AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/2/3/9462		
Aircraft Registration	**ZU-RHO**	**Date of Accident**	8 August 2015		**Time of Accident**	0519Z	
Type of Aircraft	RAF 2000 GTX SE F1– Gyroplane		**Type of Operation**		Private Operation – Part 94		
Pilot-in-command Licence Type	National Pilot Licence (NPL)		**Age**	45	**Licence Valid**	Yes	
Pilot-in-command Flying Experience	Total Flying Hours		125.0		Hours on Type	125.0	
Last point of departure	Avontuur Airfield, Eden District, Western Cape						
Next point of intended landing	Graaff-Reinet Airfield, Cacadu District, Eastern Cape						
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)							
Runway 06, Avontuur Airfield							
Meteorological Information	Wind: NNE/2kt; Temperature: 8˚C; Dew point: Unknown; Clouds: Nil; Visibility: Good.						
Number of people on board	1 + 1	**No. of people injured**	2	**No. of people killed**	0		

Synopsis

During take off from Avontuur, The pilot reported that he felt a vibration and he was unable to control the aircraft. After climbing to a height of approximately 3.2m above ground level, the aircraft sank without warning and struck the ground, sustaining substantial damage. Both pilot and passenger suffered minor injuries.

It was determined during the investigation that the aircraft experienced a rotor hub bar assembly failure during take-off. The bolt installed between the rotor hub bar and winglet broke. Both rotor blades separated and were flung several metres to the left and right of the runway some distance from the main wreckage.

The rotor hub bar assembly was taken for metallurgical examination. The metallurgist's report concluded that the bolt had broken due to fatigue and repeated exposure to reverse bending loads in the horizontal/lead-lag operational plane.

Probable Cause

Loss of control during take-off due to fatigue failure of the Hex head high-strength shear bolt.

Contributing factor: Improper maintenance due to the failure to replace old bolt with a new one.

SRP Date	08 November 2016	Release Date	20 March 2017

AIRCRAFT ACCIDENT REPORT

Name of Owner	**:** Ben Pierre Stemmet
Name of Operator	**:** Ben Pierre Stemmet
Manufacturer	**:** Rotary Aircraft Marketing CC
Model	**:** RAF 2000 GTX SE F1
Nationality	**:** South African
Registration Marks	**:** ZU-RHO
Place	**:** Avontuur Airfield
Date	**:** 8 August 2015
Time	**:** 0545Z

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 establish legal liability****.*

Disclaimer

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1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 On 8 August 2015 at about 0507Z, the pilot and passenger arrived at Avontuur airfield in the Western Cape with the intention of flying from there in a gyroplane to Graaff-Reinet in the Eastern Cape. Here an approved person (AP) was standing by in Graaf-Reinet to conduct an annual inspection of the aircraft. The pilot and passenger planned to fly back to Avontuur after the inspection.

1.1.2 The pilot stated that he carried out a pre-flight inspection and was satisfied that the gyroplane was airworthy. He and his passenger then climbed on board. He started the engine, performed the run-up checks and taxied to the threshold of Runway 06.

1.1.3 He lined up ready for take-off, applied power, started the take-off run, and rotated after approximately 200m. During the initial stages of the climb, the aircraft started to develop a severe vibration, making it difficult for the pilot to stay in control. About 3m above ground level (AGL), the gyroplane suddenly sank, striking the ground and sustaining substantial damage.

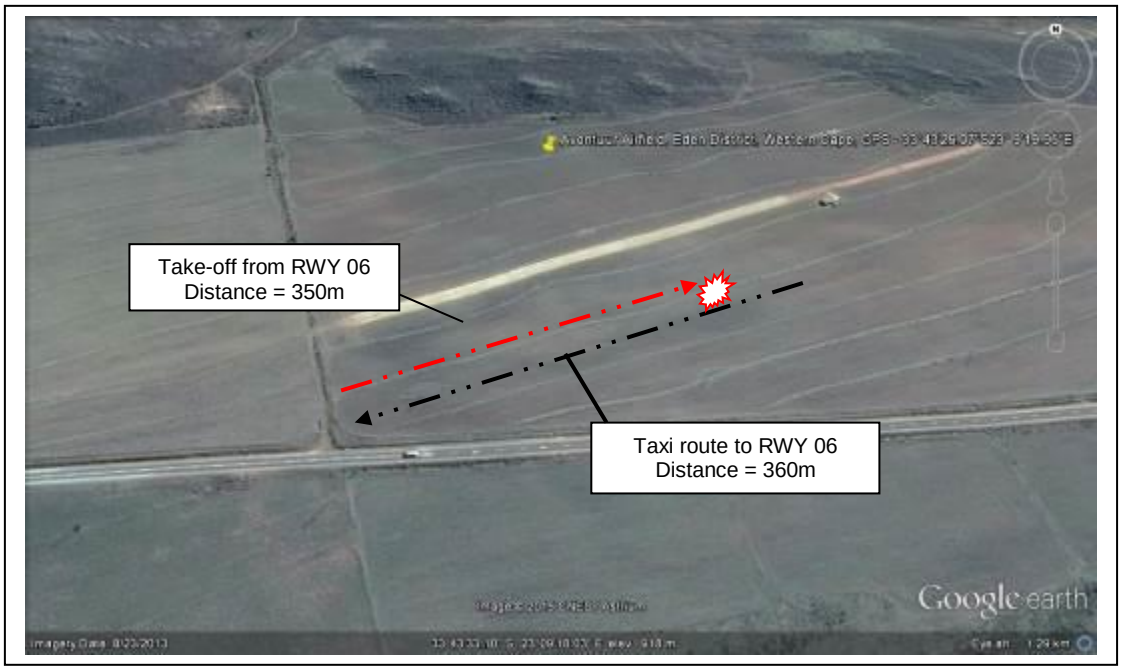


Figure 1: The position of the crash relative to the runway.

1.1.4 A farm worker on the airfield at the time of the accident saw the gyroplane taking off. After it lifted off the runway, he heard a loud bang, then saw one of the main rotor blades (winglets) separating from the aircraft. It was flung several metres towards the open grass area on the left side of Runway 06. A few seconds later, the other winglet also separated from the aircraft, landing in the open grass area on the right of Runway 06. He saw the aircraft fall and strike the ground, scattering debris and ending up on its left side. The pilot and passenger evacuated from the wreckage with minor injuries. The geographical coordinates of the accident site were 33˚43'26.07"S 023˚9'19.95"E and the elevation was 920m above mean sea level (AMSL).

1.2 Injuries to Persons

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

1.3 Damage to Aircraft

1.3.1 The aircraft sustained substantial damage in the accident.

Figure 2: Rear view of ZU-RHO, showing the extensive damage.

Figure 3: The winglet s/n B.A.A.S 6038.2 was flung onto open grass on the left of runway 06.

Figure 4: The winglet s/n B.A.A.S 6036.2 was flung onto open grass on the right of Runway 06.

1.4 Other Damage

1.4.1 None.

1.5 **Personnel Information**

1.5.1 Pilot in Command (PIC) flying experience:

Nationality	South African	Gender	Male	Age	45
Licence Number	0279016588	Licence Type	National Pilot Licence		
Licence valid	Yes	Type Endorsed	Yes		
Ratings	None				
Medical Expiry Date	The pilot had a valid Class 3 aviation medical certificate with no restrictions.				
Restrictions	The pilot had a valid Class 3 aviation medical certificate with no restrictions.				
Previous Accidents	ZU-RHO, roll-over accident in 2013				

Total Hours	125.0
Total Past 90 Days	4.0
Total on Type Past 90 Days	4.0
Total on Type	125.0

1.5.2 Approved Person (AP)

1.5.2.1 AP no. 246 had maintained the aircraft over the previous two years (2014 and 2015), carrying out the annual and 25-hour maintenance inspections.

1.5.2.2 The AP received his accreditation from Recreation Aviation Administration of South Africa (RAASA) on 15 July 2015. According to his AP certificate, he fulfilled the technical approved person scheme requirements. The AP certificate was valid until 31 July 2017. He was approved to carry out maintenance on non-type certificated aircraft (NTCA) and was rated on the RAF 2000, Ela gyroplanes, Xenon and ZEN 1. The certificate was valid until 31 July 2017.

1.6 **Aircraft Information**

Airframe

Type	RAF 2000	
Serial Number	M2-01-07-11-034	
Manufacturer	Rotary Aircraft Marketing CC	
Date of Manufacture	2012	
Total Airframe Hours (At time of Accident)	125.9	
Last Annual Inspection (Date & Hours)	13 August 2014	108.1

Hours since Last Annual Inspection	17.8	
Authority to Fly (Issue & Expiry Date)	12 September 2014	12 August 2015
C of R (Issue Date) (Present owner)	Ben Pierre Stemmet	
Operating Categories	NTCA – Part 94	

1.6.1 The aircraft documentation was inspected in the investigation to determine its validity. No anomaly was identified.

1.6.2 The aircraft maintenance documentation was also inspected, and it was found that the logbooks did not contain all the maintenance details as required by SACAA regulations. The following sections of the logbook contained no entries at all, despite an accident having taken place and compulsory checks being required:

(i) The record of major defects and damage did not contain the roll-over accident information as indicated by the pilot. He reported that the aircraft had been involved in the accident in 2013.

(ii) The record of compass swings was last certified on 28 June 2012 (almost three years before the accident in question). This indicates that the compass might not have been swung in the interval. (A check is required every two years)

(iii) The record of Class 1 product removal and replacements was not filled in. Based on the evidence of the roll-over accident, the aircraft would have sustained damage to the propeller and engine, both Class 1 products. It is likely that these products would have been removed and either repaired or replaced.

(iv) The record of modifications embodied had no entries. The evidence shows that the part namely RAF Rotor Stabilator installed on the instrument panel was not approved on the equipment list. It may therefore have been installed after the equipment list was approved.

(v) There were no entries in the mass and balance section. On 11 June 2012, the aircraft's empty mass was calculated as 341.28 kg. No further entries of mass and balance were certified. Based on the evidence of the roll-over accident, major repairs would have been carried out during the rebuild. The repairs would have affected the mass and balance of the aircraft and required it to be re-weighed.

1.6.3 During inspection of the aircraft flight folio, evidence was found that the owner/pilot had carried out oil and spark plugs changes on the aircraft himself.

Engine

Type	Subaru GTX SE F1
Serial Number	L194040

Hours since New	125,0
Hours since Overhaul	N/A

1.6.4 The aircraft had its original, factory-fitted engine when purchased by the owner/pilot. The engine was in a serviceable condition and the pilot did not report any anomaly with its performance.

Note: Rotary Air Force South Africa (RAFSA), Flight Operations Manual, Operating Limits, Rev 04, dated 28 February 2011, states:

"The Ministry of Transport, SACAA and FAA require that instruments are marked in the following manner:

Description		***RAF 2000 – EJ25 Engine***	
Max Water Temp	*Green Arc*	*150 – 215˚F*	*65.56 – 101.67˚C*
	Low Yellow Arc	*0 – 150˚F*	*0 – 65.56˚C*
	High Yellow Arc	*205 – 230˚F*	*96.1 – 110˚C*
	Red Line	*240˚F*	*115.56˚C*
Max Oil Temp	*Green Arc*	*162 – 240˚F*	*172.2 – 115.56˚C*
	Yellow Arc	*0 – 165˚F*	*0 – 73.89˚C*
	Red Line	*250˚F*	*121.1˚C*
Oil Pressure	*Green Arc*	*20 – 80 psi*	*137.89 – 551.58kPa*
Fuel Pressure	*Green Arc*	*28 psi*	*193,05 kPa*

The engine instrumentation was inspected to determine whether the instruments were marked as required above.

Figure 5: The instrument panel of the accident aircraft.

1.6.5.1 The water temperature and oil pressure markings are in degrees Celsius (˚C) and kilopascals (kPa), which differ from the degrees Fahrenheit (˚F) and pounds per square inch (psi) published in the flight operations manual. This implies that the pilot would have had to constantly make conversions throughout the flight when reading engine information. In addition, the instruments had different markings (green arc, yellow arc and red line) to those required by SACAA regulations.

Note: The pilot indicated that he was aware of the operating limitations in the flight operations manual. He was also aware of the instrument units, but had never had to do any conversions himself, as the limits had been pointed out to him during his NPL flight training.

1.6.5.2 An oil temperature gauge and fuel pressure gauge were not fitted.

Propeller

Type	Warp Drive
Serial Number	C19442
Hours since New	39,0
Hours since Overhaul	N/A

1.6.5.3 Maintenance of the propeller was inspected during the investigation. The aircraft had been fitted with propeller s/n N18083 at the time of the roll-over accident. This was damaged in the accident and exchanged with propeller s/n C19442.

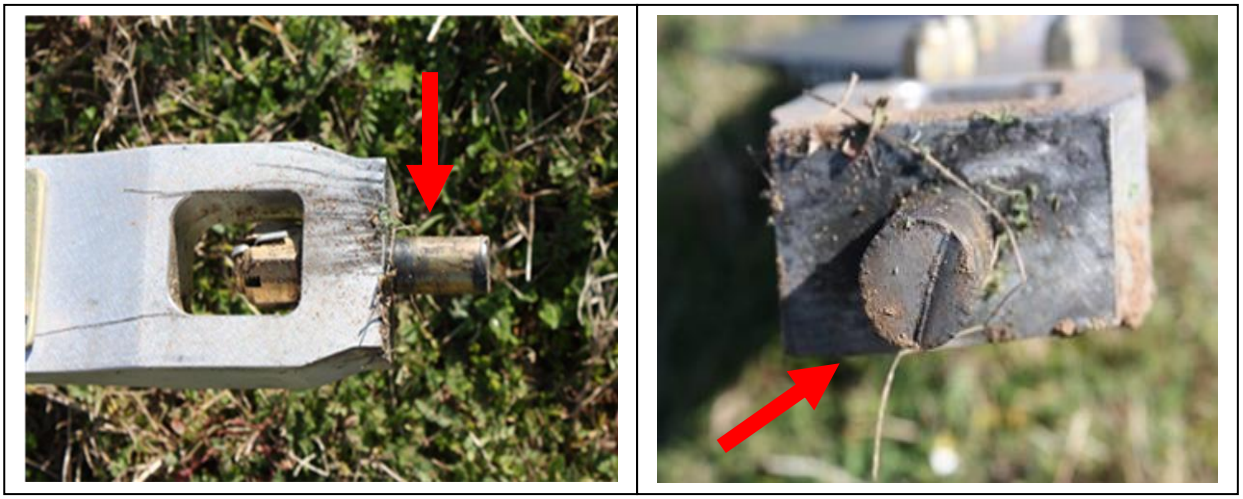
Rotor Assembly

Type	RAF fibreglass	
Hours since New	39,0	
Rotor Blades (Serial Numbers)	B.A.A.S 6038.2	B.A.A.S 6036.2

1.6.6 The rotor hub bar assembly maintenance was inspected during the investigation. The logbook entry in the scheduled inspection record states that *"the rotor winglet (blade) with s/n B.A.A.S 6006.2 and s/n B.A.A.S 6001.2 was replaced"* on 23 July 2012. The reason for the replacement is not written down. Another entry dated 5 November 2013 was recorded as an *"inspection for ATF"* where the work performed was *"done complete roll-over replacement as per manufacturer's requirements".* The above winglets were exchanged with S/N B.A.A.S 6036.2 and S/N B.A.A.S 6038.2.

1.6.6.1 The owner/pilot stated that after the aircraft had been rebuilt by RAF and transported from Upington in the Northern Cape by road to Avontuur. The winglets were removed for the road trip and installed by the AP on arrival in Avontuur.

1.6.6.2 During the onsite investigation, evidence was found indicating that the aircraft had experienced rotor hub assembly component failure. As indicated above, the winglets separated from the aircraft during take-off. The preliminary finding was that the RAF NAS bolt, part no. RAF 501012, installed to secure the winglet s/n B.A.A.S 6038.2 to the hub bar broke.



Figures 6 and 7: Side and front views of the sheared RAF NAS bolt, part no: RAF 501012.

1.6.6.3 The rotor hub bar assembly with the broken bolt was recovered from the accident scene for examination by a metallurgist to determine the cause of failure.

1.6.7 The aircraft's fuel status was inspected during the investigation. The pilot reported that he had refuelled the aircraft to capacity with 85kg BP 95 unleaded grade fuel on 6 August 2015, two days before the accident.

Note: The fuel tank was checked during the onsite investigation and found to be half-full, despite a substantial quantity of fuel having leaked from the wreckage.

1.6.8 The mass and balance was inspected and determined to be as follows:

Description	**Weight**
Maximum permissible mass	1 540 lb (698,53 kg)
Empty mass	752,39 lb (341,28 kg)
Fuel mass	187,39 lb (85,0 kg)
Occupants (pilot + passenger) mass	357,15 lb (162,0 kg)
Total take-off mass	**1 296,94 lb (588,28 kg)**

Note: Based on the above, the aircraft mass and balance was 110,25kg below the maximum permissible weight. Thus, the mass and balance was found to be within prescribed limits and did not contribute to the cause of the accident. However, it should be noted that in June 2012 when the aircraft was weighed the empty mass was calculated to be 341,28kg. If the rebuild after the roll-over accident is considered, the likelihood was that the new parts and/or components installed would have affected the empty mass. Re-weighing was required in the interest of aviation safety. The finding is that during the last maintenance, the empty mass was indicated unchanged at 341,28kg. Incorrect mass and balance are detrimental to safety.

1.7 Meteorological Information

1.7.1 The weather conditions at the time and place of the accident were submitted by the pilot in a questionnaire and are as follows:

Wind direction	NNE	Wind speed	2kt	Visibility	Good
Temperature	8˚C	Cloud cover	Nil	Cloud base	Nil
Dew point	Unknown				

1.7.2 The evidence was that the prevailing weather conditions were fine on the day and did not play a role in the accident.

1.8 Aids to Navigation

1.8.1 The aircraft was fitted with standard navigation equipment approved by the SACAA. There was no evidence of any defect or malfunction experienced by the pilot with this equipment and it was concluded that the equipment was in a serviceable condition for the flight.

1.8.2 RAFSA Flight Operations Manual, page 11 of 35, Operations Limitations Section, states: *"The Minister of Transport, SACAA and the FAA require that the instruments are marked in the following manner."* The requirements for the airspeed indicator are as follows:

Description – Airspeed Indicator	**RAF 2000 – EJ25 Engine**
Green arc	40 – 100 mph
Yellow arc	0 – 40 mph
Red line	100 mph

1.8.3 The airspeed indicator was inspected to ascertain whether it conformed to the required markings as per the flight operations manual.

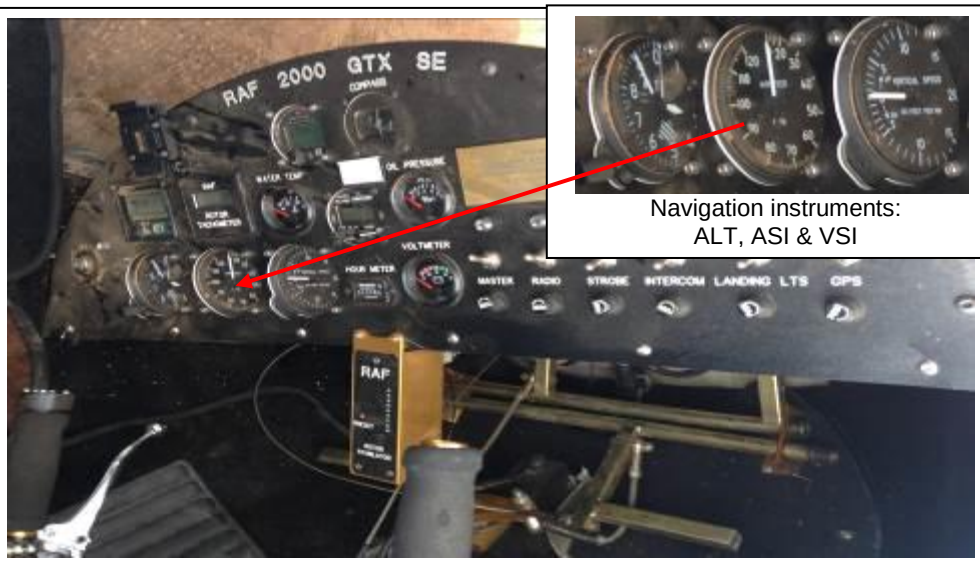


Figure 8: The airspeed indicator on the instrument panel.

Note: The airspeed indicator (ASI) was not fully compliant with the marking requirements published in the RAFSA flight operations manual. The instrument represented a danger to the pilot and occupants as it did not clearly indicate a green arc (normal operation airspeed range), a yellow arc (caution airspeed range), and a red line (never-exceed airspeed range markings).

1.8.3 The aircraft was fitted with a GARMIN AERA 500-type global positioning system (GPS). The pilot used the GPS as a navigational aid and planned to upload latitude 32˚11'30" S (-32.193600) and longitude 024˚ 32' 31" E (24.541401) into the GPS for the flight to Graaff-Reinet. The GPS was valuable to the investigators due to its recording capability. It was recovered from the accident scene in order to download its track information to assist in the investigation.

1.8.4 Avontuur airfield is an unlicensed privately operated aerodrome used by recreational pilots. It is not equipped with navigational aids.

1.9 Communications

1.9.1 The aircraft was fitted with a VHF Flight Com Model 760-type radio, approved for use as per the equipment list. There was no report of any defect or malfunction experienced by the pilot with the radio and it was in a serviceable condition.

1.9.2 Avontuur airfield is an unmanned aerodrome. There is no ground communication equipment available. All aircraft operating to and from the airfield are required to conduct their broadcasts/transmissions on the general frequency 124.8 MHz to comply with unmanned airfield communication procedures.

1.9.3 According to the pilot, there were no other aircraft operating in the airspace above the airfield when he took off. He had his radio set on frequency 124.8 MHz but no communication was required at the time. However, prior to take-off, the pilot

telephoned the AP in Graaff-Reinet to tell him he was taking off from Avontuur.

1.10 Aerodrome Information

Aerodrome Location	Avontuur, Eden District, Western Cape	
Aerodrome Co-ordinates	33˚43'26.07" S 023˚9'19.95" E	
Aerodrome Elevation	920m	
Runway Designations	06/240	
Runway Dimensions	390m x 20m	
Runway Used	06	
Runway Surface	Spoil (Gravel)	
Approach Facilities	None	

1.10.1 Avontuur airfield is an unmanned, unlicensed aerodrome primarily utilised for recreational aircraft flight operations. The airfield is located in an agricultural area. The facilities available are a small brick building hangar on the right side of the runway about 390m away from the threshold of runway 06, and a windsock on the left side about 360m from the threshold of runway 06.

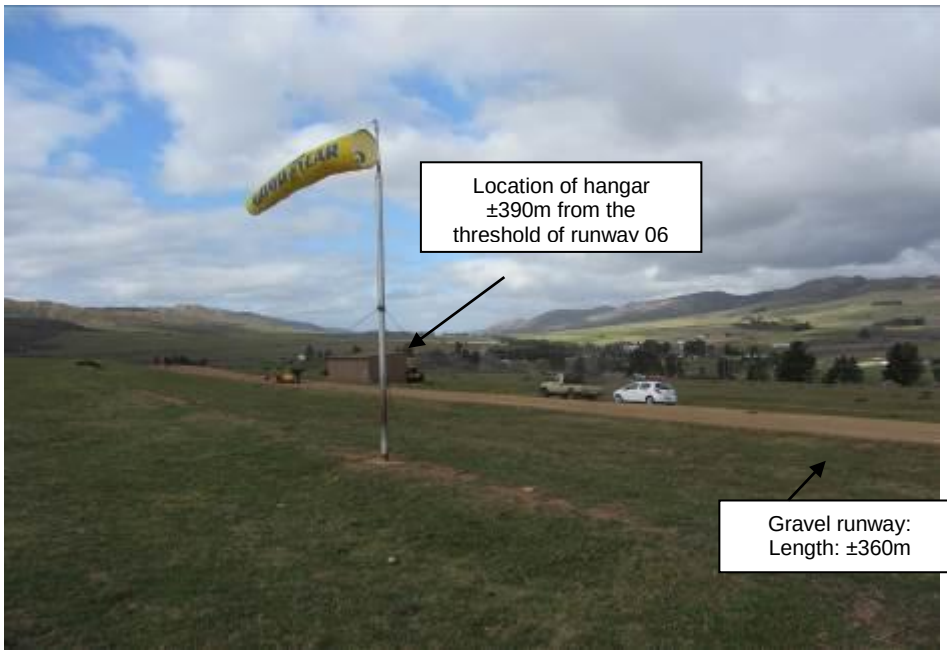


Figure 9: Avontuur airfield facilities.

1.10.2 During the investigation, horses were found grazing on the aerodrome grounds. The aerodrome was surrounded with a wire fence. Access was through a locked gate.

1.11 Flight Recorders

1.11.1 The aircraft was not equipped with any flight data recorders. None was required on this aircraft type.

1.11.2 The aircraft had a GPS installed as a form of navigation aid. It recorded limited track-flown information - date and time, longitude and latitude coordinates, altitude, indicated airspeed and true track. The GPS was recovered from the aircraft for downloading.

1.12 Wreckage and Impact Information

1.12.1 The aircraft sustained substantial damage in the accident. The investigation determined that the impact sequence took place as follows:

(i) The rotor winglet s/n B.A.A.S 6038.2 was found 195m from the wreckage on a heading of 315° true (north-westerly), at the coordinates 33°43'25.35"S 23°9'26.05"E. This was on the left side of the runway. There was no structural damage to the winglet and the leading and trailing edge were still intact. The fibre glass outer skin from the root to the tip displayed flutter damage and there were soil stains on the tip caused by ground strike. The point of impact could not be identified as the area was grassed.

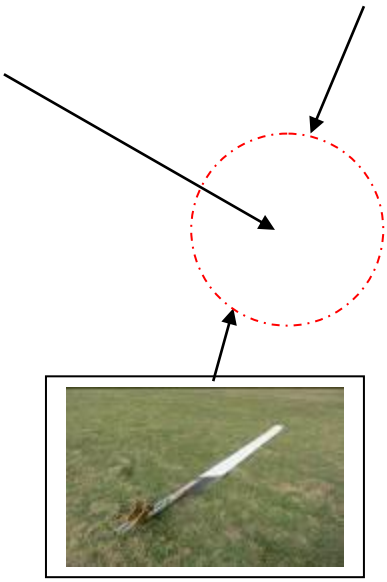
(ii) Close-up examination of this winglet showed evidence of rotor hub bar failure. The RAF 501 ANS bolt had broken, causing the winglet to separate from the aircraft during take-off. The broken bolt head had sheared off completely, resulting in the winglet disconnecting from the hub bar assembly.

(iii) The rotor winglet s/n B.A.A.S 6036.2 was found connected to the hub bar assembly. The winglet was found 95m from the wreckage on the heading 135˚ true (south-easterly) at the coordinates 33°43'28.86"S 23°9'24.60"E. This was on the right side of the runway. This winglet did not have any visually noticeable structural damage. The leading and trailing edge and fibre glass outer skin were all intact.

(iv) A visual examination of the parts showed that the bolts holding the pitch adjustment tower bearing block plate had broken. The result was that the rotor head assembly had also separated from the aircraft.

(v) Other debris scattered around the main wreckage included pieces of the right side main wheel tyre, the nose wheel assembly, pieces of rubber from the engine drive belt, and pieces of propeller blade composite material. The debris was scattered in a radius of between 20m and 30m around the main wreckage.

(vi) The main wreckage, consisting of the airframe and engine (both intact), was found 363m from the runway threshold on a heading of 063° true (north-easterly) at the coordinates 33°43'27.24"S 23°9'25.91"E. The aircraft had rolled over during the ground impact sequence. The wreckage was found lying on its left side. During the roll-over, severe damage was caused to the engine cradle metal structure, including the landing gear struts.



1.13 Medical and Pathological Information

1.13.1 The pilot had a valid Class 3 aviation medical certificate with no restrictions.

1.13.2 The pilot and passenger sustained only minor bruises in the accident.

1.14 Fire

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

1.15 Survival Aspects

1.15.1 The accident was considered to be survivable. The airframe structure was largely intact after the accident and the aircraft had experienced low impact forces. The pilot and passenger sustained only minor injuries.

1.15.2 The pilot and passenger were properly restrained with the aircraft safety harnesses. After the gyroplane rolled over and came to a halt on its left side, the pilot and passenger unbuckled their harnesses and evacuated from the aircraft.

1.15.3 No emergency medical services (EMS) were called to the accident scene.

1.15.4 The pilot stated that he was very concerned about the fuel leak as it posed a fire risk, and he therefore switched off the engine and electrical power before evacuating the wreckage. The airfield had no fire-fighting equipment, which meant that the pilot and passenger would almost certainly have been fatally injured if a fire had broken out on impact.

1.16 Tests and Research

1.16.1 The RAFSA Performance Operating Limitations Manual, Rev 04, dated 28 February 2011, states the following:

(i) *"During take-off, the engine run should be at 1 250 to 1 350 rpm. The pilot to engage the rotor clutch gently (not fully at this stage as this will cause excessive ware on the components). As rotor rpm builds up, pressure can be added to clutch. Control stick forward until 100 rotor rpm. Clutch can now be engaged fully. Control stick aft 10º (or halfway) to 125 rotor rpm. Control stick 20º aft (full) until 150 – 200 rotor rpm. Begin take-off roll with rotor clutch engaged and 150 rpm or more (ROTOR TACHOMETER READINGS ARE VERY IMPORTANT). Gradually roll on engine power with rotor clutch still engaged. Hold rudder to maintain heading. WATCH ROTOR TACH at 180 or 200 rpm. Disengage rotor clutch and when rotor rpm is at 200 or more, increase engine power to full power. For DUAL OCCUPANT, push stick forward (3°-4°) to keep aircraft nose wheel on ground. With rotor rpm at 280 the aircraft will run on main wheels and nose wheel (DO NOT balance aircraft on main wheels only) until the gyroplane lifts off runway. Dual occupancy will need a take-off speed of 35 - 45 mph to become airborne."*

1.16.2 The GPS of the aircraft was recovered for downloading by Accident and Incident Investigation Division (AIID) personnel, who retrieved the track information from its data card. This helped to reconstruct all the flights which the pilot had flown with ZU-RHO. The track information was plotted using Google Maps.

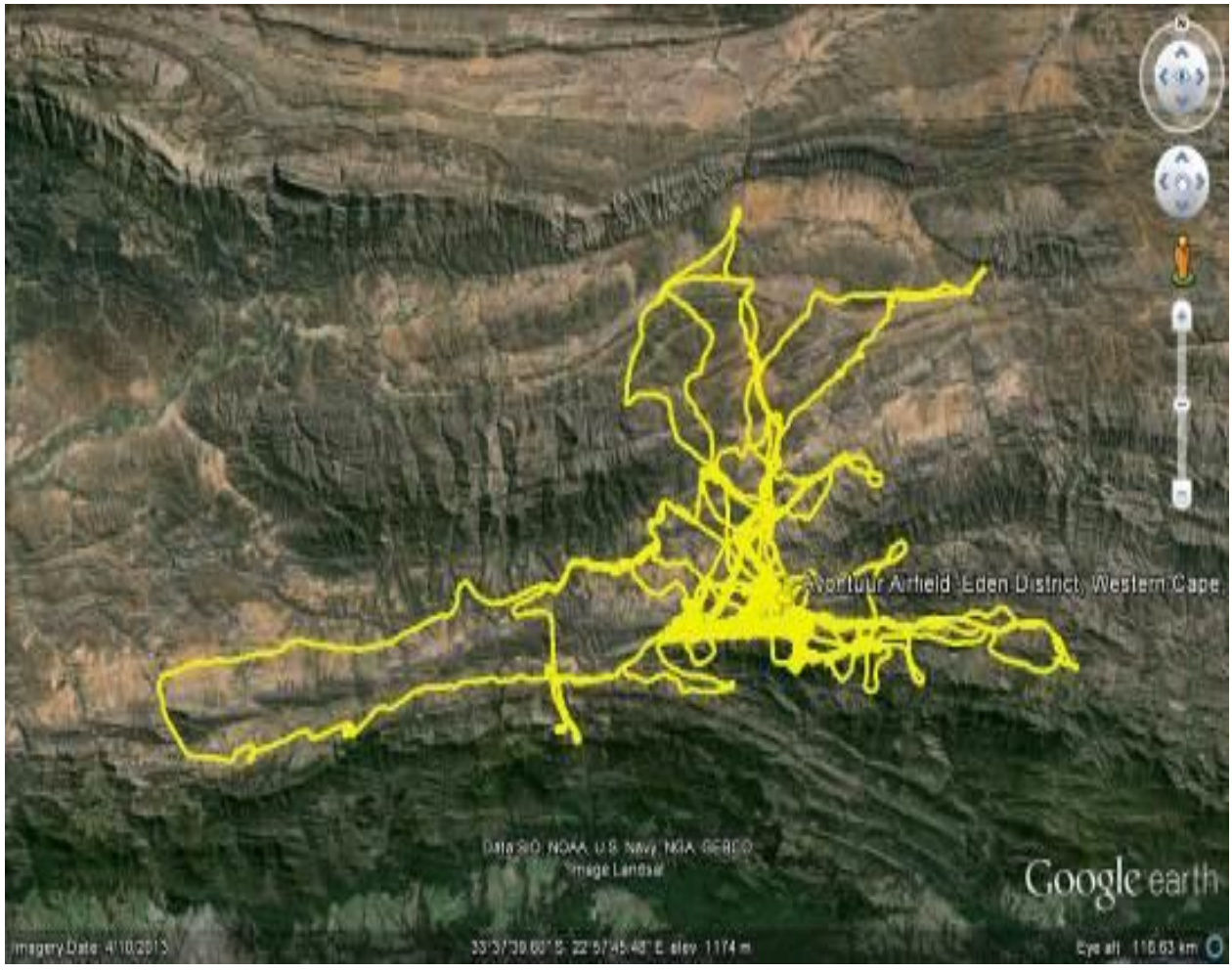


Figure 11: The tracks flown in ZU-RHO during the 18 months up until the accident flight.

1.16.3 The above map show the GPS track information from 7 February 2014 until 8 August 2015. All the flights were flown in and around Avontuur.

1.16.4 The track information for the accident flight was also downloaded and is presented below:

Date	Time (local)	Co-ordinates (latitude/longitude)	Altitude (AMSL)	Distance taxi/ take-off	Indicated airspeed	Track (true)
8 August 2015	07:07:35	S33˚43.811 E23˚09.737	118m	53m	8km/h	307˚
	07:07:58	S33˚43.794 E23˚09.709	132m	51m	5km/h	311˚
	07:08:33	S33˚43.776 E23˚09.684	147m	17m	1,3km/h	336˚
	07:09:20	S33˚43.768 E23˚09.680	153m	31m	2km/h	330˚
	07:10:34	S33˚43.753 E23˚09.670	170m	9m	1,3km/h	305˚
	07:10:59	S33˚43.751 E23˚09.665	174m	12m	10km/h	244˚
	07:11:03	S33˚43.753 E23˚09.658	174m	687m	99km/h	322˚
	07:11:28	S33˚43.461 E23˚09.384	954m	79m	12km/h	238˚
	07:11:51	S33˚43.484 E23˚09.341	942m	91m	14km/h	237˚
	07:12:14	S33˚43.510 E23˚09.292	931m	113m	16km/h	243˚
	07:12:40	S33˚43.538 E23˚09.226	931m	41m	10km/h	243˚
	07:12:55	S33˚43.548 E23˚09.202	930m	5m	5km/h	182˚
	07:12:59	S33˚43.551 E23˚09.202	930m	9m	2km/h	95˚
	07:13:17	S33˚43.551 E23˚09.208	929m	0m	0km/h	39˚
	07:18:35	S33˚43.551 E23˚09.208	929m	16m	12km/h	58˚
	07:18:40	S33˚43.546 E23˚09.218	929m	84m	51km/h	61˚
	07:18:46	S33˚43.525 E23˚09.265	927m	138m	62km/h	63˚
	07:18:54	S33˚43.491 E23˚09.345	927m	87m	78km/h	63˚
	07:18:58	S33˚43.469 E23˚09.395	925m	54m	49km/h	65˚
	07:19:02	S33˚43.457 E23˚09.427	920m	1m	0,9km/h	40˚
	07:19:07	S33˚43.457 E23˚09.428	919m	8m	0,8km/h	258˚
	07:19:44	S33˚43.458 E23˚09.422	922m	276m	0km/h	320˚
	02:18:50	S33˚43.344 E23˚09.307	118m	280m	6km/h	139˚
	02:21:36	S33˚43.457 E23˚09.426	-	-	-	-

Figure 12: The downloaded GPS information for 8 August 2015.

1.16.4.1 The explanation of the above GPS track information is as follows:

(i) The recording started at 07:07:35 and ended at 07:19:44 on 8 August 2015.

(ii) At 07:11:28, co-ordinates S33°43.461 E23°09.384, the aircraft taxied a distance of 79m on the runway, heading 238° and with a groundspeed of 12km/h to runway 06 threshold.

(iii) At 07:11:51, co-ordinates S33°43.484 E23°09.341, the aircraft taxied 91m on the runway, heading 237° and with a groundspeed of 14km/h to runway 06 threshold.

(iv) At 07:12:14, co-ordinates S33°43.510 E23°09.292, the aircraft taxied 113m on the runway, heading 243° and with a groundspeed of 16km/h to runway 06 threshold.

(v) At 07:13:17, co-ordinates S33˚43.551 E23˚09.208, the aircraft reached the threshold of runway 06. The pilot started turning to line up for the take-off. The groundspeed was reduced to 0km/h.

(vi) At 07:13:18, the take-off run was underway on runway 06. The groundspeed went from 0km/h to 12km/h over 16m, 51km/h over 84m, 62km/h over 138m, and reached a maximum of 78km/h over 87m. The total distance covered was 325m.

(vii) At 07:18:54, the groundspeed suddenly reduced from 78km/h to 49km/h over a distance of 54m, and from 0,9km/h to 0,8km/h to 0km/h.

1.16.5 The GPS information was loaded onto a software program that displayed the track points in a vertical profile graph:

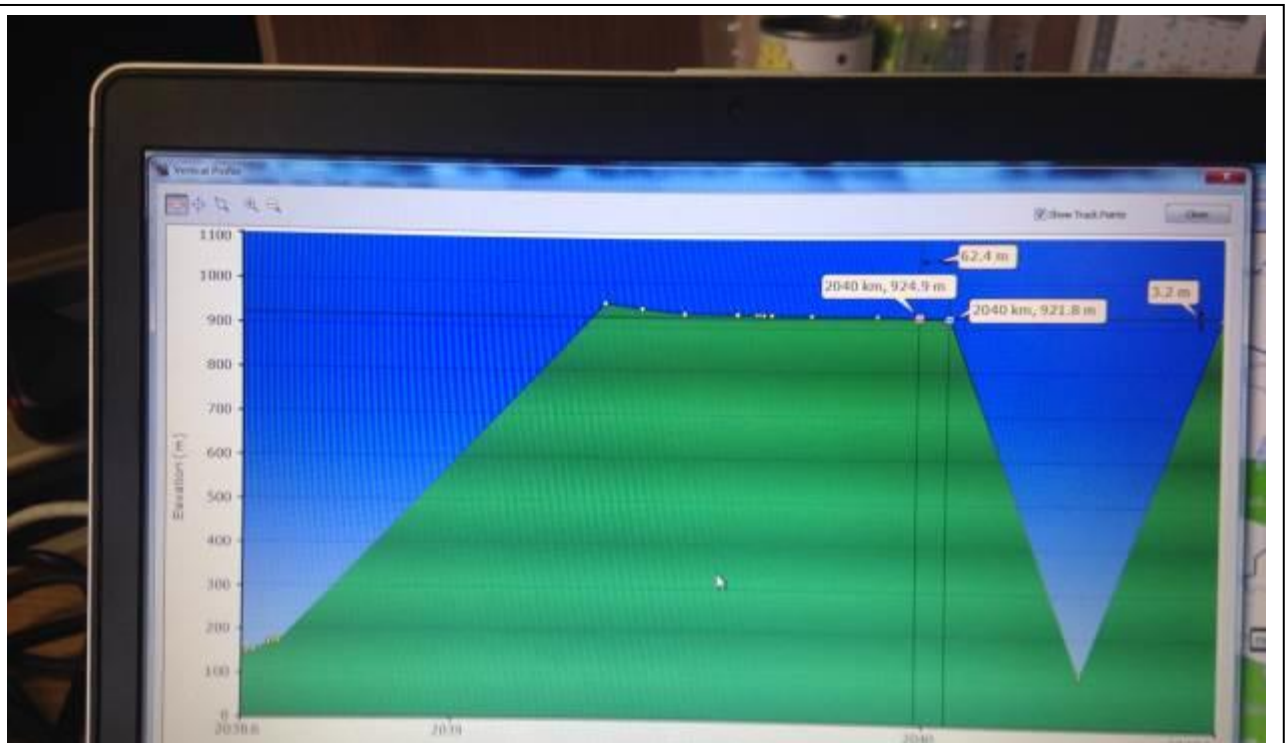


Figure 13: The flight profile of the accident aircraft presented as a vertical profile graph.

1.16.5.1 The above graph shows ground elevation, distance and track points:

(i) It shows the airfield elevation as 920m above mean sea level (AMSL). The lowest point on the runway, in the location of the hangar, is 921,8m and the highest near to the runway 06 threshold, is 953,7m. The difference between the two elevations is -31, 9 m. The runway gradient is downhill.

(ii) The runway length is 390m. The track points show that from the threshold to the point at which the aircraft lifted from the ground was 350m, heading 62,6° (NE) direction. The aircraft climbed to an altitude of 924,9m AMSL. It then fell from this height at a sharp angle of less than 30° to the ground. The main wreckage was found near the hangar on the runway at about 360m from the runway threshold. The elevation at this point is 921,8 m, which indicates that the aircraft had climbed to a height of only 3,1m above ground level (AGL).

1.16.6 The rotor hub bar assembly and broken bolt were recovered for examination by a metallurgist, who later issued a technical report – AAI-011-12-15 of 11 December 2015. His conclusions were as follows:

(i) "The investigation results revealed fatigue to be the No. 1 MR blade attachment bolt primary fracture mode while exposed to reverse bending loads in the horizontal/lead-lag MR operational plane.

(ii) The No. 2 MR blade attachment bolt revealed comparative indications of fracture initiation relative to position and orientation with bolt No. 1.

(iii) The most probable primary cause/s for the initiation of the fatigue fractures can be attributed to one, or a combination, of the following:

- *Operational Exposure. Although it is assumed for this investigation that the*

aircraft has been operated within the OEM/Authority set limits, the possibility exists that these limits may still allow exceedances concerning the overall operational capability of the MR assembly.

- *Assembly/Design. The investigation results have shown that the washers (No. 1 and No. 2) at both the bolt head ends dimensionally exceed the slotted sections in the MR blade attachment brackets. During fitment this may render a ''false'' torque value. When exposed to normal centrifugal loads during operation, the washers mechanically interact with the MR blade attachment bracket with resulting bending damages noted. This may lead to lowering the applied torque with resultant movement of the bracket/bolt assembly in the shear direction (horizontal/lead-lag) as well as the inducement of excessive forces on the fracture-prone bolt head radius".*

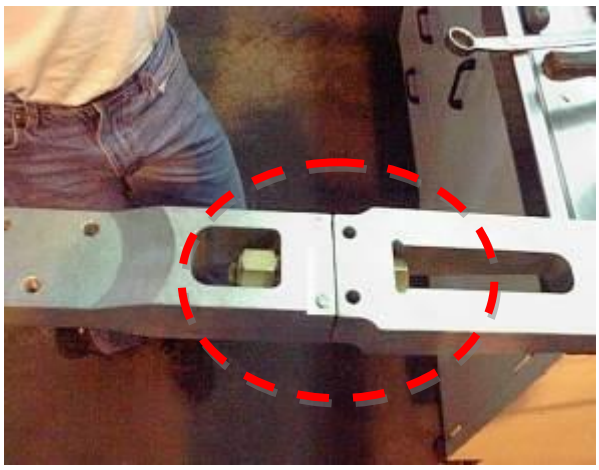
Note: See attached the complete metallurgist's report.

1.16.7 RAFSA, Procedure No. 7 issued April 2007, revised 28 February 2011 (Rev 001), provides detailed information on the hub bar assembly as follows:

(i) "A bolt p/n AN12-34A should be inserted through the large 3/4" hole at the end of hub bar from the inside so the threads are extending away from the hub.

(ii) Insert a winglet onto the extending bolt, then install a ¾-inch machined washer and secure with an AN365-1216 nut. With the blade pitch buttons facing upward, align the machined surface of the winglet to be parallel with the top surface of the hub bar. Tighten nut all the way up threads until snug.

(iii) Select two AN5-23A bolts, four AN960-516 washers and two 5/16-inch lock nuts. Position the plate onto the top of the hub bar at the end and align the holes in the plate with the holes in the hub bar. Insert a washer onto each bolt and insert bolts through the pitch adjustment plate (from the top) and through the hub bar. Insert a washer and nut onto each bolt. Torque to 150in-lbs."



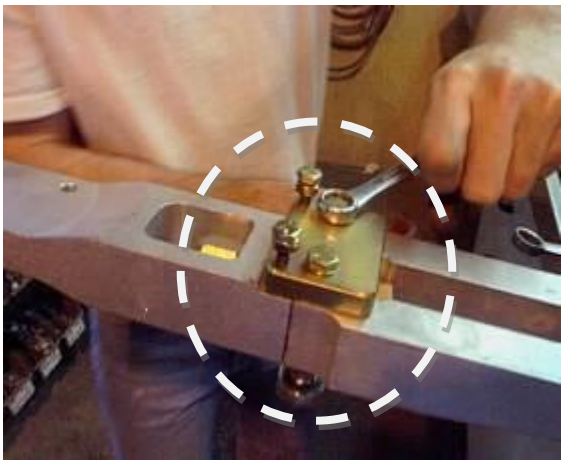


Figure 14; Hub bar winglets assembly

1.16.8 Product Notice 39 of 14 December 2004, dealing with "Hub Bar Winglets" and "AN 12 Bolt", states the following:

"Several hub bar winglets have developed cracks due to extenuating circumstances beyond RAF's control. Some have questioned the hub bar winglet's strength. Also during an incident one of the AN12 bolts suffered a catastrophic failure at the head. The AN12 bolt sustained a number of abnormal-stress loads beyond RAF's control."

1.16.8.1 Following mathematical calculations, it was determined that the centrifugal loading on the bolt was F (lb) = 11 470,9 lb. and the stress load was S (psi) = 5,735 psi. Hence RAFSA decided to exchange the bolt AN12 with AN12-34A rated at 50 000 psi to further increase the safety factor to the expected load of F (lbs.) = 11 470,9 lbs. The new AN12-34A bolt radius under the head was twice as large as that of the old AN12 bolt. A washer with a proper bevel cut to accommodate the radius was also installed. RAF's expectation was that the new AN12-34A bolt would increase its strength by 25%. Also, the hub bar and winglets were machined to eliminate the straight cuts on the top and bottom using the process of contour machining.

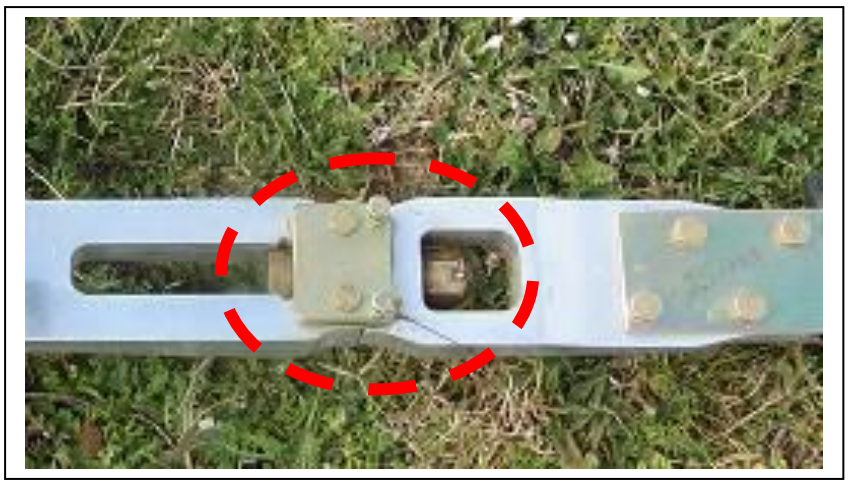
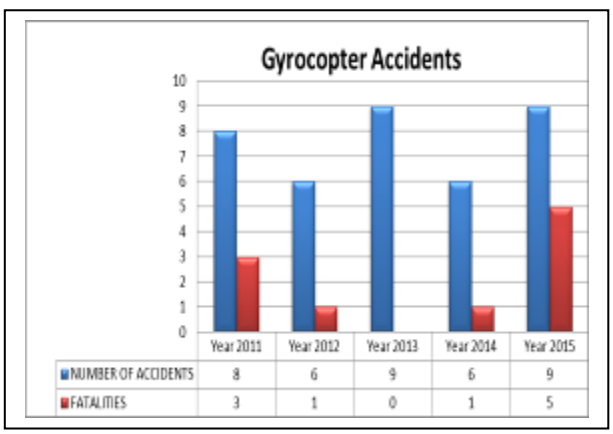


Figure 15 Hub bar winglets

1.16.9 The AIID occurrences database was checked for statistical information on gyrocopter accidents and serious incidents reported over the five years from 2011 to 2015. According to the database, 38 gyrocopter accidents and serious incidents were reported to AIID. The graphs below show the number of accidents per year and the relative number of fatalities:



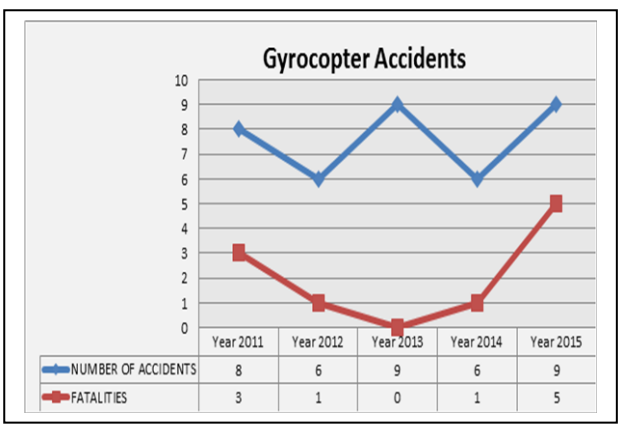


Figure 16 and 17, occurrence statistical information

1.16.9.1 The AIID incident reporting database was also checked. This showed that only three incidents involving gyroplanes had been reported by the owner/pilots operating in the NTCA environment over the same period. This situation is extremely worrying, as it means that the industry is non-compliant in terms of reporting. Incident reporting is crucial for monitoring trends, detecting potential problems in advance, and implementing corrective actions.

On request, SACAA informed the investigators that 50 RAFSA RAF 2000 aircraft were currently on the SA Civil Aircraft Register (SACAR) AR. These included the types RAF 2000 GS, GT, GTX, GTX SE and GTX FI. These aircraft are likely to be directly affected by the investigation and any other interim remedial actions taken by the aircraft manufacturer RAFSA.

1.16.9.2 In light of the above evidence, the investigator conducted a research to obtain additional information on gyrocopter accidents and fatalities worldwide to gain more insight into the safety record of the aircraft type. During the research, it was deemed critical to look into the issue of recommended design changes brought forward as a result of the UK CAA gyroplane research programme (wind tunnel and flight test activities). The evidence was as follows;

(i) Source: Gremline.com states *"Gyroplanes worldwide have a very much higher accident and fatality rate than other forms of recreational flying. The UK CAA instigated research to investigate the reasons for the unacceptably high accident/fatality rate in this class of aircraft. The research was conducted by Glasgow University. The research revealed a basic problem with the design of some, but not all, types of gyroplanes that result in inherent pitch instability in certain flight conditions."*

(ii) Source: Impact.ref.ac.uk states *"As a direct result of the University of Glasgow research, there have been no deaths in a gyroplane accident in the UK since 2009. Previously, gyroplanes had a questionable safety record. Following fifteen years of comprehensive studies, researchers recommended innovative new design standards to the Civil Aviation Authority. These recommendations led to the introduction of new civil airworthiness requirements in the UK, subsequently adopted by Australia and Canada. The implementation of these revised regulations has forced gyroplane manufacturers to change their designs. The key research findings from this extensive body of work include:*

- *Gyroplane aerodynamic properties are relatively insensitive to configurational changes;*
- *Gyroplanes exhibit a mix of stability characteristics typical of those of fixed-wing aircraft and helicopters;*
- *Raising the propeller location to ensure clearance with the aircraft keel could result in aircraft instability;*
- *A centre of gravity location above the propeller thrust line, created by lowering the keel, has a significant stability effect.*

"The key output was the 2008 report to the UK CAA recommending gyroplane design changes including lowering the keel. The recommendations were integrated into the British Civil Airworthiness Requirements (BCAR)

Section T: Light Gyroplanes, which is the legislation governing the safety of gyroplanes in the UK. The 2011 revised requirements have been adopted in Australia and Canada. The implementation of revised regulations for gyroplane design and modifications forced the European manufacturer, AutoGyro of Germany, to change its designs."

1.17 Organisational and Management Information

1.17.1 Owner/pilot and Approved Person:

1.17.1.1 The role of the owner/pilot was investigated. The evidence showed that he operated the aircraft privately (Part 24). He was responsible for the continued airworthiness of the aircraft and was required to ensure that it was operated safely. He was also required to ensure that it was maintained in accordance with applicable regulations. The logbooks show that he took the aircraft to RAFSA for maintenance in 2013. The aircraft had being involved in a roll-over accident and needed repairs. RAFSA completed these and the aircraft was returned to the owner/pilot. He appointed AP 246, who had the responsibility of continuing maintenance on the aircraft.

1.17.1.2 The role of the AP was investigated. It was deemed important to review his accreditation to carry out maintenance on the type, and RAFSA was requested to provide information in this regard. RAFSA stated that it was company policy to provide training in-house, and for this reason they had not issued training accreditation to any institution. In addition, they preferred gyroplane owners to bring their aircraft to Upington, where their facility was located, for maintenance. RAFSA records show that the last training was presented to the industry in 2014. RAFSA had no record of AP 246 attending any of their training sessions. RAFSA were unable to say where AP 246 had received the ratings authorising him to carry out maintenance on the aircraft. According to RAFSA, the only way the AP could have been issued with the rating was on the basis of an approval letter issued by the company. SACAA, Recreation Aviation Administration – South Africa (RAASA), Aeroclub and the South African Gyroplane Association (SAGPA), had been informed of this requirement. RAFSA had also written to the SACAA to make them aware of the fact that AP 246 had been servicing and certifying maintenance on RAFSA aircraft without having attended the required training.

1.17.1.3 For the purpose of the investigation, it was important to establish if AP 246 had been taught the technology of the gyroplane and trained to perform maintenance. In particular, it was important to know whether he had been trained on rotor balancing and approved to carry it out. RAFSA stated that they did not allow owners or APs to carry out any adjustments to the aircraft rotors, as they considered it a critical component that required special tools for adjustment. In order to carry out rotor balancing and tracking, sophisticated equipment was required, and this was only in RAFSA's possession in Upington. This meant that if an AP were to carry out field maintenance of balancing himself, he would most likely have done so with unapproved special tools. In this case, if carried out incorrectly, the consequence could be that the vibration had lessened, but the actual problem would be worse, putting the aircraft and its occupants in danger.

1.17.1.4 The AP's licence was obtained from RAASA. It indicated that he had fulfilled the requirements as set out by the technical approved person's scheme and thereby approved to carry out inspections on the RAF 2000. Thus, he was formally authorised to carry out maintenance as per the licence conditions.

1.17.2 Aircraft manufacturer – RAF:

1.17.2.1 RAFSA (Pty) Ltd was initially the only local distributor of the RAF 2000 kit-built aircraft, importing the type from a European-based company, Rotary Air Force Marketing Inc. At the time, all aircraft imported, including ZS-RHO, s/n M2010711034, were classified by SACAA as non-type certificated aircraft (NTCA) and approved as amateur/experimental-built aircraft. Later, on 2 April 2007, RAF Marketing Inc. acquired the marketing and manufacturing rights to RAFSA (Pty) Ltd in South Africa. RAFSA continued selling aircraft to the industry until March 2015, when it received manufacturing/assembly approval. The organisation was issued with certificate no: M688.

Note: Before 2014, RAFSA was an importer and assembler of the RAF 2000 kit aircraft. Thereafter, it has been responsible for also marketing and manufacturing it. In terms of CAR Part 148, Approval Requirements, the company has the responsibility to ensure that all production is performed to the required standards and is in continual compliance with the data and procedures identified in its manual of procedures.

1.17.2.2 Based on the above, RAFSA communicated with the AIID during the initial stages of the investigation to obtain as much information as possible to guide them on implementing preliminary preventative actions. As a result of this, on 13 August 2015 RAFSA issued Product Notice no. 51, Ref: C/Pronot.RAF-51: RAF Hub Bar – Mandatory Recall, stating "This recall affects all rotor blade shipments received from 1 April 2013". See attached copy of the product notice.

1.17.2.3 The DCA delegated the responsibility to the Aviation Safety Operations (ASO) Department, instructing that they look into the matter and pronounce further on the recommendations. The ASO deployed several of their technical personnel and continued to engage with RAFSA on the matter. The response received from SACAA included the following:

(i) A summary of the issues dealt with during engagements with RAFSA. These included reviewing the company's manufacturing and design processes, service difficulty (i.e. procedure and processes for notifying clients and the CAA), differentiation between Part 148-built and amateur-built aircraft, and the RAF hub bar mandatory recall notice). (See attached copy of the minutes on the issues discussed.)

(ii) The ASO departments concluded the matter by advising the DCA not to implement both AIID recommendations. They recommended that the amateur-built category remain de-regulated, and the CAA increase

enforcement and duty of care by ensuring that no commercial privileges or carrying of passengers (third parties) be associated with such aircraft or product. See attached copy of complete response.

1.18 Additional Information

1.18.1 RAFSA communicated with owners and operators, reminding them to refer to the RAF flight manual and operating procedures, found in the construction manual, when maintaining their aircraft. (Each RAF 2000 aircraft was shipped with its own construction manual.) After 1 May 2014, the RAF flight manual and operating procedures were printed as a separate booklet, and owners and operators were to ensure that they followed the RAFSA procedures accordingly. In addition, there were important product notices in the construction manual that the owner or operator had to adhere to at all times when performing maintenance. They included ensuring that APs had the necessary credentials and were familiar with all RAF product notices and service/maintenance schedules.

1.18.2 The description *"amateur-built aircraft*" means *"aircraft built in terms of the provisions of Part 24, including any of its components, and includes production-built aircraft from which the build standard deviated".* In terms of Part 24, all gyroplanes are defined as being amateur-built aircraft. Part 24 also states that "*an AP rated in accordance with Part 66 shall not be required to guarantee the airworthiness of the aircraft and that the owner or operator of the aircraft shall at all times be responsible for the airworthiness status of the aircraft".*

1.18.3 In terms of Part 24, Sub-Part 3, Approval of Organisations, the regulation clearly states that an applicant for the approval of a manufacturing or assembling organisation shall meet those provisions of Part 148. RAFSA was issued with a manufacturing/assembling organisation approval in March 2015.

1.19 Useful or Effective Investigation Techniques

1.19.1 None

2. ANALYSIS

2.1 The owner/pilot planned to fly gyroplane ZU-RHO from Avontuur private airfield in the Western Cape to Graaff-Reinet in the Eastern Cape for maintenance by an AP. He was to be accompanied by a passenger, his son. The gyroplane, parked in a hangar, was considered serviceable and airworthy, and contained 85ℓ of BP 95 unleaded fuel, having been refuelled two days before.

2.2 The pilot and passenger pushed the gyroplane out of the hangar and the pilot

conducted a pre-flight inspection. Everything was found to be in order. He started the engine, performed his pre-flight checks, and taxied to the threshold of runway 06. The GPS instrument on board was later downloaded by the investigators to provide a timeline of the aircraft's position, altitude, airspeed and track during take-off and flight.

2.3 The aircraft faced in a north-easterly direction into the wind with the brakes on. The pilot carried out his last engine run-up checks for just over five minutes. Then, with the engine speed at 1 250 rpm to 1 350 rpm, in adherence to the pilot's operating handbook, he engaged the rotor clutch gently for the rotor rpm to build up, and slowly applied forward stick control until 100 rpm was attained. He then engaged the rotor clutch fully, applying control stick aft 10° to 125 rotor rpm and again to aft 20° until 150 rpm to 200 rotor rpm was reached, ready to begin the take-off roll.

2.4 During the take-off roll, the pilot is required to keep a close eye on the rotor tachometer readings to ensure that the gyroplane rolls gradually on engine power, with the rotor clutch still engaged, while the rudder is held to maintain the heading. When there are two occupants, the gyroplane requires a take-off speed of 35 mph to 45 mph to become airborne. It is certified to climb at 900ft/min. According to the GPS data, the pilot started the take-off roll at 05.18:35Z and became airborne 19 seconds later about 200m from the threshold

2.5 The pilot stated afterwards that he did not experience any defect or malfunction with the gyroplane during the taxi run or take-off roll. Eight seconds after initiating lift-off, when he had reached a height of 2m, he felt a vibration in the fuselage and on the control stick, and found the gyroplane difficult to control. He did not know what caused the vibration, but due to its frequency and strength, described it as "severe". The vibration might have been due to a problem with the linkage between the control stick and rotor head assembly. Due to the severity of the situation, the pilot had only one option: to ensure the safety of himself and his passenger.

2.6 The aircraft climbed to a maximum height of 3,2m AGL, then sank rapidly in a nose-down attitude and yawing to the right. It struck the ground in that attitude.

2.7 The crash was witnessed by a farm worker. He reported seeing the gyroplane take off and the winglets separating from the rotor head assembly and being flung a considerable distance. Immediately thereafter, he saw the gyroplane fall and strike the ground, ending up on its left side, with the pilot and passenger trapped inside.

2.8 The aircraft sustained substantial damage, including broken fuel lines. Aware of the danger of fire, the pilot and passenger quickly vacated the wreckage. They had sustained only minor injuries.

2.9 During the subsequent investigation, the farm worker was able to confirm the separation of the winglets. Winglet s/n B.A.A.S 6038.2 was found lying 195m away on a heading of 315° relative to the wreckage and rotor blade s/n B.A.A.S 6036.2, still attached to the hub bar assembly was found 95m away on a heading of 135°.

(i) S/n B.A.A.S 6038.2) was inspected visually to determine the cause of failure. It was found was that the bolt (p/n AN12-34A) installed between the hub bar and winglet had failed. The broken bolt was recovered and examined by a metallurgist to determine the cause of the failure.

(ii) According to the metallurgist's report, the failure of the bolt was associated with fatigue fractures after exposure to reverse bending loads in the horizontal/lead-lag operational plane. The primary cause can be attributed to operational exposure or assembly/design issues, or both. More significantly, the metallurgist found that the washer installed at the bolt head end exceeded the dimensions of the slotted sections in the hub bar. This might have resulted in a false torque value during fitment of the bolt. Thus, when exposed to normal centrifugal loads during operation, this washer mechanically interacted with the hub bar, as seen by the resulting bending damages. This might have led to lowering the applied torque, with resultant movement of the hub bar/bolt assembly in the shear direction (horizontal/lead-lag) as well as the inducement of excessive forces on the fracture-prone bolt head radius.

(iii) The winglet S/N B.A.A.S 6036.2 was also inspected visually. It was found that its bolt (p/n AN12-34A) installed between the hub bar and winglet was still intact. However, this bolt revealed indications of fracture initiation that bore similarities with the bolt of winglet s/n B.A.A.S 6038.2.

2.10 Five days after the occurrence, the agent for gyroplane in South Africa, RAFSA, issued a product notice – Ref. C/PRONOT.RAF-51, RAF 2000 Gyroplane, RAF Hub Bar – Mandatory Recall to all RAF Owners – in the interest of aviation safety. This notified the industry and owners of the mechanical failure of the bolt and measures that the company was taking to correct the problem. They indicated that as a precautionary measure all hub bars must be returned to them immediately for inspection – and replacement if required, using proper torque settings. The product notice was labelled mandatory and had to be complied with by those who had received rotor blades shipments from 1 April 2013 onwards.

2.11 Based on the above information, the role of RAFSA was investigated. The evidence found showed that RAFSA had acquired all gyroplane marketing and manufacturing rights from the original manufacturer – Rotary Air Force Marketing Inc. in 2007. It meant that RAFSA took over all the responsibilities vested in Rotary Air Force Marketing Inc. involving the gyroplane. According to the SACAA, they were aware that RAFSA had acquired the indicated rights and were in the process of obtaining the necessary authority for them in South Africa. While RAFSA was preparing to comply with the requirements, they continued supplying and giving support to gyroplane owners. It took them eight years – from 2007 until March 2015 – before the SACAA eventually found them to be compliant and issued them with a manufacturing/assembly approval.

2.12 Previously, when RAFSA was operating as an agent under the stewardship of Rotary Air Force Marketing Inc, the company imported the gyroplanes as kit-built aircraft. RAFSA would then assemble the kits on behalf of the owners, in compliance with Part 24, and deliver them to their owners with all the operational and maintenance manuals required to safely operate the aircraft. RAFSA was also responsible for supplying the necessary parts, components and equipment as required by the owners on behalf of Rotary Air Force Marketing Inc.

2.13 It should be noted that RAFSA prefers to carry out maintenance on the gyroplanes

themselves. However, an owner has the option to appoint an AP for the task. Whenever an AP is appointed, RAFSA requires that he or she should undergo RAFSA training on the type. The training certificate will then be used to issue the successful candidate with a RAASA licence. The owner of ZU-RHO decided to appoint AP 246, giving him the responsibility of maintaining the gyroplane. But RAFSA has no record of AP 246 ever attending any of its training courses, nor has he ever been approved by RAFSA to carry out maintenance on the gyroplane. RAFSA thus questions the validity of the gyroplane rating on AP 246's RAASA licence.

2.14 The investigators spoke to AP 246 on several occasions during the investigation, questioning him about the maintenance activities certified by him in the aircraft logbooks. Due to the fact that the winglets separated from the aircraft, the investigation deemed it important that he should clarify certain issues about their installation. He admitted reinstalling the two rotor blades on the aircraft after they were removed by RAFSA, but apparently did not carry out any rotor balancing or tracking tests afterwards. The owner of the gyroplane confirmed that the AP had reinstalled the winglets. RAFSA emphasises that in order to carry out balancing and tracking, the AP needs special tools and testing equipment. The company does not allow any AP to carry out the tests themselves, as they are not trained for this nor have the required test equipment.

2.15 The above indicates why RAFSA issued Product Notice 51. However, the company singled out the winglets received from 1 April 2013. This does not make sense, considering that Rotary Air Force, Ref. W/Product Notice 39 refers to hub bar winglets and AN12 bolts dated 15 December 2004. The product notice indicates that another but similar incident occurred where the AN12 bolt suffered a catastrophic failure at the head. The bolt was taken to a metallurgist, who found that it had sustained a number of abnormal stress loads beyond RAF's control. This led to the decision to further increase the bolt's safety factor. According to RAFSA, "*the AN12 bolt was rated at 50 000 psi with an expected load of 11 470.9 psi, which is a four times safety factor"*. It employed a new bolt (RAF NAS 501-012 AFC) with a radius under the head twice large as the normal NAS bolt, and a washer with bevel cut to accommodate this radius. The new NAS bolt was claimed to be 25% stronger.

Note: Ref. NASBOLTS.CO.UK, NAS shear bolt has a hex head used in only shear applications with no threads exposed in the shear plane. A countersunk (or chamfered) high-strength, heat-treated washer matches the radius under the bolt head to clear the under-head shank radius. These bolts are used in applications where a high-strength bolt is required. A small, lightweight, self-locking, precision-formed hexagonal (six-point) nut is used.

2.16 It is evident from the above that it is incumbent on RAFSA to use the date of 15 December 2004 instead of 1 April 2013. The reason is that the bolt failure problem remains unresolved: the new RAF NAS bolt, like the AN12 bolt, also failed due to fatigue, this time as a result of the washer combined with the stress loads acting on it. The product notice should have been a recall of all the rotor head hub bar assemblies worldwide to urgently inspect for damage and carry out non-destructive testing (NDT) examination for fatigue on each one. RAFSA should go back to the drawing board to revisit their design standard of the rotor hub bar winglets and bolts installation, specifications and limitations.

2.17 A memorandum was written to the DCA proposing safety recommendations which in the opinion of Investigator in Charge (IIC) needed to be addressed immediately. The DCA forwarded this to the department of aircraft safety operations (ASO), which was charged with implementing a corrective action plan. ASO engaged with RAFSA accordingly, and responded as follows:

(i) ASO advised the DCA not to implement the proposed safety recommendations from AIID. It indicated that "amateur-built aircraft", which include gyroplanes, should remain "de-regulated". ASO proposed to the DCA that the SACAA should "increase enforcement". It is the opinion of the IIC that this action by ASO would be difficult to do if amateur-built aircraft were "de-regulated".

2.18 The accident and incident statistics of the RAF 2000 gyroplane's operations in South Africa were reviewed to examine the safety record of the type. A total of 50 RAF 2000 gyroplanes were registered on the SACAR. Over the five years 2011 to 2015, a total of 38 gyroplanes were involved in accidents and serious incidents, with 10 occupants being fatally injured. On their own, these statistics clearly show that the DCA should continue to regulate amateur-built aircraft in order to ensure the safety of their occupants, the public, industry and the environment.

3. CONCLUSION

3.1 Findings

3.1.1 The owner/pilot, accompanied by a passenger, intended embarking on a private flight from Avontuur private airfield in the Western Cape to Graaff-Reinet in the Eastern Cape.

3.1.2 The owner/pilot had a valid national pilot's licence (NPL) issued by RAASA, with the gyroplane rating endorsed on it.

3.1.3 The owner/pilot also had a valid Class 2 aviation medical certificate with no restrictions assued to him.

3.1.4 The owner/pilot carried out a pre-flight inspection on the gyroplane before take-off. He completed the pre-flight inspection, satisfied that the aircraft was in a serviceable condition and airworthy.

3.1.5 The airfield used was an unlicensed aerodrome that had no taxiways and only one smoothly graded gravel surface runway 390m in length and 20m wide.

3.1.6 The owner/pilot taxied to runway 06, lined up at the threshold, carried out his engine run-up checks and performed an uneventful take-off run. Seconds after the aircraft became airborne, at approximately 200m down the runway and at a height of 3,5m AGL, the rotor hub bar assembly sustained a catastrophic mechanical failure.

3.1.8 The owner/pilot reported that he felt a severe vibration just before this happened, and he had trouble controlling the gyroplane. The investigation discovered that the vibration came mainly from the main rotor transmission control system, and secondly from the airframe.

3.1.9 The owner/pilot was unaware that the aircraft had experienced a rotor hub bar assembly failure. The NAS hex head high-strength shear bolt – RAF 501-012 AFC – broke, and as a result the winglet (s/n B.A.A.S 6038.2) separated from the rotor hub bar and was found on the left side of the runway on an open grassy area 195m (heading 315˚) from the main wreckage in the direction of flight.

3.1.10 The other winglet (s/n B.A.A.S 6036.2), still connected to the rotor hub bar, also separated. It was found on the right side of the runway in an open grassy area about 95m (heading 135˚) from the main wreckage in the direction of flight.

The main wreckage was found on the runway 363m from the threshold of runway 06.

3.1.12 The NAS bolt that broke was recovered for further investigation by a metallurgist, who concluded that it had failed as a result of fatigue due to reverse bending loads in the horizontal/lead-lag operational plane.

3.1.13 The other NAS bolt was also examined by the metallurgist, who found that it had indications of fracture initiation similar to bolt No. 1.

3.1.14 The investigation revealed evidence of a previously reported incident of an AN 12 bolt suffering a catastrophic failure at the head. This was referred to in the Product Notice 39 dated 12 December 2004 issued by Rotary Air Force Marketing Inc. The product notice indicated that the AN12 bolt had sustained a number of abnormal stress loads beyond RAF's control, hence the decision to introduce the NAS hex head high-strength bolt to address the problem.

3.1.15 The metallurgist's report indicated that closer inspection of the NAS hex head, high-strength shear bolt, heat-treated washer and attachment bracket interface revealed extensive mechanical interaction at opposite positions.

3.1.16 Rotor hub bar assembly installations are carried out exclusively by the manufacturer, Rotary Air Force South Africa Pty Ltd (RAFSA). The industry is not authorised or approved to carry out the installation. If for any reason a defect is experienced with the rotor hub bar assembly, the gyroplane should be returned to RAFSA for the required repairs.

3.1.17 The gyroplane was involved in a roll-over accident in 2013 and all repairs were carried out by RAFSA. After the repairs were completed, the gyroplane was returned to the owner/pilot without rotor blades installed. These were later installed by AP 246.

3.1.18 AP 246 was responsible for carrying out maintenance on the gyroplane. There was no anomaly identified with the AP's accreditation issued by RAASA and it had the gyroplane rating endorsed on it. This was despite the fact that he did not attend any of RAFSA's prerequisite training.

3.1.19 The evidence was that the AP was also an owner/pilot of his own gyroplanes and familiar with RAFSA's maintenance requirements and documentation. He performed all the maintenance on ZS-RHO.

3.2 Probable Cause/s

3.2.1 Loss of control during take-off due to fatigue failure of the Hex head high-strength

shear bolt.

Contributory Factors

3.2.2 Improper maintenance due to the failure to replace old bolt with a new one.

4. SAFETY RECOMMENDATIONS

4.1 It is recommended that SACAA conduct similar research to that carried out by the University of Glasgow, on gyroplane aircraft registered in South Africa. Alternatively, it should adopt its research findings and conclusions.

4.2 It is recommended that the SACAA Certification Department assist RAFSA to correct the designs and manufacturing issues relating to the rotor hub bar bolts that caused it to fail. This intervention is required urgently, as all indications show that over last few years RAFSA has been unable to get it right themselves.

4.3 It is recommended that SACAA change its approach to dealing with NTCA aircraft operations. The responsibility of safety oversight ultimately lies with the Regulator, irrespective of the category of operation.

4.4 It recommended that the SACAA accept the metallurgist report recommendations and implement as required.

4.5 It is recommended that the SACAA reconsider their position into the matter of implementing the proposed recommendations made in memorandum dated 24 August 2015 which is attached to the report.

5. APPENDICES

5.1 **Appendice A:** Copy of Product Notice 5.

5.2 **Appendice B:** Copy of memorandum with initial recommendations forwarded to SACAA for consideration.

5.3 **Appendice C:** SACAA and RAFSA meeting into the matter.

5.4 **Appendice D:** The SACAA response to the IIC preliminary recommendations.

5.5 **Appendice E:** Copy of the Metallurgist Report.

5.6 **Appendice F:** Product Notice 39

ROTARY AIR FORCE SA PTY LTD
PO Box 2071, Upington, 8800
South Africa
Tel: +27 54 331 3534
Fax +27 54 332 3628
Email: info@rafsa.co.za
Web: www.rafsa.co.za

ROTARY AIR FORCE SA PTY LTD
Hanger 3
Upington International Airport
Upington, 8801
VAT Reg No: 4230236772
Company Reg No: 2007/012378/07
Emergency: 0833758841

ROTARY AIR FORCE PRODUCT NOTICE	REF: C/PRONOT.RAF-51 RAF 2000 GYROPLANE

NO. 51: RAF HUB BAR – MANDATORY RECALL

Rotary Airforce South Africa continues to ensure the safety of our RAF Owners. Further to the above, please accept the following information:

There has been 1 incident where play occurred between the HUB BAR and the Winglet resulting in the failure of the RAF 501 bolt head, as a precautionary measurement All HUB BARS **MUST** be returned to the ROTARY AIRFORCE SA FACTORY, **COMPLETE**, effective immediately. ROTARY AIRFORCE SA will inspect and replace the HUB BAR if required, and or replacement of all hardware and torque to the proper torque settings.

THIS RECALL IS MANDATORY AND MUST BE COMPLIED WITH.

THIS RECALL AFFECTS ALL ROTOR BLADE SHIPMENTS RECEIVED FROM 01 APRIL 2013.

PROCEDURE:

1. **RETURN THE COMPLETE HUB BAR. *NOTE: DO NOT REMOVE TENSION STRAPS FROM ROTOR BLADES.** Mark with a felt marker on the centre section of the HUB BAR the number of hours that the HUB BAR has been in service and the Serial No. of the ROTOR BLADES.

2. Return the HUB BAR to ROTARY AIR FORCE SA, 233B DIEDERICKS ROAD, GENERAL AVIATION HANGERS, UPINGTON INTERNATIONAL AIRPORT, UPINGTON, 8801, TEL: 0027 54 3313534, EMAIL: parts@rafsa.co.za by courier or the postal system.

   ***NOTE: INTERNATIONAL SHIPMENTS**, RAFSA will freight a new HUB BAR, proof of destroyed previous HUB BAR to be received first before shipment will commence. Photo's to be emailed to eben@rafsa.o.za of the destroyed HUB BAR.

   ALL SHIPPING COSTS are the responsibility of the RAF 2000 owner. For International shipments, if necessary, the shipping costs will be pre-paid and invoiced, all custom duties and cost is for the responsibility of the RAF 2000 owner. South African shipments will be sent out freight collect.

3. The HUB BAR will be shipped out on a first come first served basis.

Issue Date: 13 August 2015 Revision Date: - Revision No: 001

ROTARY AIR FORCE SA PTY LTD
PO Box 2071, Upington, 8800
South Africa
Tel: +27 54 331 3534
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Email: info@rafsa.co.za
Web: www.rafsa.co.za

ROTARY AIR FORCE SA PTY LTD
Hanger 3
Upington International Airport
Upington, 8801
VAT Reg No: 4230236772
Company Reg No: 2007/012378/07
Emergency: 0833758841

COSTS:

Inspection, dismantle & assemble, new and used HUB BAR - ZAR 570 + VAT per hour x 2

FUTURE PREVENTION:

1. Refer to the RAF Flight Manual and Operating Procedures, found in the Construction Manual. Each RAF 2000 was shipped with this Construction Manual. Since 1 May 2014, the RAF Flight Manual and Operating Procedures, was printed as a separate booklet, and all RAF 2000 Gyroplanes from 01 May 2014, purchased from ROTARY AIRFORCE SA, have received these sets of manuals. Ensure that you follow the procedures as set out in the manuals you received from the FACTORY.

2. Refer to all the Product Notices, also found in the Construction manual – a Product Notice is a living in-force document and must be adhered to at all times, by any individual wishing to conduct an inspection on a RAF 2000 Gyroplane.

3. Ensure that the individual inspecting your aircraft has the necessary credentials and are familiar with all RAF Product Notices and Service/Maintenance Schedules and that they comply. We strongly suggest that, where possible, you bring your aircraft to the FACTORY for the Annual Inspection, or you contact ROTARY AIRFORCE SA to enquire about a qualified individual we can recommend for your Annual Inspection.

4. Follow and adhere to your pre-flight inspection procedures before commencing with any flights, the pre-flight inspection procedures can be found in your construction manual under the section RAF Flight Manual and Operating Procedures.

5. When in doubt or experiencing sudden vibration, please cease any flight operations until you have contacted and spoken to our Technical team at ROTARY AIRFORCE SA.

6. It is your responsibility to ensure that you comply and ensure compliancy at all times, this is for your own safety.

Should not be in possession of these documents, please contact us and we will submit the electronic documents to the RAF owner.

RAFSA is there to ensure that you Stay Current, Be Safe and that you enjoy your RAF 2000 Gyroplane!

Issue Date: 13 August 2015 Revision Date: - Revision No: 001

Appendix B: Copy of memorandum with initial recommendations forwarded to SACAA for consideration.

To: Director of Civil Aviation (DCA)

CC: Executive Manager (EM) Act. and Senior Manager (SM) Act.

From: Mr. Jeremiah Visser (Senior Aircraft Accident and Incident Investigator)

Re: Accident Investigation of RAF2000 Gyroplane_ZU-RHO_Non-fatal_CA18/2/3/9462

Date: 24 August 2015

Purpose

The AIID received report of an accident on 8 August 2015 involving a RAF 2000 Gyroplane, registration ZU-RHO, serial number M2-01-07-11-034.

Background

The pilot reported that during take-off from the runway at Avontuur, Eden District in the Western Cape Province he was experiencing a severe vibration prior to the RAF 2000 Gyroplane impacting the ground. The pilot was accompanied by a passenger (his son). They sustained only minor injuries – bruises to the body.

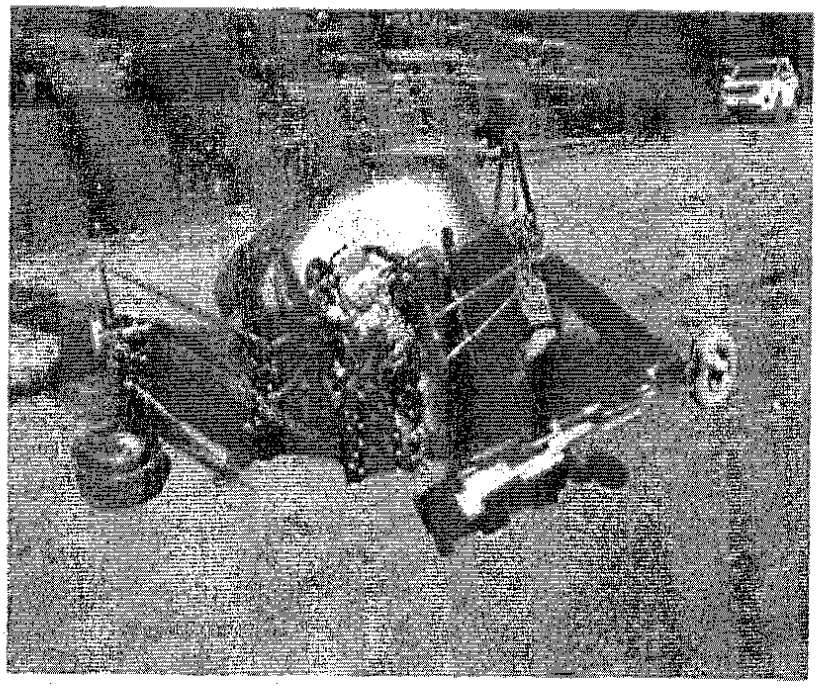


Figure 1 shows the wreckage of the accident aircraft

After the accident was reported, the AIID dispatched to the scene to conduct an onsite investigation. The investigation determined that during the take-off phase, the winglet (main rotor blade) of the aircraft broke and separated from it in the initial climb. Both winglets were subsequently found approximately 200 meters in different directions away from the main wreckage.

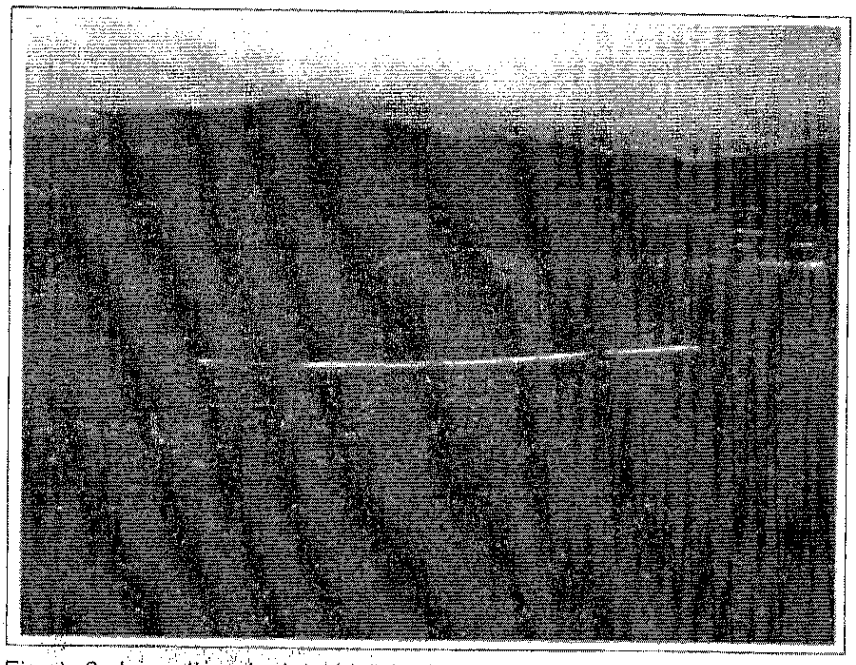
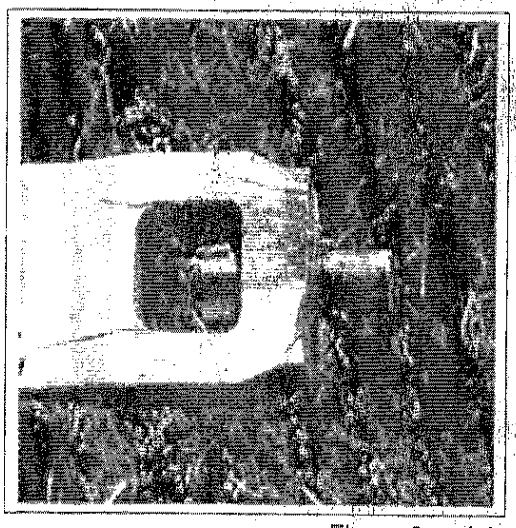


Figure 2 shows the winglet which broke and separated from the aircraft

Further investigation was conducted to determine the cause of the winglet failure. It was determined that the bolt (Part No: RAF 501012) which are installed between the rotor hub bar and winglet assembly failed. The head of the identified bold broke off as indicated below:



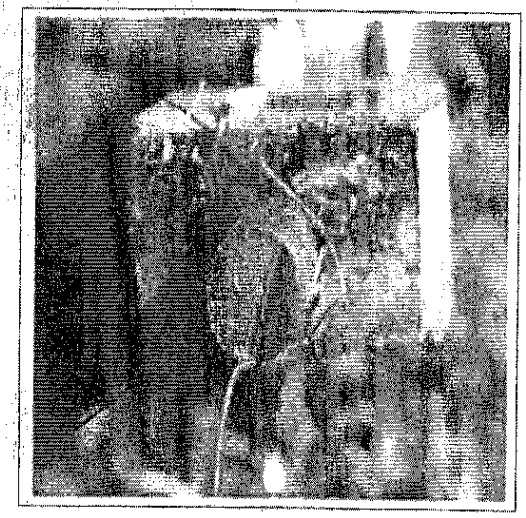


Figure 3 and 4 shows the broken bolt

During the investigation, the AIID had discussions with all the relevant parties involved (i.e. Owner/Operator, Aircraft Manufacturer and Approved Person). All parties were required to submit additional documentations to clarify issues raised during the onsite investigation.

The AIID recovered the main rotor hub bar assembly, particularly the broken bolt for further purpose to carry out metallurgical testing. This process is still on-going. However, the information of a Product Notice No 51 RAF Hub Bar – Mandatory Recall, Ref: C/PRONOT.RAF-51, dated 13 August 2015 issued by the Aircraft manufacturer – Rotary Air Force SA Pty Ltd.

Note: In short the identified product notice stipulates that as a precautionary action by the manufacturer, they recall all hub bars and **MUST** be returned **COMPLETE**, effective immediately. The manufacturer indicated that the recall affects all rotor blades shipments received from 01 April 2013. (Find a copy of the product notice attached to the memo).

Based on the above product notice information, in the interest of aviation safety, the AIID decided to bring the information to the attention of the Director of Civil Aviation (DCA). The information is important due to the fact that a total of 50 Rotary Air Force RAF 2000 type Gyroplane aircraft are currently registered with the SACAA. Implying that the identified product notice may affect a large number (unknown) of the Gyroplanes on the register, which means that effectively some if not all the Gyroplanes may be a potential safety risk as described by the product notices information.

Recommendation

1. It is recommended that the Director of Civil Aviation (DCA) should through the relevant department in the SACAA ensure that the information of Product Notice No 51 RAF Hub Bar – Mandatory Recall, Ref: C/PRONOT.RAF-51, dated 13 August 2015 issued by the Aircraft manufacturer – Rotary Air Force SA Pty Ltd by applicable means become widely known to the aviation industry with the aim that all owners/operators comply.

2. It is recommended that the Director of Civil Aviation (DCA) should through the relevant department in the SACAA to have an engagement with Rotary Air Force SA Pty Ltd into the product notice with the aim to determine the level of safety risk and possible grounding of the affected Gyroplanes if required.

(See attached supporting documentation)

Jeremiah Visser
Senior Accident and Incident Investigator

SOUTH AFRICAN
CIVIL AVIATION
AUTHORITY

Minutes of the meeting at RAFSA (Following ZU-RHO accident)

The minutes cover activities occurred during the visit at RAFSA by the SACAA Aircraft Safety Operations team on 21 September 2015. The items covered in the minutes are per the debriefing provided to during the closing of the meeting.

The scope of the visit included the review of the manufacturing and design processes, Service difficulty (Procedure and processes for notifying clients/CAA, differentiation between Part 148 built and amateur-built aircraft and finally, the RAF Hub Bar Mandatory Recall Notice.

Below is the information as per the debriefing:

1. Although the organisation RAFSA has been distributing the RAF 2000 aircraft in South African aviation industry for a while, the RAF Hub Bar recall notice (REF: C/PRONOT.RAF-51) only affect aircraft manufactured from 01 April 2013. This period seem to cover only 17 aircraft. RAFSA had contended that they have recalled aircraft form 01 April 2015 as it is the date they started assembling the Hub Bar from their facility as prior that period the Hub Bar came fully assembled from RAF Air Force Canada, dating back to 1992.

   The SACAA representatives did not accept this information on the basis that, although the organisation, RAFSA, may wish to be absolved from any responsibility for any aircraft before 01 April 2013, they were still responsible for distributing the aircraft within South Africa. All aircraft regardless of when they started to assemble the Hub Bar at their facility may still be affected by the same information contained in the notice as the design has not changed. The notice should therefore cover all aircraft of similar design distributed by RAFSA for safety consideration regardless of when they started assembling the Hub Bar at their facility.

2. The organisation, RAFSA, provided the SACAA representatives with the information that the Hub Bar, where the affected bold is situated, is a critical area that only the OEM in South Africa has the training, skills and the necessary equipment like, amongst others, torque range, vibration analysis, tracking lights and other associated special tools. All aircraft must be returned to the OEM for any Hub Bar adjustments or activities.

   However the SACAA representatives found that this critical information was omitted from the RAF notice. The organisation was also unable to provide, during the visit at their

facilities, any evidence where such critical information was contained in any of the manuals provided to aircraft owners.

3. Although the RAF Hub Bar-Mandatory recall was issued following the accident of the RAF 2000 aircraft ZU-RHO and stating the failure of RAF 501 bolt head as the problem, they were unable to provide any objective evidence that the bolt itself was the issue or any other area in the Hub Bar or what exactly happen for the bolt to shear.

   In the absence of established facts the SACAA found the notice to have been issued pre-maturely and in panic primarily taking into account that there was no evidence available of any such an incident to the aircraft since the aircraft was first brought into operation in 1992. Further the mandatory recall did not comply with minimum requirements for a service bulletin or notices as required by the CAA.

4. During the visit the organisation stated that they received all the bolts from RAF Air Force in Canada. However they were unable to provide, within the information at their disposal, any objective evidence that the bolts so received complied with the design data as documented under the bolts drawing, part number 501-012. The drawing stipulated that the bolt must comply with the NAS6212-42D, the Certificate of Conformance received from Rotary Airforce and the associated invoice provided by the organisation did not provide any such confirmation.

5. The organisation stated during the visit that the parent company in Canada is no longer in operation since 2006 and they are no longer receiving any assistance, as a manufacture they produce everything in Upington except of general spares and bought out items. They will send such evidence to the SACAA to the effect that RAF Air Force in Canada is no longer operational.

6. The organisation was able to provide information or objective evidence that they do send service difficulty to clients as they keep every owner's detailed records.

7. The organisation was unable to provide the design data, not even in the form of a drawing, of the washer used with the affected bolt during the visit. They stated that the washer was deemed a standard item.

8. During the debriefing the organisation did point out that the problems associated with their aircraft is primarily not the design or manufacturing faults of the aircraft but individuals that maintains them. They insisted that all aircraft must be returned to their facility for the Hub Bar maintenance.

The SACAA representative found this statement being overly punitive and not cost effective primarily as most of the aircraft distributed by the organisation are amateur-built aircraft where such owners resume the maintenance responsibility and there are no mandatory regulations requirements associated with the category.

The organisation was only approved as a manufacturing organisation from March 2015.

Appendics D: The SACAA response to the IIC preliminary recommendations.

SOUTH AFRICAN
CIVIL AVIATION
AUTHORITY

ASO DEPARTMENT REPORT ON RECOMMENDATIONS BY THE AIID FOLLOWING ZU-RHO (RAF2000 GYROPLANE AIRCRAFT) ACCIDENT

Report no. 0001 RAFSA

12/10/2015

INTRODUCTION

Following the accident of a RAF2000 Gyroplane, registration ZU-RHO, in August 2015, AIID recommended to the Director of Civil Aviation (DCA) that:

1. the DCA should through the relevant department in the SACAA ensure that the information of the Product Notice No. 51 RAF Hub Bar – Mandatory Recall, Ref: C/PRONOT.RAF-51 dated 13 August 2015 issued by the Aircraft Manufacturer, Rotary Air Force SA (Pty) Ltd (RAFSA), by applicable means, become widely known to the aviation industry with the aim that all owners/operators comply,

2. the DCA should through the relevant department in the SACAA to have an engagement with RAFSA into the product notice with the aim to determine the level of safety risk and possible grounding of the affected Gyroplanes, if required.

EXECUTIVE SUMMARY

The affected product is an amateur-built aircraft and the recommendations as put forth by AIID are beyond the scope of the aircraft category.

ENGAGEMENT WITH RAFSA

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[1] On receipt of the AIID recommendations from the DCA's office the ASO department convened a meeting on 15 September 2015 to deliberate on the AIID recommendations. The meeting resolved that an ASO department team comprised of Defect Reporting, Manufacturing and Engineering sections should visit the aircraft manufacturer with the aim to make a determination on implementation of the AIID or depending on the outcome of the engagement with RAFSA advice alternately. The three ASO team members assembled for the mission, albeit being mangers and acting managers at the time, remains highly trained quality auditors and skilled inspectorates within the SACAA.

[2] ASO team visited or engaged RAFSA at their facilities in Upington, Northern Cape, on 21 September 2015. The scope of the visit included the review of the,

(i) manufacturing and design processes,

(ii) service difficulty (Procedure and processes for notifying clients/CAA),

(iii) differentiation between Part 148 built and amateur-built aircraft and

(iv) the RAF Hub Bar Mandatory Recall Notice.

The review or inspection at RAFSA revealed the following:

[3] Although the organisation RAFSA has been distributing the RAF 2000 aircraft in South African aviation industry for a while, the RAF Hub Bar recall notice (REF: C/PRONOT.RAF-51) only affect aircraft manufactured from 01 April 2013. This

period seem to cover only 17 aircraft. RAFSA had contended that they have recalled aircraft from 01 April 2015 as it is the date they started assembling the Hub Bar from their facility as prior that period the Hub Bar came fully assembled from RAF Air Force Canada, dating back to 1992.

The SACAA representatives did not accept this information on the basis that, although the organisation, RAFSA, may wish to be absolved from any responsibility for any aircraft before 01 April 2013, they were still responsible for distributing the aircraft within South Africa. All aircraft regardless of when they started to assemble the Hub Bar at their facility may still be affected by the same information contained in the notice as the design has not changed. The notice therefore ought to have covered all aircraft of similar design distributed by RAFSA for safety consideration regardless of when they started assembling the Hub Bar at their facility.

[4] The organisation, RAFSA, provided the SACAA representatives with the information that the Hub Bar, where the affected bolt is situated, is a critical area that only the manufacturer in South Africa has the training, skills and the necessary equipment, amongst others, torque range, vibration analysis, tracking lights and other associated special tools. All aircraft must be returned to the manufacturer for any Hub Bar adjustments or activities.

However the SACAA representatives found that this critical information was omitted from the RAF notice. The organisation was also unable to provide, during the visit at their facilities, any evidence where such critical information was contained in any of the manuals provided to aircraft owners.

[5] Although the RAF Hub Bar-Mandatory recall was issued following the accident of the RAF 2000 aircraft ZU-RHO and stating the failure of RAF 501 bolt head as the problem, they were unable to provide any objective evidence that the bolt itself was problematic or any other area in the Hub Bar or what exactly happen for the bolt to shear.

In the absence of established facts the SACAA representatives found that the notice to have been issued pre-maturely and in panic primarily taking into account that there was no evidence available of any such an incident to the aircraft since the aircraft was first brought into operation in 1992. Further the mandatory recall did not

comply with minimum requirements for a service bulletin or notices as required by the CAA.

[6] During the visit the organisation stated that they received all the bolts from RAF Air Force in Canada. However they were unable to provide, within the information at their disposal, any objective evidence that the bolts so received complied with the design data as documented under the bolts drawing, part number 501-012. The drawing stipulated that the bolt must comply with the NAS6212-42D, the Certificate of Conformance received from Rotary Airforce Canada and the associated invoice provided by the organisation did not provide any such confirmation.

[7] The organisation stated during the visit that the parent company in Canada is no longer in operation since 2006 and they are no longer receiving any assistance, as a manufacturer and they produce everything in Upington except of general spares and bought out items. They will send such evidence to the SACAA to the effect that RAF Air Force in Canada is no longer operational.

[8]The organisation provided information or objective evidence during the visit that they do send service difficulty to clients as they keep every owner's detailed records.

[9] The organisation was unable to provide the design data, not even in the form of a drawing, of the washer used with the affected bolt during the visit. They stated that the washer was deemed a standard item.

[10] During the debriefing the organisation did point out that the problems associated with their aircraft is primarily not the design or manufacturing faults of the aircraft but individuals that maintains them. They insisted that all aircraft must be returned to their facility for the Hub Bar maintenance.

The SACAA representative found this statement being overly punitive and not cost effective primarily as most of the aircraft distributed by the organisation are amateur-built aircraft where such owners resume the maintenance responsibility and there are no mandatory regulations requirements associated with the category.

Of concern here is that:

[11] RAFSA was only approved as a manufacturing organisation under Part 148 from March this year (2015). The aircraft in question was registered in 11 April 2012 way before RAFSA was approved and therefore the aircraft remains amateur-built product.

Amateur-built aircraft are aircraft intended for civil aviation development and do not have to comply with any airworthiness design standards, that is, not compelled to have identical and approved configurations, therefore not limited by regulations or standards on which components or parts to fit or install on their aircraft. Hence they are for the owner's education and recreational purposes only.

CONCLUSION

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[12] The ASO team do not recommend that the DCA implement the first recommendation by AIID that the notice issued by RAFSA be widely known and complied to by the civil aviation industry. On the basis that:

- for the CAA to insist that amateur-built aircraft comply to a manufacturer notice will defeat the whole notion of developmental and will further be tantamount to compelling such aircraft to have identical configuration and components, which is not supposed to be the case in this aircraft category.
- The cause for the bolt failure has not been determined either by AIID or the manufacturer. Further, there is no objective evidence or reliable data or trend availed thus far to support the idea that the bolt was continually problematic. The manufacturer contended that the incident was the first of its kind since the aircraft entered service 23 years ago (1992).

[13] The ASO team also recommend to the DCA not to implement the second recommendation by AIID to ground the affected Gyroplanes. On the basis that:

- The aircraft is categorised as amateur-built where, as an unapproved aeronautical product, the serviceability of the aircraft lies with the owner rather than the CAA.
- The high level of safety risk is always inherent with any novice products during developmental phases. Amateur-built aircraft resides within such a developmental sphere.

[14] In order to foster civil aviation growth and development, the ASO team recommend to the DCA that the amateur-built category should remain de-regulated, however the CAA should increase enforcement and duty of care by ensuring that no commercial privileges and carrying of passengers (third parties) is associated with such aircraft or products.

Appendics E: Copy of the Metallurgist Report

COMPILED BY	CrashLAB	PAGE 1 OF 7
COMPILED FOR: S.A. Civil Aviation Auth.	INVESTIGATION REPORT: MAIN WING BOLT FAILURE, RAF 2000 GTX GYROPLANE, ZU-RHO	DOCUMENT NUMBER AAI-011-12-15
		DATE 2015-12-11 / ISSUE 2

ITEM: **MAIN WING ATTACHMENT BOLT, MAIN ROTOR ASSEMBLY, RAF 2000 GTX GYROPLANE, AIRCRAFT NUMBER ZU-RHO**

1. INTRODUCTION

1.1. The main rotor head assembly (Photo 2) from a RAF 2000 GTX Gyroplane, aircraft number ZU-RHO (Photo 1), was submitted to determine the most probable failure mode of the No 1 main rotor blade attachment bolt during operation.

Photo 1:RAF 2000 GTX Gyroplane – comparative aircraft[1]

Photo 2: Supplied components (digital)

1.2. This report is divided into the following sections:

2. APPLICABLE DOCUMENTS

(a) None.

[1] www.microlighters.co.za

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)	MR	Main Rotor
(f)	NDT	Non-Destructive-Testing

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 and Digital Camera.

(b) The methodology included a visual examination of supplied parts followed by sectioning to remove a sample for a Microscope investigation.

6. INVESTIGATION

6.1. The visual inspection revealed a fractured attachment bolt of the No 1 Main Rotor blade (Photo 3, red arrow).

The fracture surface showed clear indications towards fatigue as the primary failure mode (Photo 4) while the direction of fracture progression (red dashed arrows) suggests exposures to bending loads in the horizontal/lead-lag plane of MR operation. *This was affirmed by orientating the remainder of the No 1 bolt similar to the still attached No 2 bolt, assuming corresponding fitment techniques.*

The No MR blade attachment bracket and No 1 bolt were sectioned for removal and inspection purposes (Photo's 5 and 6).

Extensive surface scuffing marks and damages to the protective cadmium coating were noted on the No 1 bolt (Photo's 6 and 7, yellow dashed circles) attributable to mechanical interaction between the bolt and the bracket during operation.

The fracture surface analysis confirmed fatigue to be the primary mode of failure with clear progression directions (Photo 8, red dashed arrows), typical fatigue induced 'beachmarks' (yellow arrow) and final fracture area (red arrow).

Inspection of the No 2 MR blade attachment bracket and bolt (Photo 9) revealed slight movement in the horizontal plane (grey solid arrows) at the bracket and MR head interface (red arrow). *It could not be confirmed whether the slack was within OEM limits.*

On removal of bolt No 2, comparative surface marks with the No 1 bolt were noted (Photo 10, yellow dashed arrows) suggesting similar operational exposures.

Closer inspection of the No 2 washer/bolt interface revealed extensive mechanical interaction at opposite positions (Photo 11, red dashed circles). These damages inflicted by relevant movement between the washer and bolt during operation compares favorably with similar damages noted on the bolt No 1 (Photo 7, yellow dashed circle).

Inspection of the washer/No 2 MR blade attachment bracket interface revealed mechanical damages (Photo 13, red dashed circles) corresponding with the bending damages noted on the No 2 bolt head end washer (Photo 12, blue dashed circles). Although the No 1 bolt head end and washer were not retrieved for this investigation, similar damages were noted (Photo 13).

The No 2 MR blade attachment bolt was exposed to an appropriate NDT inspection and revealed clear indications of fracture initiation at similar positions than bolt No 1 (Photo's 14 and 15, red arrows).

The No 2 bolt head specification stamp showed "RAF 501-012 AFC". Whether bolt No 2 conforms to OEM specifications could not be confirmed. No break-torque values could be determined.

Photo 3: Position of fractured No 1 MR blade attachment bolt (digital)

Photo 4: Fracture surface orientation (digital)

Photo 5: Sectioned No MR Blade attachment bracket (digital)

Photo 6: Surface damages, No 1 bolt, sectioned (digital)

Photo 7: Surface damages, No 1 bolt (digital)

Photo 8: Fracture surface, No 1 bolt (stereo)

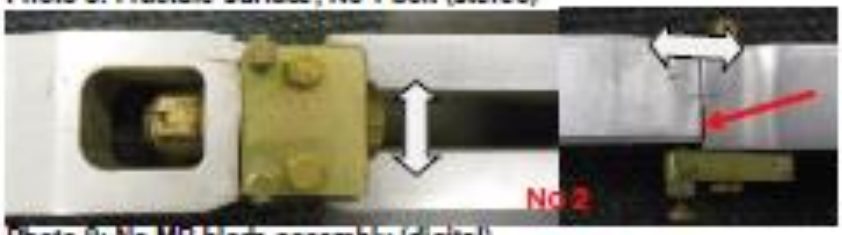

Photo 9: No MR blade assembly (digital)

Photo 10: Surface damages, No1 and 2 bolts (digital)

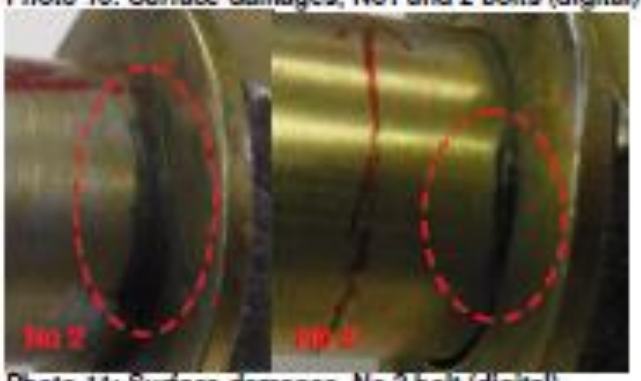

Photo 11: Surface damages, No 2 bolt (digital)

Photo 12: Washer, bolt head end, No 2 bolt (digital)

Photo 13: Washer and MR blade attachment bracket interface, No 1 and 2 bolts (digital)

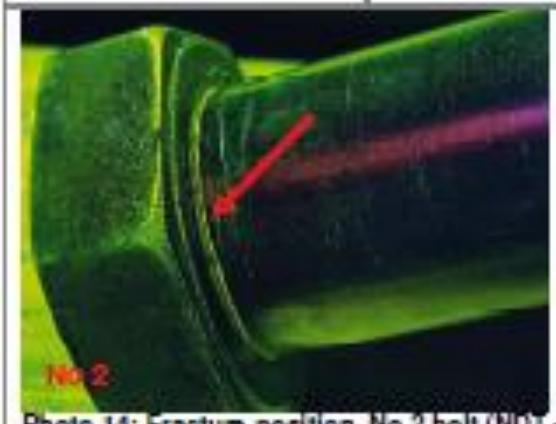

Photo 14: Fracture position, No 2 bolt (NDT - digital)

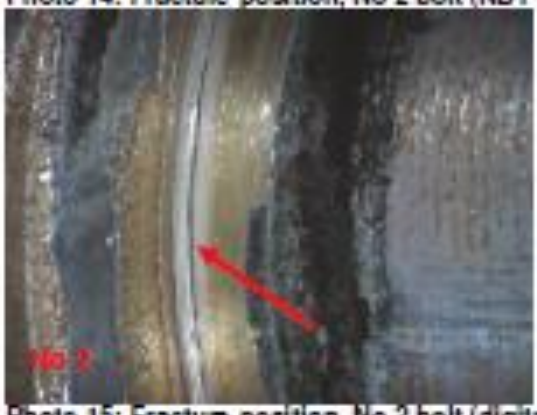

Photo 15: Fracture position, No 2 bolt (digital)

Photo 16: Specification stamp, No 2 bolt (digital)

7. DISCUSSION AND CONCLUSIONS

The conclusions are based on the investigation results obtained from the supplied parts/components only. The following assumptions have reference:

1. *All parts supplied conforms to OEM specifications.*
2. *Applied torque values conforms to OEM specifications.*
3. *Aircraft was operated within OEM/Authority set limits.*

7.1 The investigation results revealed fatigue to be the **No 1 MR blade attachment bolt** primary fracture mode while exposed to reverse bending loads in the horizontal/lead-lag MR operational plane.

7.2. The **No 2 MR blade attachment bolt** revealed comparative indications of fracture initiation relative to position and orientation with bolt No 1.

7.2. The most probable primary cause/s for the initiation of the fatigue fractures can be attributed to one, or a combination, of the following:

7.2.1. Operational Exposure. Although it is assumed for this investigation that the aircraft has been operated within the OEM/Authority set limits, the possibility exists that these limits may still allow exceedances concerning the overall operational capability of the MR assembly.

7.2.2. Assembly/Design. The investigation results have shown that the washers (No1 and No 2) at both the bolt head ends dimensionally exceeds the slotted sections in the MR blade attachment brackets. During fitment this may render a "false" torque value. When exposed to normal centrifugal loads during operation, the washers mechanically interact with the MR blade attachment bracket with resulting bending damages noted. This may lead to lowering the applied torque with resultant movement of the bracket/bolt assembly in the shear direction (horizontal/lead-lag) as well as the inducement of excessive forces on the fracture prone bolt head radius.

8. RECOMMENDATIONS

8.1. Considering the detrimental effect of such a failure on Flight Safety, the following are recommended:

8.1.1. Inspection to determine the conformance of the relevant bolts, washers and nuts to OEM specifications.

8.1.2. Revisiting the design of the MR blade attachment bracket.

8.1.3. Reconsidering the operational limits of the relevant aircraft, if applicable.

9. DECLARATION

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

Appendics F: Product Notice 39

ROTARY AIR FORCE **REF: W/ PRODUCT NOTICE-39**

PRODUCT NOTICE **RAF 2000 GYROPLANE**

15 December 2004

NO. 39: *Hub Bar Winglets, and AN12 Bolt* **Page 1 of 2**

Several Hub Bar Winglets have developed cracks due to extenuating circumstances beyond RAF's control. Some have questioned the Hub Bar Winglet's strength. Also during an incident one of the AN12 Bolts suffered a catastrophic failure at the head. The AN12 Bolt had sustained a number of abnormal stress loads beyond RAF's control. The following mathematical formulas give the specifications in detail for these questioned components:

Centrifugal loading

F (in lbs.) = G x M (in lbs.) x R (in inches) x $(RPM)^2$ x K
F (lbs.) = 1 x 48 x 73 x $(340)^2$ x 0.00002850
F (lbs.) = 11470.9 lbs

Stress

$$S\ (psi) = \frac{F\ (lbs.)}{A\ (inch)^2} = \frac{11470.9}{2\ sq.\ in.} = 5.735\ kpsi$$

In addition, add the stress of the Hub Bar as a result of the bending moment created by the lift at each end transposed to the centre. This stress is represented by:

$$\frac{(M/2) \times G \times L}{(W^2/6) \times A} = 3M \times G \times L / (W^2 \times A)$$

Take the weight of the aircraft to figure the stress caused by the weight resisting centrifugal loading use the following s = 3MxGxL/ WxWxA. Where S stress due to bending of the Hub Bar in psi.
M = mass of the gyroplane
G = Loading Factor
L = Half the length of the Hub Bar (20.25 inches)
W= thickness (1 inch)
A = is the width of the Hub Bar (2 inches) = looks
The aircraft weight approximately 1320 lbs. the stress is 3960 psi. The total stress is 8.755 kpsi = 5.735+3.960 kpsi. The yield stress for 6061-T6 Aluminium is 44 kpsi so there is a safety factor of (44/8.755) = 5.

The forgoing preamble is to establish the current strength and methodology used. What follows are the steps taken by RAF to further increase the safety factor of the already generous margins with this item.

The AN12-34A Bolt is rated at 50,000 psi with an expected load of 11,470.9 psi this is a 4 times safety factor.

RAF is introducing the following improvements:
A new RAF NAS bolt where the radius under the head is twice as large as the normal NAS bolt, the installation of a washer with the proper bevel cut to accommodate this radius. This new bolt will increase the strength by 25%.

RAF recently purchased a new software program for contour machining. The Winglets and Hub Bar are being machined to eliminate the straight cuts on the top and bottom using the process of contour machining. See following page for picture of Hub Bar Winglets and Bolt.
Continued...