Section/division Accident and Incident Investigations Division

Form Number: CA 12-12a

AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/2/3/8777
Aircraft Registration	**ZS-SCS**	**Date of accident**	10 April 2010	**Time of Accident**	0730Z
Type of Aircraft	Robinson R22 Beta			**Type of Operation**	Training
Pilot-in-command Licence Type	Commercial	**Age**	25	**Licence Valid**	Yes
Pilot-in-command Flying Experience	Total Flying Hours	2015.6		Hours on Type	870
Last point of departure	Cape Town international aerodrome - FACT (Western Cape province).				
Next point of intended landing	Cape Town international aerodrome - FACT (Western Cape province).				
Location of the accident site with reference to easily defined geographical points (GPS readings if possible)					
At the helipad at GPS position determined as S33° 59. 07´ E18° 36.13´. Elevation 151 Feet AMSL.					
Meteorological Information	Clear skies: Visibility 10 km.				
Number of people on board	1 + 1	**No. of people injured**	0	**No. of people killed**	0

Synopsis

The certified flight instructor accompanied by a student pilot embarked on a training flight under Visual Flight Rules (VFR) from Cape Town international aerodrome (FACT) with the intention to return to the same aerodrome. The helicopter was refuelled before departing. The flight instructor reported that after being cleared by FACT tower, the student pilot took control of the helicopter and lifted off. As the helicopter was stable and hovering at about two feet above the helipad, the instructor took control and positioned it to go through transition.

While the helicopter was hover taxiing above the helipad, the instructor heard a loud bang coming from the engine. The engine immediately stopped and the helicopter spun ±90 degrees before coming to rest on its skids at the helipad. After a few seconds the instructor noticed fuel (Avgas LL100) leaking from the helicopter. The instructor quickly shut off the fuel valve, pulled the mixture and turned all the switches off. Both the instructor and the student pilot vacated the helicopter unharmed, but the helicopter was substantially damaged.

After the accident and subsequent examination by the Metallurgical Engineer, it was noted that the forward flex plate failed in fatigue on takeoff, resulting in extensive damage to the helicopter.

Probable Cause

Forward flex plate fractured after lift-off, resulting in a tail rotor drive shaft failure.

IARC Date		Release Date	

AIRCRAFT ACCIDENT REPORT

Name of Owner/Operator	: Heli Marketing (PTY) Ltd
Manufacturer	: Robinson Helicopter Company
Model	: Robinson R22 Beta
Nationality	: South African
Registration Marks	: ZS-SCS
Place	: Cape Town International on the helipad
Date	: 10 April 2010.
Time	: 0730Z

All times given in this report is 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 The certified flight instructor accompanied by a student pilot embarked on a training flight under Visual Flight Rules (VFR) from Cape Town international aerodrome (FACT) with the intention to return to the same aerodrome. The helicopter was refuelled before departing. The flight instructor reported that after being cleared by FACT tower, the student pilot took control of the helicopter and lifted off. As the helicopter was stable and hovering at about two feet above the helipad, the instructor took control and positioned it to go through transition.

1.1.2 While the helicopter was hover taxiing above the helipad, the instructor heard a loud bang coming from the engine. The engine immediately stopped and the helicopter spun ±90 degrees before coming to rest on its skids at the helipad. After a few seconds the instructor noticed fuel (Avgas LL100) leaking from the helicopter. The weather at the time was reported to be fine. The instructor quickly shut off the fuel valve, pulled the mixture and turned all the switches off.

1.1.3 Both the instructor and the student pilot vacated the helicopter unharmed, but the helicopter was substantially damaged. The accident happened during daylight conditions at the GPS position determined as South 33° 59.07´ East 18°36.13´, elevation 151 feet above mean sea level (AMSL).

1.2 Injuries to persons

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

1.3 Damage to aircraft

1.3.1 The helicopter was substantially damaged during the accident sequence.

NB: The forward flex plate on the gearbox sheared off. The drive shaft ripped open both main and auxiliary fuel tanks, pulling all the wires off and out of loom and off the frame. The aft flex plate on the free wheel bent, but did not break. The clutch was fully engaged and was bent to one side. Both V-belts climbed off the pulleys and sheared. The sheave alignment rod was bent and the rod end pulled off the bearing. The aft cross tube was bent from hard landing. Below is the helicopter after it was recovered to the facility.

Figure 1: View of the helicopter in the hanger after recovery

1.4 Other damage

1.4.1 No other damage was caused.

1.5 Personnel information

Nationality	South African	Gender	Male	Age	25
Licence Number	***************	Licence Type	Commercial		
Licence valid	Yes	Type Endorsed	Yes		
Ratings	Night Rating, Instrument Rating, Instructor Rating and Test pilot Rating.				
Medical Expiry Date	17 December 2018				
Restrictions	Nil				
Previous Accidents	None				

Flying experience

Total Hours	2015.6
Total Past 90 Days	66.4
Total on Type Past 90 Days	66.4
Total on Type	870

1.6 Aircraft information

Airframe

Type	Robinson R22 Beta	
Serial No.	4268	
Manufacturer	Robinson Helicopter Company	
Date of Manufacture	2008	
Total Airframe Hours (At time of accident)	1025.3	
Last MPI (Hours & Date)	1000.4	26 March 2010
Hours since Last MPI	24.9	
C of A (Issue Date)	18 March 2008	
C of A (Expiry Date)	17 March 2011	
C of R (Issue Date) (Present owner)	03 August 2008	
Operating Categories	Standard	

1.6.1 The Robinson R22 Betta is a light two-seat reciprocating engine powered helicopter with a two-blade teetering rotor system. It is manufactured in the USA, with over 3000 units in operation worldwide. It is frequently used as a low-cost initial student training aircraft. The two seats are side by side in an enclosed cabin with a curved two-panel wind screen. The flying controls are all mechanical. The cyclic control stick (known as the "T" bar cyclic) is mounted between the pilots and with handgrips on a swing arm, which gives access from either seat for instructional purposes. The pilot sits in the right seat, and the left cyclic pitch control and left collective control can be easily removed for solo flight.

Engine

Type	Textron Lycoming
Serial No.	L41014-36E
Hours since New	1025.3
Hours since Overhaul	Not reached

1.7 Meteorological information

1.17.1 The following weather information was obtained from the pilot questionnaire.

Wind direction	150°	Wind speed	15 knots	Visibility	Clear
Temperature	17°C	Cloud cover	Few clouds	Cloud base	Few clouds
Dew point	9ºC				

1.8 Aids to navigation

1.8.1 The helicopter was fitted with standard navigation equipment for this helicopter type as approved at the time of certification.

1.9 Communications

1.9.1 No difficulties with communications were known or reported prior to the accident. No malfunction of any of the equipment was reported at the time of the accident.

1.10 Aerodrome information

Aerodrome Location	Cape Town International	
Aerodrome Co-ordinates	S33º 58′05.2′ E018º 36′16.7′.	
Aerodrome Elevation	151 feet	
Aerodrome Status	Licensed	
Runway Designations	01/19	3 322 x 300
Runway Dimensions	16/34	1 820 x 150
Runway Used	Helipad	
Runway Surface	Asphalt	
Approach Facilities	PAPI, NDB,ILS, VOR, DME, Runway lighting	

1.11 Flight recorders

1.11.1 The helicopter was not fitted with a Cockpit Voice Recorder (CVR) or a Flight Data Recorder (FDR) and neither was required by regulations to be fitted to this type of helicopter.

1.12 Wreckage and impact information

1.12.1 The helicopter's tail rotor drive shaft failed while hover taxiing over the helipad. The instructor immediately landed the helicopter on its skids as a safety precaution.

1.13 Medical and pathological information

1.13.1The flight instructor and the student pilot sustained no injuries as result of this accident.

1.14 Fire

1.14.1 There was no evidence of pre- and post-impact fire

1.15 Survival aspects

1.15.1 The accident was considered survivable because both occupants were properly restrained and secured by making use of three-point safety harnesses.

1.15.2 The cockpit/cabin area remained intact after the accident sequence.

1.16 Tests and research

1.16.1 With the assistance of maintenance personnel, the helicopter was recovered to the hangar, where it was inspected for any possible mechanical failure or malfunction that could have contributed to the accident. During the inspection, it was noted that the crack initiated under the bonded washers and extended outwards until it failed in fatigue resulting in the following.

- The forward flex plate on the gearbox sheared off.
- The drive shaft then ripped open both main and auxiliary fuel tanks, pulling all the wires off and out of loom and off the frame.
- The aft flex plate on the free wheel bent, but did not break.
- The clutch was fully engaged and was bent to one side. Both V-belts had climbed off the pulleys and sheared.
- The sheave alignment rod was bent and the rod end had been pulled off the bearing.
- The aft cross tube was bent from the hard landing.

Figure 2: Fractured forward flex plate

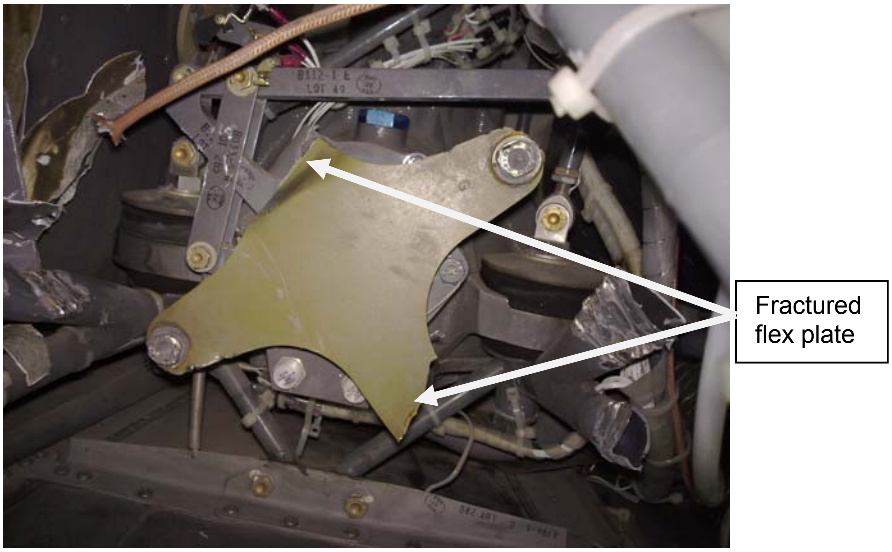

Figure 3: View of failed forward flex plate (both sides)

Figure 4: View of a destroyed forward yoke in main tank

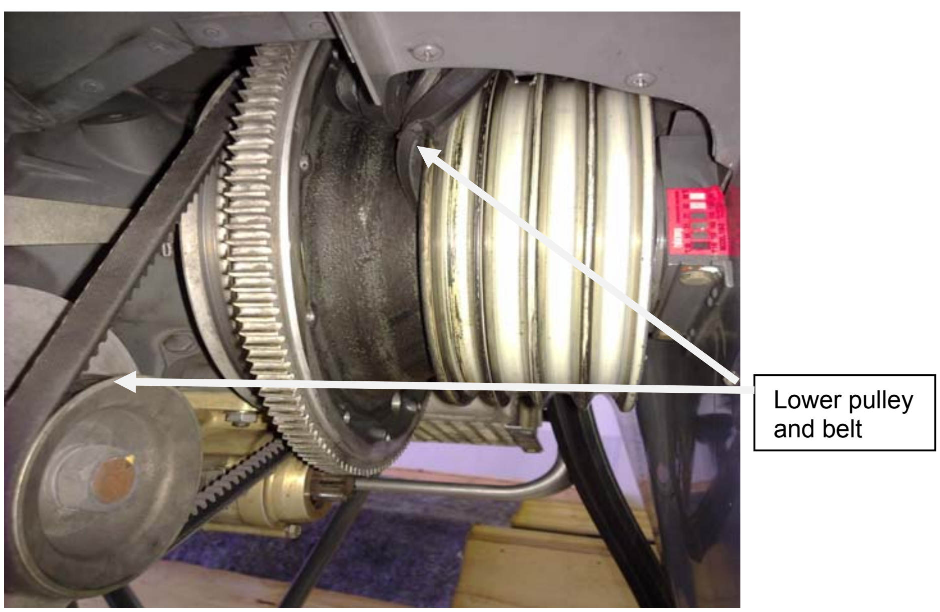

Figure 5: View of the lower pulley and belt

1.16.2 The flex plate was subjected to an examination by the metallurgist:

- ❖ Expert metallurgical examination revealed that the forward flex plate failed in fatigue on takeoff, resulting in extensive damage.

1.17 Organisational and management Information

1.17.1 This was a training flight.

1.17.2 The last MPI (mandatory periodic inspection) that was carried out on the helicopter prior to the accident was certified at 1000.4 hours on 26 March 2010 by the AMO (Aircraft Maintenance Organisation). The person who certified the task held a valid approved person accreditation from the SACAA as well as an AME (Aircraft Maintenance Engineer) licence.

1.18 Additional information

1.18.1 Forward flex plate

- ❖ Power to drive the main and tail rotors is transmitted from the engine to the rotor drive train through a vee-belt drive system.

- ❖ Flexible couplings are located at the input to the main rotor (also known as the forward flexible couplings) and at both ends of the tail rotor drive shaft. The flexible coupling at the forward end of the tail rotor drive shaft is commonly known as the intermediate flexible coupling.

- ❖ The flexible coupling in the R22 drive train accommodates differences in drive shaft axial alignment during helicopter operation. They are constructed by bolting a single, four armed, thin stainless plate between the main rotor gearbox yoke and the drive shaft yoke.

1.18.2 Forward flex plate fracture control

- ❖ The safe operation of the Robinson R22 helicopter depends on maintaining the integrity of the main rotor and tail rotor drive train during each flight. Torque from the engine is transmitted along a single load path to both rotors; no redundant load paths are provided.

- ❖ The threat of coupling failure to flight safety is managed by flex plate replacement after a prescribed period of time and correct assembly during manufacture and maintenance. The coupling is required to have sufficient strength to transmit the torque created during all phases of helicopter operation within the designed operational limits.

- ❖ It is also required to have enough strength to resist the initiation and growth of fatigue cracks under the local alternating stress state created by repeated torque application and repeated flexing of the plate during helicopter operation within the designed operational limits. In general terms, fatigue cracking occurs in response to exposure to a loading environment that creates alternating local stresses in a component. Crack initiation is dependent on the number and magnitude of the local alternating stress cycles. There is an adverse relationship between stress cycle magnitude and number of stress cycles to fatigue failure.

- ❖ The threat of fatigue failure in the case of components subjected to many alternating loading cycles for the duration of its expected life is controlled by limiting the magnitude of the local stresses developed at the bolt hole during operation to a value below the fatigue limit for the component. The fatigue limit for a component is a function of alloy strength, surface finish and detailed geometry, and in the case of the flex plate, the presence of bonded reinforcement.

- ❖ The region surrounding each bolt hole is reinforced by adhesively bonded reinforcing plates. The magnitude of stress created at the edge of the bolt hole during helicopter operation is affected by the presence of the bonded reinforcing plates. Flex plate fracture control depends on limiting the magnitude of the local stresses at the flex plate bolt holes.

1.19 Useful or effective investigation techniques

1.19.1 None.

2. ANALYSIS

2.1 Available information indicated that fine weather conditions prevailed in the area at the time of the flight and subsequent accident. The prevailing weather conditions were therefore not considered to have had any bearing on the accident.

2.2 The helicopter was properly maintained and no documented evidence was found indicating any defect and/or malfunction on the helicopter prior the flight that could have contributed to or caused the accident. The helicopter had flown a total of 24.9 hours since the last maintenance inspection was certified.

2.3 The pilot held a valid pilot's licence as well as a valid aviation medical certificate that was issued by a SACAA accredited medical examiner. After the accident and subsequent examination by the metallurgical engineer, it was noted that the forward flex plate failed in fatigue on takeoff, resulting in extensive damage to the helicopter.

2.4 It was evident that fatigue cracking in the forward flex plate started at the bolt hole and propagated under the washers of the bolted joint towards the edge of the flex plate. It was also evident from the fracture surface features that crack growth had occurred over a number of flights prior to the accident flight. The reliability of a general visual inspection (for example, pre-flight inspections) is affected by lighting, the ability to get close to the component (proximity), and dirt and dust from the operating environment. Reliable detection of a specific defect would require a directed detailed inspection.

3. CONCLUSION

3.1 Findings

(i) The flight instructor was a holder of a commercial pilot's licence with the helicopter type licence endorsed in his logbook.

(ii) The flight instructor’s medical certificate expired on 17 December 2018.

(iii) The flight instructor held the required ratings at the time of the accident.

(iv) The flight instructor and the student pilot were engaged in a training flight.

(v) The AMO that had certified the last inspection was accredited by the SACAA.

(vi) The certificate of airworthiness (C of A) was valid at the time of the accident.

(vii) The tail rotor shaft failed after lift-off.

(viii) The flight was conducted in fine weather conditions.

3.2 Probable cause/s

3.2.1 Forward flex plate fractured after lift-off resulting in a tail rotor drive shaft failure.

3.3 Contributing factor/s

3.3.1 Metal fatigue.

4. SAFETY RECOMMENDATIONS

4.1.1 It is recommended that the Director for Civil aviation instruct the Airworthiness Department of the SACAA to:

4.1.1 In consultation with the Federal Aviation Administration of the USA, review the need for the defining of a service life of the forward flex plates as installed on Robinson R22 series helicopters;

4.1.2 In consultation with the Federal Aviation Administration of the USA, review the need for the defining of an inspection interval of the forward flex plates as installed on Robinson R22 series helicopters.

5. APPENDICES

5.1 Appendix 1 Metallurgical report

Report reviewed and amended by the Advisory Safety Panel on 20 July 2010

-END-

Appendix 1

Report No: MR(10)277

Examination of Transmission Flex Plate from Robinson R-22 ZS-SCS

by

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

Submitted to: Mr F Motaung,
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20th May 2010

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TJC/tc

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Abstract

A flex plate, used to accommodate slight movements in the drive train between the engine and transmission in a Robinson R-22 helicopter failed in fatigue on take-off, causing the helicopter to crash and resulting in extensive damage. Failure was due to fatigue and no metallurgical or material defect or deficiency was found which would have caused initiation. It is recommended that all R-22 flex plates are changed at 500 hours to prevent any recurrence.

1. Introduction.

The transmission flex plate from Robinson R-22 helicopter registration ZS-SCS was submitted to Tim J Carter Consulting after it failed during take-off, causing the aircraft to fall from a height of 2 - 3 metres, sustaining extensive damage.

2. Examination.

2.1 Background.

The flex plate connects the engine output to the transmission input within the drive train of the helicopter. Failure of the flex plate therefore cuts off all power to the rotor and tail rotor systems, causing the aircraft to descend rapidly.

It was reported that this plate had completed a total of 1025 operating hours, and that the aircraft had had a periodic inspection less than 50 hours prior to the failure. It was also reported that, whilst clearly a critical component, the flex plate did not have a fixed life after which replacement is mandatory.

2.2 Visual Examination.

The plate bore identification markings, one presumed to be a part number, A947-1G and a lot number, lot 281. Also present was an inspection identification RHC 6 USA. These are reproduced in figure 1.

The plate had fractured adjacent to one of the four fixing holes, figure 2, with the fracture surface showing clear indications and features typical of fatigue, figure 3. Close examination showed that the origin of the fracture was a small thumb-nail shaped crack, figure 4, initiating underneath the reinforcing washer. The surface of this initial crack was discoloured, indicating that it had been present for a significant period of time. The opposite fixing hole had torn away with this second fracture exhibiting features indicating ductile overload, figure 5.

2.3 Metallographic Examination.

A section was cut from the plate and embedded in thermo-setting resin before being mechanically polished to a 1 µm finish using diamond abrasive. After etching in acid ferric chloride, a fine-grained structure of fine carbides in a martensitic matrix was observed, figure 6.

2.4 Hardness Testing.

Using the specimen previously prepared for metallographic examination, hardness tests were carried out using a Vickers-type hardness test with a diamond pyramid indenter and a load of 300g, and the following results were obtained. These results were converted to an approximate tensile strength using an algorithm based on, *inter alia*, data from ASTM A370.

	HV 0.3	Average	Equivalent UTS, MPa.
Flex Plate	396, 408, 402	402	1300

The tensile strength derived from the hardness indicates that the material is most likely in the H-1025 condition.

2.5 Chemical Analysis.

A sample of the material was submitted for chemical analysis to determine the material of construction and the composition obtained is given in appendix 1. From this it can be seen that the material conforms to the requirements of alloy 630, more commonly known as 17-4 PH stainless steel. This alloy is considered a suitable material for the application.

3. Discussion.

The flex plate has clearly failed in fatigue, with the failure initiating beneath the reinforcing washer at one fixing hole, where detection would be difficult. The discolouration of this initial crack indicates that it had been in existence for a significant period, and had, in that condition, been relatively benign. It is probable that a relatively minor overload situation had caused the crack to commence growth, eventually reaching a critical length where catastrophic failure ensued. The opposite fixing hole then, being unable to withstand the additional load and mis-alignment, tore away in the resulting ductile overload mechanism.

The flex plate has been manufactured from 17-4 PH high strength stainless steel, most probably in the H-1025 condition, a material considered suitable for this highly loaded application.

It is considered surprising that this component, being subjected to heavy loading and continual cyclic bending loads through minor mis-alignment between the engine and the transmission, should have an unlimited life expectancy.

Since failure of the flex plate will result in the immediate probable loss of the aircraft, it should be considered a "vital part" and subject to regular and detailed non-destructive examination, preferably by magnetic particle examination. Such a procedure would, however, be both complex and time consuming, requiring that the part be removed from the aircraft and dismantled, with the reinforcing washers removed prior to removal of the paint before examination. The plate would then require re-assembly and re-painting before re-identification with the part, lot and inspection identification markings and re-assembly to the aircraft. It is considered probable that simple replacement would most likely be more cost effective.

4. Conclusions.

This heavily loaded and very critical part has failed in fatigue, causing major damage. Had the aircraft not been so close to the ground, it is probable that the crew would have been either seriously injured or, more probably, killed.

No metallurgical defect or deficiency to which failure initiation could be attributed was found, and the material of construction is considered suitable for the application.

It is recommended that this component, rather than being subjected to a complex and time-consuming and therefore costly inspection at regular intervals, for which no manufacturer's recommended procedure appears to exist, should be replaced at intervals representing half the life to failure of this component, *i.e.*, at intervals of not more than 500 service hours. It is further recommended that each component should be identified with a unique serial number and replacement recorded in the aircraft maintenance records.

Figure 1. The flex plate as received, showing failure location and identification markings.

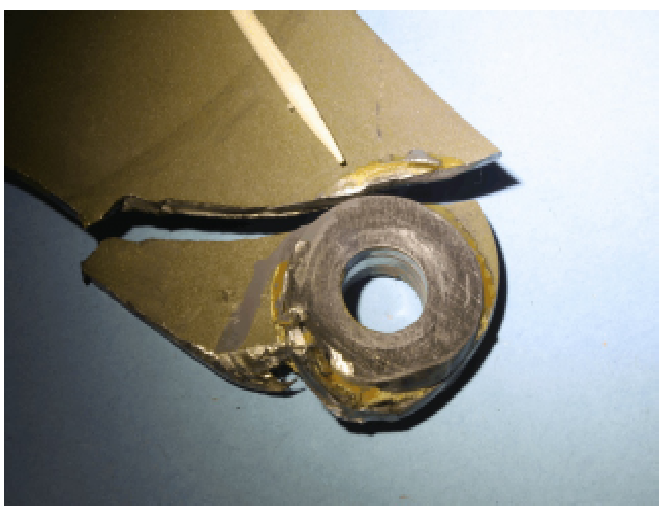

Figure 2. Location of the fracture adjacent to fixing hole.

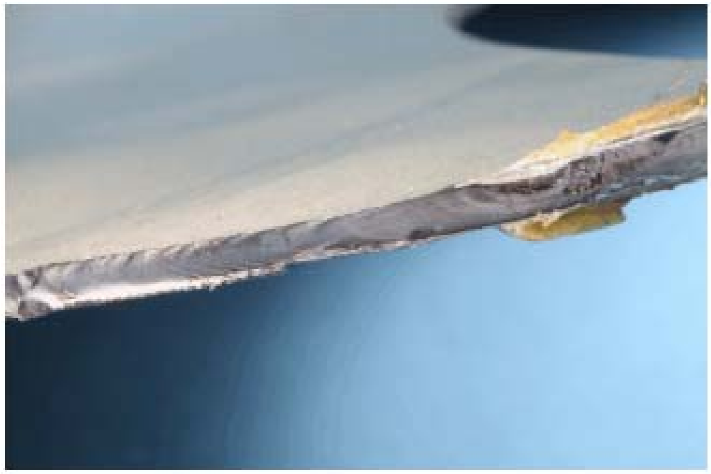

Figure 3. The fracture surface, showing typical fatigue features.

Figure 4. Thumb-nail feature, indicating initiation site, concealed beneath reinforcing washer.

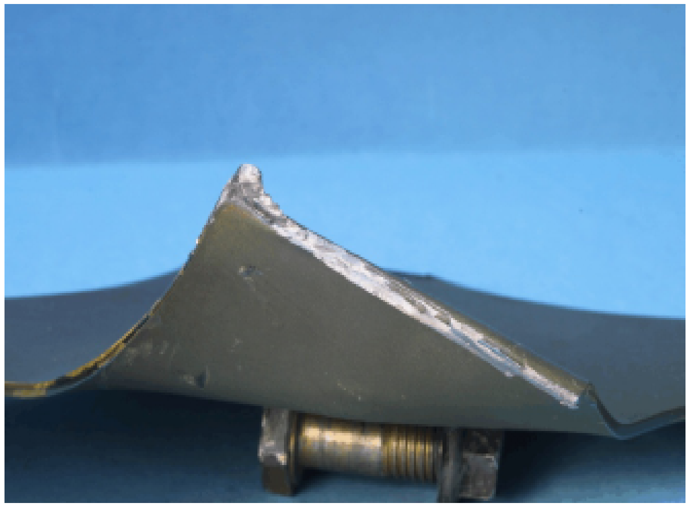

Figure 5. The opposing side fracture, showing only ductile overload features.

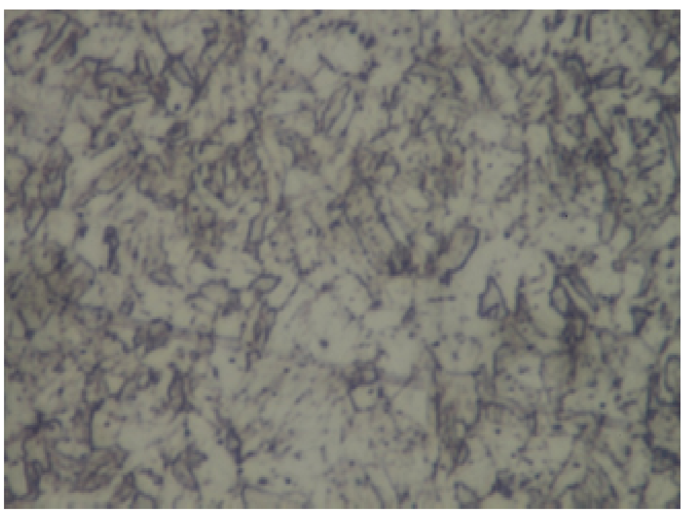

Figure 6. Microstructure of fine carbides in martensite. Etched acid ferric chloride, Approx. x 400.

Appendix 1.

Chemical Analysis Results.

		Flex Plate	17-4 PH
Carbon	%	≤0.041	≤0.07
Manganese	%	0.45	≤1.00
Silicon	%	0.31	≤1.00
Sulphur	%	≤0.005	≤0.030
Phosphorus	%	0.015	≤0.040
Nickel	%	4.27	3.0 - 5.0
Chromium	%	16.3	15.5 - 17.5
Molybdenum	%	0.21	-
Copper	%	3.48	3.0 - 5.0
Aluminium	%	0.007	-
Niobium	%	0.303	0.15 - 0.45
Vanadium	%	0.027	-
Titanium	%	0.011	-
Boron	%	0.0010	-
Iron		Balance	Balance