ITEM: **PROPELLER ASSY., BANTAM LIGHT SPORT AIRCRAFT, NUMBER ZU-CZU**

## 1. INTRODUCTION

1.1. The failed propeller assembly (Photo 1) originating from a Bantam Light Sport Aircraft, number ZU-CZU, was submitted to determine the possible reasons/s for failure (Photo 2) during operation.

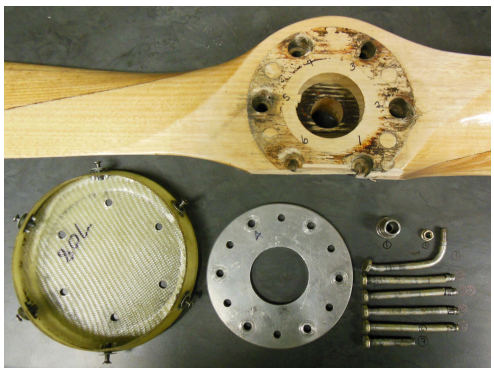

**Photo 1: Supplied parts (digital)**

**Photo 2: Propeller failure incident (courtesy Aviation Assessing Services)**

1.2. Sequence of relevant events preceding the incident:

(a) ZU-CZU was involved with a propeller strike incident. This resulted in a SACAA required shock load inspection to be completed on the engine before certified airworthy.
(b) ZU-CZU was then transported by road to Micro Aviation SA for engine removal.
(c) The engine shock load inspection was completed by Jabiru SA. Noted corrosion damages to the propeller flange was removed by Jabiru SA and repainted.
(d) Micro Aviation SA refitted the engine and propeller and following applicable testing, released the aircraft to the owner.
(e) After 10.6 flying hours the propeller severed from the propeller flange. ZU-CZU sustained minimal in-flight damages and was able to complete a safe landing procedure successfully.

1.3. This report is divided into the following sections:

(a) INTRODUCTION Par. 1
(b) APPLICABLE DOCUMENTS Par. 2
(c) DEFINITIONS Par. 3
(d) INVESTIGATOR Par. 4
(e) APPARATUS AND METHODOLOGY Par. 5
(f) BACKGROUND INFORMATION Par. 6
(g) INVESTIGATION Par. 7
(h) DISCUSSION AND CONCLUSIONS Par. 8
(i) RECOMMENDATIONS Par. 9
(j) DECLARATION Par. 10

## 2. APPLICABLE DOCUMENTS

(a) Propeller Report from Micro Aviation (attached)
(b) Jabiru Aircraft Propeller Instruction Manual dated 28/08/2001 (attached)
(c) Jabiru Aircraft Service Bulletin No JSB 014-2 dated 09/06/2011 (attached)
(d) Jabiru Aircraft Service Bulletin No JSB 009-1 dated 04/04/2005 (attached)
(e) Jabiru Aircraft Propeller Service Manual JPM3L01-1 dated 04/2008 (attached)
(f) Jabiru Constructors Manual (attached)

## 3. DEFINITIONS

| | | |
|---|---|---|
| (a) | OEM | Original Equipment Manufacturer |
| (b) | SACAA | South African Civil Aviation Authority |
| (c) | FOD | Foreign Object Damage |
| (d) | TSN | Total operational hours since new |
| (e) | TSO | Total operational hours since last overhaul |
| (f) | AAS | Aviation Assessing Services |
| (g) | SEM | Scanning Electron Microscope |
| (h) | AMO | Air Maintenance Organization |

## 4. PERSONNEL

(a) The investigative member and compiler of this report is Mr C.J.C. Snyman, ID number 6406105057080. Mr Snyman is a qualified Physical Metallurgist (H.N.Dip Metallurgical Engineering, Tech. PTA), Radiation Protection Officer (RPO) registered with the National Nuclear Regulator (NNR) and Aircraft Accident Investigator (SCSI).

## 5. APPARATUS AND METHODOLOGY

(a) The apparatus employed for this investigation are Stereo- and Scanning Electron Microscopes, Digital Camera and Micro-Hardness Tester.
(b) The methodology included a visual investigation of supplied parts, tear-down and a Stereo- and SEM investigation.

## 6. INVESTIGATION RESULTS

The visual investigation revealed five of the total of six bolts failed during operation (Photo 2) leaving the propeller attached to the propeller flange by a single remaining bolt.

The guide/bush related to the remaining bolt was still found attached to the propeller flange. A second guide/bush was recovered (Photo 3) for this investigation.

The wood-based propeller failed during operation (Photo 4). The position of the guide/bush when fitted is shown.

Inspection of the forward spinner flange revealed a slight bend corresponding with the position of the remaining bolt (Photo 5) after failure. Severe rotational mechanically induced marks were noted (Photo's 6 and 7, red arrows) corresponding with the load bearing surface width of the bolt heads (Diagram 1, green arrow). This is an indication that no washers were employed during fitment (refer to Jabiru Aircraft Propeller Instruction Manual). As the spinner flange may have been refitted an undeterminable number of times, these damages could not conclusively attributed to the most recent fitment.

The spinner fiberglass cup revealed no significant damages indicative towards the cause/s for the failure of the propeller bolts during operation (Photo 8).

The single guide recovered for this investigation revealed some indications of rotational and axial scuffing/fretting relating to possible movement inside the propeller flange area during operation (Photo 9, green arrow). The outside diameter of the insert end of the guide measured 13.92 mm and proved to be in accordance with the propeller flange fitted to the 2200 series Jabiru engines. The relevant propeller flange was not removed from the engine or made available for this investigation. Damages to the (~1-1.5mm thickness) protective paint layer on the propeller flange (Photo's 17 and 18) confirmed the fitted positions after removal by the relevant AMO.

The remaining bolt (Photo 10, no 1) revealed extensive bending damages inflicted after the in-flight failure of the other five bolts. This bolt also revealed extensive stretching damages. Although measurement results revealed that the no 1 bolt is an approximate 5mm longer than the other five (5) bolts retrieved, this elongation may be attributed to the low-carbon steel, hex cap bolt type (Grade 2, rolled thread) under tensile conditions. While the variation in dimension can be attributed to the exposed tensile and/or bending loads it is possible that a longer bolt was fitted to accommodate balancing weights (washers). This investigation was not involved with the initial teardown after the incident and no photographic evidence were submitted towards confirmation from either the SACAA or the AMO involved.

The remaining bolt's (No 1) as found orientation indicates that the threaded end was facing aft (towards the engine) with (referring to the corresponding positions of fracture) the remaining 5 bolts revealing similar orientations.

Damages noticed on the relevant bolt heads, radiuses and shank areas (Photo's 10 and 11) indicates that the set of bolts were refitted on more than one occasion.

The remaining five bolts revealed comparable fractures within the threaded areas (Photo's 10 and 12). Bolt no 5 (Photo 12, yellow arrow), and to some degree No 6, revealed extensive 'polishing' of

the shank/grip area adjacent to the thread roll-out that may be attributed to these bolts being loose resulting in in-service movement inside the bush inserts. At higher magnification the corresponding fracture surface from bolt no 5 revealed clear signs of fatigue induced beach-marks (Photo's 13 and 14) as well as striations (Photo 15). The remainder of the fracture surfaces revealed ductile geometries (Photo 16). It is clear from the results that bolt no 5 most probably failed first.

Inspection of the threaded areas revealed conforming thread control and no clear indications of over-torque damages (Photo's 19 and 20).

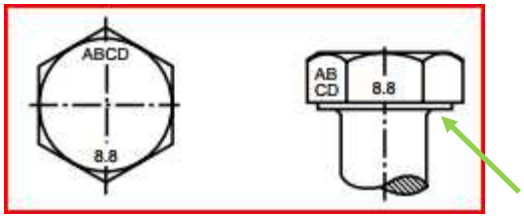


**Diagram 1: Typical bolt head markings and design**

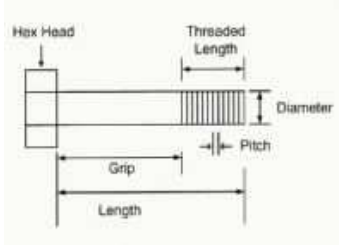


**Diagram 2: Typical bolt nomenclature**

**Photo 3: Propeller flange (digital)**

**Photo 4: Propeller with guide fitted (digital)**

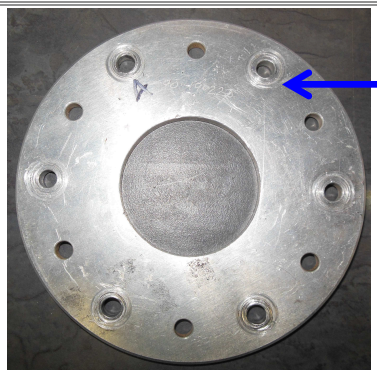

**Photo 5: Spinner flange (digital)**

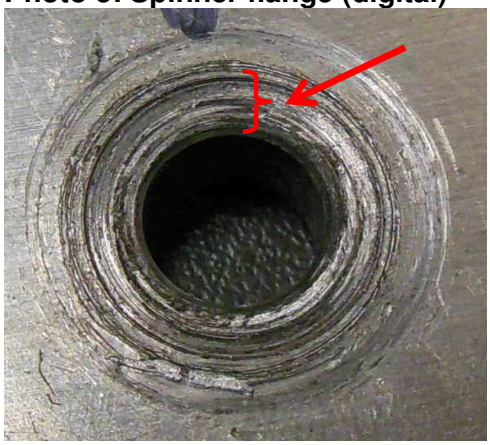

**Photo 6: Spinner flange showing rotational marks (digital)**

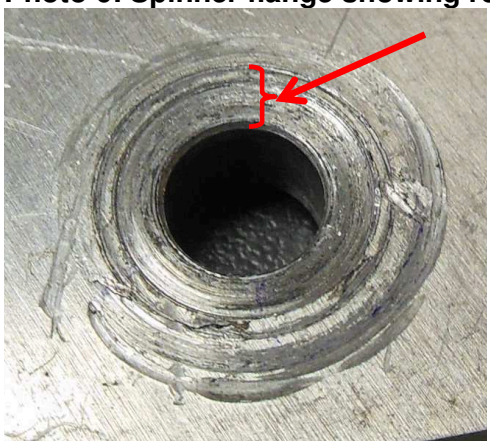

**Photo 7: Spinner flange showing rotational marks (digital)**

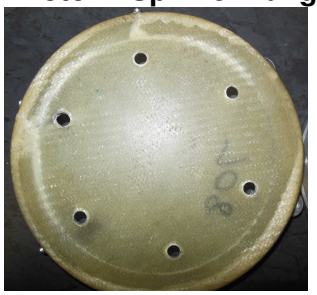

**Photo 8: Spinner fiberglass cup (digital)**

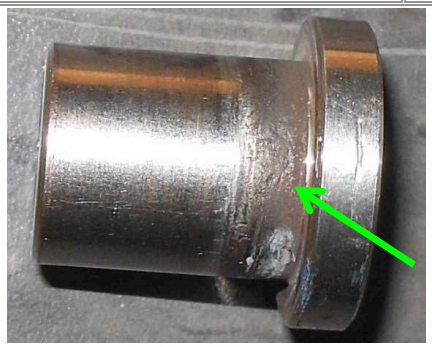

Photo 9: Guide showing mechanical damages (digital)

Photo 10: Supplied bolts, nut and guide (digital)

Photo 11: Bolt heads (digital)

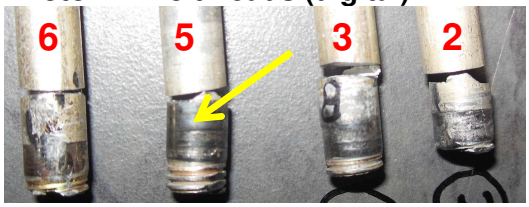


Photo 12: Fracture positions (digital)

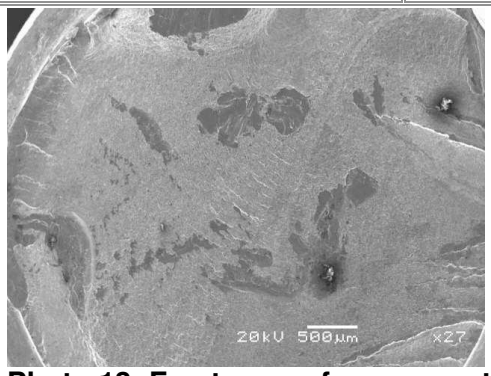


**Photo 13: Fracture surface geometry; bolt no 5 (x27, SEM)**

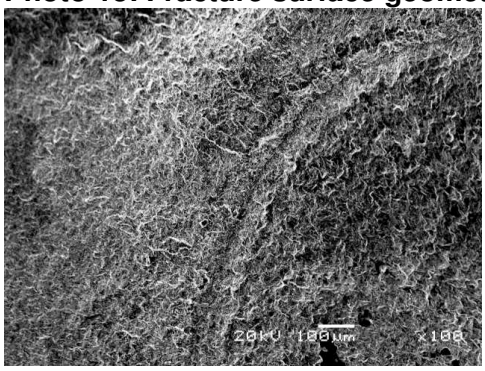


**Photo 14: Fracture surface geometry showing beach-marks; bolt no 5 (x100, SEM)**

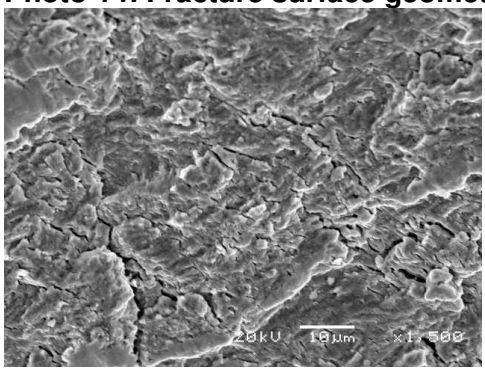


**Photo 15: Fracture surface geometry showing fatigue striations; bolt no 5 (x1500, SEM)**

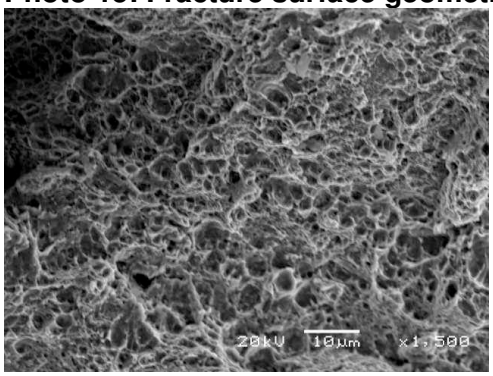


**Photo 16: Fracture surface geometry showing typical ductile features; remaining bolts (x1500, SEM)**

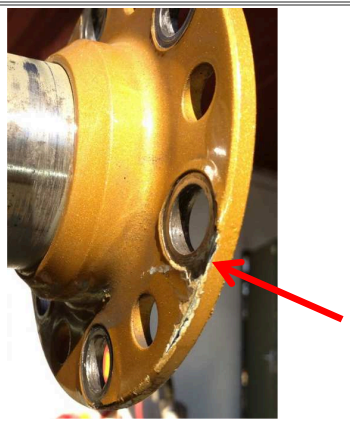

**Photo 17: Propeller flange showing paint layer (courtesy Micro Aviation)**

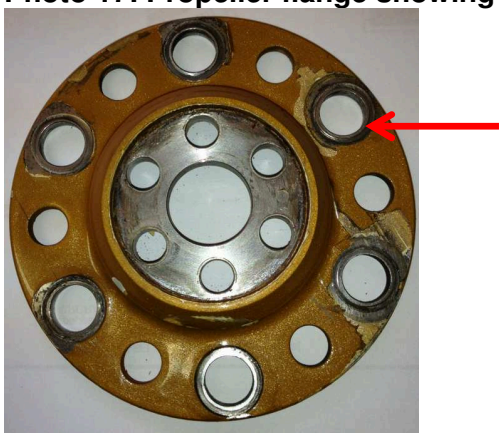

**Photo 18: Propeller flange showing paint layer (courtesy Micro Aviation)**

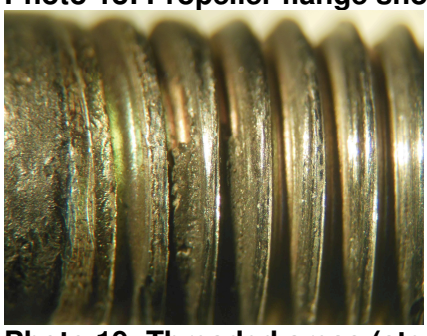

**Photo 19: Threaded areas (stereo)**

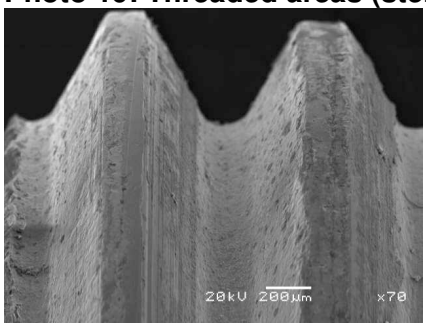


**Photo 20: Threaded areas (x70, SEM)**

8. DISCUSSION AND CONCLUSIONS

*Applicable Notes:*

1. *The relevant propeller assembly was not removed by, or under the supervision of the investigator from the incident aircraft.*
2. *All conclusions are based on the investigation results obtained from the supplied parts only.*

8.1. Most Probable Contributing Causes (in no particular order):

8.1.1. Incorrect Fitment. The photographic and on-site evidence clearly shows that the 6x propeller bolts were fitted with the threaded end facing aft. This in contravention to the prescribed methodology as stated in Jabiru Aircraft Service Bulletin No JSB 014-2, page 5, par. 4.2, dated 09/06/2011, where it refers to Jabiru Aircraft Service Bulletin No JSB 009-1, dated 04/04/2005, as the correct assembly method (Diagram 3, Excerpt 2 and 3). Although no clear reason/s for this orientation of the bolts are described in said documents, it can be derived that this method will not only allow for easier fitment of the (prescribed) Belleville washers (Figure 1), but also for better access to the nut end to ease the application of the torque wrench (Photo 22). No Belleville- or flat washers (Photo 21) were fitted to the assembly under investigation as per JSB 009-1.

It is considered good practice for the torque to be applied to the nut end rather than the bolt head end (as per SKF Bolt Tightening Handbook). The damages inflicted to the softer aluminium spinner flange by the bolt heads clearly indicate that the torque wrench was most probably applied to the forward facing bolt heads rather than the aft facing nuts. The final tightening load (torque) are dependent on the corresponding friction coefficients related to the bolt and nut threads as well as the contact surfaces between the nut/bolt head and the flange. In this case the 'binding' effect between the harder steel bolt head and the much softer aluminium based flange surface will render a torque wrench reading that may correspond with the prescribed value whilst a lower than desired axial tension stress on the bolt are in fact present, leaving it under-torque and subsequently prone to loosening, and failure, within the 10.6 operational hours.

8.1.2. Break-down of Painted Layer. The relative thick (1mm+) layer of protective paint applied to the propeller flange (aft side) revealed severe break-down damages at the guide bush insert positions. The break-down of this layer of paint during service will cause the bolts to be relieved of the prescribed torque and may have resulted in the failure thereof within the 10.6 operational hours. No vibration checks could be made for this investigation to exclude possible propeller vibration forces induced on the assembly and the (softer) paint layer.

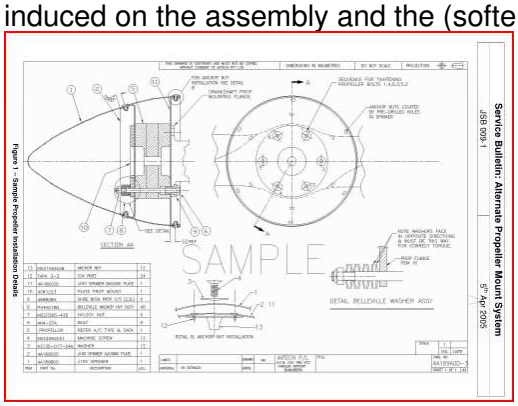


**Diagram 3: Propeller Installation (courtesy Jabiru JSB 009-1)**

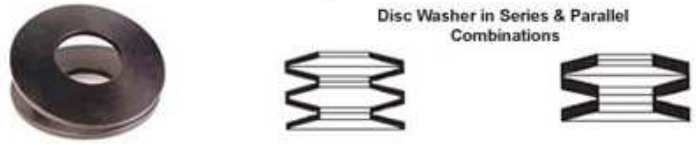


**Figure 1: Belleville washers**

**Photo 21: Fitment of washers (courtesy Jabiru Constructors Manual)**

**Photo 22: Fitment of Belleville washers and torque wrench application (courtesy Jabiru Constructors Manual)**

| Engine Maintenance Manual | Jabiru Aircraft Pty Ltd |
|---|---|
| JEM0002-1 | Jabiru Model 2200 & 3300 Aircraft Engines |

**5.13 Torque Application Procedure**

- Good torque application technique is essential if an accurate bolt torque reading is going to be obtained.
- Firstly the nut must be tightened smoothly. Any jerks or bumps can cause the torque reading to be obtained prematurely.
- The torque must be obtained while the nut is turning. If you stop to reposition the torque wrench and then the required torque reading is obtained without the nut turning, the nut needs to be loosened a little and then tightened again so the torque reading is obtained while turning.
- Unless specified otherwise all torque settings given in this manual are "dry" – i.e. no special lubricant is applied to the threads or parts. Where directed otherwise it is vital that the directions are followed exactly.

**Excerpt 1: Notes on torque application (courtesy Jabiru Manual JEM0002-1)**

v) Re-fit the propeller to the aircraft using the longer bolts and Belleville washer stack as shown generally in Figure 1 below (contact Jabiru Aircraft or our local representative for aircraft specific details). Note that the bolts must be oriented with the threaded end facing away from the engine. Details of the variations to the propeller installation for the different Jabiru models are available from Jabiru Aircraft or our local representative.

**Excerpt 2: Propeller bolt orientation (courtesy Jabiru Service Bulletin JSB 009-1)**

**6.3.3 Procedure - Propeller installation**

1. Figure 1 shows typical propeller installation details.
2. Ensure that Propeller drive bushes – 6 off, are in place in the Crankshaft Propeller Flange. Where equipped, fit the rear spinner backing plate to the flange.
3. Fit propeller to flange. Ensure that the drive pins are snug fit in the propeller.
4. Fit Propeller Bolts - 6 off.

| ISSUE | 1 | | | | | | | | Dated : Apr 2008 | Issued By: DPS | Page: 8 of 22 |
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| Jabiru Aircraft Pty Ptd | |
|---|---|
| Propeller Service Manual | JPM3L01-1 |

5. Fit front spinner backing plate to front of propeller. Fit Aluminium Propeller Flange, Belleville Washers - 42 off: (8 per Bolt: assembled in pairs as shown)
6. Progressively tighten bolts ensuring equal distribution of load and in a normal criss-cross torque sequence.
7. Using Torque Wrench, tighten Bolts to 6lb.ft (72 inch/lbs).
8. Check tracking of Propeller by locating a fixed object on a flat floor so that it just clears the Propeller tips when rotating the Propeller by hand. Check that each blade clears the object by the same amount. If the Propeller is outside the approved tolerance, refer to JABIRU Aircraft Pty Ltd or a JABIRU Approved Service Centre.
   Maximum Tracking Error Tolerance is +/- 2mm.
9. Locate Spinner on Spinner Flange and fix with Machine Screws through tinnerman Washers.
10. Check Spinner tracking by locating a fixed object on a flat floor to just clear the lower edge of the front dome of the Spinner. Rotate the propeller by hand and check that the Spinner runs true.
11. Correct any run-out by loosening machine screws, realigning spinner then retightening machine screws.
12. Leading edge tape can be applied between the inner edge of the urethane leading edge and the spinner. This optional tape protects the propeller and reduces the chances of moisture ingress.
13. After the first flight following the propeller installation the spinner must be removed and the propeller bolts checked for correct tension.

**Excerpt 3: Propeller assembly methodology (courtesy Jabiru Propeller Service Manual JPM3L01-1)**

8.2. The investigation results revealed no clear indications of incorrect thread control and/or over-torque of the fitted bolts.

## 9. RECOMMENDATIONS

9.1. The investigation revealed the absence of the prescribed “Belleville” washers (Diagram 3 & Figure 1) in the propeller assembly. This is in non-compliance on the AMO’s part to JSB 014-2 (dated 06/2011) that refers to JSB 009 (dated 04/2005) as the accepted assembly methodology. The presence of Belleville washers will maintain the applied torque, within limits, to the propeller bolts and may have prevented this incident. Taking into account the decisive function of the relevant assembly

towards Aviation Safety, it is strongly recommended that the applicable OEM Instruction Manuals to be adhered to at all times.

9.2. The investigation revealed incorrect toque application to the propeller bolts and nuts. Although no clear indications towards over-torque damages where noted, the assembly method followed may leave the propeller bolts under conditions of under-torque. Taking into account the decisive function of the relevant assembly towards Aviation Safety, it is strongly recommended that the applicable Standard Practices regarding the application of torque be adhered to at all times (refer to Excerpt 1).

9.3. The OEM (Jabiru SA) revealed to the investigation that the primary reason for the paint application to the propeller flange is corrosion control and also under the instruction from the SACAA. *No formal documentation stipulating the paint application method were presented following a request to both parties, leaving this investigation with no option but to assume that such documentation does not exist.* Although the motive for the paint application is sound, the inclusion of a weaker component in an assembly to be exposed to torque as well as vibration and other loads during service, should be based on sound engineering principles as well as a rigorous testing phase. It is strongly recommended that the OEM revisit this paint application process in coalition with the Regulating Authority (SACAA).

9.3. The investigation noticed that the bolts (and single nut) were refitted for an undeterminable number of times. Taking into account the applied torque, the relatively low cost as well as the importance of the related parts to flight safety, it is strongly recommended that theses bolts/nuts are not refitted after use.

## 10. DECLARATION

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