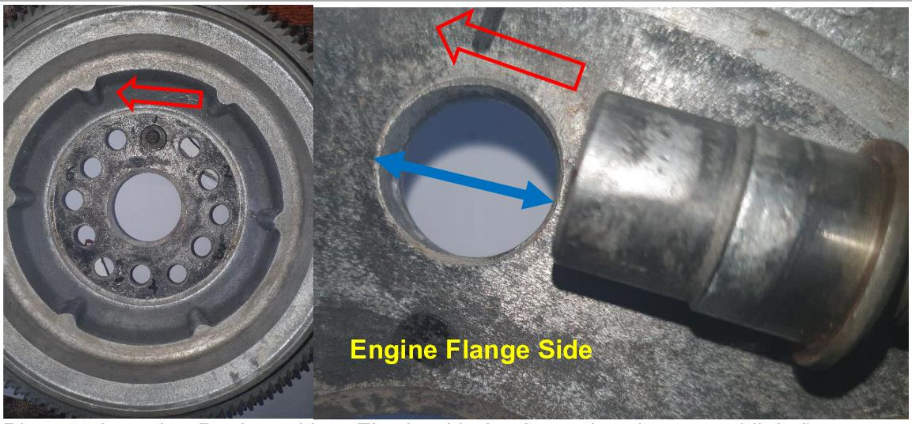


Photo 5: Locating Bush position; Flywheel hole elongation damages (digital)

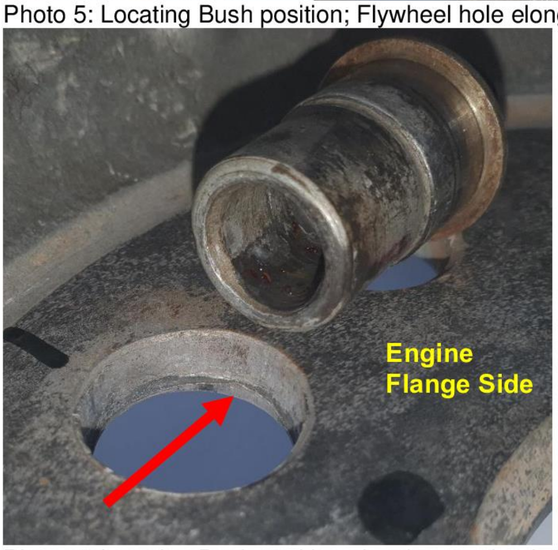
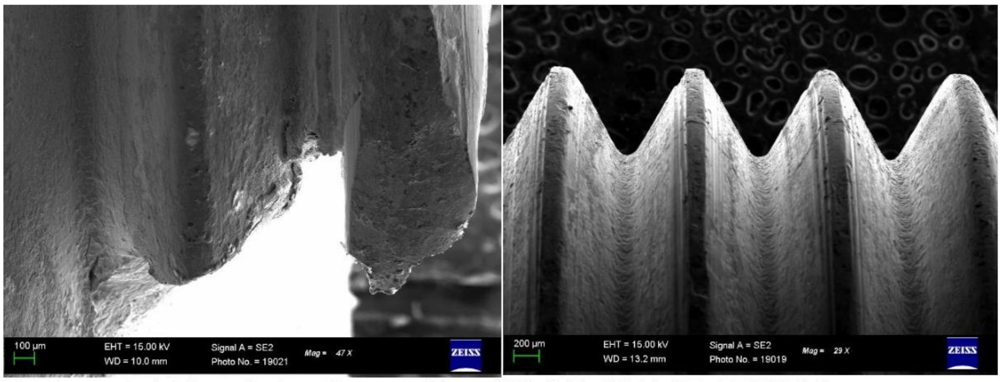


Photo 6: Locating Bush position showing mechanical smearing/lip (Stereo)

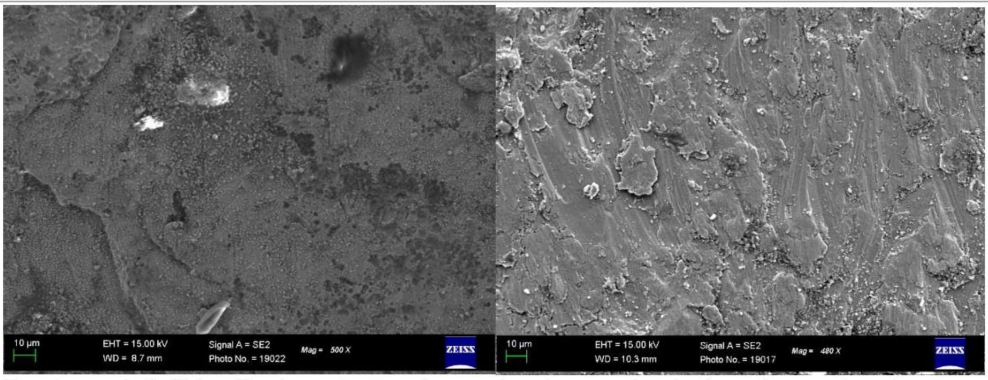
Photo 7: Locating Bush and Bolt Fracture surface (digital)

Number	# Bush Contact OD (mm)	Flywheel ID at Contact # (mm)	Clearance (mm)	% Clearance
1	17.06	17.5	0.44	**2.5%**
2	15.86	17.25	1.39	**8.1%**
3	15.87	17.27	1.4	**8.1%**
4	15.87	17.27	1.4	**8.1%**
5	15.86	17.22	1.36	**7.9%**
6	15.86	17.29	1.43	**8.3%**

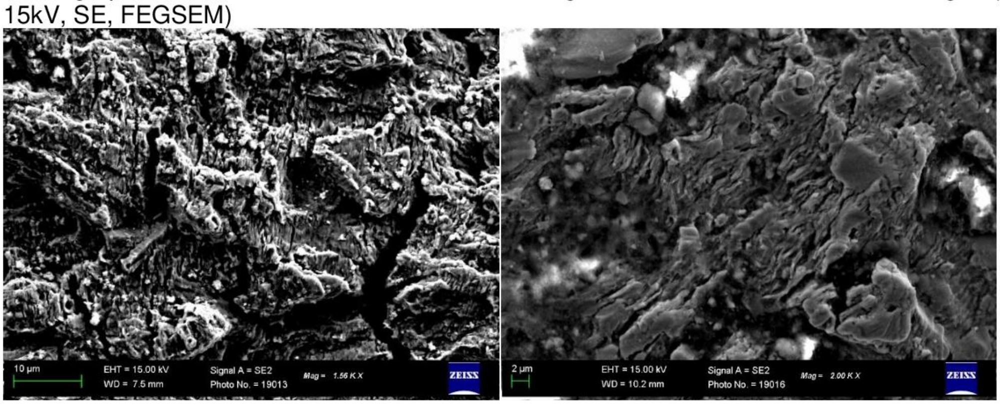
Table 1: Dimensions; Flywheel Inside Diameter (ID) versus Drive Bush Outside Diameter (OD); Clearances (*refer Diagram 1, red dashed circle*)



Fractograph 1: Threaded section conditions (29-47X, 15kV, SE, FEGSEM)



Fractograph 2: Drive Bush contact surfaces showing mechanical- and corrosion damages (480-500X, 15kV, SE, FEGSEM)



Fractograph 3: Bolt fracture surfaces showing fatigue striations (1560-2000X, 15kV, SE, FEGSEM)

7. DISCUSSION AND CONCLUSION/S

<u>Note 2</u>: *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.*

<u>Note 3</u>: *Refer to the supplied **Fault Tree** for ease of reference.*

7.1. **A: Maintenance/Fitment Influences (Fault Tree)**

A.1. *The actual applied torque during fitment could not be affirmed by this investigation.*

However, the condition of the various threaded sections does not suggest over-torque during fitment to be a possible contributing cause i.e. lack of secondary fracture initiation/s, plastic deformation of the thread/s, thread surface damage/s.

Considering the noted elongation damages at all 6 flywheel holes, it can be derived that **under-torque** of the attachment bolts allowed for movement of the drive bushes in the rotational plane while under an applied load (engine).

The extent of the elongation damages at the locating drive bush location again suggest **under-torque** as the primary contributing factor while the damages at the remaining 5 positions suggest a combination of **under-torque and bush/flywheel hole dimensional variations**. *The reason for the latter discrepancy could not be ascertained by this investigation (see Recommendations).*

Contributing to the above is the use of a singular locating drive bush thus allowing for radial movement of the remaining 5 bushes within the rotational plane under load.

The resultant detrimental influence on propeller vibration due to the loosened attachment bolt and drive bush movement undoubtedly enhanced the fatigue fracture initiation and progression rate.

A.2. Could not be affirmed by this investigation (see Recommendations).

A.3. Could not be affirmed by this investigation (see Recommendations).

7.2. **B: Operational/Environmental Influences (Fault Tree)**

B.1. Could not be affirmed by this investigation.

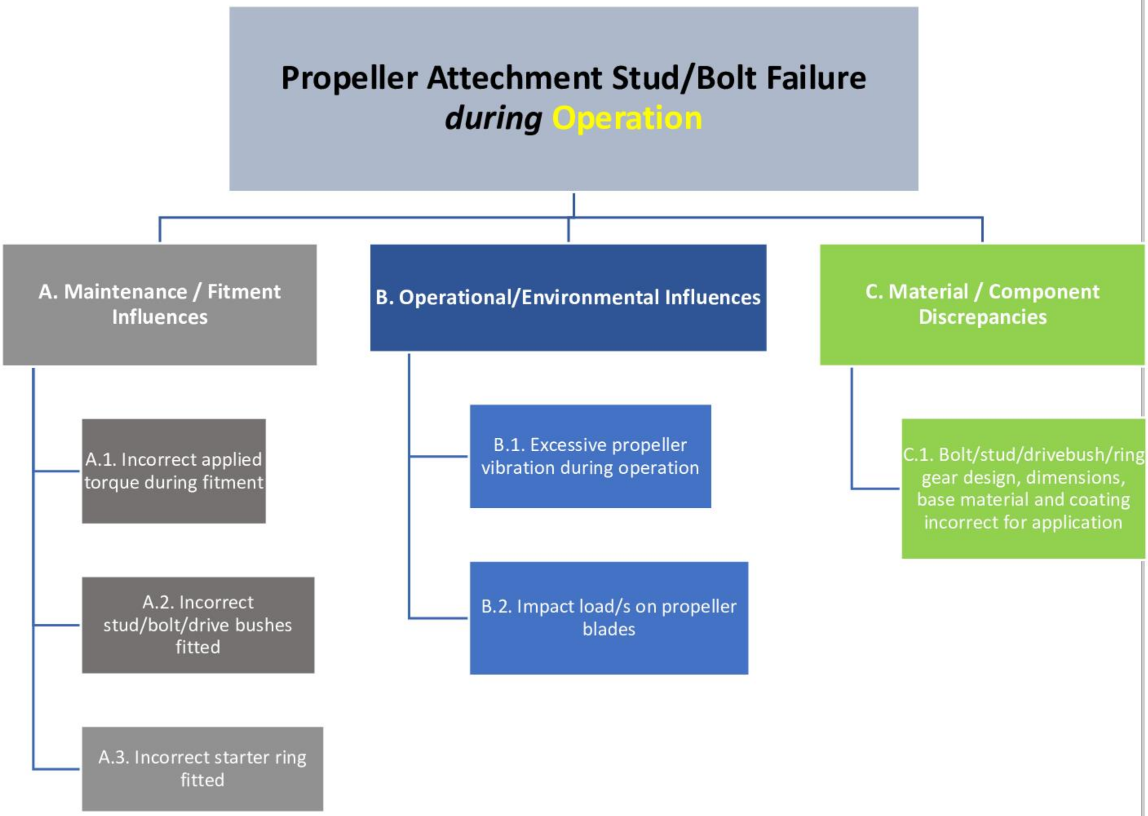
B.2. Could not be affirmed by this investigation.

7.3. **C: Material/Component Discrepancies (Fault Tree)**

C.1. No specifications were supplied towards comparison.

7.4. **Conclusion**: The 6x attachment bolts revealed a time-dependant fatigue failure mode with undeterminable sequence.

The most probable contributory causes are (a) incorrectly applied torque during fitment (under-torque) and/or (b) selecting incorrect non-locating drive bush sizes (non-locating types - 5x).



8. RECOMMENDATIONS

8.1. Considering the detrimental effects on Flight Safety of a propeller assembly failure during operation, it is strongly recommended that all OEM specifications relating to drive bush sizes, flywheel/starter ring dimensions and fitment are revisited prior to concluding.

9. DECLARATION

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