SOUTH AFRICAN CIVIL AVIATION AUTHORITY

AIRCRAFT INCIDENT REPORT AND EXECUTIVE SUMMARY

Reference:	CA18/3/2/1058

Aircraft registration	**ZU-FTC**	**Date of incident**	6 June 2014	**Time of incident**	0720Z
Type of aircraft	Jabiru SP (aeroplane)	**Type of operation**	Training (Part 141)		
Pilot-in-command licence type	Private	**Age**	29	**Licence valid**	Yes
Pilot-in-command flying experience	Total flying hours	104.4	Hours on type	9.2	
Last point of departure	George Aerodrome (FAGG), Western Cape Province				
Next point of intended landing	George Aerodrome (FAGG), Western Cape Province				

Location of the accident site with reference to easily defined geographical points (GPS position)

Keurboomstrand, 3nm east of Plettenberg Bay (GPS position: 34°01'35.51" South 023°24'04.57" East)

Meteorological information	Surface wind: 330°/5kt; Temperature: 12°C; Visibility: +10km				
Number of people on board	1 + 0	**No. of people injured**	0	**No. of people killed**	0

Synopsis

The pilot, who was the sole occupant on board, was engaged in a cross-country navigational flight from George aerodrome to Tsitsikamma and back to George. As he passed abeam Beacon Island at Plettenberg Bay, he initiated a climb from 1 500ft to 3 500ft above mean sea level (AMSL). At 2 500ft AMSL, the engine started running rough. The pilot felt a vibration on the control column and throttled back.

He then turned left towards Plettenberg Bay aerodrome (FAPG) and broadcast a Pan Pan Pan on the Cape Town Information East frequency. As he completed the turn, the propeller suddenly separated from the crankshaft flange, and flew forward, up and over the cockpit. The pilot broadcast a Mayday on the same frequency, saying that he was going down. Ahead of him was an open stretch of beach and he opted to land here. The aircraft came to a halt approximately 60m after touchdown. The first people who arrived on the scene were members of the local sea rescue station who had responded to the Mayday call that was relayed to them via the air navigation services.

Nobody was injured in the incident.

Probable cause

The pilot executed a forced landing on an open section of beach following a catastrophic engine failure in flight.

ASP date		Release date	

AIRCRAFT INCIDENT REPORT

Name of Owner	: W.H. Waldeck
Name of Operator	: Flight Training College
Manufacturer	: Jabiru
Model	: SP
Nationality	: South African
Registration Marks	: ZU-FTC
Place	: Keurboomstrand near Plettenberg Bay
Date	: 6 June 2014
Time	: 0720Z

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 (1997), 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 establish legal liability**.*

Disclaimer

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

1. FACTUAL INFORMATION

1.1 History of flight

1.1.1 The pilot, who was the sole occupant on board, departed George aerodrome (FAGG) on a cross-country navigational flight bound for Tsitsikamma and thereafter returning to George. The flight was conducted under visual flight rules (VFR) and the pilot had filed a flight plan.

1.1.2 After take-off, the pilot climbed to 1 500ft above mean sea level (AMSL). As he was passing Beacon Island at Plettenberg Bay, he initiated a climb to 3 500ft AMSL. At

2 500ft, he felt a strong vibration on the control column and noticed that the engine was running rough. He throttled back and executed a left turn with the intention of flying to Plettenberg Bay aerodrome (FAPG). During the turn, he broadcast "Pan Pan Pan" on the Cape Town Information East frequency (127,575 MHz), informing them about the rough-running engine and that he was turning towards Plettenberg Bay aerodrome.

1.1.3 As he rolled the wings level at about 2 500ft, the propeller suddenly separated from the engine, flying forward, then up and over the cockpit. He immediately broadcast "Mayday Mayday Mayday" on the same frequency, informing the controller that the propeller had separated and he was going down.

1.1.4 His decreasing altitude produced interference on the frequency and he was unable to communicate clearly with the controller. Another aircraft in close proximity at a higher altitude relayed his message to Cape Town Information East.

1.1.5 The pilot decided to land on an open stretch of beach straight ahead of him. He touched down safely and the aircraft came to a halt within 60m. According to the pilot, this stretch of beach was not easily accessible by foot and the first people on the scene were members of the Plettenberg Bay sea rescue station, who arrived in a rubber duck. The following day, the same members recovered the propeller of the aircraft from where it had washed up onto rocks some distance to the southeast.

1.1.6 The incident occurred during daylight conditions. The pilot executed a forced landing on an open beach at the geographical position that was determined to be 34°01'35.51" South 023°24'04.57" East. He was not i njured in the incident.

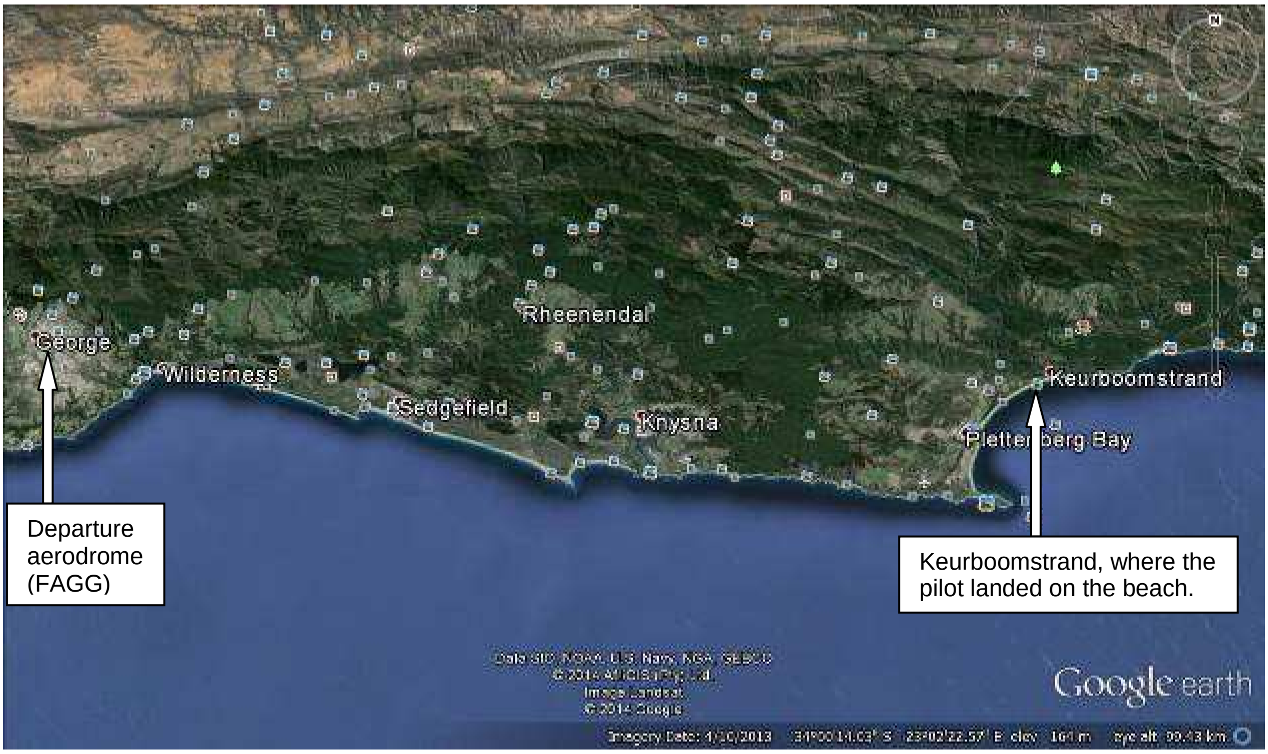

Figure 1. The Google Earth map indicating the point of departure (George) and the landing area (Keurboomstrand).

1.2 Injuries to persons

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

1.3 Damage to aircraft

1.3.1 Apart from the propeller that separated from its attachment point on the engine flange, the damage to the aircraft was limited to the nose structure and the engine, which had seized in operation.

1.4 Other damage

1.4.1 There was no other damage caused.

1.5 Personnel information

Nationality	South African	Gender	Male	Age	29
Licence number	0272455320	Licence type	Private Pilot		
Licence valid	Yes	Type endorsed	Yes		
Ratings	Night rating				
Medical expiry date	31 March 2015				
Restrictions	None				
Previous incidents	None				

Flying experience

Total hours	104.4
Total past 90-days	9.2
Total on type past 90 days	9.2
Total on type	9.2

1.6 Aircraft Information

Airframe

Type	Jabiru SP	
Serial number	44	
Manufacturer	Shadow Lite CC	
Year of manufacture	2009	
Total airframe hours (at time of incident)	678.9	
Last Annual inspection (hours & date)	589.3	24 March 2014
Hours since last Annual inspection	89.6	
Authority to Fly (Issue date)	25 March 2014	
Authority to Fly (Expiry date)	24 March 2015	
C of R (Issue date) (present owner)	24 November 2009	
Operating categories	Training	

Engine

Type	Jabiru 2200A
Serial number	22A 3311
Hours since new	678.9
Hours since overhaul	TBO not yet reached

Propeller

Type	Sensenich 42”
Serial number	AH-6802
Hours since new	678.9
Hours since overhaul	TBO not yet reached

Weight and balance

The aircraft’s empty weight, as determined on 23 March 2010, was 309kg. The pilot, who was the sole occupant on board at the time of the incident, weighed 85kg. Approximately 50ℓ of fuel, equating to 36kg, remained in the aircraft. Together, these brought the total landing weight to 430kg. The aircraft’s maximum certified take-off weight (MTOW) limitation was 500kg.

1.7 Meteorological information

1.7.1 The weather information tabled below was obtained from the pilot’s questionnaire as well as the meteorological aerodrome report (METAR) issued for George aerodrome on 6 June 2014 at 0800Z.

Wind direction	330°	Wind speed	5kt	Visibility	+10km
Temperature	12℃	Cloud cover	Clear	Cloud base	Clear
Dew point	5℃				

1.8 Aids to navigation

1.8.1 The aircraft was equipped with the standard navigational equipment as approved by the regulating authority. There were no recorded defects to the equipment prior to or during the flight.

1.9 Communication

1.9.1 The aircraft was equipped with standard communication equipment. The pilot was in radio contact with Cape Town Information East on the VHF frequency 127.575 MHz. He declared a Pan Pan Pan after his engine began to run rough. Shortly thereafter, the propeller suddenly separated from the engine and he broadcast a Mayday on the same frequency. As he descended, communication with Cape Town Information East was disrupted, and another aircraft in the vicinity at a higher altitude relayed the message for him.

1.10 Aerodrome information

1.10.1 The incident did not occur at or near an aerodrome.

1.11 Flight recorders

1.11.1 The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR). Neither was required by SACAA regulations to be fitted to this type of aircraft.

1.12 Wreckage and impact information

1.12.1 This was not an on-site investigation. The information contained below was based on third party observations and photographic material made available for the purpose of the investigation.

1.12.2 The pilot landed in a westerly direction on an open section of beach. He touched down above the shoreline. The aircraft came to a halt approximately 60m after touchdown. Just before it stopped, the nose wheel dug into the soft sand and the aircraft tipped forward, momentarily digging its nose section into the sand before falling back onto its main wheels, as shown in Figure 3. The propeller was recovered by members of the National Sea Rescue Institute (NSRI) on a rocky section of the shoreline to the east of the landing area, where it had washed up.

Figure 2. The tyre marks of ZU-FTC on the beach.

Figure 3. The aircraft after it came to rest.

Figure 4. The sheared propeller attachment bolts (engine side).

Figure 5. The sheared propeller attachment bolts (rear of the propeller)

1.13 Medical and pathological information

1.13.1 Not applicable.

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 incident was survivable. The cockpit was undamaged and the pilot made use of the aircraft-equipped three-point inertia harness.

1.16 Tests and research

1.16.1 Engine teardown inspection

The aircraft was fitted with a Jabiru 2200A engine, serial No. 22A 3311. This is a four-cylinder, four-stroke, horizontally-opposed, air-cooled engine that develops 80HP at 3 000 rpm. The propeller is driven directly by the crankshaft with no reduction gearbox. Cooling of the engine is effected by two ram air ducts mounted on either side of the engine cylinders. The ducts take air from scoops at the front of the engine and direct this cool air over the cylinders and cylinder head fins, exhausting the air below the engine. The engine in question had completed 678.9 hours.

The engine could not be rotated after the incident. During further examination, it was evident that the lower crank case was deformed. An engine teardown inspection was conducted, during which it was found that a catastrophic failure had occurred: the number two piston was completely destroyed and the connecting rod had failed and deformed to such an extent that it had jammed in the crankcase (Figure 6).

The head of the number two cylinder exhaust valve was retrieved from the oil sump. The valve stem from the exhaust valve was stuck in its valve guide (Figure 7). Further inspection showed that the valve guides were worn out of tolerance and a substantial amount of carbon had built up on the valve stems. All four cylinder heads were removed from the cylinders and three out of the four displayed signs of ‘blowing’.

The design of the cylinder is such that there is no gasket between the cylinder and the head. A gas seal is achieved by relying solely on the recessed fit between cylinder and head, and on the torque of the cylinder head bolts. The latter must be checked for correct torque every 50 hours. This is due to the bolts tightening up against the head, compromising the gas seal in the process, rather than pulling the head onto the cylinder.

During the inspection of the aircraft and engine logbooks, it was noted that a differential compression test had been carried out every 50 hours on this engine. The last differential compression test prior to the incident flight had been carried out on 26 May 2014 at 666.2 hours and the results were satisfactory. The logbook entry was as follows:

Cylinder No. 1	-	76/80
Cylinder No. 2	-	72/80
Cylinder No. 3	-	72/80
Cylinder No. 4	-	74/80

Following the test, the engine operated for a further 12.7 hours before the failure that resulted in the incident.

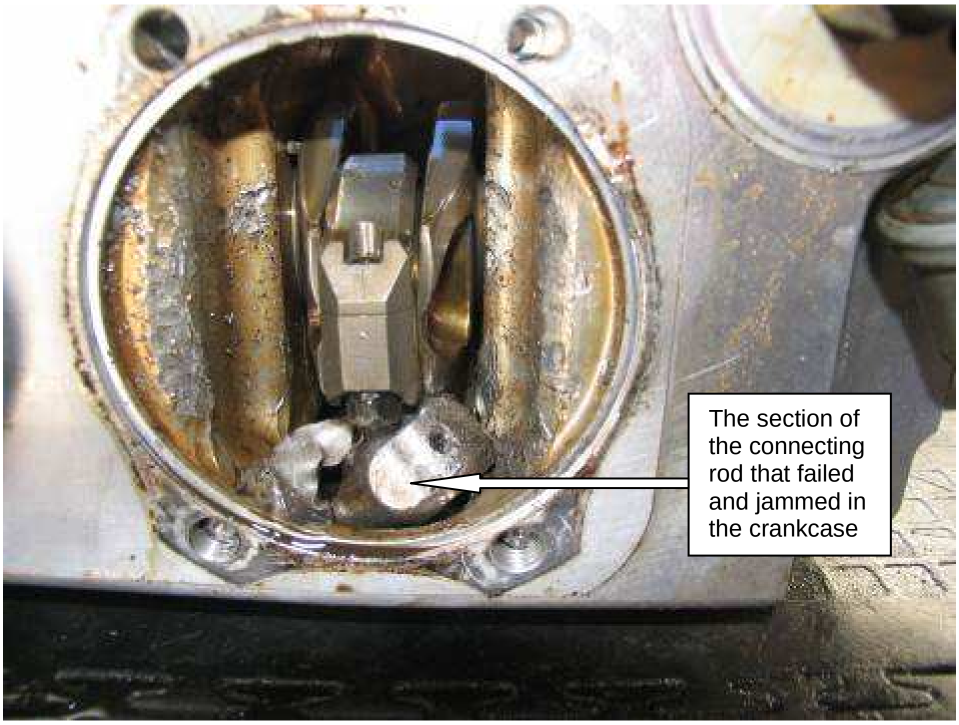

Figure 6. The No. 2 connecting rod that failed.

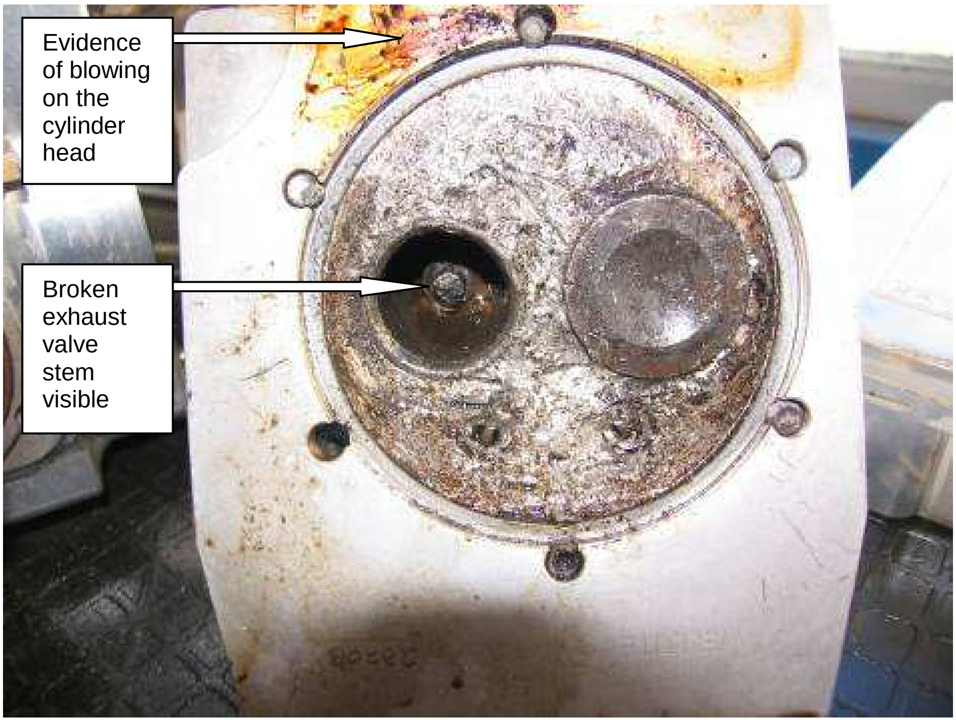

Figure 7. The damage caused to the No. 2 cylinder head.

Figure 8 shows two exhaust valves that were removed from the engine during the tear-down inspection. Substantial carbon build-up can be seen on the lower valve stem area.

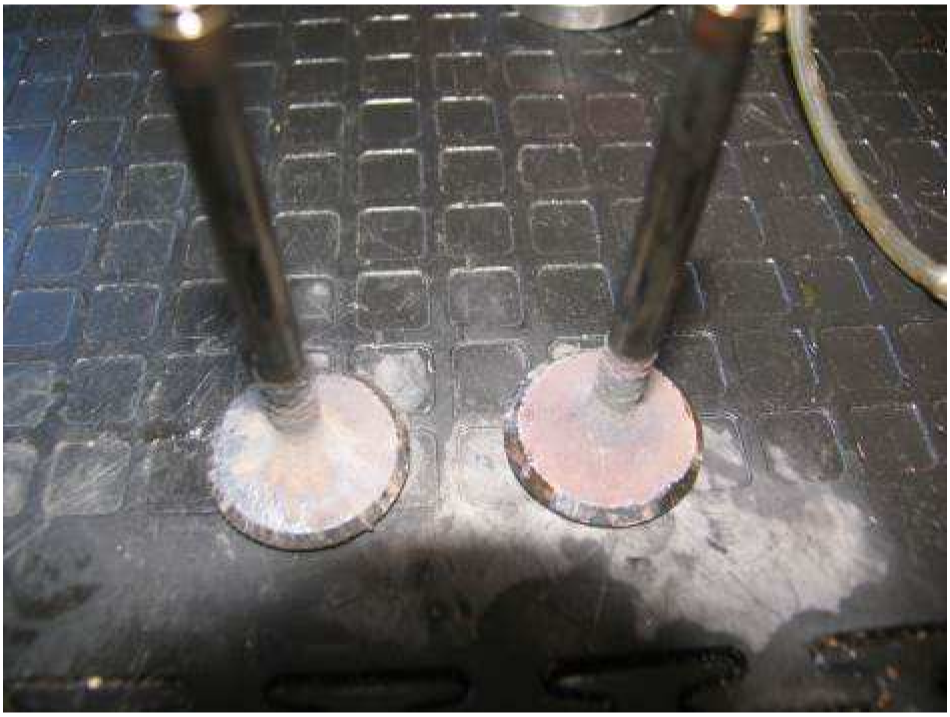

Figure 8. Carbon build-up on two of the valves removed from the engine.

1.16.2 The propeller flange and associated parts were recovered and made available for metallurgical examination. The primary purpose of this was to determine if the engine failed before or after the propeller separated from the crankshaft flange. The examination revealed that the engine failed first, and this had been induced by an exhaust valve failure on the No. 2 cylinder. A reverse load applied to the still rotating propeller resulted in the shearing of all 6 flange attachment bolts and the subsequent separation of the propeller in flight. The examination report is attached to this report as Annexure A.

1.17 Organisational and management information

1.17.1 The aircraft was utilised for flight training under the auspices of an approved aviation training organisation (ATO). The pilot was duly authorised to conduct the flight.

1.17.2 The aircraft was maintained by an approved aviation maintenance organisation (AMO) in possession of a valid AMO approval certificate.

1.18 Additional information

1.18.1 Jaburi Service Bulletin JSB-022-1

Subject – Propeller Flange Attachment

Jabiru Service Bulletin JSB-022-1 was issued on 28 July 2008. This was incorporated on this aircraft on 23 October 2012 at 413.9 airframe hours. Subsequent to the work being carried out, the aircraft flew a further 265 hours. Under questioning from the investigator, the AMO indicated that the bolts had been re-used to meet the bulletin’s requirements. The bulletin allowed for this, provided a detailed visual inspection of the bolts was first carried out. A copy of the service bulletin is attached to this report as Annexure B.

1.18.2 Jaburi Service Bulletin SL8

Service Bulletin SL8 was issued on 14 December 2010. It was introduced to allow for better oil scavenging around the cylinder heads, as excessive oil in the rocker chamber flows down the valve guides and burns onto the valves, causing carbon build-up on the stems. If enough carbon is allowed to build up, it could cause the valve to become stuck in the open position, causing the piston to collide with the valve. The latter would then break, damaging the piston and connecting rod. However, the service bulletin was not incorporated on this engine as it was not mandatory. A copy of the service bulletin is attached to this report as Annexure C.

1.19 Useful or effective investigation techniques

1.19.1 There were no new methods used.

2. ANALYSIS

2.1 Man (Pilot)

The pilot was the holder of a valid private pilot's licence. He had conducted several flights in ZU-FTC prior to the incident flight. He was in radio contact with air traffic control and communicated with them throughout the flight, informing them that the engine was running rough. When the propeller suddenly flew off the crankshaft flange he declared a Mayday. He executed a forced landing on an open section of beach identified from the air. This resulted in minor damage to the aircraft, and no injury to the pilot.

2.2 Machine (Aircraft)

The aircraft was utilised by an aviation training organisation (ATO) and maintained by an approved AMO. All scheduled maintenance inspections were complied with and the aircraft was in possession of a valid Authority to Fly. The last differential compression test carried out on the engine was during the last 50-hour inspection before the incident flight, certified on 16 May 2014. This was 12.7 hours before the engine failed. All four compression readings were above 70 psi, indicating that the engine was operating satisfactory.

According to the pilot, he experienced a rough-running engine and shortly thereafter the propeller detached from the crankshaft flange. The engine tear-down inspection revealed that excessive carbon build-up on the No. 2 exhaust valve stem had caused the valve to become stuck in the open position within the valve guide. As a result, the valve made contact with the piston, resulting in engine seizure. According to the aircraft logbooks, Service Bulletin SL-8 had not been incorporated on the engine. This was not a mandatory bulletin, as it had been created in an effort to prevent carbon build-up on the valve stems, thereby ensuring that the valves sealed properly.

According to the aircraft logbooks, Service Bulletin JSB-022-1 was incorporated and the aircraft flew a further 265 hours after this. The failure of the propeller attachment bolts was a secondary event caused by the sudden reverse load applied to the still-rotating propeller. This sheared the bolts and the propeller separated in flight.

2.3 Environment

The flight was conducted in fine weather conditions that had no bearing on the incident. The pilot was familiar with the area and had flown the incident aircraft several times prior to the flight in question.

2.4 Conclusion

The pilot executed a forced landing on an open section of beach after a catastrophic engine seizure in flight. This was caused by the failure of the No. 2 exhaust valve, which became stuck in the open position due to excessive carbon build-up on the valve stem. The force of the sudden engine seizure caused the propeller to separate from the crankshaft flange. The detachment of the propeller was thus secondary to the engine failure.

3. CONCLUSION

3.1 Findings

3.1.1 The pilot was the holder of a valid private pilot's licence and had the aircraft type endorsed on this licence.

3.1.2 The pilot was the holder of a valid aviation medical certificate issued by a CAA-approved medical examiner.

3.1.3 The aircraft was in possession of a valid Authority to Fly.

3.1.4 The aircraft flew for 265 hours subsequent to the incorporation of Jabiru Service Bulletin JSB 022-1.

3.1.5 The propeller attachment bolts were re-used by the AMO that carried out Jabiru Service Bulletin JSB 022-1 on 23 October 2012. The failure of the bolts was found to be secondary to the engine failure.

3.1.6 Jabiru Service Bulletin SL8 was not incorporated on this engine.

3.1.7 A differential compression test was carried out on the engine during the last 50-hour inspection before the incident in question. This was certified on 26 May 2014. Subsequent to the test, the aircraft flew without a problem for 12.7 hours before the incident.

3.1.8 A catastrophic engine failure followed when the No. 2 cylinder exhaust valve failed in operation at 678.9 engine hours.

3.1.9 The separation of the propeller from the crankshaft flange was found to be secondary to the engine failure.

3.2 Probable cause

3.2.1 The pilot executed a forced landing on an open section of beach following a catastrophic engine failure in flight.

4. SAFETY RECOMMENDATION

4.1 It is recommended that all aircraft owners fitted with Jabiru engines ensure that 50-hour compression checks are complied with and no unauthorised modification be done to the ram air ducting in order to ensure adequate cooling takes place at all times during all flight regimes. Any sign of ‘blowing’ and/or overheating/discolouring of the cylinder heads should immediately be brought to the attention of maintenance personnel, whereupon a detailed inspection should be conducted on the engine before the next flight.

4.2 In the interest of aviation safety, it is recommended that all owners of aircraft fitted with Jabiru engines comply with Service Bulletin SL8. This was issued to prevent carbon build-up in the engine and ensure that the valves seal more positively. This bulletin is not mandatory. However, it is recommended that the Civil Aviation Authority elevate the status of the bulletin to ensure that compliance is met by all aircraft owners.

4.3 It is recommended to the Director of Civil Aviation that the Jabiru Service Bulletin JSB-022-1 (attached to this report) be amended and reissued following review by the authority. JSB-022-1, page 2, paragraph (e) states that the flange bolts can be re-used providing they are of the correct length and there is no visible damage to the bolt. Considering the forces to which these bolts are exposed, it is recommended that this practice be removed from the bulletin and the re-use of any bolts be disallowed in the interest of aviation safety.

It is further recommended that all aircraft on which the Jabiru Service Bulletin JSB 022-1 was carried out be subjected to an inspection to ensure that none of the bolts securing the propeller flange to the crankshaft have fractured in operation. Any such bolts, or any suspect bolts, should immediately be replaced by new bolt(s).

5. APPENDICES

5.1 Annexure A (Metallurgical report on engine and propeller failure mode)
5.2 Annexure B (Jaburi Service Bulletin JSB-022-1)
5.3 Annexure C (Jabiru Service Bulletin SL8)]

ANNEXURE A

COMPILED BY	**Crash** LAB	PAGE 1 OF 12
COMPILED FOR: S.A. Civil Aviation Auth.	INVESTIGATION REPORT: JABIRU 2200A ENGINE FAILURE, AIRCRAFT No ZU-FTC	DOCUMENT NUMBER AAI-005-08-14
		DATE 2014-08-01 — ISSUE 1

ITEM: **2200A ENGINE, JABIRU J160 AIRCRAFT, NUMBER ZU-FTC**

1. INTRODUCTION & BACKGROUND INFORMATION

1.1. Selected parts (Photo 1) from a failed model 2200A Jabiru aircraft engine and propeller flange assembly, serial number 22A 3311, originating from Jabiru J160 aircraft, number ZS-FTC, were submitted to determine the most probable cause/s for failure during operation.

1.2. The relevant aircraft was involved in an emergency landing (Photo 2) following the separation of the propeller in flight.

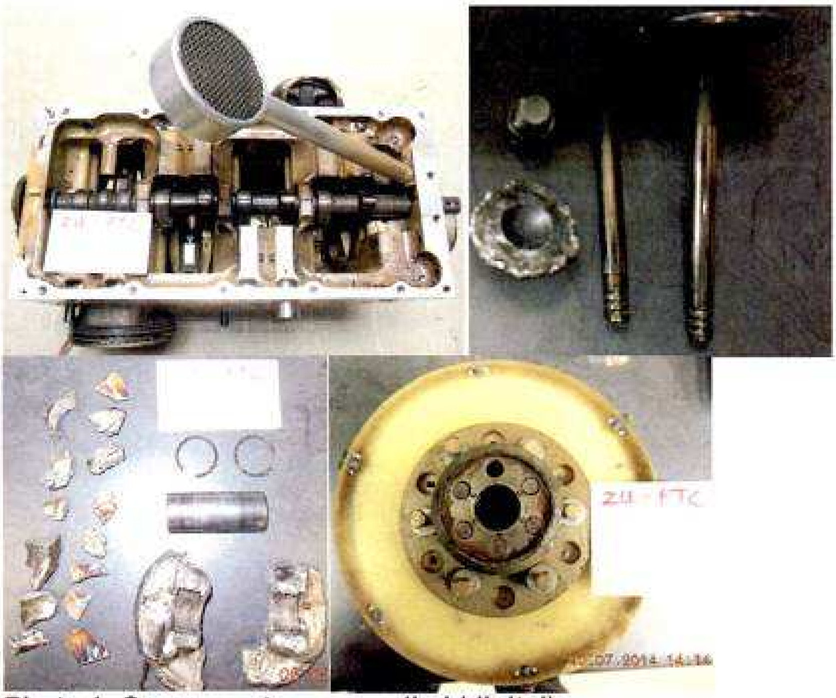

Photo 1: Components, as supplied (digital)

Photo 2: Accident aircraft, on site (courtesy SACAA)

JABIRU 2200A ENGINE FAILURE ZU-FTC

1.3. The Exhaust Valve Seat Interface. The exhaust valve face to seat interface is responsible for up to 75% of all heat transfer. Poorly adjusted valves accumulate combustion deposits on the valve face leading to inadequate sealing that will result in a lower rate of heat transfer. With typical exhaust temperatures ranging between 870 - 1090°C, the condition will only deteriorate. The 'riding valve' phenomenon will result in excessive temperature exposures to the exhaust valve leading to valve distortion and ultimate catastrophic failure.

1.4. Exhaust Gas Residue Deposits. Problematic carbon build-up is not limited to the valve seat interfaces but also to the remainder of the exhaust valve, particularly the valve stem areas. Excessive carbon build-up on the stem area may lead to the 'sticky valve' phenomenon resulting in contact between the piston and valve.

1.5. This report is divided into the following sections:

2. APPLICABLE DOCUMENTS

(a) Investigation Report: Exhaust Valve Failure Jabiru 3300 engine, MET 003-3-07, dated 2007-03-14 (attached).
(b) AAIB Bulletin No: 10/2002 (attached).

3. DEFINITIONS

(a)	OEM	Original Equipment Manufacturer
(b)	SACAA	South African Civil Aviation Authority
(c)	SEM	Scanning Electron Microscope
(d)	EDS	Energy Dispersive Analytical System (x-ray)
(e)	AMO	Aircraft 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-, Electron Microscopes (with EDS) and Digital Camera.

(b) The methodology included a visual examination of supplied parts, sectioning for sample preparation purposes followed by a Microscope/EDS investigation.

6. INVESTIGATION

6.1. **Investigation Results.** The inspection revealed the following:

The applied force/rotational direction of the engine are displayed by a red dashed arrow on all pictures for reference.

6.1.1. Propeller Flange Assembly: All 6 propeller flange attachment bolts (Photo 3) fractured at the engine drive flange position. The no 1 bolt was found removed from its position. At low magnification all 6 bolts revealed a similar macro fracture surface geometry with no clear indications of fatigue. At higher magnifications the fractographs from selected bolts (No's 3, 4 and 5) revealed no clear indications of fatigue or other pre-existing fractures prior to final failure. The fracture surfaces revealed a clear directional orientation in geometry (Photo's 7, 8 and 9) pointing towards a shear- rather than a pure tensile type failure mode.

The propeller attachment bolts revealed severe bending damages (Photo 4, red arrow). The propeller bolt guides showed impact damages similar in shape and relative position (Photo's 5 and 6, blue arrows). Considering the applied force during operation (red dashed arrows), the unidirectional bending of the propeller attachment bolts and the fact that no inflight propeller strike was reported, it can be derived that the propeller attachment bolts impacted the guides due to a reverse directional force imposed from the engine end.

The threaded sections revealed no clear indications of sub-fracture initiation (Photo's 10 and 11) as expected under a pure tensile load condition.

Photo 3: Engine propeller flange (digital)

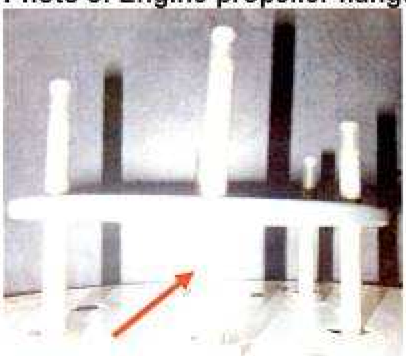

Photo 4: Propeller attachment bolts (digital)

Photo 5: Impact damages to propeller bolt guides (digital)

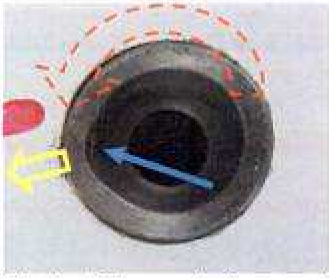

Photo 6: Impact damage to guide (digital)

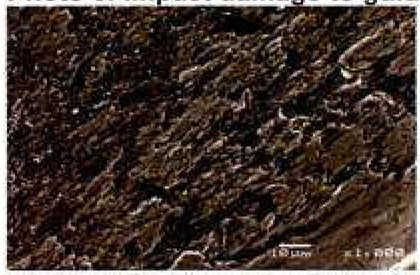

Photo 7: Fractograph - Bolt 3 (x1000, SEM)

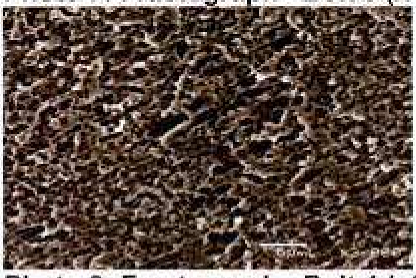

Photo 8: Fractograph - Bolt 4 (x3000, SEM)

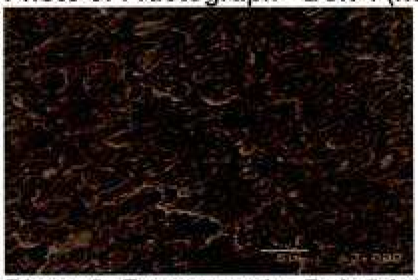

Photo 9: Fractograph - Bolt 5 (x3000, SEM)

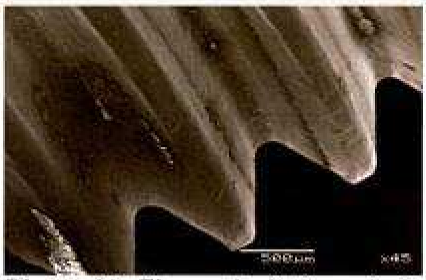

Photo 10: Flange bolt threaded section (x45, SEM)

Photo 11: Flange bolt threaded section (x50, SEM)

6.1.2. Engine Block Assembly: The inspection revealed the no 2 connecting rod (Photo's 12 and 13, red arrows) still attached to the crankshaft at the big end with no clear fracture/s. Damages inflicted to the inner sections of the crankcase (Photo 13, blue arrow) can be attributed to the connecting rod impacting following the failure of the no 2 piston.

The (small end) piston gudgeon/wrist pin revealed no clear evidence of possible contact with the sleeve during operation (Photo 14) suggesting that the 'circlips' was intact and in position at the time of piston failure (*refer Jabiru SB 033-1*).

The no 2 piston revealed severe impact damages (Photo 15). Inspection of the resultant, and relatively undamaged, fracture surfaces (Photo 16) exposed no clear indications of pre-existing fractures.

The no 2 cylinder head (Photo 17) showed severe damages that can be attributed to multiple impacts by the remains of the fractured exhaust valve during operation. It can therefore be derived that the exhaust valve most probably failed first in the sequence of events allowing the parts thereof to be forced into the cylinder head by the still oscillating piston. These impact forces ultimately would have caused the failure of the piston itself. Small, hard object impact marks in close proximity to the top end of the cylinder sleeve (Photo 19, red arrow) also confirms that the exhaust valve most probably failed first and allowed to be contained in the combustion area for a short period of operational time. Both the exhaust and inlet valve seats were found in position.

The no 2 exhaust valve head fractured from the stem at the radius (Photo 20) with extensive damages to both fracture surfaces ends (Photo's 20 and 21, yellow arrows). At higher magnification, fractographs from the stem end (Photo 24) confirmed the extensive impact and other damages inflicted post-failure while no clear evidence of pre-existing fracture initiation was noted.

Extensive carbon deposits were noted on all the piston surfaces (Photo 12, yellow arrow) as well as in the exhaust exit duct and valve stem guide areas (Photo 18, red arrows). Similar deposits were noted on the exhaust valve stem (Photo's 20 and 23, red arrows) adjacent to the valve stem guide entrance position. The exhaust valve stem revealed extensive scraping marks (Photo 22, red arrow) induced by the valve stem guide as well as copper based deposits (yellow arrow) originating from the guide.

Photo 12: Engine block - No 2 piston damages (digital)

Photo 13: Position of No 2 connecting rod (digital)

Photo 14: Gudgeon pin – small end No 2 (digital)

Photo 15: No 2 piston damages (digital)

Photo 16: No 2 piston fracture surfaces (digital)

Photo 17: No 2 head damages (digital)

Photo 18: No 2 exhaust exit duct and valve guide (digital)

Photo 19: No 2 pod damages (digital)

Photo 20: No 2 exhaust valve damages (digital)

Photo 21: No 2 exhaust valve fracture surface, stem end (digital)

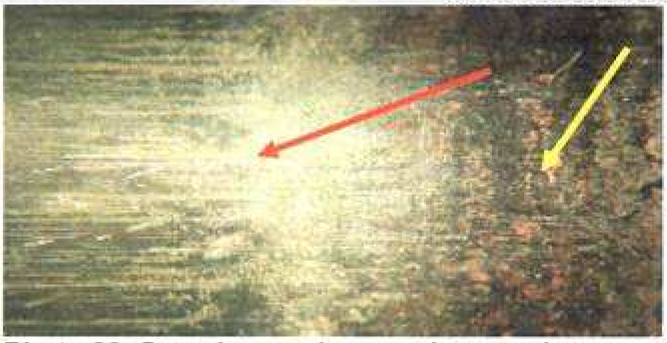

Photo 22: Scraping marks on exhaust valve stem (stereo)

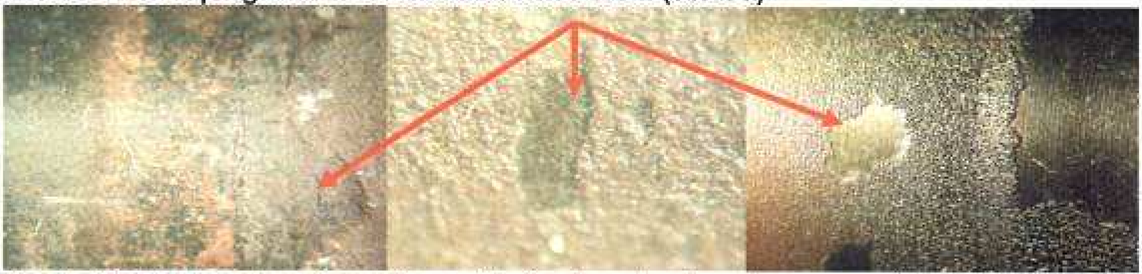

Photo 23: Hard carbon deposits on No 2 exhaust valve stem areas (stereo)

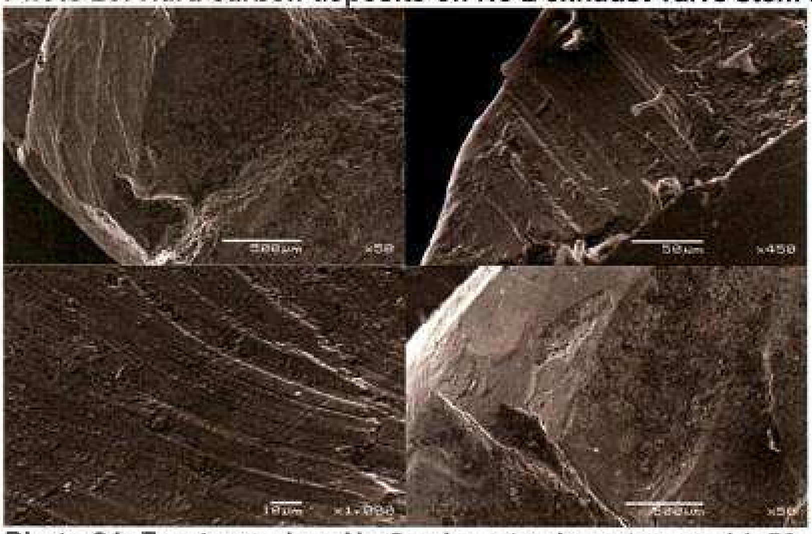

Photo 24: Fractographs - No 2 exhaust valve, stem end (x50 – x1000, SEM)

7. DISCUSSION AND CONCLUSIONS

The conclusions are based on the investigation results obtained from the supplied parts/components only.

7.1 The investigation results point towards the following as the most probable **sequence of events** leading up to the separation of the propeller during flight:

7.1.1. Considering the severity and hard object indentation damages inflicted unto the no 2 cylinder head and inner sections of the cylinder sleeve, it is suggested that the no 2 exhaust valve failed first.

7.1.2. While the piston was still connected to the connecting rod and thus under load, the impacts with the severed exhaust valve head resulted in the ultimate catastrophic failure thereof.

7.1.3. With the piston disintegrated, the connecting rod was free to move within the crankcase until it jammed into the as-found position. This resulted in the sudden stoppage of the engine during flight.

7.1.4. The reverse load applied to the still rotating propeller resulted in the shearing of all 6 flange attachment bolts and the subsequent separation of the propeller in flight.

A comparable failure was noted on a similar aircraft in Kwa-Zulu Natal, South Africa (Photo 25).

Photo 25: Similar failure of the propeller flange bolts following an engine failure (courtesy SACAA)

7.2. The buildup of surface carbon deposits proved to be a contributing factor to accidents and incidents in the past involving similar aircraft (*refer AAIB Bulletin No: 10/2002 and Investigation Report: Exhaust Valve Failure Jabiru 3300 engine, MET 003-3-07, dated 2007-03-14 - By the same investigator*). In this case, again, the clear buildup of hard carbon deposits on the exhaust valve seat as well as on the vulnerable stem area, in close proximity to the valve stem guide point of entry, proved to be the most probable contributor. In the majority of the cases the resultant effect of these flaking carbon deposits (Photo 26 – *from historic case*) proved to be a 'sticky' valve inside the valve stem guide leading to catastrophic consequences.

7.3. Consultation with various aircraft engine shop owners bared a general consensus that the current utilization of 100LL (low-lead) fuel generally results in much harder carbon deposits when compared to the phased-out leaded fuel varieties. These deposits proved to be difficult to remove and when present on piston heads, may even contribute to incidences of pre- and/or post detonation during operation.

Photo 26: Flaking of hard surface carbon deposits

8. RECOMMENDATIONS

8.1. Inflight engine failures are severely detrimental to Flight Safety. It is therefore strongly recommended that the OEM, owners and relevant AMO's sensitise operators regarding the dangers of carbon deposits and the correct inspection methodology to detect out of limit accumulation.

9. DECLARATION

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

ANNEXURE B

JABIRU AIRCRAFT PTY LTD

P.O. Box 5792
Bundaberg West
Queensland, Australia.

Phone: +61 7 4155 1778
Fax: +61 7 4155 2669
Email: info@jabiru.net.au

SERVICE BULLETIN: **JSB 022-1**

Issue: **1**

Date: **28th July 2008**

Subject: **Propeller Flange Attachment**

1 Applicability

All Jabiru Engines.

Note: For aircraft in Light Sport Aircraft categories this Bulletin is equivalent to a Manufacturer's Safety Direction.

2 Background:

Recently there have been several cases where propeller flanges have separated from the crankshaft due to improper installation. These have occurred on Jabiru 2200, 3300 and 5100 engines. In some cases the wrong grade of retaining compound was used, in others the wrong bolt length was used and in one case the screws were not tightened when the flange was installed.

This Bulletin is intended to raise operator awareness of the correct method of fitting the propeller flange.

3 Compliance – Implementation Schedule

3.1 Factory Complete Aircraft Built By Jabiru Aircraft Australia:

No new maintenance or inspection requirements are required by this Bulletin.

3.2 Other:

Operators who have fitted propeller flanges using a procedure other than that detailed below:

- Re-fit the propeller flange following the procedure detailed below at the next scheduled maintenance or within the next 50 hours, whichever is the sooner.

4 Procedure:

4.1 Propeller Flange Installation:

Due to the importance of this work, owners who are not confident are strongly recommended to have an aircraft maintainer (such as a LAME, RA-Aus Level 2 or equivalent) carry out the work.

b) With the flange removed, fit the attachment screws through the propeller flange and check the amount of thread which will screw into the crankshaft. There must be no less than 9mm (0.0.354") of **full** thread engagement – which generally equates to a total of around 11-12mm (0.433-0.472") measured from the tip of the screw to the flange mating face. If a Belleville (cone or spring washer) is used, the compressed thickness of the washer must be accounted for – the numbers given here assume a std Jabiru Belleville washer is fitted (and compressed) while measuring.

c) Hold the propeller flange to the front face of the crankshaft. Ensure that the flange fits cleanly. Note that the socket of Jabiru propeller flanges are not designed to be a high-tolerance tight fit onto the end of the crankshaft – a small amount of clearance is normal here.

d) Visually inspect the front face of the crankshaft and the mating face of the propeller flange. Ensure both faces are clean, free from rust and defects.

e) The screws used to fit the original flange may be re-used provided they are the correct length and are not visibly damaged. If the screws are replaced then high-strength cap screws must be used – "Unbrako 1960" type or equivalent.

f) If the screws are to be re-used their threads must be cleaned with a wire brush or similar.

g) Clean the threads of the screws using Loctite 7471 activator (primer) & allow to air dry. After priming, ensure the threads stay clean – contamination with oil (even skin oils from fingers) can reduce the strength of the bond of the retaining compound.

h) If a flange has been removed to allow a different type to be fitted then the screw threads in the crankshaft must carefully be cleaned using a 3/8" UNF tap – this removes leftover retaining compound from the threads and gives a better bond. Care must be taken to not cross-thread the tap or otherwise damage the thread in the crankshaft. Blow out the holes using dry compressed air.

i) Clean the threads in the crankshaft using Loctite 7471 activator (primer) & air dry.

j) Apply a small amount – approximately the size of a large match head – of Loctite 620 retaining compound to the flange screws.

k) Apply the same amount (approximately the size of a large match head) of Loctite 620 to the threads in the crankshaft.

l) Fit the flange to the crankshaft & fit the screws by hand, then tension the screws using a calibrated torque wrench **immediately**.

m) Tension the screws in a standard diagonal tightening pattern. Torque all screws first to 20 lb.ft, then all to 25 lb.ft, and finally all to 30 lb.ft.

n) Lock-wire may be applied. If it is used the screws should be wired in pairs.

o) Allow the retaining compound time to cure (refer to manufacturer specifications) before starting the engine.

4.2 General Notes:

- This job must be done in one session. In one case the operator screwed the flange on to the crank by hand and then went on with other jobs – the screws were never tightened above "finger tight" and the flange separated from the engine on the aircraft's first flight approximately 300' above the ground.

- Jabiru Aircraft have no objection to lock-wire being used; the standard flange fitted to Jabiru Engines is lock-wired at the factory. However, lock-wire on it's own has proven to be insufficient restraint for the screws. Loctite 620 *MUST* be used – all other restraints are optional. Jabiru Aircraft Australia does not use lock-wire on all it's factory-built aircraft.

- Torque wrenches are a precision instrument which must be periodically calibrated to ensure they are accurate. A wrench which is within it's calibration period must be used for this job.

- Loctite 620 is used because of it's high temperature tolerance. The crankshaft runs at approximately oil temperature – around 80°C – 90°C and other retaining compounds have lost significant strength at this temperature.

- Before removing a screw which has been installed with Loctite 620 the part should be gently heated using an electric hot air gun to carefully warm the parts. Care must be taken so that the front seal of the engine is not heated too much – a damp rag can be used to block the hot air & keep it cool. If this is not done there is a chance that the screw will fail before the retaining compound bond is broken & the thread will be left embedded in the crank.

- Dowel holes are drilled in the crankshaft for use by aftermarket propeller manufacturers (Ø8.00mm x 12 deep, PCD 41.5mm).

- Only propeller flanges made by Jabiru Aircraft or other approved manufacturers must be used. High quality machining with close tolerances is required to ensure the flange fits properly and the propeller runs true.

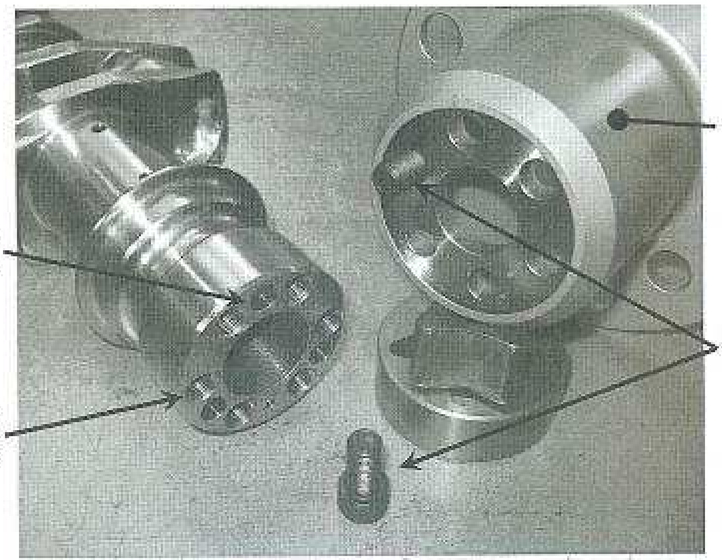

Figure 1 – Flange & Crankshaft

5 Airworthiness Note:

- Operating an engine with a loose propeller flange is potentially extremely damaging for the engine. The increased vibration can cause severe engine damage including crankshaft failure. If the flange is found to be loose please contact your local Jabiru representative for information on what inspections are required for safe continued operation.
- Where required, any work called for by this Bulletin must be carried out by authorised personnel. For the aircraft detailed herein this may mean the owner, an RA-Aus Level 2 holder, a Licensed Aircraft Maintenance Engineer (LAME) or equivalent – as appropriate to the aircraft's registration and use (Private or Air Work operations).
- On completion of the work, the authorised person must note the completion of the actions required by this bulletin in the aircraft's maintenance logbook. This note should include the date of the work and the identity (including licence number where appropriate) of the person carrying out the work.

JABIRU SERVICE BULLETIN

Number SL8

REVISION 1

Hydraulic Lifters

1 Introduction

We have been monitoring the engines over years and we have noticed that with the Hydraulic Lifting Engines up and till Hollow Pushrod Engines series, carbon build up on the valves and inside the cylinder heads builds up over time.

We have tried various methods and have now come to the conclusion that by fitting different type of hydraulic lifter with a better check valve and opening up the pushrod bleed hole allows the lifters to work more efficiently.

This allows the valve to seal more positively preventing the carbon build up and the valve seat faces and stay cleaner longer.

2 Applicability

All Hydraulic Lifting Jabiru Engines up and till Hollow Pushrod Engines series.

3 Approval

Approval of this procedure is provided by signatory indicated in the approval block at the footer of Page#1, for and on behalf of Shadow Lite c.c.

4 Priority

It is recommended that by the next service this upgrade is done.

REVISION	0	1					20-Oct-11	SHADOW LITE C.C.	PAGE 1 of 2
APPROVED BY	SIGNATURE							APPROVING AUTHORITY	APPROVAL DATE
	[signature]							SHADOW LITE C.C.	14-Dec-10

5 Requirements

This is mandatory

Man hours to complete : 7 hours

Purchasing of hydraulic lifters, manifolds (p/n SA00ALKZ) manifold pushrods and pushrod tubes

6 Acceptable Methods

Only appropriatedly trained and rated persons to carry out the work

Step	Task	Action and Description
1	Remove exhaust intakes and inlet tubes	Refer to engine manuals
2	Remove cylinder head	Refer to Engine manuals
3	Remove push rod tubes and send to Shadow Lite CC	Refer to engine manuals
4	Remove and replace hydraulic lifters.	Refer to engine manuals
5	Push rods to be modified.	Refer to engine manuals
6	Jig drill and tap, drain and manifold holes	Refer to engine manuals
7	Shorten pushrod tubes	Refer to engine manuals
8	Assemble manifolds p/n SA00ALKZ and ensure correct sealants & o-rings	Refer to engine manuals
9	Assemble newly modified pushrods and tubes.	Refer to engine manuals
10	Reassemble engine.	Refer to engine manuals
11	Run and check engine.	As per engine manual Record Blow bys in log book
12	Record in logbook	According to SACAA requirements