AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/3/2/0909		
Aircraft Registration	**ZU-BTT**	**Date of Incident**	19 April 2012	**Time of Incident**	1242Z		
Type of Aircraft	Falco F8L		**Type of Operation**	Private			
Pilot-in-command Licence Type		Private Pilot	**Age**	67	**Licence Valid**	Yes	
Pilot-in-command Flying Experience		Total Flying Hours	367.5		Hours on Type	79.35	
Last point of departure	Kimberley Aerodrome (FAKM) – Northern Cape						
Next point of intended landing	Beaufort West - Western Cape						
Location of the incident site with reference to easily defined geographical points (GPS readings if possible)							
Approximately 50 km south of Victoria West in the Northern Cape.							
Meteorological Information	Wind : Westerly 5 – 10 kt, Temperature: 12˚C, Cloud base: CAVOK..						
Number of people on board	1 + 1	**No. of people injured**	0	**No. of people killed**	0		

Synopsis

On 19 April 2012 at approximately 1055Z, the pilot accompanied by a passenger departed from Kimberley aerodrome (FAKM) on a private flight to Beaufort West in the Western Cape.

The flight en-route to Beaufort West was uneventful, but after a flight time of approximately 1.85 hours, the propeller suddenly separated from the engine attachment flange during cruise in mid-air with the engine at 2500 RPM.

The pilot then executed a successful forced landing on the N12 National tar road, approximately 50 km south of Victoria West that was clear of any traffic travelling on the road at the time.

The aircraft sustained no damage during the forced landing, and was repositioned off the N12 to a private gravel road nearby.

The pilot and passenger sustained no injuries.

Probable Cause

Propeller Attachment bolts failed during flight

Contributory Factors:
Material Failure.

IARC Date		Release Date	

AIRCRAFT INCIDENT REPORT

Name of Owner/Operator	**:** B D Nelson
Manufacturer	**:** Sequoia Aircraft Plans/Nelson
Model	**:** Falco F8L
Nationality	**:** South African
Registration Marks	**:** ZU-BTT
Place	**:** Approx 5 km south from Victoria West.
Date	**:** 19 April 2012
Time	**:** 1240Z

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

Purpose of the Investigation :

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (1997) this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and ***not to establish legal liability****.*

Disclaimer:

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

1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 On 19 April 2012 at approximately 1055Z, the pilot accompanied by a passenger departed from Kimberley Aerodrome (FAKM) on a VFR private flight to Beaufort West in the Western Cape.

1.1.2 The pilot stated that the flight en-route to Beaufort West was uneventful, but at approximately 1240Z, after a flight time of approximately 1.85 hours, the propeller suddenly separated from the engine attachment flange during cruise at 145kt true air speed (TAS) in mid-air with the engine at 2500 RPM.

1.1.3 The propeller subsequently impacted the engine cowling including the left wing as it separated from the engine.

1.1.4 The pilot then executed a successful forced landing on the N12 National tar road, approximately 50 km south of Victoria West that was clear of any traffic travelling on the road at the time.

1.1.5 The aircraft sustained no damage during the forced landing, and was repositioned off the N12 onto a private gravel road nearby.

1.1.6 The pilot and passenger sustained no injuries. .

Injuries to Persons

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

1.3 Damage to Aircraft

1.3.1 The aircraft sustained substantial damage when the propeller separated from the engine in mid-air and impacted the engine cowling and left wing.

1.4 Other Damage

1.4.1 There was no other damage sustained in the incident.

1.5 Personnel Information

1.5.1 Pilot-in-command:

Nationality	South African	Gender	Male	Age	67
Licence Number	0270137466	Licence Type	Private Pilot		
Licence valid	Yes	Type Endorsed	Yes		
Ratings	Night Rating & Flight Test - Single Engine Piston				
Medical Expiry Date	28 February 2013				
Restrictions	Corrective Lenses				
Previous Accidents	None.				

1.5.2 Flying Experience:

Total Hours	367.5
Total Past 90 Days	5.6
Total on Type Past 90 Days	5.6
Total on Type	79.35

1.6 Aircraft Information

1.6.1 Airframe:

Type	Falco F8L	
Serial No.	820	
Manufacturer	Sequoia Aircraft Plans/Nelson	
Date of Manufacture	31 December 1999	
Total Airframe Hours (At time of Incident)	99.0	
Last Annual Inspection (Date & Hours)	15 October 2011	93.4
Hours since Last Annual Inspection	5.6	
Authority to Fly (Issue Date)	15 January 2012	
C of R (Issue Date) (Present owner)	20 December 2007 B D Nelson	
Operating Categories	Private Operation Authority to Fly	

1.6.2 Engine:

Type	Lycoming O-320 B2A
Serial No.	L-919-39
Hours since New	99.0
Hours since Overhaul	Not reached.

1.6.3 Propeller:

Type	P Prop - Champion
Serial No.	N2467FE264
Hours since New	99.0
Hours since Overhaul	December 2009

1.6.4 The aircraft model; Falco F8L, was manufactured by Sequoia Aircraft Plans/Nelson in 1999.

1.6.5 According to the pilot, he reassembled the aircraft and also performed the maintenance work on the aircraft. The maintenance work carried out on the aircraft was duly inspected and certified by an approved person (AP) of the Aero Club of South Africa.

1.6.6 The aircraft documentation (e.g. certificate of registration, authority to fly and certificate of release to service etc.) on board the aircraft were reviewed during the investigation and found to be valid in compliance with applicable regulation CAR, Part 91.

1.6.7 Aircraft Maintenance :

a) According to the aircraft maintenance records, the last Annual Inspection was certified by an Approved Person (AP). The aircraft operated without any defect and/or malfunction until the day of the incident.
b) The aircraft airframe logbook was reviewed after the incident occurred and no mechanical defects were recorded which could have contributed to the cause of the incident.

1.6.8 Pre-Flight Inspection:
According to the pilot, he performed a pre-flight inspection on the aircraft prior to the flight. There were no defects or malfunction identified on the aircraft. The pilot observation was that the aircraft were serviceable for the planned flight.

1.6.9 Fuel Status:
The aircraft carried on board a total of 125 litres of Avgas fuel when it took off from Kimberley. The intended destination was Beaufort West. According to the pilot, the aircraft flew for approximately 1.8 hours en route to Beaufort West. The aircraft burned off 45 litres of fuel before the incident occurred. The fuel remaining found on board was 80 litres that was sufficient for the planned flight.

1.6.10 Component Failure
The propeller suddenly separated from the engine propeller attachment flange during

cruise. The propeller and engine was inspected in order to establish the cause of propeller to separate from the engine during flight. The following defects were noted:

(i) All six (6) propeller bolts that secure the propeller onto the attachment flange on the engine ring gear fractured and subsequently caused the propeller to separate from the engine.

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Figure 1, shows engine on aircraft without propeller.

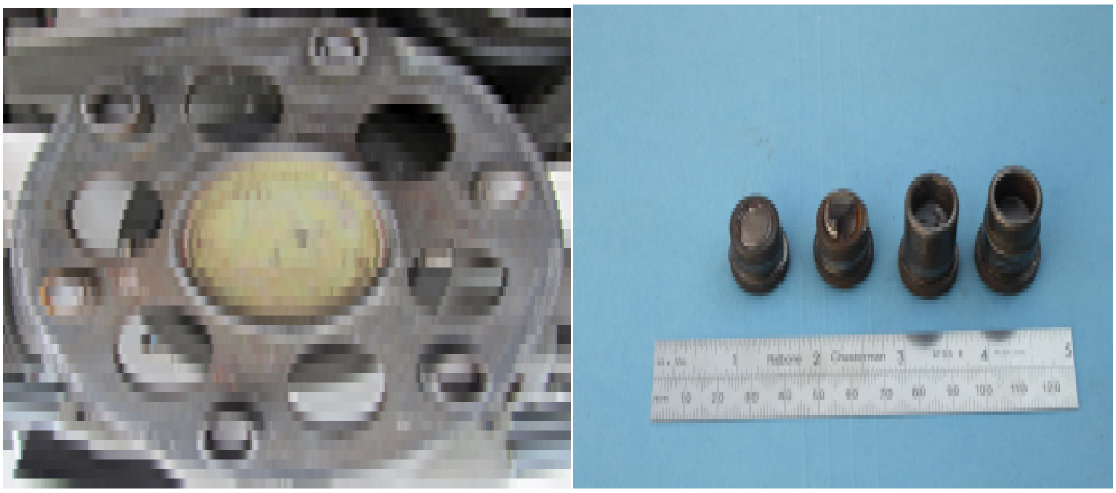

Figure 2, shows propeller attachment flange with fractured bolts.

1.6.11 Propeller Maintenance:

According to the aircraft file, the information shows the following:

(i) The propeller was manufactured in 2005. The propeller was delivered to the Owner of aircraft registration ZU-BTT in April 2005. The aircraft operated for duration of 93 hours until it was removed for minor services on 18 December 2009.

(ii) After the propeller was removed by the owner of the aircraft, it was sent to the manufacturer for minor services. The manufacturer concluded that the minor services that was carried out, was as follows:

a. Propeller lightly sanded;
b. Small impact marks filled;
c. Propeller blades smoothed and re-balanced;
d. The glass fibre was laid up on the immediate both sides of the hub as small bulging impressions were visible and could be felt by touch as well. This was an indication of very slight, but not serious at all, over tightening of the bolts. These small bumps were lightly sanded down and fibreglass applied.

(iii) After the minor services were completed, the propeller was returned to the owner who installed it back onto the engine. The aircraft operated for 5.6 hours when the propeller separated from the engine attachment flange in mid-air during flight.

1.7 Meteorological Information

1.7.1 The weather information below was taken from pilot questionnaire.

Wind direction	Westerly	Wind speed	5 to 10 kts	Visibility	CAVOK
Temperature	12˚C	Cloud cover	Nil	Cloud base	Nil
Dew point	N/A				

1.8 Aids to Navigation

1.8.1 The aircraft was equipped with standard navigation equipment, approved for the type aircraft. The additional navigation equipment installed was included on the approved equipment list. The pilot reported that all the navigation equipment was in a serviceable condition at the time of the incident.

1.9 Communications.

1.9.1 The aircraft was fitted with ICOM IC-A200 type of VHF transmitter radio communication equipment. The pilot did not report any defect or malfunction with the radio equipment. The radio equipment of the aircraft was serviceable during the flight and at the time of the incident.

1.10 Aerodrome Information

1.10.1 The aircraft was involved in the accident outside the boundaries of an aerodrome. The pilot executed a forced landing on the N12 national road and repositioned the aircraft to a private gravel road nearby.

Figure 3, shows gravel road where aircraft was repositioned

1.11 Flight Recorders

1.11.1 The aircraft was not fitted with a flight data recorder (FDR) and cockpit voice recorders (CVR), nor was it required by regulation.

1.12 Wreckage and Impact Information

1.12.1 During cruise on a private flight, the propeller suddenly separated from the engine in mid-air. After the propeller separated from the engine at the engine attachment flange, it impacted the engine cowling on the left and the left wing, causing substantial damage to the cowling and left wing.

1.12.2 The pilot managed to execute a successful forced landing on the N12 national road with no further damage caused to the aircraft.

1.12.3 The propeller could not be located during the investigation.

1.13 Medical and Pathological Information

1.13.1 The pilot had a valid Class 2 aviation medical certificate with a waiver to wear corrective lenses. The pilot did not have any medical condition which may have prevented him from operating the aircraft.

1.13.2 The pilot and passenger did not sustain any injury in the incident.

1.14 Fire

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

1.15 Survival Aspects

1.15.1 The incident was considered to be survivable as both occupants were restrained by the safety harnesses installed on the aircraft. The pilot also managed to glide and landed the aircraft safely during the forced landing without any impact forces involved.

1.15.2 After the successful forced landing, the occupants exited the aircraft without any injuries.

1.16 Tests and Research.

1.16.1 According the P Prop propeller manufacturer, the P Prop is described as being a high quality wood and composite hybrid propeller. Meaning laminated wood core covered by carbon fibre and glass weave over 70% of the blade area. Each propeller is designed using the latest state of the art engineer airfoil programs, developed and tested to the most exacting BSO ISO 1011 military standards.

Engine and Propeller Details

- The propeller flange which is attached onto the engine is 149.95 mm in diameter with a thickness of 7 mm (as per hand drawing supplied by the owner/builder).
- The propeller locating boss o/d 57.2 mm and depth is 19 mm (as per hand drawing supplied by the owner/builder).
- The propeller ring gear is 6.5 mm.
- Final depth for propeller is 12.5 mm (as per hand drawing supplied by the owner/builder).
- There are 6 bolts of 7/16 or 11.1mm used to install it on the engine.
- The propeller hub width over engine flange face is 160 mm and thickness is 100 mm.
- PCD of the bolts holes is 120 mm and boss depth 12.5 mm if ring gear fitted.
- Once installed on the aircraft, after engine start rotation will be clock wise (to the right).

Metallurgist Report

1.16.2 The starter disk and four propeller mounting bolts were submitted for testing to determine the cause of failure. During the examination, the following was observed:

(i) The starter disk showed distinct burring around two of the mounting bolts holes.

(ii) The bolts had rust deposits on the threads, indicating that they had been assembled without any protective coating. There was no evidence of any thread locking compound being used either.

(iii) The fracture surface of one bolt showed features indicating failure in fatigue. Two other fracture surfaces showed features which may indicate early stages of fatigue, i.e. apparent ratchet marks at the apparent origin.

(iv) The structure in the thread roots was examined; compression of the structure and small surface laps and folds indicated that the threads had been formed by rolling rather than cutting.

1.16.3 The examination of the bolts showed that the fasteners had failed due to fatigue, usually associated with under tightening on assembly or dynamic overloaded, such as contact between the propeller and some solid object, some period of time prior to failure that occurred.

1.16.4 The examination was concluded as follows: Whilst the bolts have failed in fatigue, the common cause for fatigue initiation and failure, under-tightening during assembly, is not considered to have been the primary cause in this instance. The presence of crack-like lap defects in the thread roots, formed during the thread rolling operation, is considered to be the primary cause. It is considered that these fasteners may not have been manufactured and tested to the quality standards normally applied to aircraft (civil aviation) components, and their origins should be investigated. *(See attached copy of metallurgist report)*

1.17 Organizational and Management Information

1.17.1 The pilot that operated the aircraft was also the owner of the aircraft in question. The aircraft was operated in his private capacity as a Non Type Certificated Aircraft (NTCA) category which was in accordance with Part 94. There was no anomalies found with the operation of the aircraft.

1.17.2 The maintenance work carried out on the aircraft was by the pilot who is also the owner of the aircraft. Any maintenance performed on the aircraft was duly inspected and certified by an approved person (AP) by the Aero Club of South Africa.

1.18 Additional Information

1.18.1 None.

1.19 Useful or Effective Investigation Techniques

1.19.1 None.

2. ANALYSIS

2.1 On 19 April 2012 at approximately 1055Z, the pilot accompanied by a passenger departed from Kimberley Aerodrome (FAKM) on a VFR private flight to Beaufort West in the Western Cape. The flight en-route to Beaufort West was uneventful after a flight time of approximately 1.85 hours when the propeller suddenly separated from the engine attachment flange during cruise at 145kt true air speed (TAS) in mid-air with the engine at 2500 RPM.

2.2 The propeller subsequently impacted the engine cowling including the left wing as the propeller separated from the engine attachment flange. The pilot then executed a successful forced landing on the N12 National tar road, approximately 50 km south of Victoria West without any traffic travelling on the road at the time.

2.3 The aircraft sustained no damage during the forced landing, and was repositioned off the N12 to a gravel road nearby. The pilot and passenger sustained no injuries. .

2.4 The maintenance history of the aircraft was scrutinized especially that of the propeller in order to determine whether the maintenance on the aircraft was carried out as specified. Evidence found indicated the following:

(i) The propeller was installed on the aircraft as a new product seven (7) years ago when the aircraft was assembled after manufacture. The aircraft operated with the propeller installed on the engine and no defects or malfunctions reported.

(ii) The Propeller was then removed for minor servicing conducted by the manufacturer in December 2011. During the minor service, the manufacturer determined that the glass fibre laid up on the immediate sides of the propeller hub (both sides) had small bulging impressions which were visible and could be felt by touch as well. This was an indication of very slight – not serious at all – over tightening of the propeller bolts.

2.4 The propeller was then returned to its owner after the minor services were completed. The information of over-tightening of the propeller bolts was most probably relayed to the owner at the time to alert him and to prevent over-tightening the bolts during the installation. It appears that the owner did take notice of the manufacturers concern of over tightening, which explains the finding of the metallurgist identifying that "*whilst the bolts have failed in fatigue, the common cause for fatigue initiation and failure in this regard was under-tightening during assembly, but not considered to be the primary cause in this instance".*

2.5 Based on the above identified manufactures and metallurgist findings of over-tightening and under-tightening, it became apparent that further investigation is required to determine if the proper torque value was used when installing the propeller. In this regard, the owner of the aircraft indicated that the torque value 14 foot pounds were used to torque the bolts during the propeller installation. This torque value was in accordance with the propeller manufacture maintenance requirements.

2.6 It was also noted during the on-site investigation that the six propeller bolts fractured that finally caused the propeller to separate from the engine flange. Four of the six fractured bolts were removed from the engine flange and submitted for metallurgist examination. The metallurgist concluded in his report that the cause of the propeller bolts failure was as follows:

(i) "*Whilst the bolts have failed in fatigue, the common cause for fatigue initiation and failure, under-tightening during assembly, is not considered to have been the primary cause in this instance. The presence of crack-like lap defects in the thread roots, formed during the thread rolling operation, is considered to be the primary cause."*

2.7 The metallurgist observation was that the bolts may have not been manufactured and tested to the quality standards applied to aircraft (civil aviation) components or parts; hence suggested that the bolts origins should be investigated further. Due to unavailability of relevant maintenance information of the origins of the bolts, the owner was requested for more information. The owner indicated that he obtained the bolts from a private non-aviation supplier and he decided to use the bolts as he was convinced that the bolts were manufactured according to similar standards as per aviation requirements.

2.8 Since this aircraft was registered as a Non Type Certificated Aircraft (NTCA), the airworthiness of the aircraft, the owner or operator shall be the sole responsibility in accordance with generally accepted practices for such aircraft. Thus the aircraft shall have been maintained in accordance with the provisions of Part 24 and 43 as applicable to the aircraft.

(i) Relevant to the bolts that fractured, the identified regulations states the following: "Any Class I, Class II or Class III part, component or product, whether new or previously used, for which no historical records are available or traceable, or for which the available records do not confirm that they have been approved by a responsible aviation authority, shall be considered to be unserviceable and may not be fitted to any type-certificated aircraft, nor to any non-type certificated aircraft operated or intended to be operated in terms of Part 96.

(ii) Based on the above regulatory requirement, initially when the bolts were obtained, the historical records were available and traceable. The issue was that they were not approved by a responsible aviation authority, as they were obtained from a private non-aviation supplier. However, since the aircraft was not being operated or intended to be operated in terms of Part 96. It appears as though the identified regulation does not apply in this regard.

(iii) Apart from this regulation which limits the use of unapproved aviation components or products on non-type certificated aircraft operating or intended to be operating in terms of Part 96, there are no other regulation that prevent installation of unapproved components or products on aircraft operating or intended to be operated in terms of Part 94 as it is the case with ZU-BTT aircraft. This implies that the owner who was also the approved builder of the aircraft, he could exercise the option of installing unapproved components or products on the aircraft. But only if the components or products are according to the approved design criteria and build standard; in compliance with special conditions of above identified regulations and not making the aircraft type unsafe for its intended use.

2.9 In conclusion, it is important to note that the owner visited the private supplier and obtained the bolts that subsequently fractured on the aircraft. The private supplier most probably manufactured all different kinds and sizes of fasteners or bolts at the time. The aircraft owner visited the supplier and selected the required bolts he deemed fit for the installation of the propeller. At the time, the manufacturing standards used in producing the bolts were not considered important by the owner, as the aircraft was being assembled. Every component and product was still undergoing test of being subjected to proving flights. At the end of the assembly and proving flights, the aircraft was considered to be airworthy with the bolts installed.

3. CONCLUSION

3.1 Findings

3.1.1 The pilot had a valid private pilot license (PPL) and the aircraft type rating was endorsed on it.

3.1.2 The pilot had a valid aviation medical certificate with the restriction to wear corrective lenses.

3.1.3 The pilot was accompanied by a passenger on board the aircraft when the incident occurred.

3.1.4 The pilot was also the owner of the aircraft and operated the aircraft on a private flight which was in accordance with requirements of Part 94.

3.1.5 The aircraft was issued with a valid Private Authority to Fly in accordance with Part 94.

3.1.6 The wooden P prop that was manufactured by Pieter De Necker and fitted to the engine, separation from the engine attachment flange in mid-air whilst the aircraft was cruising on a private flight and impacted the engine cowling and left wing.

3.1.7 Due to the loss of the propeller in mid-air, the pilot glided the aircraft towards the N12 National tar road that was the only available option to carry out a possible successful forced landing. With no traffic travelling on the N12 at the time, the aircraft landed safely on the tar road without further damage to the aircraft or property.

3.1.8 After landing, the pilot noted that the propeller separated from the engine at the propeller attachment flange after the 6 securing attachment bolts fractured.

3.1.9 According to the Metallurgist that examined some of the bolts that fractured, the bolts fractured due to the following reason: "*Whilst the bolts have failed in fatigue, the common cause for fatigue initiation and failure, under-tightening during assembly, is not considered to have been the primary cause in this instance. The presence of crack-like lap defects in the thread roots, formed during the thread rolling operation, is considered to be the primary cause."*

3.1.10 The propeller manufacturer was contacted during the investigation, as the manufacturer performed minor services on the propeller on December 2011. The propeller manufacturer concluded that the minor services carried out were as follows: "*The glass fibre laid up on the immediate sides of the propeller hub (both sides) had small bulging impressions which were visible and could be felt by touch as well. This was an indication of very slight – not serious at all – over tightening of the propeller bolts".*

3.1.11 Both metallurgist and manufacturer findings of over-tightening and under-tightening were considered in the investigation and concluded that the torque value 14 foot pounds were used to fasten the bolts, which was in accordance with maintenance requirements. However, it appears as though just a few weeks after the incident the propeller manufacturer increased the identified torque value 14 foot pound to 21 foot pound.

3.1.12 The metallurgist finding of "*the presence of crack-like lap defects in the thread roots, formed during the thread rolling operation, is considered to be the primary cause"* were also considered during the investigation and concluded that the fasteners or bolts were obtained from an private non-aviation supplier. Therefore it is possible that non-standard aviation practice were used in the manufacturing of the fasteners or bolts.

3.1.13 The fasteners or bolts were installed on the aircraft inclusive of the "*approved design criteria and build standard"* and also subjected to required "*proving flight testing"* and found to airworthy hence issuance of Authority to Fly, which was renewed yearly since first issuance.

3.2 Probable Cause/s

3.2.1 Propeller Attachment bolts failed during flight

3.3 Contributing Factor:

3.3.1 Material Failure

4. SAFETY RECOMMENDATIONS **Kev to draft a memo to DCA(e-mail)**

MEMO from Kev

5. APPENDICES

5.1 Appendix A: Metallurgist Report

Compiled by:

.... Date: ……………..
For: Director of Civil Aviation

Investigator-in-charge : ……………………………… Date: ……………..

Co-Investigator : ……………………………… Date: ……………..

Report No: MR(12)323

Examination of Starter Disk and Propeller Mounting Bolts from for South African Civil Aviation Authority.

by

T.J.Carter C.Eng., FIMMM.

Submitted to: Mr J Visser,
South African Civil Aviation Authority.

By e-mail: visserj@caa.co.za

14th July 2012
Tim J Carter Consulting.
Suite 26, Pvt Bag X3, Atlasville, 1465.
TJC/tc

T J Carter C.Eng., FIMMM

Abstract

Four propeller mounting bolts from a set of six were submitted after failure in service. They were found to have failed through fatigue, a phenomenon normally associated with under-tightening when found in threaded fasteners. In this case, however, crack-like defects, associated with the thread rolling operation were found. These act as stress-raisers, greatly increasing the stresses present and acting as initiators for the fatigue mechanism, and failure is attributed to their presence.

1. Introduction.

A starter disk and four of six propeller mounting bolts were submitted to Tim J Carter Consulting for examination after in-service failure of the bolts. The identification of the aircraft and the circumstances surrounding the failure were not submitted.

2. Examination.

2.1 Background.

The starter disk bore a number of identifying markings, 76628-ASS'Y, presumed to be a serial or part number, LI-7 within a circle, B15 within a hexagon and L155 within a double circle, believed to be inspection marks, figures 1 to 3.

2.2 Visual Examination.

The starter disk showed distinct burring around two of the mounting bolt holes, figures 4 & 5.

The bolts were submitted within recess nuts, figure 6, and were extracted with difficulty since attempts appear to have been made to drill them out, partially destroying the hexagonal recess in the bolt end. Once removed, rust was observed to be present on the threads, figure 7, indicating that they had been in place for some time and had been assembled without any protective coating. No evidence of thread locking compound was observed.

The fracture surface of one bolt showed unmistakable features indicating failure in fatigue, figure 8. Two other fracture surfaces showed features which may indicate the early stages of fatigue, i.e. apparent ratchet marks at the apparent origin, figures 9 & 10.

2.3 Metallurgical Examination.

2.3.1 Metallographic.

A section was cut longitudinally from one bolt sample and embedded in thermo-setting resin before being mechanically polished, finishing with a diamond abrasive to give a 1μm finish.

After etching in Nital-2 (2% nitric acid in ethanol) to reveal the structure, a microstructure of lightly tempered martensite was observed, figure 11. When the structure in the thread roots was examined, compression of the structure and small surface laps and folds indicated that the threads had been formed by rolling rather than cutting, figure 12.

2.3.2 Chemical Analysis.

Threaded fasteners are not in general specified by material, but by mechanical properties, thus no compositional determination was attempted.

2.3.3 Hardness Testing.

Using the specimens previously prepared for metallographic examination, hardness tests were carried out using a Vickers-type test with a diamond pyramid indenter and a load of 30kg. Results obtained were as follows:

	HV 30	Average	UTS, MPa
Fastener	294, 295, 295	294.7	927

This value for UTS indicates that the fasteners are most probably of strength grade 8.8.

3. Discussion.

It seems most probable that the fasteners have failed by fatigue, usually associated with under tightening on assembly or dynamic overload, such as contact between the propeller and some solid object, some period of time prior to failure.

In this instance, however, surface defects which were crack-like in nature were observed in the roots of the threads. Such defects are very harmful, causing both an increase in stress and acting as initiators for the fatigue mechanism.

Formed during the thread-rolling process, crack-like laps in the thread roots are most commonly caused by over-filling of the rolls. Since they are a commonly found defect, aircraft grade fasteners, which are generally manufactured in small batches, are subject to destructive testing of representative samples to ensure that fasteners so affected are not released for use. This in turn suggests that these fasteners were not manufactured and tested to the appropriate standards and may not have been intended for aircraft use.

The burring and scoring found on the disc itself indicate that failure had been in progress for some time before final fracture. It is considered probable that the two holes so affected were the location of the two missing fasteners, which probably failed and were lost shortly before final failure.

4. Conclusions.

Whilst the fasteners have failed in fatigue, the common cause for fatigue initiation and failure, under-tightening during assembly, is not considered to have been the primary cause in this instance.

The presence of crack-like lap defects in the thread roots, formed during the thread rolling operation, is considered to be the primary cause.

It is considered that these fasteners may not have been manufactured and tested to the quality standards normally applied to aircraft components, and their origins should be investigated.

Figure 1. Assembly number stamped onto disk.

Figure 2. Inspection marks stamped onto disk.

Figure 3. Inspection marks stamped onto disk.

Figure 4. Burring of bolt holes on disk.

Figure 5. Burring of bolt holes on disk.

Figure 6. The fasteners as submitted, within recess nuts.

Figure 7. Corrosion observed on the threads after removal from the nuts.

Figure 8. Characteristic features of fatigue observed on one fracture surface.

Figure 9. Apparent ratchet marks observed on another fastener indicating early stages of fatigue.

Figure 10. Apparent ratchet marks observed on another fastener indicating early stages of fatigue.

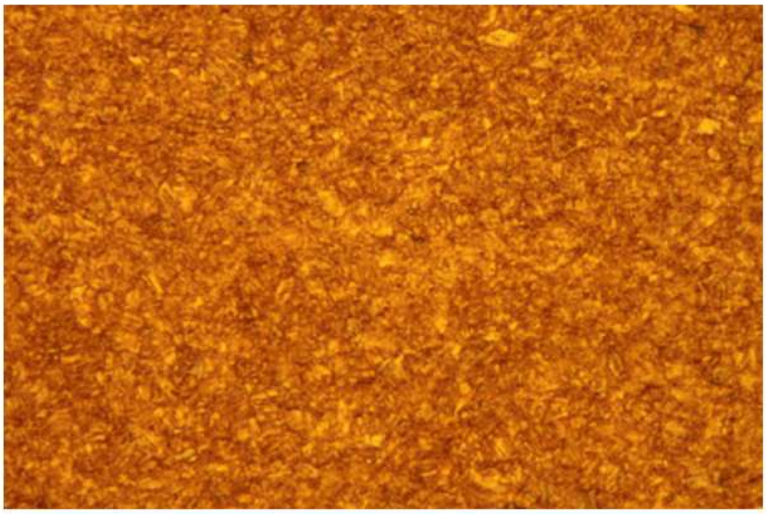

Figure 11. Microstructure of lightly tempered martensite. Approx x 400, etched Nital-2.

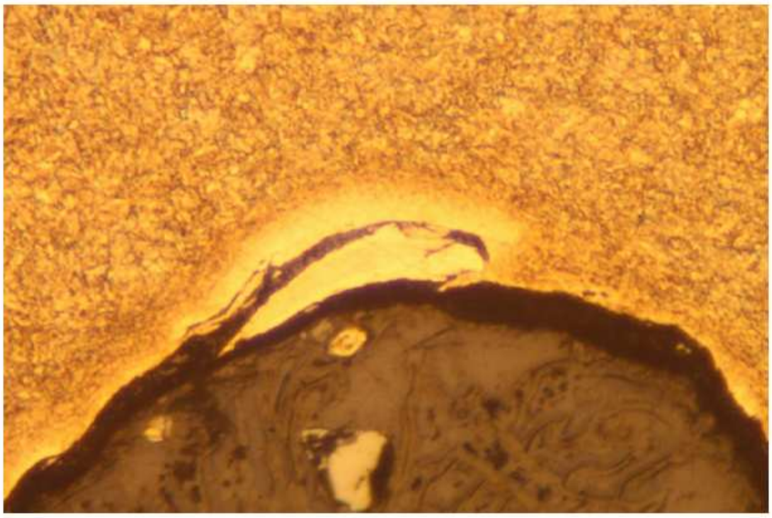

Figure 12. Crack-like lap defect observed in thread root. Approx x 400, etched Nital-2.