Havarikommissionen
Accident Investigation Board Denmark

FINAL REPORT

HCLJ510-2012-86	**Serious incident**		
Type of aircraft:	Boeing MD-82	Registration:	SE-DIL
Engines:	2 P&W JT8D-217C	Type of flight:	Scheduled passenger, IFR
Crew:	5 - no injuries	Passengers:	130 - no injuries 5 - minor injuries
Place of occurrence:	Copenhagen Airport, Kastrup (EKCH)	Date and time:	5.2.2012 at 0738 UTC

The Aviation Unit of the Accident Investigation Board Denmark (AIB DK) was informed about the incident from the Area Control Centre at Copenhagen Airport, Kastrup on 5 February 2012 at 0748 UTC.

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FACTUAL INFORMATION

History of flight

The serious incident flight was a scheduled international passenger flight from Copenhagen Airport Kastrup (EKCH), Denmark with Gardermoen Airport Oslo (ENGM) in Norway as planned destination.

After deicing, the aircraft taxied to runway 22R. When the aircraft was cleared for take-off, the Pilot in command (PIC) as flying pilot applied engine power and the aircraft started rolling down the runway.
After a few seconds of take-off acceleration, the flight crew heard two puffs and noticed a slight yaw movement of the aircraft. From the left hand engine instruments, the PIC observed no EPR (Engine pressure ratio) or N1 (Rotational speed of low-pressure compressor) indications and suspected a damaged engine.
The flight crew aborted the take-off roll from a ground speed of about 40 knots and the left engine was shut down by using the fire handle. At the same time, smoke entered the cabin.
PIC called and questioned Kastrup TWR about indications of fire or smoke outside the aircraft. Kastrup TWR reported that everything looked normal.

Because the cabin crew reported that smoke still was present in the cabin and because the lavatory smoke detector alarms were on, the PIC decided to shut down the right engine and immediately initiated an evacuation of the aircraft.

The aircraft was evacuated in approximately 1:30 minutes. During the evacuation, 5 passengers suffered minor injuries.

Both crew and passengers were transported to the airport terminal area by airport personnel. In the terminal, the passengers were debriefed by the crew and personnel from the operator of the aircraft.
None of the persons that were exposed to the smoke reported breathing problems.

The serious incident took place in daylight and under visual meteorological conditions (VMC).

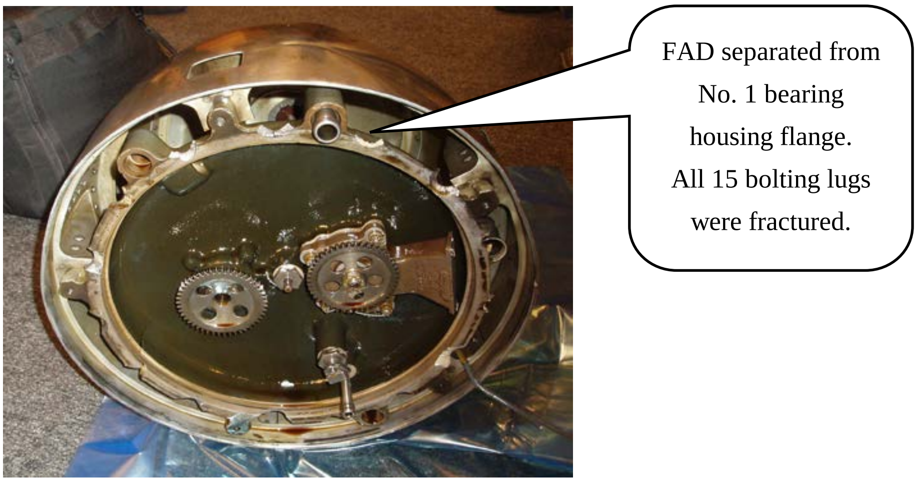
Initial investigation
A visual inspection of the left hand engine (ENG #1) air intake revealed that ENG #1 Front Accessory Drive (FAD) with the Nose Dome attached had separated from the engine.

The investigation revealed oil in the engine hot section and exhaust section.

The picture below shows the left engine air intake and the separated FAD and Nose Dome at the inlet guide vanes.

The investigation found the FAD support lugs fractured.
All studs and nuts holding the remains of the 15 lugs were in place at the engine No. 1 bearing housing flange.

The picture below shows the liberated Nose Dome and FAD.



Engine information

The engine was manufactured in USA by Pratt & Whitney as JT8D-217C Serial number P726014D.

	Flight Hours	Flight Cycles
Time since new (TSN)	41695.57	33590
Time since overhaul (TSO)	2510.57	1973
Time since inspection (TSI)	2510.57	1973

The engine was installed on the aircraft on 8 November 2010. TSO/TSI was at that time 0 hrs.
The FAD was part of the engine when delivered from the company that performed the overhaul.

Maintenance information & -investigation

The 15 nuts that held the remains of the FAD lugs were removed from the engine No. 1 bearing housing flange.
The release torque was measured and none of the nuts or studs was found to be loose or over-torqued.

In December 1995 as a reaction to reports on Nose Dome liberations, the engine manufacturer called operators attention to the cautionary note mentioned in the JT8D-200 Engine Manual & the AMM as follows:
Caution: *Do not draw front accessory drive group into place with bolts or damage to parts may result. Torque bolts in cross pattern to avoid misaligning front accessory support.*

In March 2001, the engine manufacturer believed that the liberation problem was due to the following:

1. *Over-torque of the studs.*

2. *Mishandling on the tooling during removal of the inlet cone.*
3. *Incorrect installation or incorrect torqueing of the attach nut.*

In March 2001, the following actions were suggested by the engine manufacturer to minimize the possibility of additional accessory support lug fractures:

1. *Inspect all front accessory supports of P/N 803290 configuration (and pre SB 5680 supports P/N 777190) by both a visual inspection and FPI inspection at the earliest convenience.*
2. *Replace all cracked or suspect P/N 803290 and P/N 777190 supports with a P/N 803605 or the current P/N 805770 support. Supports P/N 803605 and P/N 805770 have an increased thickness lug of 40 % when compared to P/N 803290 supports. We have only one report on a lug crack with the thicker supports.*
3. *Verify that dimensional inspections are accomplished during engine repair (overhaul) for the support, bearing support assembly and the inlet case. Verify that visual and FPI inspections are also accomplished.*
4. *Accomplish a visual and FPI inspection of the front accessory supports P/N 803290 and or P/N 777190 after each on wing removal of the support (ex during a fan removal).*
5. *Insure that all new personnel are aware of the required torqueing procedure as described in the Engine Manual (P/N 773128, Section 72-00-21, Installation -01, page 403.*

The FAD assembly was removed and reinstalled in December 2011 in connection with a 1st stage compressor fan disk and blade assembly replacement.

The engine shop maintenance personnel used the Aircraft Maintenance Manual (AMM) 72-21-00 chapter 2 (Engine Manual 72-00-21) for the FAD installation and were aware of the installation cautions and the torque procedure.
According to the maintenance personnel the FAD bolts were torqued to standard (85 lb-in) in accordance to the AMM 70-00-00 Figure 202 page 270.

The investigation found no rubbing or wear marks on the FAD and there was no sign of incorrect use of tooling.

After reinstallation, engine test-run and vibration check was performed without remarks.

Laboratory examination
The complete laboratory examination report is attached as appendix to this report.
The below mentioned lug numbers can be identified in the laboratory examination report.

The laboratory examination of the AMS 4418 magnesium alloy FAD revealed that 13 of the 15 fractures were fatigue fractures with the fatigue cracking in general occupying more than 80 % of the fracture surface.
One lug (7) contained a small fatigue crack but the main part of the fracture was pure shear off (overload fracture).
One lug (8) fracture had no signs of fatigue only shear off failure overload fracture type.

Two lugs (1 & 15) on top of the FAD was 100 % fatigue, i.e. no final rupture. Lug 14 had developed a fatigue crack deep into the FAD cover.
According to the laboratory report, these three lugs (1, 14, & 15) were presumed to be the first to develop fatigue cracking, whereas lug 7 was the last one developing fatigue. Lug 8 had no fatigue but was fractured off at the same time as or just after shear off of lug 7.

No cracks were found initiated from any of the 15 bolt holes.

All the fatigue cracks initiated at the sharp edge in the transition from the lug surface to the FAD cover cf. lug 1 shown re-positioned on the picture below.

There was no indication of material defects or deficiencies being causative or contributory to fracture initiation or propagation.

FAD assembly and modification status

The FAD assembly part number (P/N) was re-identified from P/N 777190 to P/N 803290 indicating that the FAD was modified according to the engine manufacturers Service Bulletin (SB) 5680.

SB 5680 May 1986.

Engine – support assembly, front accessory – replacement of or modification of by increasing inside diameter and blending the 15 lugs.

Excerpt from SB 5680:

Reason

1. *Objective: To minimize the potential of cracking of the front accessory support assembly mount lugs.*
2. *Problem: Cracks initiating at the mount lug spotface run-out area.*
3. *Cause: The existence of sharp edges at the lug spotface run-out area is believed to cause stress concentrations.*
4. *Background: Reports of lug cracking to varying degrees, and lug fractures.*

Etc…..

Description

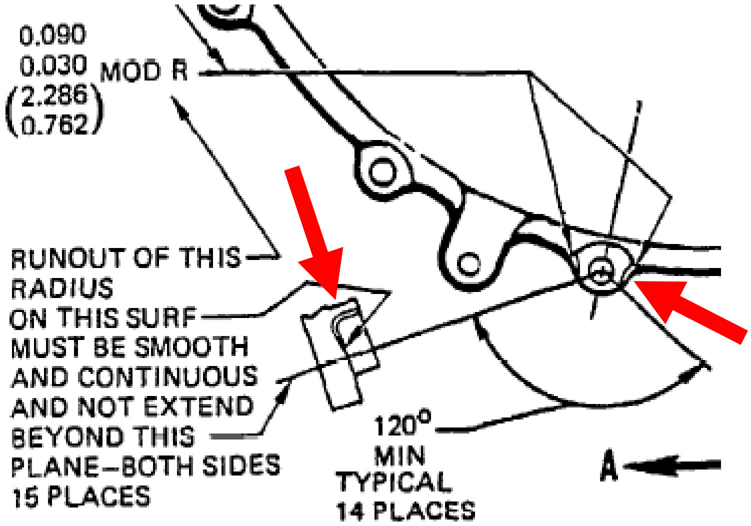
Replace the old support assembly with a new support assembly or modify the old support assembly by blending the 15 lugs and, if required, increasing inside diameter.

Accomplishment Instructions

Replace Front Accessory Support Assembly, PN 777190, with Support Assembly, PN 803290 or 803605 **(FAD P/N 803605 replaced P/N 803290 and incorporates not only blended lug radii, but increased thickness lugs to provide resistance to cracking.),** *or modify the support assembly as follows:*

1. *Inspect and, if required, machine to increase Diameter from 11.980 – 11.982 inches etc…*
2. *At the mounting lug locations, blend a 0.030 – 0.090 inch modified radius to smooth transition 30 places (15 lugs). Etc…*
3. *Fluorescent penetrant inspect all blended areas etc...*
4. *Brush on Chromate Conversion Treatment etc…*
5. *Re-identify modified front accessory Support Assembly as PN 803290.*

The drawing shown below is extract from SB 5680 Figure 2 Sheet 1.



Sharp edges of the 15 lugs blended to be smooth and continuous (red arrows).

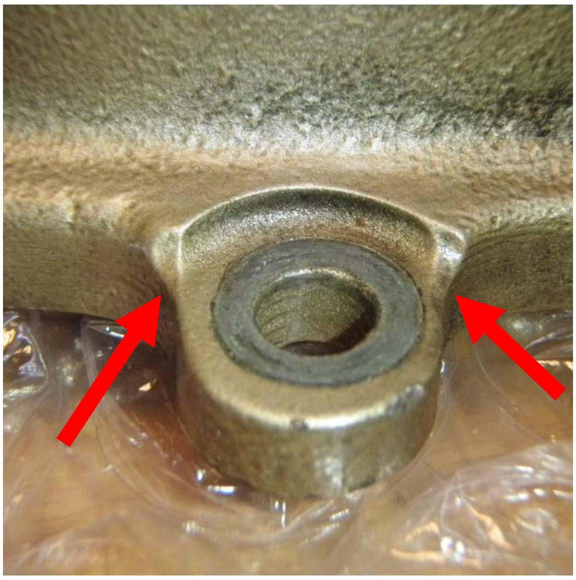
FAD lug comparison

The incident FAD re-identified as P/N 803290 was compared to another FAD taken from another engine. The FAD used for comparison was (during this investigation in 2012) the current assembly P/N 805770 that incorporates not only blended lug radii, but increased thickness lugs to provide resistance to cracking.

One of the 15 mount lugs from the incident FAD is shown below left. The run-out area has sharp edges.

One of the 15 mount lugs from the P/N 805770 FAD is shown below right. The run-out area is smooth and without sharp edges.

Run-out areas are marked with red arrows.



Cracking initiated at the sharp edges at the run-out area of the lugs.

ANALYSIS

Engine oil through an engine compressor section will cause smoke in the cabin because the heat and vent system use engine air for cabin pressurization and air conditioning purposes.
Following the serious incident, nobody reported breathing problems as a result of the smoke. The AIB DK considers the limited time of exposure to the smoke as a reason for this.
The investigation revealed that the smoke came from lubricating oil that was dragged into the engine compressor section from the bearing no. 1 housing, when the FAD support fractured and broke away from the bearing housing flange.

The aircraft was evacuated in approximately 1:30 minute. In respect to the required time limitation of 90 seconds, no further investigation was performed on that subject.

All 15 FAD support lugs was found fractured leading to liberation of the Nose Dome.
The engine manufacturer believed that maintenance could be a problem leading to cracking and liberation of the nose cone.
The FAD was removed and reinstalled in December 2011 however, the investigation found no signs of mishandling, over-torque or incorrect torqueing of the support lugs and found that the maintenance personnel was aware of the cautions presented by the manufacturer.
The AIB DK concludes that maintenance performed by the operator maintenance organization was not a contributing factor to this serious incident.

The fractured FAD was identified to original being a P/N 777190. The FAD was modified and re-identified to P/N 803290 when SB 5680 (issued 1986) was performed to minimize the potential of cracking.
SB 5680 recommended replacement of the FAD to P/N 803290 or 803605 or to modify P/N 777190.
Because a modified P/N 777190 will be re-identified as P/N 803290 and P/N 803290 did not have increased thickness lugs to provide resistance to cracking, the AIB DK found this information incomplete.

According to the laboratory report, 13 lugs were fatigue fractures and the cracking initiated at the sharp edge in the transition from the lug surface to the FAD cover.
The two lugs on top of the FAD were 100 % fatigue fractures. Therefore, the AIB DK determines that cracking began at the top of the FAD. The AIB DK cannot exclude that cracks were present when the engine was installed on the aircraft in November 2010 after overhaul. The fatigue developed over time.

Modification by blending the sharp edges according to SB 5680 should prevent cracking because existence of sharp edges at the lug run-out area could cause stress concentrations.
The investigation had doubts about the lugs being sufficiently blended according to SB 5680. Compared to another FAD, it seems that they were not.
The AIB DK did not conduct any further investigations into this issue. As a part of the engine, the FAD was delivered to the operator from overhaul.

As informed to operators in 2001, the engine manufacturer recommended replacement of cracked or suspected P/N 803290 with P/N 803605 or the newer version P/N 805770 that both had the increased thickness lugs.

It is the opinion of the AIB DK that installation of these versions with blended edges and increased thickness lugs could prevent FAD support lug cracking and therefore Nose Dome liberations. The AIB DK would like to point out the importance of following recommendations issued by the engine manufacturer.

CONCLUSION

Fatigue cracking initiated at the sharp edges at the run-out area of the FAD support lugs. The FAD support lugs fractured and the Nose Dome liberated from the front of the engine leading to this serious incident.
A contributing factor to the cracking was probably insufficient blending of the sharp edges according to accomplishment instructions in SB 5680.

RECOMMENDATIONS

Based on this investigation, the AIB DK issued no recommendations.
However, the AIB DK advises operators and maintenance organizations of JT8D engines to follow up on the information issued by the engine manufacturer in the JT8D SIR March 2001 regarding Nose Dome liberation.

Safety initiatives taken during the investigation

The following safety initiatives were taken during the investigation.

- The operator of the serious incident aircraft decided to implement crack inspections of the Front Accessory Drive Group supports of its engines.

APPENDIX

Laboratory report

Examination of mount lug fractures, Front Accessory Drive Group Support Assembly 23 pages.

Examination of mount lug fractures, Front Accessory Drive Group Support Assembly

Requested by: Accident Investigation Board, Civil Aviation, Kurt Færch Madsen

Reported by: FORCE Technology, Curt Christensen

Reviewed by: FORCE Technology, Hans Peter Nielsen

Our ref.: 112-22802 CC/mal

15 February 2012

CORROSION AND METALLURGY

Reviewed by:	Reported by:
Hans Peter Nielsen	Curt Christensen

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Introduction

The Aviation investigation Board submitted the Front Accessory Drive support assembly of a jet engine with the request to document and characterise the experienced failures.

The FAD support assembly broke loose during preparations for take-off on 5 February 2012 at 8:38 local time from Copenhagen Airport, leaving the assembly and the attached bullet nose hanging in the wires.

The engine details are as follows:

Engine:	P&W JT8D-217C
Engine S/N:	P726014D
Total Flight hours:	41,695.57

The support assembly is made of a magnesium alloy. It was last dismounted in connection with exchange of the first stage compressor and fan blades on 21 to 22 December 2011.

The dismantling and re-mounting of the FAD was performed according to AMM 72-21-00. The applied bolt torque was 85 in lb.

Scope of work

Photo documentation of fractures in mounting lugs
Photo documentation of contact surface between washer and lug
Characterisation of the fractures
Identify sequence of fractures, if possible

Results

The FAD support assembly is shown in figures 1 and 2. The bolting arrangement for the bullet nose was intact, whereas all 15 mount lugs keeping the front cover in place were fractured. The lugs are shown in figure 3. They are marked 1 through 15 in figure 3 in clockwise direction when viewing in the flight direction.

The typical appearance of the fractures in the lugs is represented by lug 1. The overall appearance in figure 4 and the typical crack arrest lines, beach marks, in figure 5 are typical features of fatigue cracking. The cracking initiates at the positions marked by the arrows in figures 4 and 5.

Figures 6 to 21 show the fracture surfaces in the lugs as well as the washer contact surfaces. The fracture surfaces are all akin to fatigue cracking with the fatigue cracking in general occupying more than 80 % of the fracture surfaces. The only exceptions are lugs 7 and 8. Lug 7 does contain a small fatigue crack but the main part of the fracture is pure shear off. There is no fatigue cracking in lug 8 only shear off failure.

The cracking in lugs 1 and 15 are 100 % fatigue, i.e. no final rupture. Lug 14 has developed a fatigue crack deeply into the cover. These three lugs are presumed to be the first to develop fatigue cracking, whereas lug 7 is the last one developing fatigue. Lug 8 has no fatigue crack but is simply sheared off at the same time as or just after shear off of lug 7.

The fatigue cracking always initiates at the sharp edge in the transition from the lug surface to the cover, cf. figure 4.

The contact face between the washers and the lug are easily recognisable. There are no indications of bolts being loose at any time during service. In many cases the contact face has been slightly changed in connection with re-mounting leaving two or more sets of circular depressions in the lug surface, but the contact surface is smooth and even. The fractures in lug 7 and 8 partly follow the edge of the washers, but these fractures are characterised as shear fractures belonging to the final detachment events.

There is no indication of material defects or deficiencies being causative or contributory to fracture initiation or propagation.

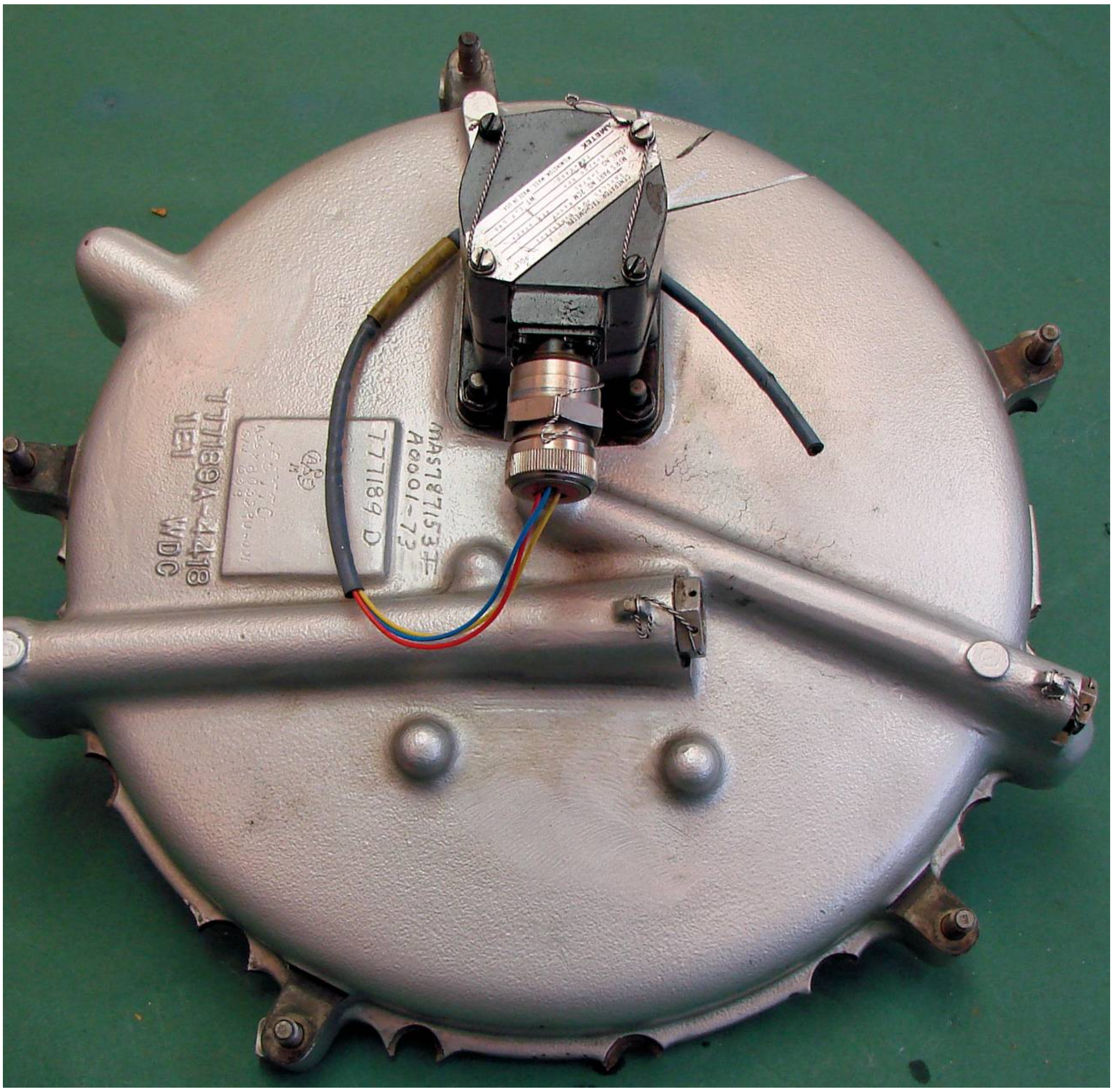

Figure 1 View of FAD support assembly looking aft relative to flight direction.

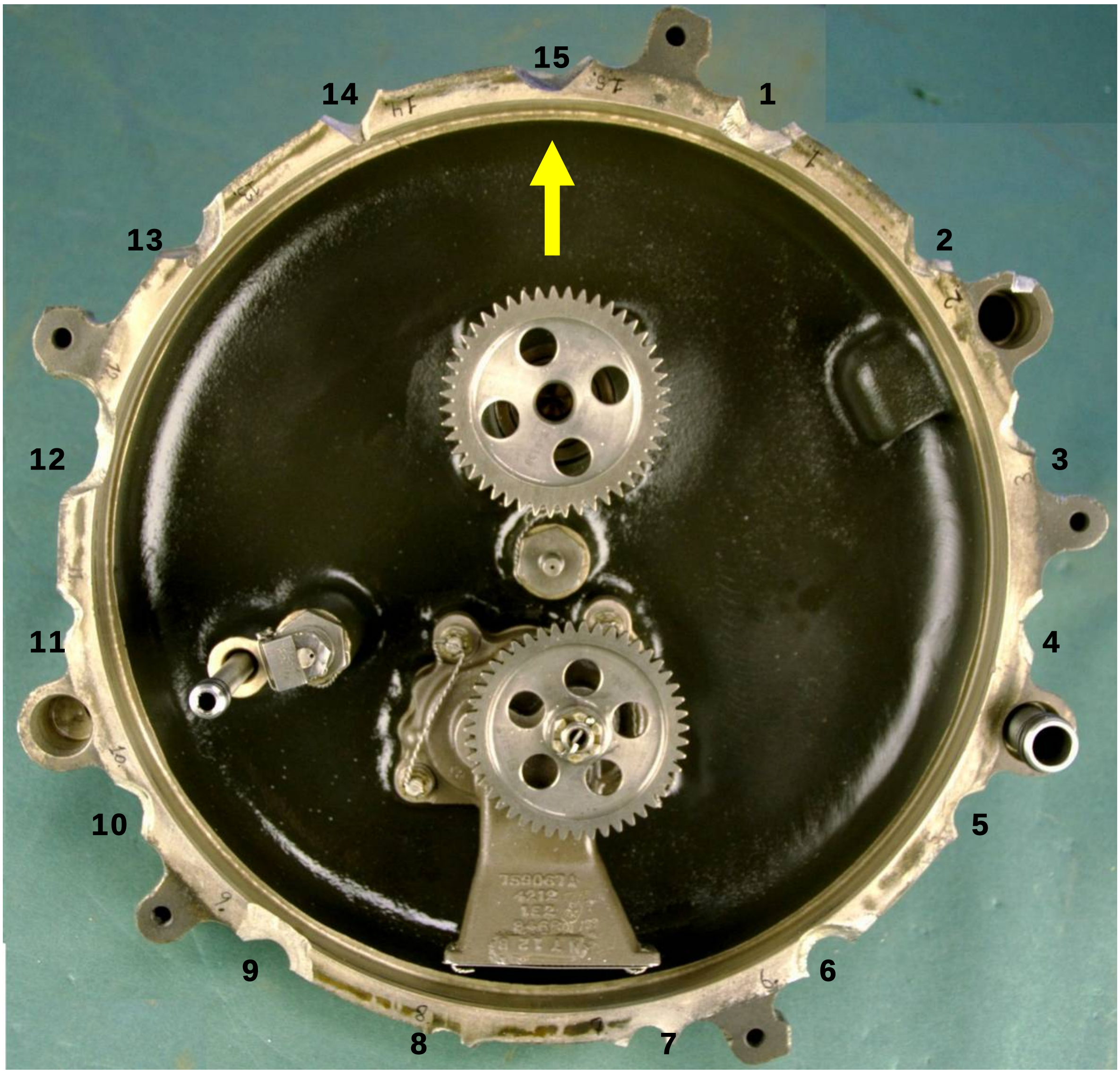

Figure 2 Inside of FAD support assembly. The yellow arrow indicates upwards direction.

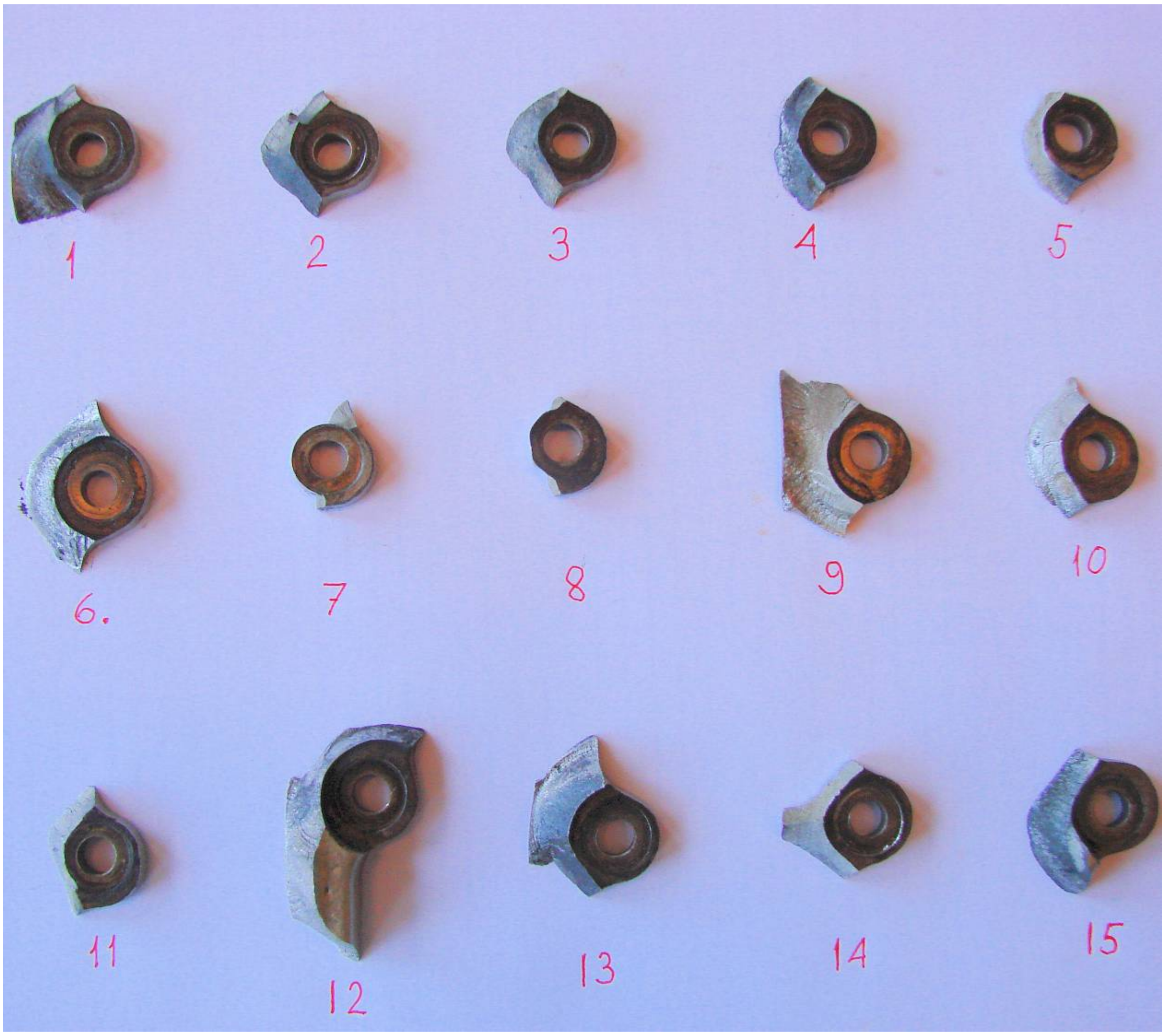

Figure 3 Broken off mounting lugs from the support assembly.

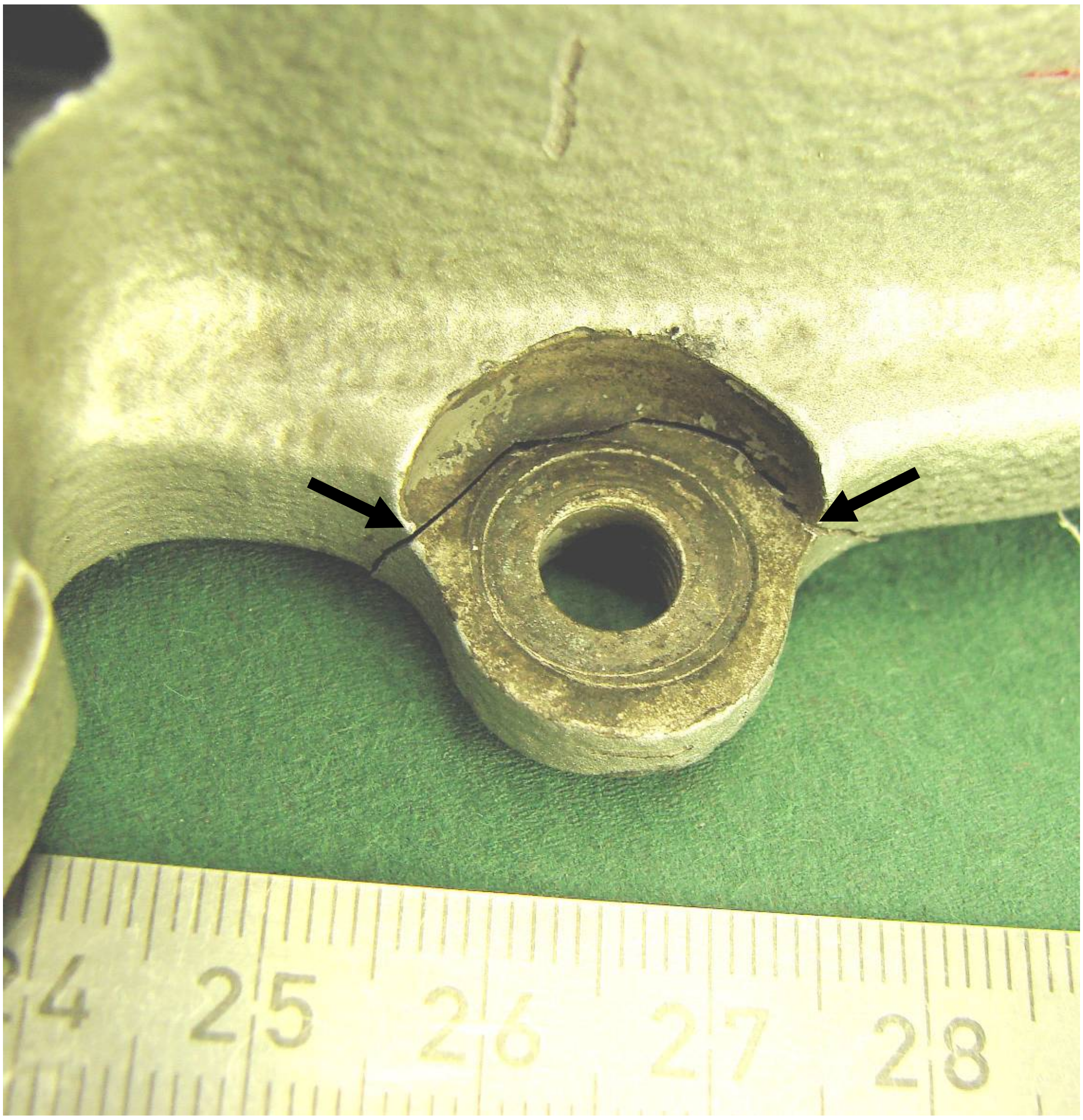

Figure 4 View of re-positioned mounting lug 1.

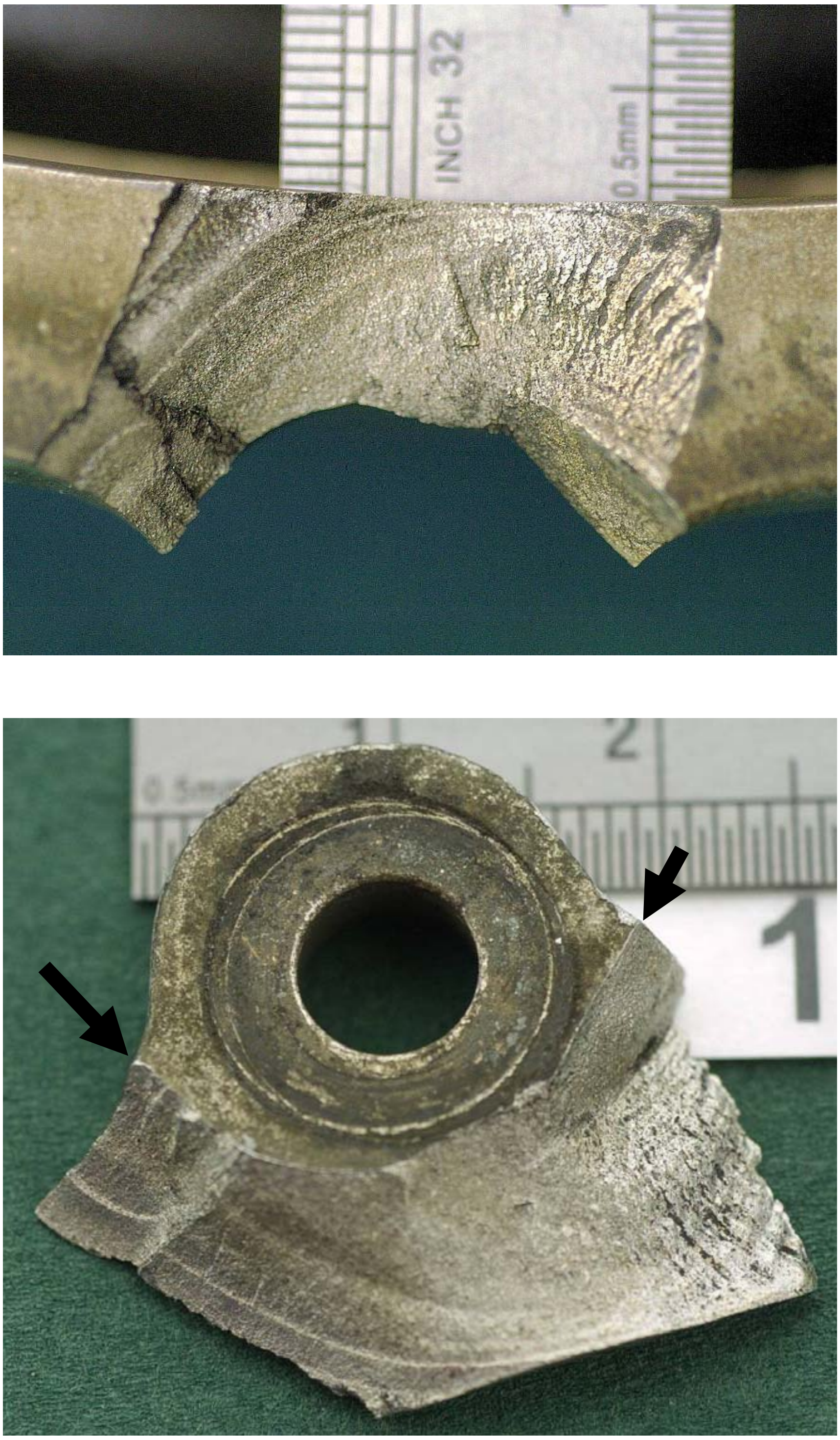

Figure 5 a&b Opposing fracture surfaces in mounting lug 1. Fatigue cracks have initiated at the positions marked by arrows. The progression of the cracks have left crack growth marks, beach marks, in the fracture surface.

Figure 6 a&b View of opposing fracture surfaces in lug 2.

Figure 7 a&b View of opposing fracture surfaces in lug 3.

Figure 8 a&b View of opposing fracture surfaces in lug 4.

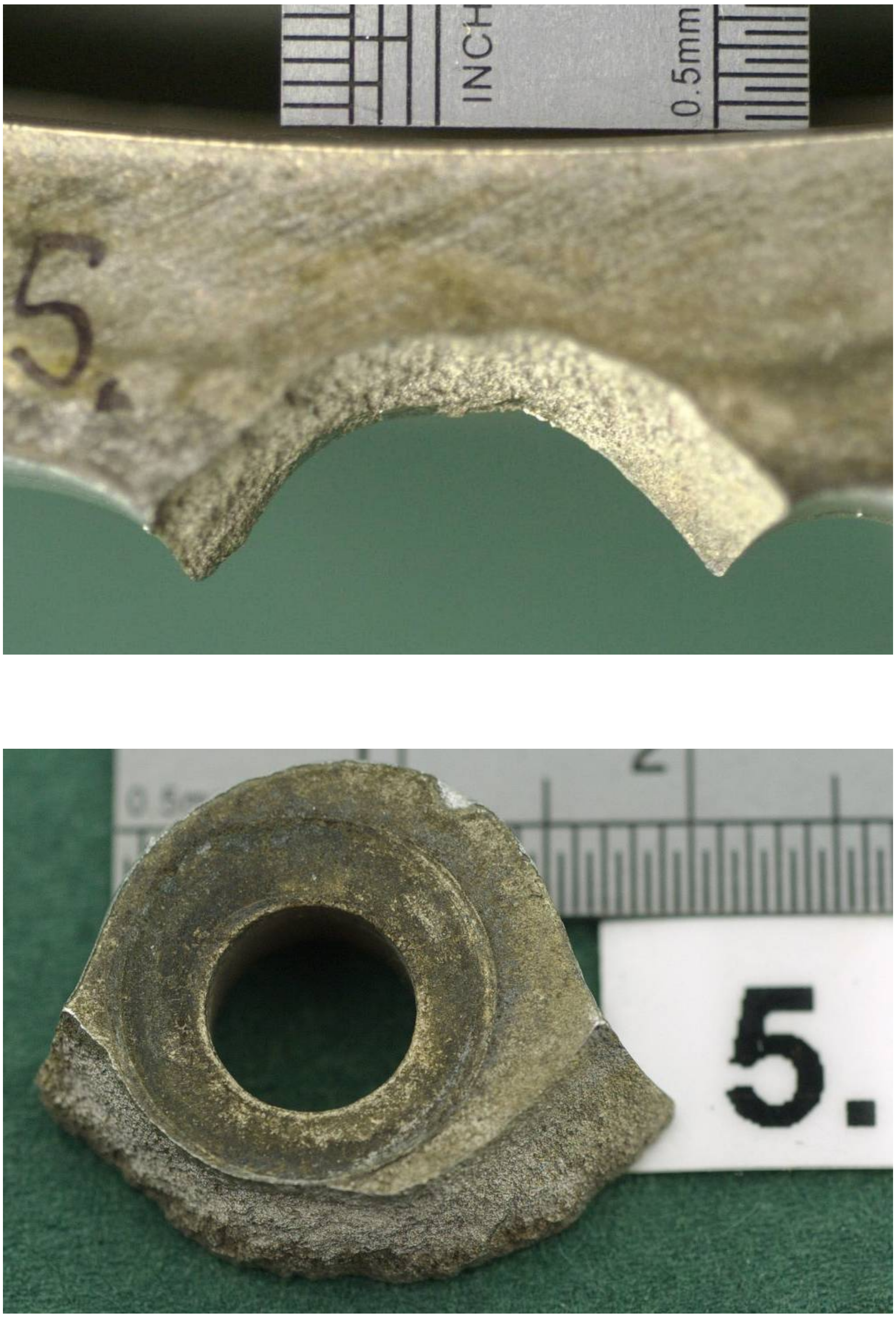

Figure 9a&b View of opposing fracture surfaces in lug 5.

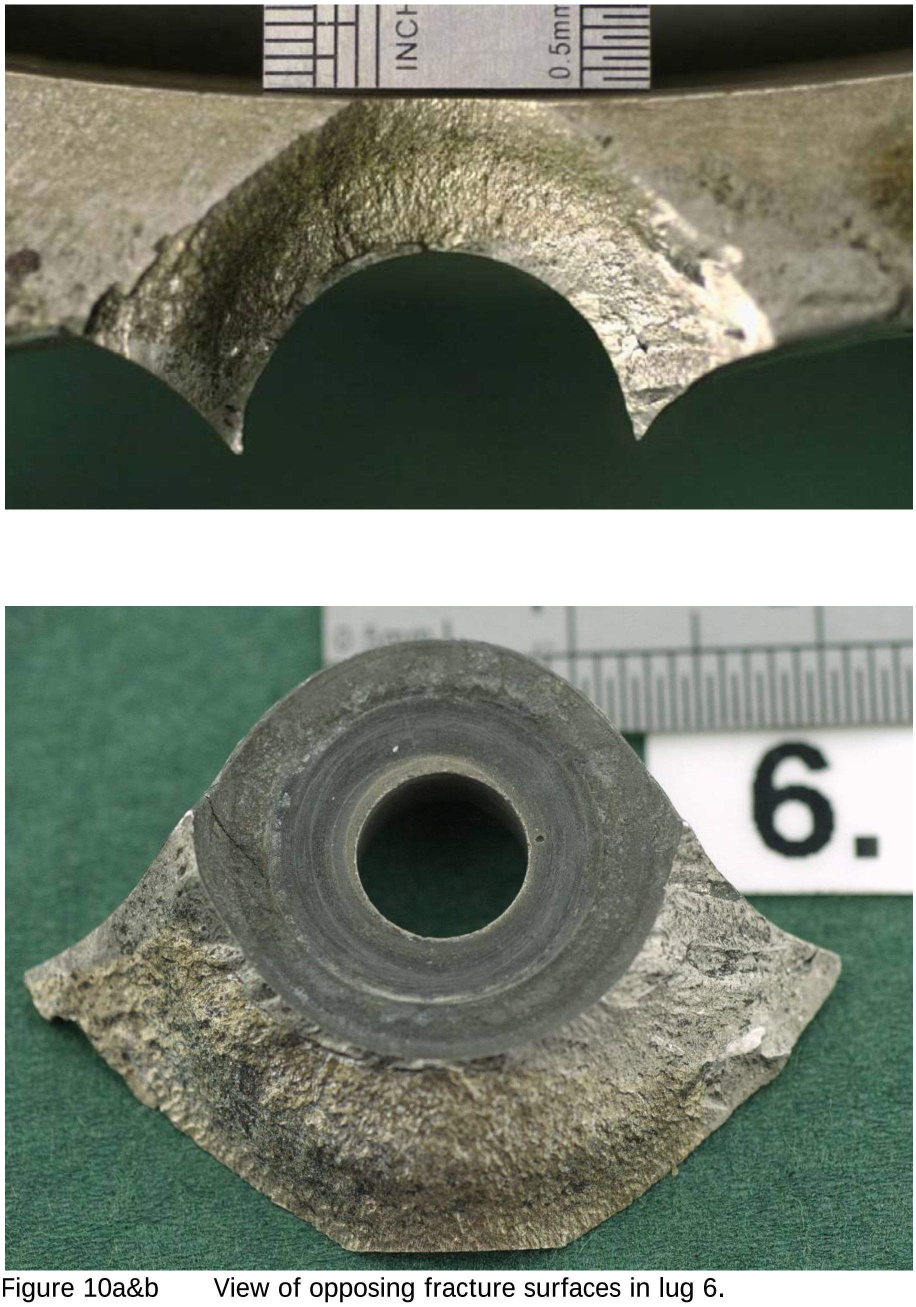

Figure 10a&b View of opposing fracture surfaces in lug 6.

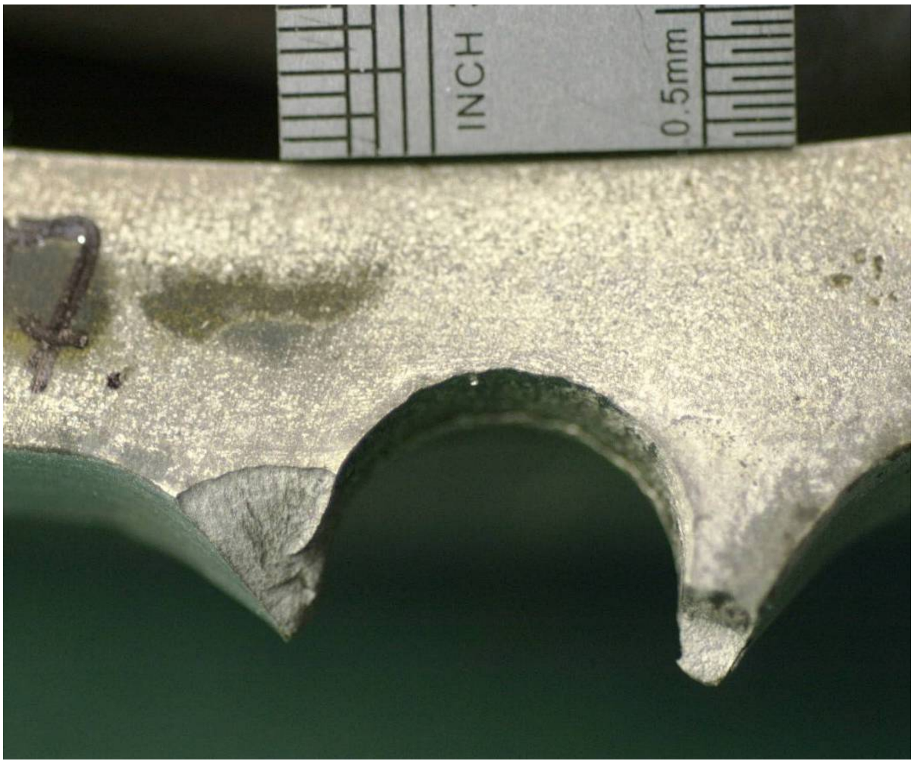

Figure 11a&b View of opposing fracture surfaces in lug 7.

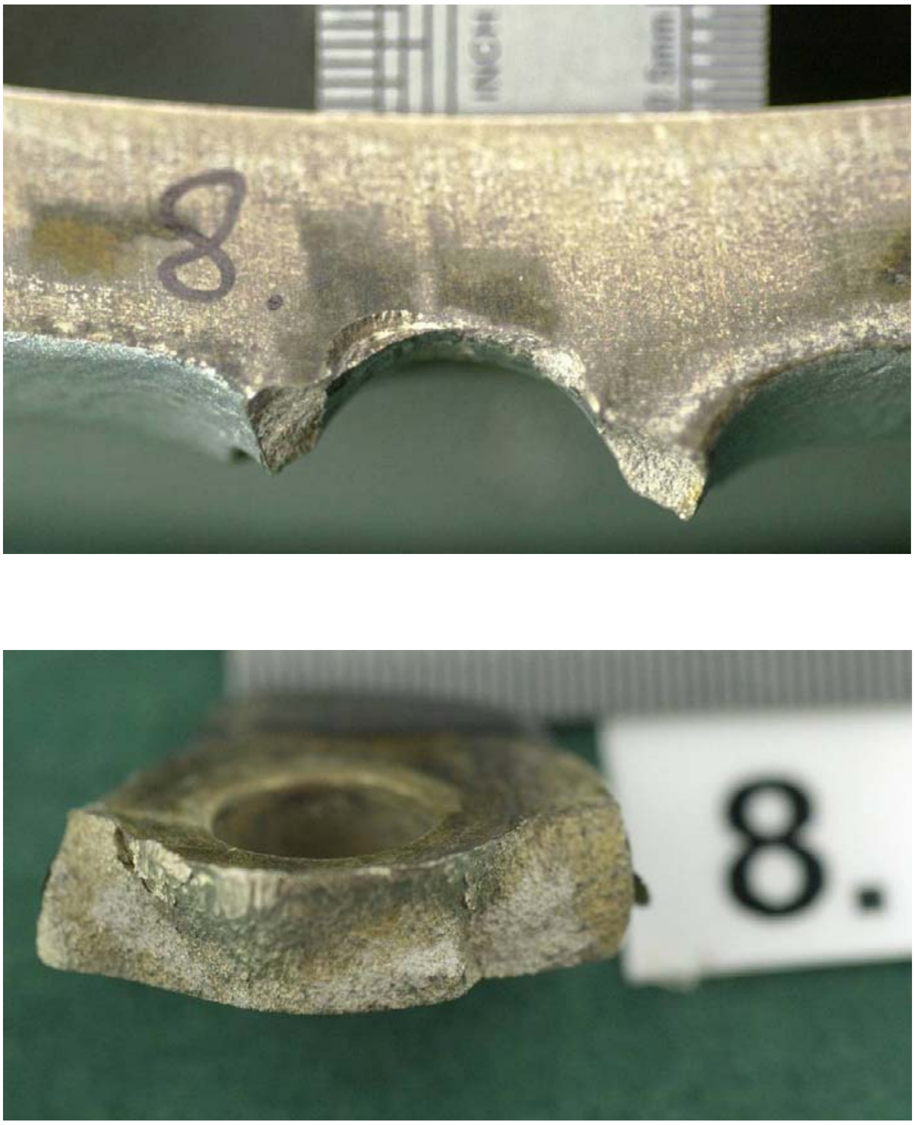

Figure 12a&b View of opposing fracture surfaces in lug 8.

Figure 13a&b View of opposing fracture surfaces in lug 9.

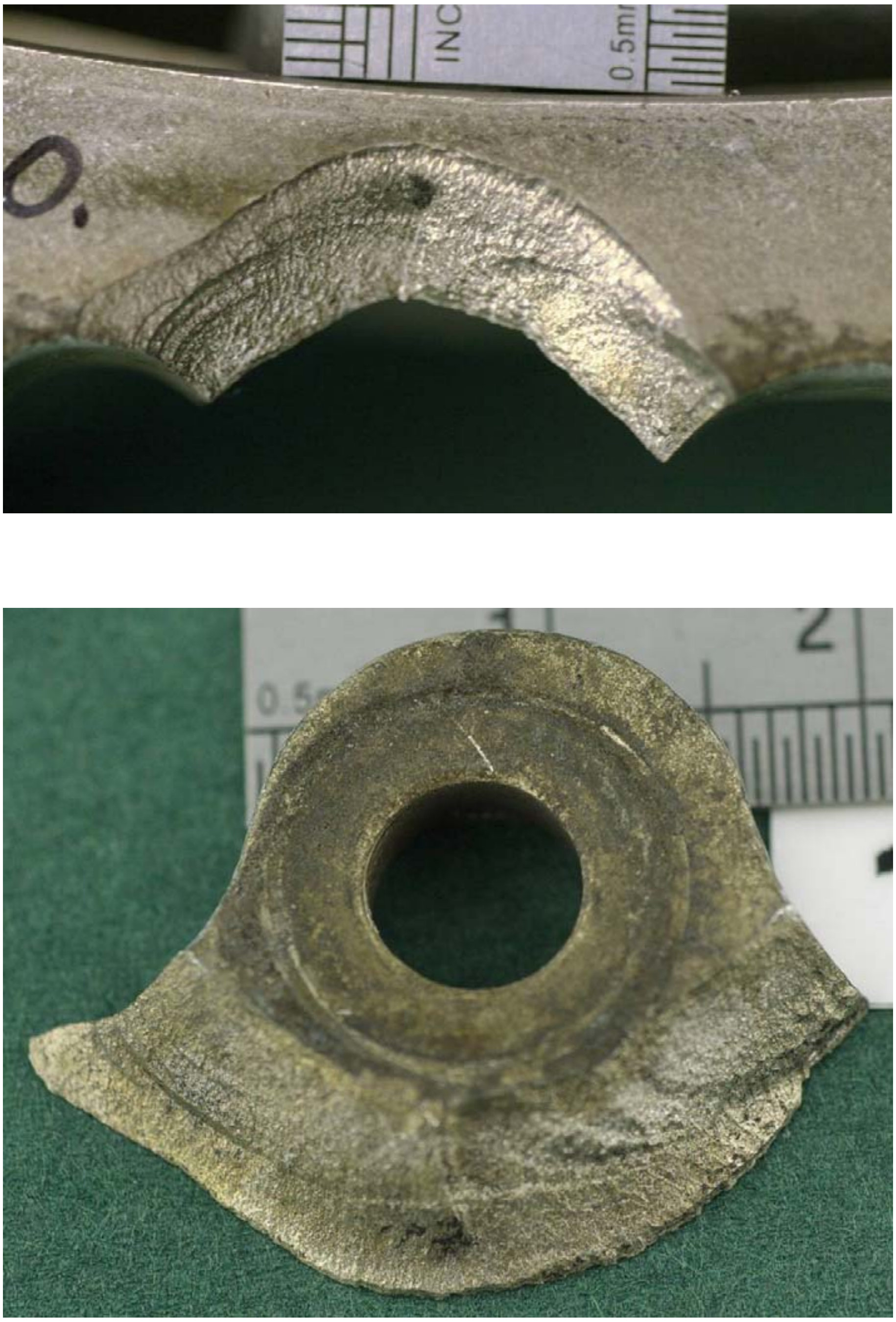

Figure 14a&b View of opposing fracture surfaces in lug 10.

Figure 15a&b View of opposing fracture surfaces in lug 11.

Figure 16a&b View of opposing fracture surfaces in lug 12.

Figure 17a&b View of opposing fracture surfaces in lug 13.

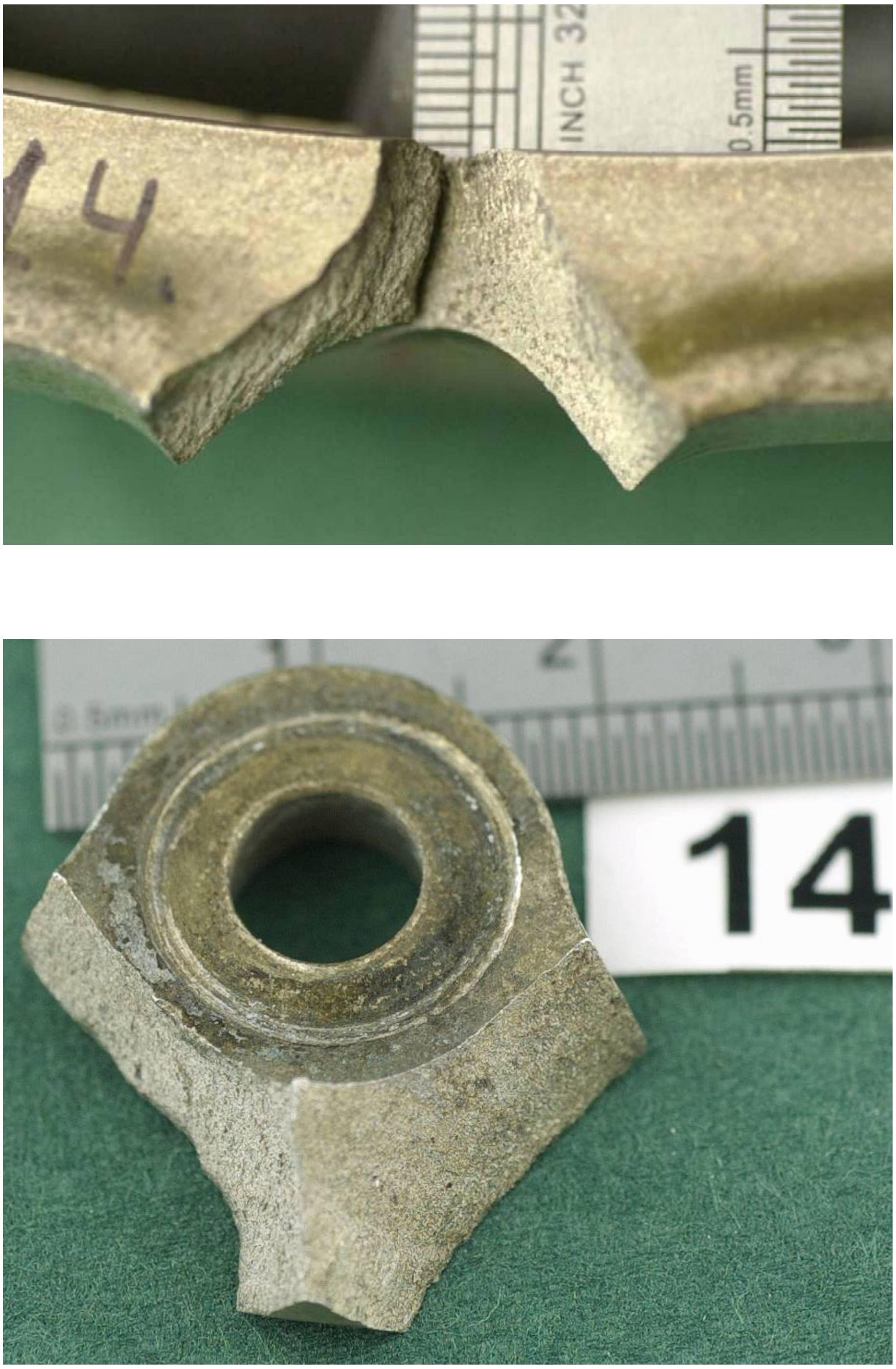

Figure 18a&b View of opposing fracture surfaces in lug 14.

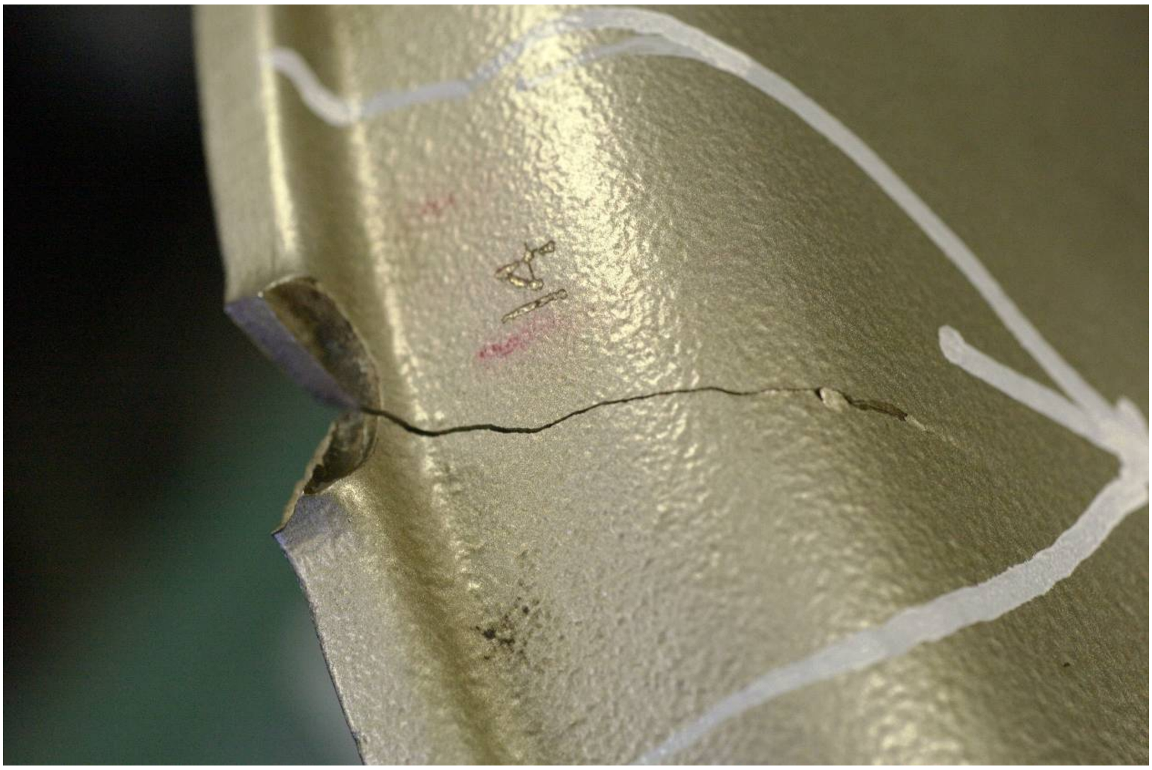

Figure 19 Fatigue crack extension into the cover at lug 14.

Figure 20a&b Opposing fracture surfaces in fatigue crack extension at lug 14.

Figure 21a&b View of opposing fracture surfaces in lug 15.

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4. Warranty

4.1. Subject as hereinafter set out, FORCE Technology shall undertake to remedy any defects resulting from faulty design, materials or workmanship.

4.2. This liability is limited to defects which occur or are discovered within twelve (12) months from the time of delivery.

4.3. In respect of special components the warranty period will be the same as the warranty period which FORCE Technology is able to obtain from their suppliers.

4.4. In the event that the client wishes to submit a claim under the warranty he shall without delay notify FORCE Technology in writing of any defect that has arisen. On receipt of such notification FORCE Technology shall if the defect is one that is covered by this clause at their option:

a) repair the defective Goods or parts in situ; or
b) have the defective Goods or parts returned for repair; or
c) replace the defective Goods or parts in order to enable the client to carry out the necessary repairs at the expense of FORCE Technology.

4.5. In the event that FORCE Technology has received defective Goods for replacement or repair, the client shall bear the costs of transport and risk of damage.

4.6. Defective Goods or parts replaced in accordance with these provisions shall be made available to FORCE Technology.

4.7. The liability of FORCE Technology shall apply only to defects that occur under proper use. In particular it does not cover defects arising from faulty installation and maintenance or repairs carried out by individuals other than FORCE Technology's personnel or their agent, or alterations carried out without the consent in writing by FORCE Technology; nor does it cover normal wear and tear.

4.8. The warranty period in respect to spare parts and accessories shall operate in the same manner as the warranty period for the replaced part itself.

5. Liability

5.1. FORCE Technology shall only be liable for loss or damage if it is proved that the loss or damage is due to errors or negligence of FORCE Technology in connection with production or performance of a task.

5.2. FORCE Technology shall not be liable for any consequential loss, such as but not limited to loss of time or loss of profits.

5.3. Tasks are solved and opinions and guidance are given by FORCE Technology on the basis of the knowledge and technology available to FORCE Technology. FORCE Technology shall only be liable if it is proved that this knowledge or technology were faulty at the time of the completion of the task.

5.4. FORCE Technology shall not accept liability for loss or damage that may occur in connection with the client's use of provided data or test results which lies outside the scope of the task and purpose in connection with which FORCE Technology's opinion has been given.

5.5. FORCE Technology shall not accept liability for errors in connection with opinions given regarding which it has been stated that they are based on an estimate.

5.6. When performing verification and testing, FORCE Technology shall only be liable for damage which might occur owing to FORCE Technology's failure to notify the client, in time, of existing defects.

5.7. FORCE Technology shall not be liable for damage occurring if such damage is due to a property of a product or an application of a product which has either not been tested or examined and described in the testing or examination report, or which differs from FORCE Technology's description in the testing or examination report of the property of the product or of a possible application of the product.

5.8. FORCE Technology shall not accept liability for damage occurred if a product causing damage has not actually been tested by FORCE Technology, unless the client proves that the product is identical with a product actually tested and verified by FORCE Technology.

5.9. If a third party claims damages from FORCE Technology on grounds which lie beyond the liability to pay damages undertaken by FORCE Technology in accordance with clauses 5.1 to 5.8, the client shall be under an obligation to take over the conducting of the case and indemnify and hold harmless FORCE Technology for all costs and damages.

6. Disputes

Any dispute between the client and FORCE Technology arising out of or in connection with the performance of a task or the interpretation of the agreement shall if such dispute cannot be solved through negotiation between the parties be settled by Copenhagen Arbitration in accordance with Danish law.

2007.07

Den Danske Akkrediterings- og Metrologifond (DANAK)

DANAK akkrediterede ydelser leveres i henhold til Erhvervsfremme Styrelsens Bekendtgørelse om akkreditering af laboratorier til teknisk prøvning m.v., henholdsvis Sikkerhedsstyrelsens Bekendtgørelse om akkreditering af virksomheder til certificering af personer, produkter og systemer, samt til inspektion. De respektive standarder i DS/EN 45000 serien og EN ISO/IEC 17000 serien samt relevante ISO/IEC Guider er en del af akkrediterings-vilkårene. DANAK specifikke krav til kalibreringscertifikaters indhold medfører bl.a. en bedømmelse af laboratoriets måleevne og dets sporbarhed til nationale normaler.

The Danish Accreditation and Metrology Fund (DANAK)

All DANAK accredited services are supplied in accordance with the National Agency of Industry and Trade's statutory Accreditation of laboratories for technical testing etc. respectively The Technical Safety Council statuory of Accreditation of organisations for certification of personnel, products and systems, and for inspection. The respective standards in the DS/EN 45000 series, the EN ISO/IEC 17000 series and the relevant ISO/IEC Guides are part of the conditions for accreditation. The DANAK specific demands to the content of calibration certificates imply an assessment of the measurement capability of the laboratory and its traceability to recognised national standards.