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Materials Investigation

Laboratory report

ME16964FS

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Materials Investigation – Laboratory Report

(2013/04)

Investigation performed in accordance with MCL Manual Section AC-35

Part No.: 3042101, 3114594-01	RFA No: 17FL00003	Report No.: ME16964FS
Part Name: BLADE-LOW COMPRESSOR ROTOR / FAN BLADE, SHAFT ASSY-LOW COMPRESSOR / LOW COMPRESSOR SHAFT	Date Received: 2017-07-28	Page 3 of 18
Serial No.: ---	Engine Model: JT15D-4	Eng. Serial No.: 070301
Service time: TSN: --- CSN: --- TSO: --- CSO: ---	Service time: TTSN: 7943 TCSN: 8045.8 TTSO: 1566 TCSO: 1788.1	
Material Specification: LC shaft: CPW 245M	Installation: CESSNA CITATION II MODEL 550	
Heat Code: ---	Operator: ---	
Process Specification: ---	Event Type: Uncontainment (1)	
Supplier: ---	Event Category: ---	
Additional information: In December of 2016, engine involved in a bird strike event where the LC shaft sheared and thus the fan and boost assemblies were ejected from the engine. The fan & boost recovered one month later by citizen (found in marsh land). Engine disassembled in June 2016 to recover remaining portion LC shaft and examine engine (see attached summary).		
Investigation Required: NTSB are requesting the that LC shaft be examined to verify fracture mode (appears as if overload). I've included the recovered fan/boost LC shaft assembly, although that fracture surface heavily corroded due to time spent in the marsh. Please also verify material properties of LC shaft. PN listed may not be actual PN, based on condition of components (researched logbook for configuration). Also, there are 8 off fan blades that are fractured just above the platform. Please visually examine fracture surfaces to confirm overload fractures.		
Requested by: [REDACTED]	Organization: [REDACTED]	
CONCLUSIONS 1- The Low Compressor Shaft fractured in two distinct locations. The shaft portion located on the downstream side of the engine exhibited evidence of permanent twisting in the opposite direction to the LC shaft direction of rotation and also exhibited evidence of necking near the fracture. Examination of the middle fragment fractures were selected for fractographic examination since they were in better condition than their mating fractures. Middle fragment downstream fracture: The downstream fracture exhibited evidence of shear and tensile ductile overload fracture. Based on the shape and orientation of the torsional shear dimples, this fracture occurred in the opposite direction to the shaft rotation. This suggests that the middle fragment suffered some deceleration in respect to the driving shaft portion on the downstream side. Middle fragment upstream fracture: The upstream fracture also exhibited evidence of shear and tensile ductile overload fracture. Based on the shape and orientation of the torsional shear dimples, this fracture occurred in the opposite direction to the shaft rotation. This suggests that the middle fragment suffered some deceleration in respect upstream portion of the shaft attached to the fan assembly. Conclusions continued next page...		
Reported by: [REDACTED]	Approved by: [REDACTED]	2017.10.03 14:20:44 -04'00'

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...Conclusions continued:

- 2- Visual examinations of the eight (8) fractured blades from the Low Compressor Rotor were consistent with bending (from the airfoil pressure side to the suction side) ductile overload fractures. No evidence of fatigue was observed.
- 3- Tensile Test performed on the sample from the shaft by [REDACTED] showed that the Yield Strength and Tensile Strength obtained meet requirements of CPW 245M standard. The sample does not meet the Elongation and Reduction Area requirements. However, note that the sample was extracted from the section of the shaft that was twisted, which may have decreased these mechanical properties.
- 4- Chemical composition analysis of the shaft material performed by the PWC Chemical Technology & Test department (see Report no. C17112669R0 attached in Enovia) meets requirements of CPW 245M.
- 5- Microstructure of the shaft meet drawing requirements of CPW 300J standard. No anomalies were observed.

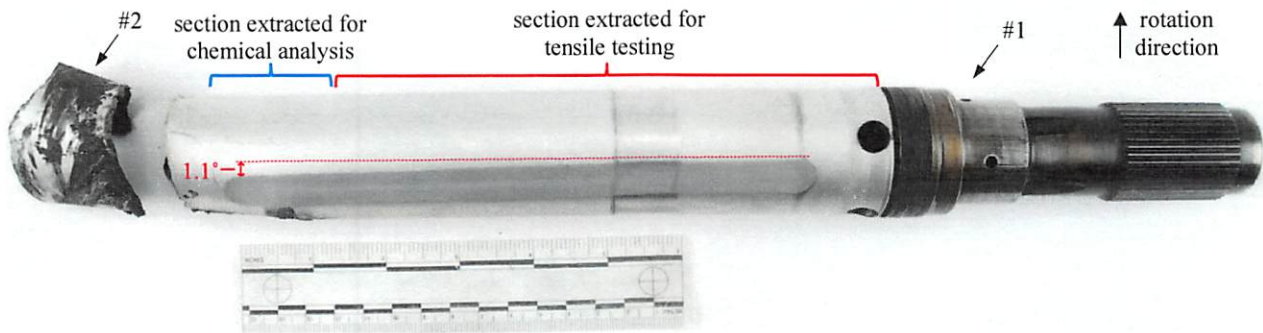


Figure 1. General view of the Low Compressor Shaft Assy (P/N: 3114594-01) which fractured in two locations. The fragments were arbitrarily numbered as #1 (fractured shaft assy) and #2 (small separated fragment from the shaft) as shown. The Low Compressor Rotor assembly with the other portion of the Low Compressor Shaft fracture (arbitrarily numbered as #3) was also submitted for examination (see fig. 26).

Visual examination showed that the downstream portion of the shaft is permanently twisted approximately 1.1° in the direction opposite to the rotation direction. Moreover the shaft fragment #1 exhibits evidence of necking near the fracture plane.

The section of the shaft marked by the red bracket (length of 7.5 inch) was sectioned and sent for Tensile Testing (Genitest Inc). The section of the shaft marked by the blue bracket was sectioned and submitted to the PWC Chemical Technology & Test department for chemical analysis of the shaft base material.

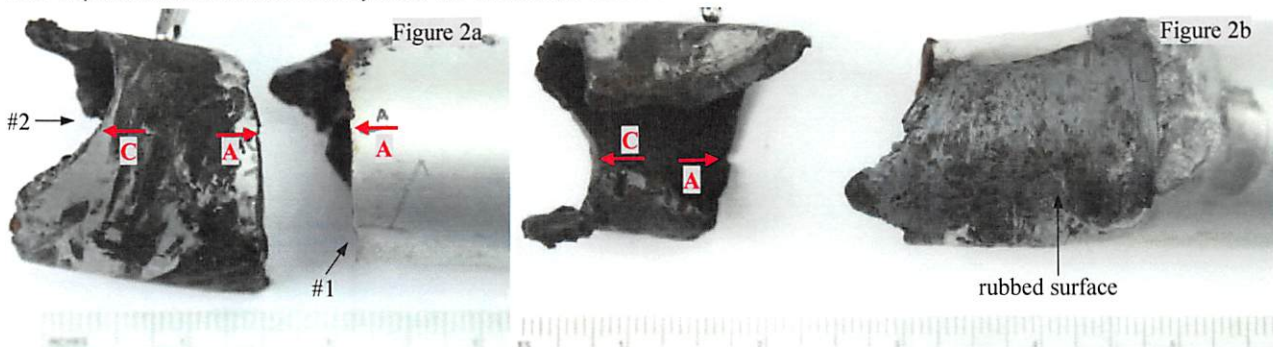


Figure 2. Fig. 2a: View of shaft fragment #1 with the adjacent matching fragment #2. Fig. 2b: View of the same configuration, rotated ≈ 180 degrees in respect to Figure 2a, showing visible rubbing on the outside diameter (OD) surface.

Macroscopic fractographic features allowed to match the mating fracture surfaces of all three shaft fragments. Reference points are marked with capital letters "A" and "C" and serve throughout the report for orientation purpose.

Figure 3.

View of the fracture surface on the shaft fragment #1 with reference marking point "A".

The fracture surface was rusted and obscured any underlying fractographic features.

Marked area is shown at higher magnification in Figure 6.

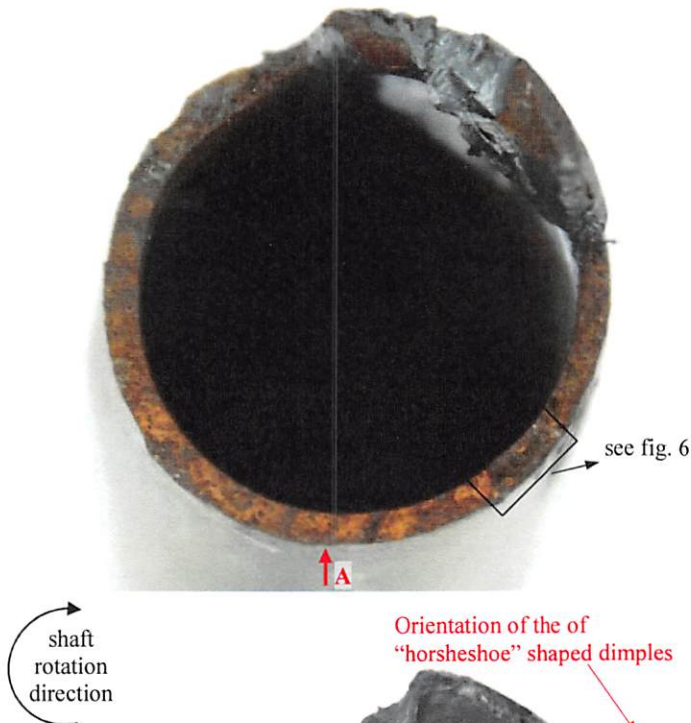
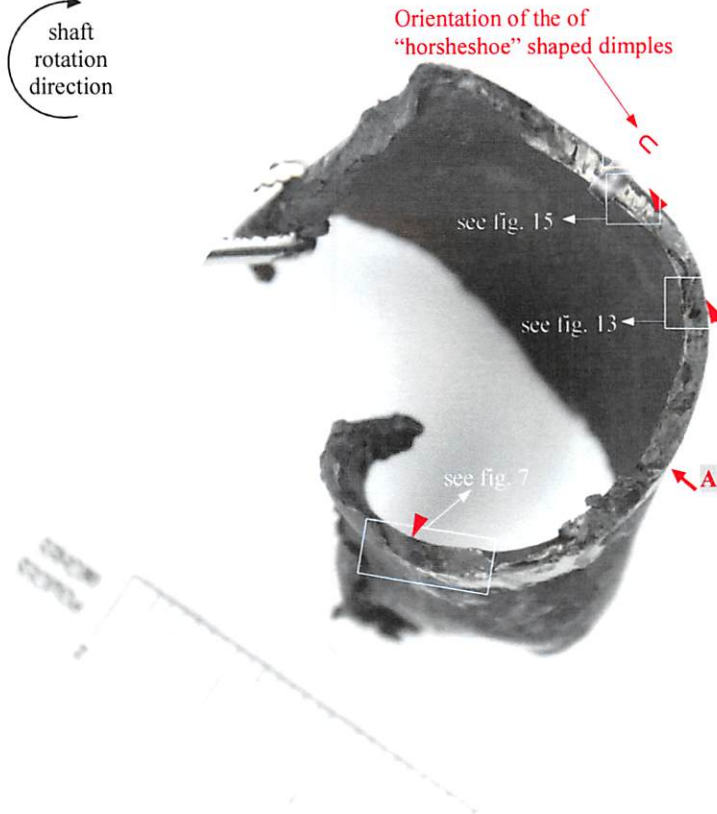


Figure 4.

General view of the fracture surface on the shaft fragment #2 with reference marking point "A".

Although this fracture surface exhibited some rusting and that some regions of the fracture surface suffered secondary damage, several areas remained in relatively good condition, see Figures 7-16.

Characterisation of the fracture surface, carried out using the Scanning Electron Microscope (SEM), showed the presence of both tensile and torsional shear dimples suggesting that the shaft fractured in torsion and tension. Based on the torsional shear dimples "horseshoe" shape, this fracture occurred in the opposite direction to the shaft rotation. This indicates that this side of the sample was decelerated in respect to the downstream portion of the shaft which is driving.



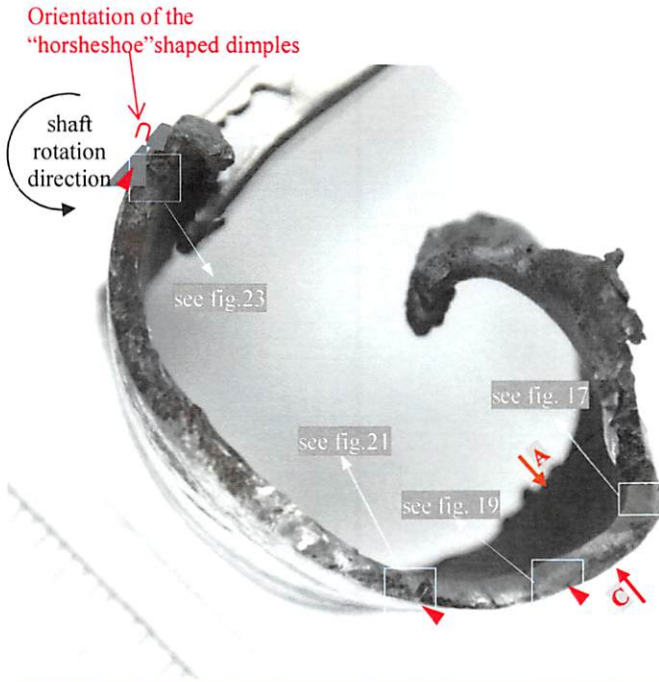


Figure 5.

General view of the fracture surface on the shaft fragment #2 with reference marking point "C".

Examination of the fracture surface, similarly to what was observed on the other side of this fragment (side "A"), showed the presence of both tensile and torsional shear dimples suggesting that the shaft fractured in torsion and tension. Based on the torsional shear dimples "horseshoe" shape, this fracture occurred in the opposite direction to the shaft rotation. This indicates that this side of the sample was decelerated in respect to the upstream portion of the shaft (attached to the fan) still rotating likely as a result of the fan assembly inertia.

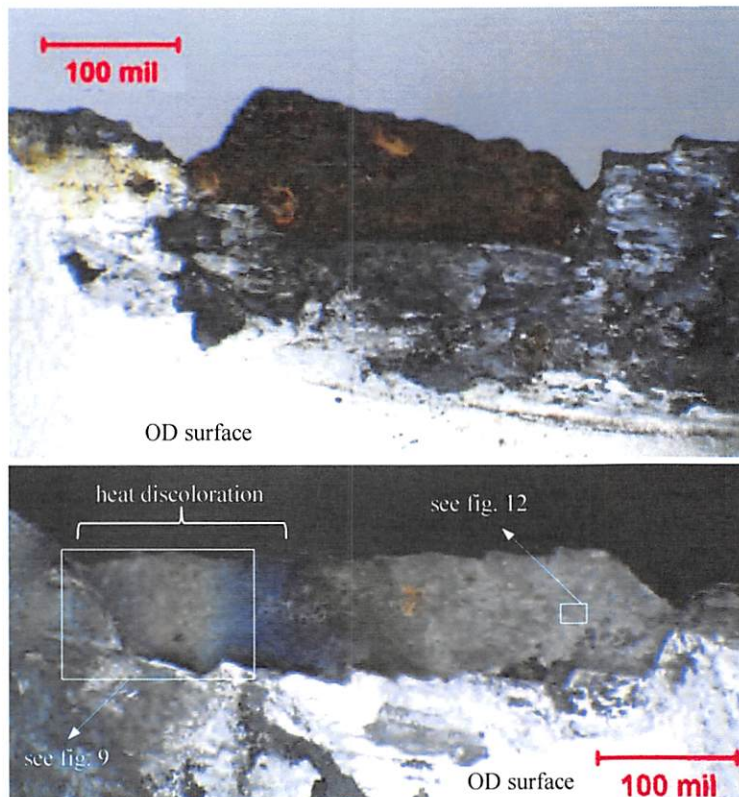


Figure 6.

Side view of the shaft fragment #1 fracture surface close to reference marking point "A".

Shaft fractured at approximately 45° in reference to the shaft longitudinal axis in this location, which is typical for an overload fracture.

Figure 7.

Side view of the shaft fragment #2 fracture surface with reference marking point "A".

Heat discoloration on the fracture surface was observed which suggest that heat was generated by the shat rubbing observed on the OD against a mating element. Note that the fracture surface in this location has a 45° slant, as for the shaft fragment #1 (see fig. 6). Fracture surface was further examined, see Figures 9-12.



Figure 8.

Magnified view of the fracture surface on the shaft fragment #2 from reference marking point "A" side.

Heat discoloration and similar aspect of fracture surface were observed as in Figures 6 and 7.

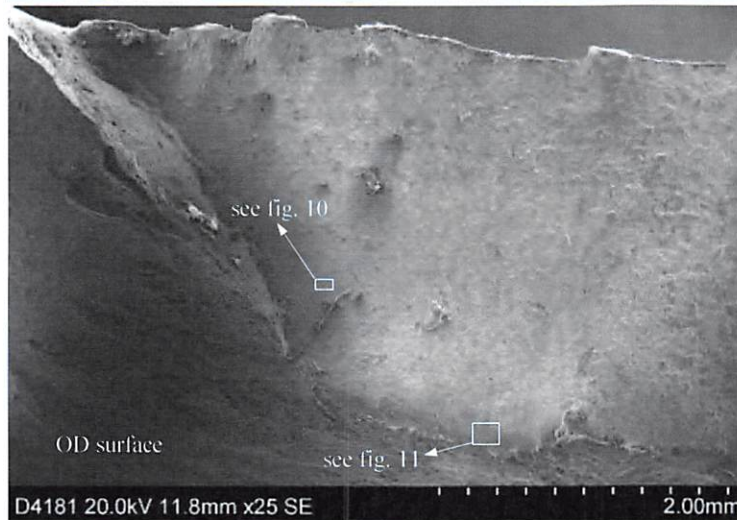


Figure 9.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "A" side.

Transgranular ductile mode of overload fracture was observed. Marked areas were further examined, see Figures 10 and 11.

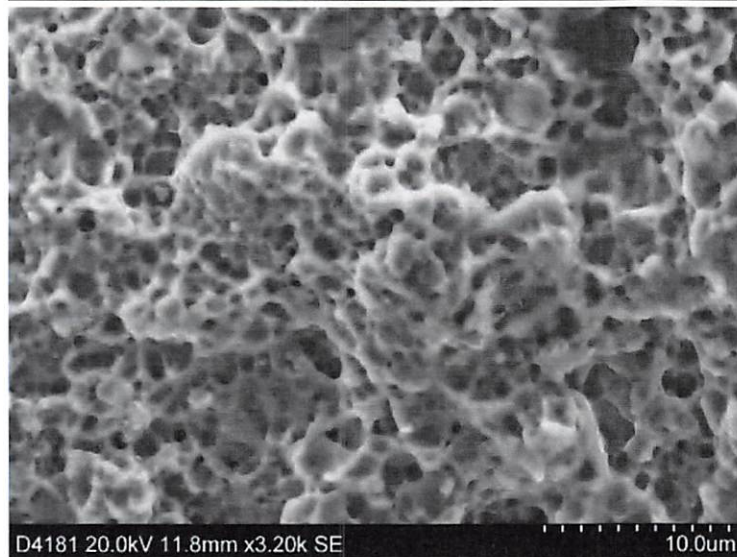


Figure 10.

SEM magnified view of the fracture surface on the shaft fragment #2 from reference marking point "A" side.

Ductile dimples suggestive of overload ductile fracture were observed. Slight oxidation of the fracture surface was observed, likely as a result of the heat generated by the shaft OD rubbing.

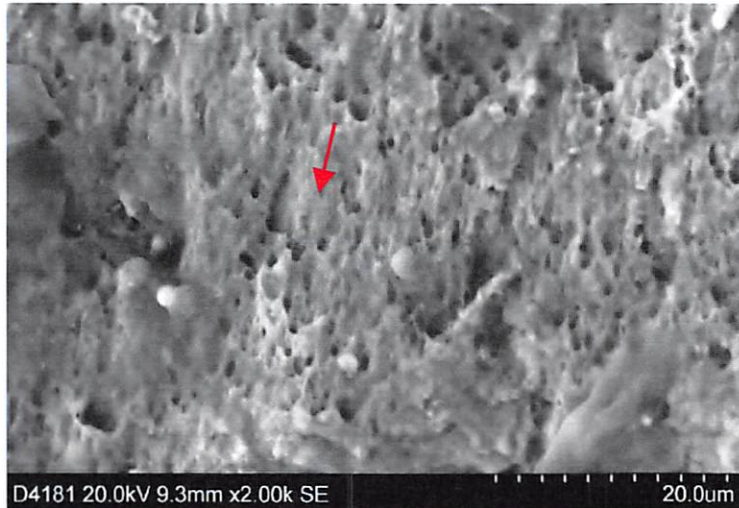


Figure 11.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "A" side.

Shear dimples were observed suggestive of shear overload ductile fracture. The red arrow shows the direction of shear.

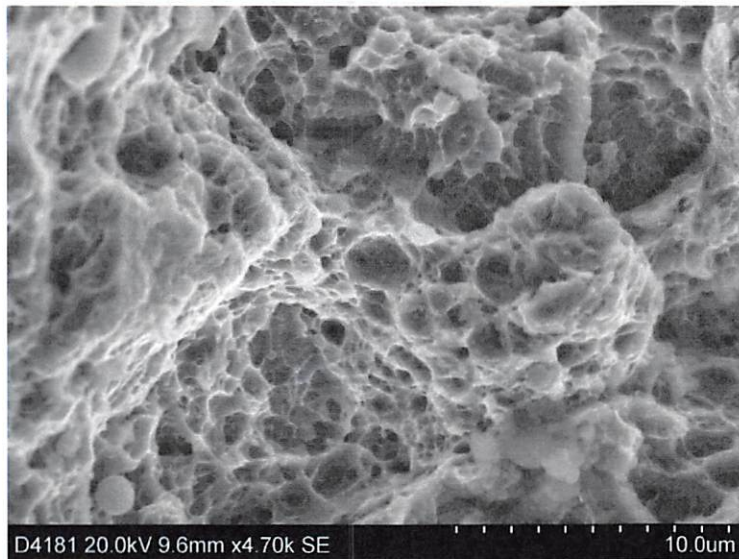


Figure 12.

SEM magnified view of the fracture surface on the shaft fragment #2 from reference marking point "A" side.

Presence of tensile ductile dimples suggestive of overload fracture was noted.

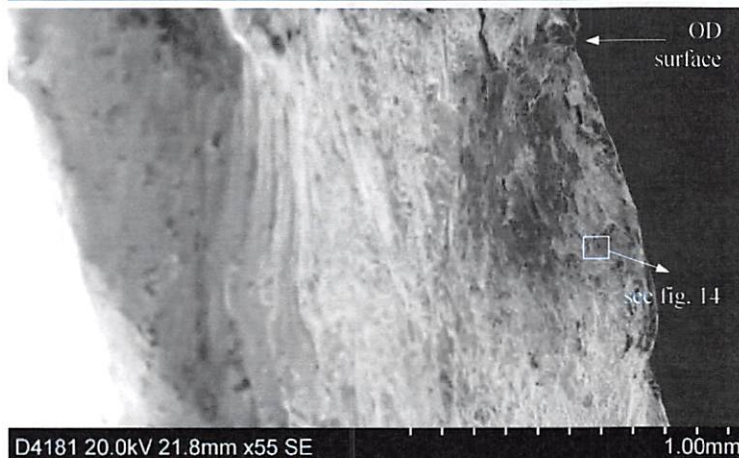


Figure 13.

SEM magnified view of the fracture surface on the shaft fragment #2 from reference marking point "A" side.

Marked area was further examined (see fig. 14).

Figure 14.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "A" side.

Shear dimples were observed. The red arrow shows the direction of shear.

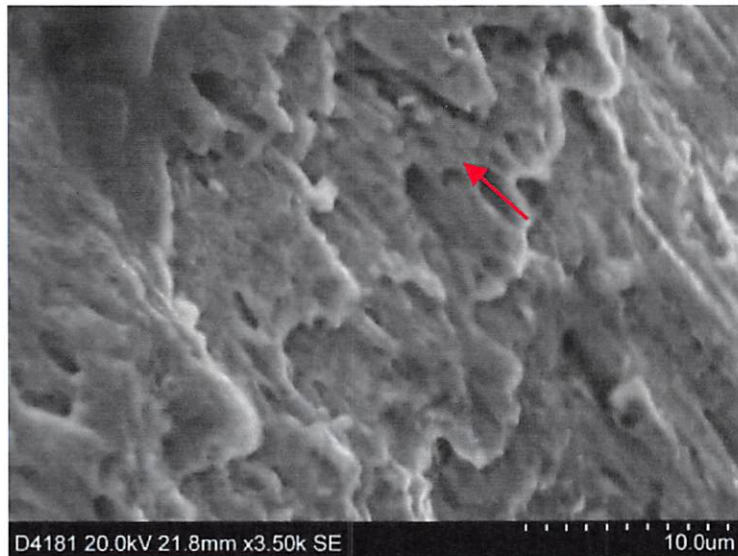


Figure 15.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "A" side.

Marked area was further examined (see fig. 16).



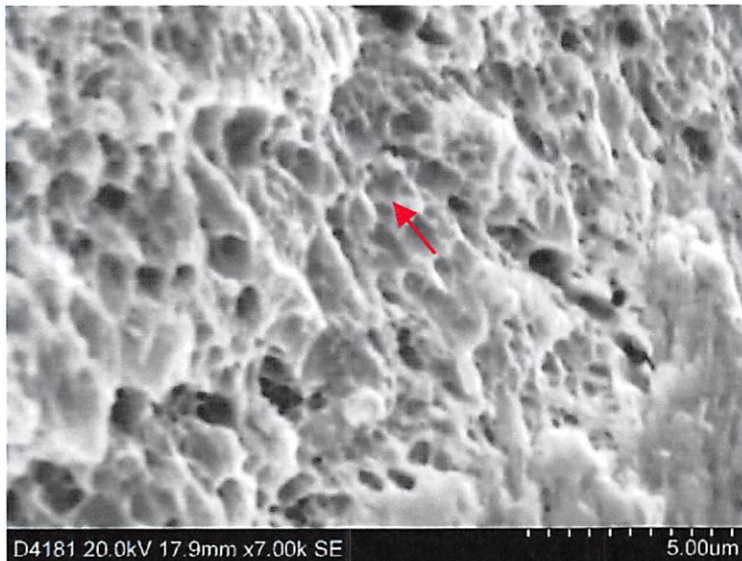


Figure 16.

SEM magnified view of the fracture surface on the shaft fragment #2 from reference marking point "A" side.

Shear dimples were observed. The red arrow shows the direction of shear.

Observations of fracture surface from reference marking point "A" side, in all examined areas examined, showed presence of overload transgranular tensile ductile/shear ductile fractures.



Figure 17.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "C" side.

Marked area was further examined (see fig. 18).

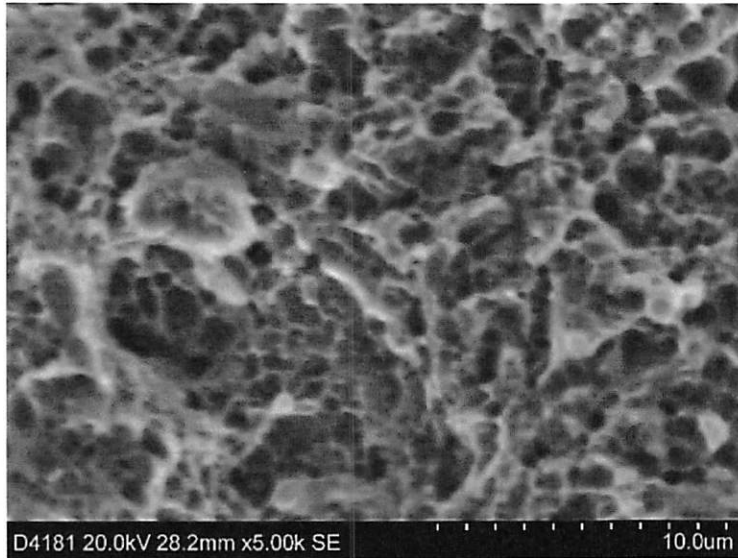


Figure 18.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "C" side.

Presence of tensile ductile dimples suggestive of overload fracture was noted.

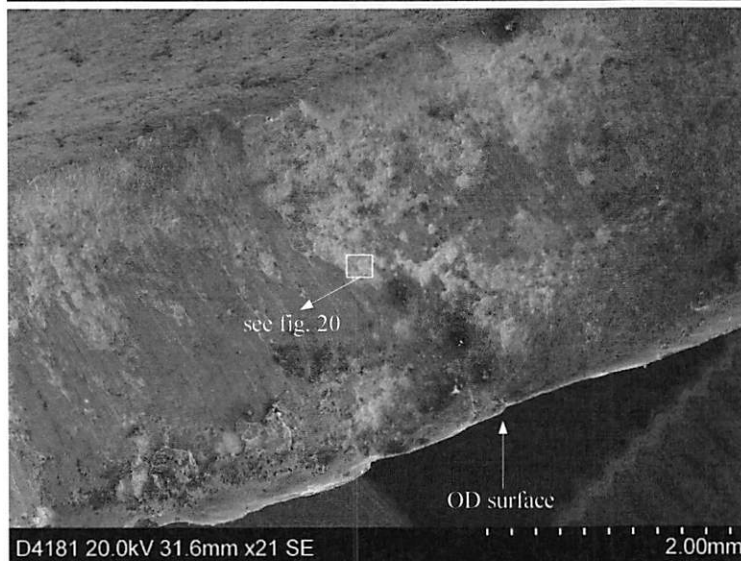


Figure 19.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "C" side.

Marked area was further examined (see fig. 20).

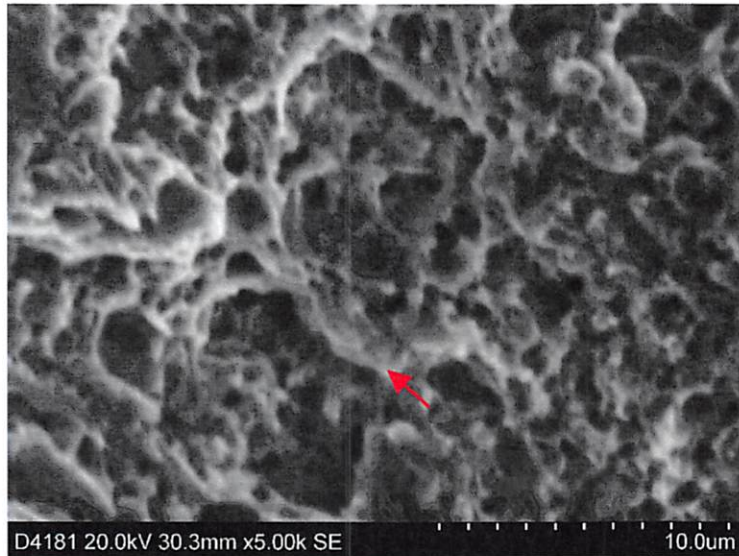


Figure 20.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "C" side.

Shear dimples were observed, suggestive of shear overload ductile fracture. The red arrow shows the direction of shear.



Figure 21.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "C" side.

Marked area was further examined (see fig. 22).

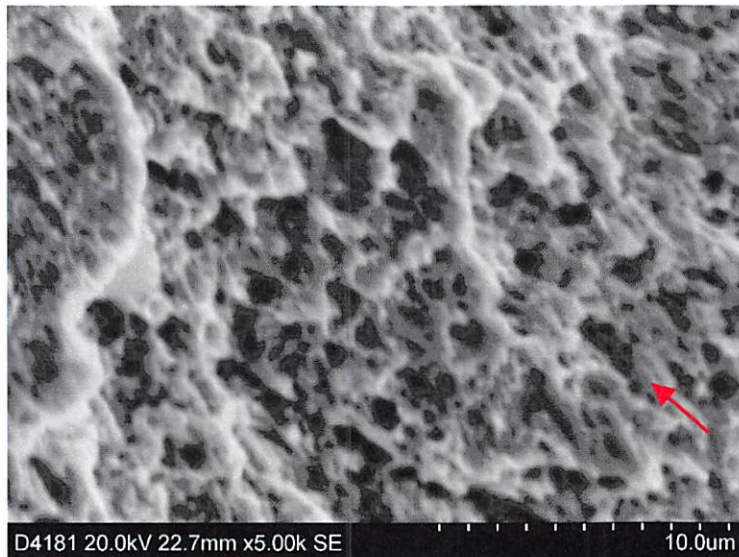


Figure 22.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "C" side.

Shear dimples were observed. The red arrow shows the direction of shear.

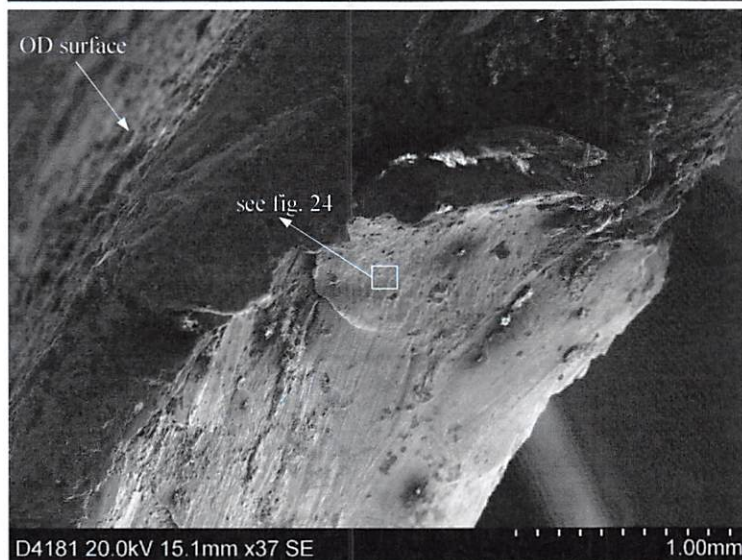


Figure 23.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "C" side.

Marked area was further examined (see fig. 24).



Figure 24.

SEM low magnification view of the fracture surface on the shaft fragment #2 from reference marking point "C" side.

Shear dimples were observed and the red arrow shows the direction of shear.

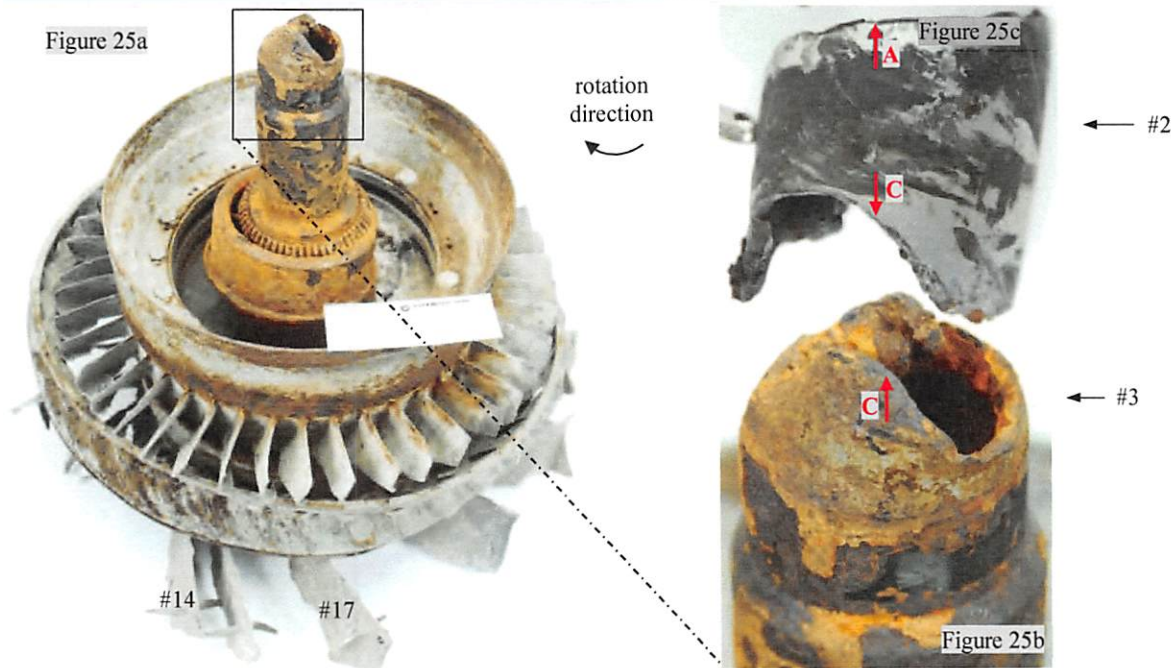


Figure 25. Fig. 25a: General view of downstream side of bladed-Low Compressor Rotor in as received condition.

Fig. 25b: Magnified view of fractured and significantly rusted Low Compressor Shaft fragment marked as #3.

Note that the observed shaft corroded fracture was likely the result of secondary damage due to immersion and/or atmospheric exposure for one month in the marsh. This matching fracture was not examined due to the presence of corrosion products obscuring any possible underlying fractographic details. Note that the matching fracture with fragment #2 (fig. 25c), which was not as significantly corroded, was examined in details and identified as an overload fracture.

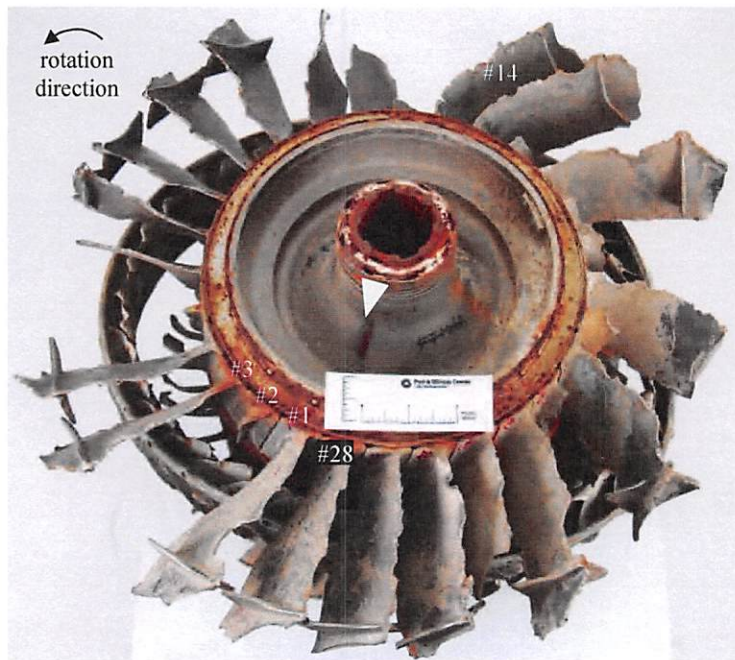


Figure 26.

General view of upstream side of the bladed Low Compressor Rotor assembly.

The red marking (indicated with white arrowhead) on the fan ring indicates the TDC position (12 o'clock position) of the engine. Fan blades were numbered from #1 to #28 in the opposite direction of rotation as shown.

Fan blades exhibited significant damage and bending from the airfoil's pressure side towards the suction side. Blades #2, #5, #13, #16, #18, #19, #21, #23 were fractured close to the platform and their fracture surfaces are shown in Figure 27. Blades #6, #11, #12 and #20 were fractured away from the platform.

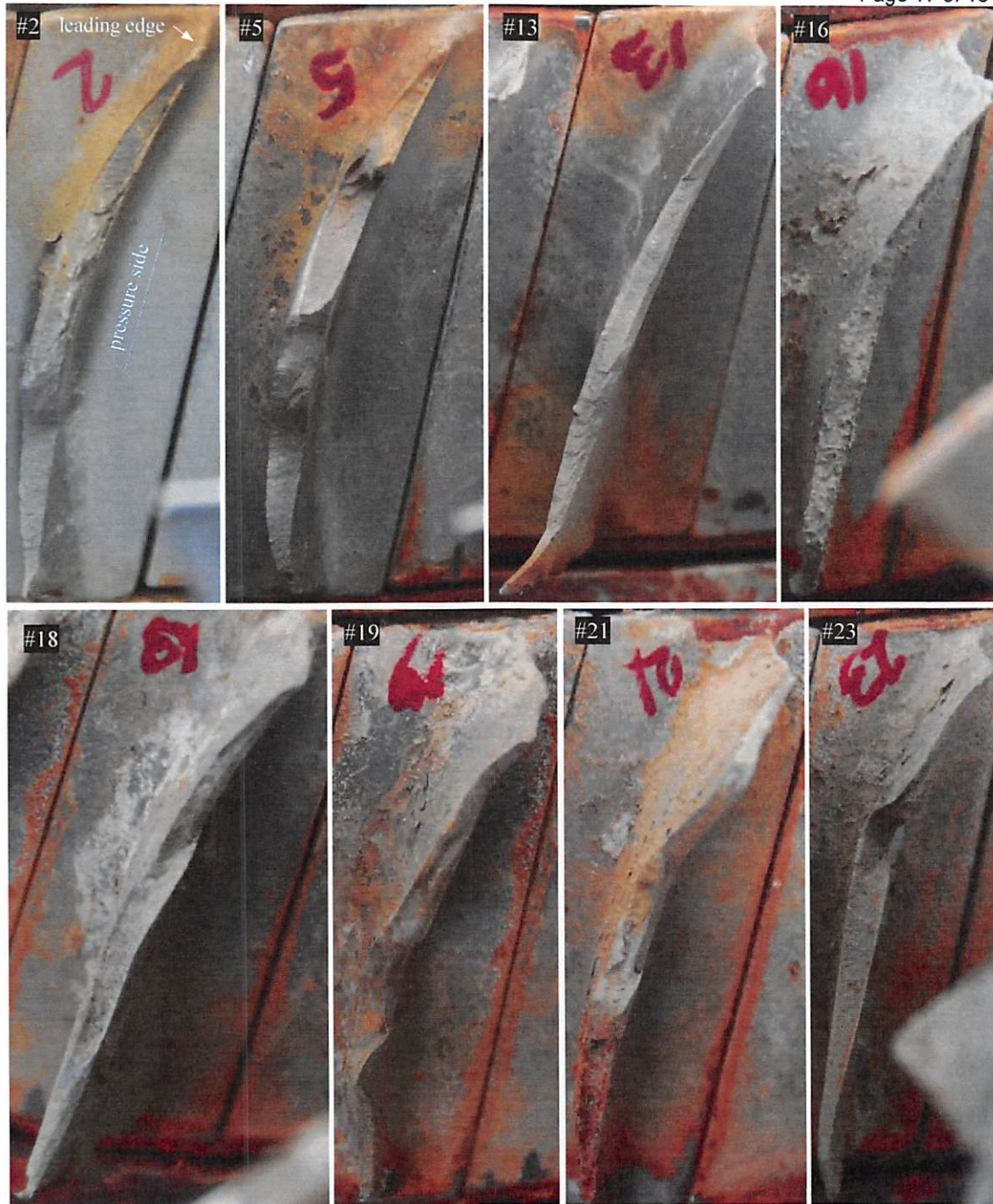


Figure 27. View of the fracture surfaces of eight (8) fractured fan blades close to the platform in the "as received" condition.

No evidence of fatigue fracture features was found. All these blades fractured by overload in a similar manner, and no anomalies were observed.

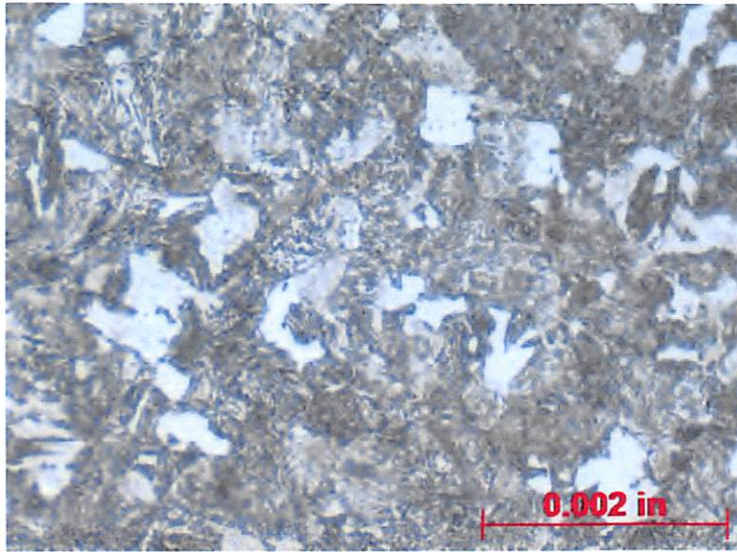


Figure 28.

Shaft, metallographic cross-section, etched: Nital 2%.

Microstructure of the shaft is consistent with tempered martensite of CPW 245M steel, according to CPW 300J standard.