NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

October 13, 2005

MATERIALS LABORATORY FACTUAL REPORT Report No. 05-104

A. ACCIDENT

Place : Los Angeles, California
Date : September 21, 2005
Vehicle : Airbus 320
NTSB No. : LAX05IA312
Investigator : Mike Hauf

B. COMPONENTS EXAMINED

Upper support and two fractured lugs.

C. DETAILS OF THE EXAMINATION

Disassembly of Nose Landing Gear

The nose landing gear assembly was disassembled at the Messier Services overhaul facility, Sterling, Virginia, on September 29 and 30, 2005, under the supervision of investigators from the National Transportation Safety Board and with participation of designated parties to the investigation. Figure 1 shows a photograph of the disassembled inner cylinder assembly. The upper end of this inner cylinder assembly contained two anti-rotating lugs, see figure 1. Inspection with a magnifying glass of the upper end of the inner cylinder assembly revealed that the anti-rotating lugs were intact and contained no evidence of a crack.

When the nose gear is intact and in the assembled condition, the anti-rotating lugs on the inner cylinder are inserted into slots that are located on the upper support assembly. As the nose landing gear was disassembled, two lug pieces from the upper support were found fractured. The two fractured lug pieces and upper support were sent to the Safety Board Materials Laboratory.

Laboratory Examination

Figures 2A and 2B show photographs of the as-received upper support and fractured lugs. The edge of the outer support was impression stamped with Messier-Dowty part number “D59831 and characters “EM18604”. The upper support was manufactured with four lugs, arbitrarily labeled “1” through “4”, as shown in figure 2A. Anti-rotating lugs from the inner cylinder (see figure 1) are inserted into corresponding slots between lugs 1 and 4, and between lugs 2 and 3 in figure 2A. Lug 1 contained a fracture at the base that extended slightly above the slot area. When measured on the outside diameter face along the fracture path (along the curved portion of the fracture), the fracture measured approximately 1.4 inch. When measured on the inside diameter face of lug 1 along the fracture path, the length of the fracture measured approximately 1.1 inch. The results of the measurements indicate that the length the fracture on the outer diameter surface was longer compared to the length of the fracture on the inner diameter surface. Lug 2 also fractured at the base. The size and contour of the fracture on lug 2 was similar to lug 1. Lug 3 contained a crack that intersected the fillet radius at the base portion of the lug, see figure 2A. The length of this crack along its fracture path on the outer diameter face measured approximately 1.2 inch. Lug 4 contained a crack that intersected the fillet radius at the base. This crack can be seen from the inner and outer diameter surface. Figure 4 shows a photograph of the crack when viewed from the outer diameter surface. This crack measured approximately 0.1 inch. The fracture at the base of lugs 1 and 2, and the cracks in lugs 3 and 4 intersected the fillet radius at the slot that corresponded to the anti-rotating lugs for the inner cylinder.

Lug 1

Figures 5 and 6 show close-up photographs of the fracture face from lug 1. Bench binocular microscope examination of lug 1 revealed the fracture face contained ratchet marks (radial lines), typical of a fatigue crack, that originated within the radius between the slot side of the lug and the lower surface of the upper support, near the inner diameter of the upper support, as indicated by arrow “O” in figures 2A, 5 and 6. The fatigue crack propagated through more than 95% of the fracture face. The fracture face was covered with a black-brown deposit that extended between the fatigue origin and the area indicated by a dashed line in figure 5. The black-brown region extended through approximately 75% of the fracture length, which calculates to about a 1-inch crack along the fracture path when viewed from the outer diameter face of the lug.[1] X-ray energy dispersive spectroscopy (EDS) analysis of the fracture face in the region that contained no evidence of a deposit produced a spectrum that contained a major elemental peak of iron and minor elemental peaks of carbon, chromium, manganese, molybdenum, nickel, and silicon, consistent with the specified Timken Latrobe Lescalloy 35NCD16 VAC-ARC High Strength Alloy Steel. An EDS spectrum of the black-brown region contained the same elemental peaks as in the base metal and a minor elemental peak of oxygen. The composition and appearance of the black-brown deposit are consistent with iron oxide.

Visual and scanning electron microscope (SEM) examination of the lug revealed the surface of the radius at the fatigue origin area showed no evidence of mechanical damage, such as a gouge. The black-brown iron oxide region at the fatigue origin area covered the fine fracture features, see figure 7. The fracture face in the area slightly outside of the iron oxide region contained fatigue crack features (parallel fissures) that were mixed with regions of ductile dimple, see figure 8. The distance between the parallel fissures

[1] 75% of a 1.4-inch crack equals 1-inch.

increased as the distance from the iron oxide region was increased. Figure 9 shows an SEM photograph near the end of the fracture. The last 5% of the fracture length showed for the most part ductile dimple features typical of overstress separation (picture not shown).

The fracture face was ultrasonically cleaned in acetone. This cleaning procedure did not remove the black-brown iron oxide region on the fracture surface. The lug was electrolytically cleaned with Endox 214, a solution that removes oxides from ferrous metals. This cleaning process removed iron oxide deposit in isolated areas of the fracture and exposed fatigue crack features. Figure 10 shows a photograph of fatigue crack features in an area where iron oxide was removed.

The upper support was coated with silver paint. The fractured lug was immersed in a commercial paint stripper, and this process removed the paint. This paint stripping process left a residual dark-gold tint on the fracture face. EDS analysis of the lug surface produced a spectrum that contained elemental peaks of cadmium, an indication that the surfaces were plated with cadmium as required by Messier-Dowty engineering drawing D59831-1 for the upper support. The radius at the base of the lug in the area that corresponds to the slot for the anti-rotating lugs of the upper cylinder, indicated by “R1” in figure 4, was measured with a Smart Scope measuring instrument and found to be approximately 1.52 millimeter (mm), which was within the specified range (between 1.4 and 1.8 mm).

A metallurgical section was made through the lug in the area and orientation indicated by section line “A-A” in figure 5. The section was metallurgically prepared and etched with 2% Nital reagent. Examination of the section reveled a microstructure of tempered martensite, typical of quenched and tempered steel. No anomalies were noted in the microstructure. Rockwell hardness testing of the section produced an average hardness of HRC 41. This converts[2] to an ultimate tensile strength of approximately 1,300 Mega-Pascal (MPa), which was within the specified range (between 1,230 MPa and 1,370 MPa). The corner radius between the slot and inner diameter face, indicated by “R2” in figure 4, measured between 1.43 and 1.5 mm, which was within the specified range (between 1.0 mm and 2.0 mm).

Lug 2

Figure 11 shows a close-up photograph of the fracture face from lug 2. The fracture face contained ratchet features (radial lines) typical of a fatigue crack that emanated from the radius between the slot side of the lug and the lower surface of the upper support, near the inner diameter of the upper support, as indicated by arrow “O” in figures 2A and 11. Visual and SEM examination of the fracture face revealed parallel fissure typical of fatigue crack features near the origin of the fracture. The fatigue crack propagated through more

[2] Conversion from hardness to ultimate tensile strength is published in ASTM 370, titled “Standard Methods and Definitions for Mechanical Testing of Steel Products”.

than 95% of the fracture face. The last 5% of the fracture length showed for the most part ductile dimple features typical of overstress separation.

Approximately 50% of the length of the fracture face at the fatigue origin end was covered with a yellow deposit. This calculates to about a 0.7-inch portion of the fatigue crack when viewed from the outer diameter face of the lug.[3] The yellow deposit region extended from the fatigue origin to the area indicated by a dashed line in figure 11. EDS analysis of the fracture face in the yellow deposit region produced a spectrum that contained the elemental peaks that were found in the base metal, in addition to a major elemental peak of silicon and minor peaks of barium, chromium, aluminum, magnesium, copper, carbon and oxygen. Mastinox is an anti-seizing compound that is applied to many parts of the airplane. This compound is yellow and typically is applied as a paste. A sample of Mastinox was received from Messier Services for analysis. EDS spectrum of the Mastinox compound contained a major elemental peak of silicon and minor peaks of barium, chromium, aluminum, magnesium, carbon and oxygen. The EDS spectrum of the yellow deposit on the fracture face contained elemental peaks that were consistent with the elemental peaks that were found on the EDS spectrum from a sample of Matinox, see attachment 1 for comparison of the two EDS spectra.

Lug 3

The contour of the crack at the base of lug 3 was similar to the contour of the fracture path on lugs 1 and 2. A saw cut was made through the remaining intact wall portion of lug 3 until it intersected the end of the crack. The exposed fracture face, see figure 13, contained crack arrests features typical of a fatigue crack that originated at the radius between the slot side of the lug and the lower surface of the upper support, near the inner diameter of the upper support, as indicated by arrow “O” in figure 11. Visual examination of the surface of the upper support in the vicinity of the origin area revealed the fatigue crack propagated through the exposed fracture face. A portion of the fracture face at the fatigue origin end was covered with Mastinox (verified by EDS analysis). The Mastinox region extended between the fatigue origin (arrow “O”, figure 13) and the area indicated by a dashed line in figure 13. The length of the Mastinox region measured approximately 0.2 inch, when viewed from the outer diameter face of the lug.

Lug 4

The crack at the base of lug 4 measured approximately 0.1 inch. The crack was not excised for examination.

Upper Support

The upper support contained nine-through holes for attachment bolts. The parts were received in the laboratory, with an attachment bolt inserted part way into one of the through-holes. This bolt is visible in figure 2A and can also be seen in figure 2B and figure

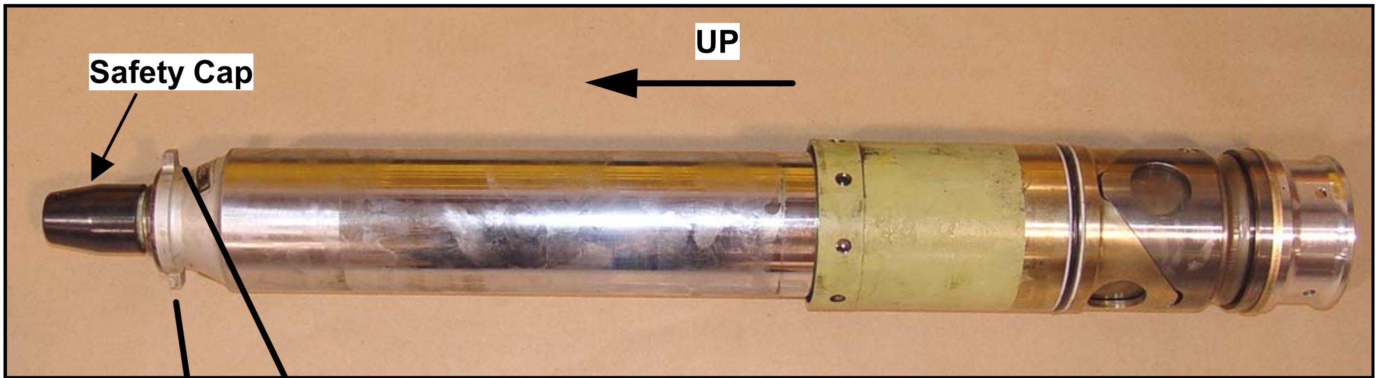
[3] 50% of the 1.4-inch equals about 0.7 inch.

3. This attachment bolt could not be removed under hand forces. The lower surface of the upper support adjacent to two other through-holes was covered with a yellow paste deposit, as can be seen in figure 2A. EDS analysis of a sample from the yellow deposit removed from one of the two holes prior to cleaning produced a spectrum that was consistent with the spectrum from Mastinox.

Portions of the upper support were covered with grease. The head of attachment bolt contained red grease, indicated by arrow "G1" in figure 2A. Samples of grease were removed prior to any cleaning process. EDS analysis of a sample of the red grease produced a spectrum that contained a major elemental peak of silicon and minor peaks of aluminum, magnesium, carbon, oxygen, sodium, calcium, iron, phosphorus, and molybdenum. The shank portion of the attachment bolt and portions of the adjacent lower surface of the upper support contained dark gray grease; in the area indicate by arrow "G2" in figure 2A. A sample of this grease was removed and analyzed. The EDS spectrum from this grease contained the same elemental peaks as in the red grease, with additional peaks of copper and potassium. The upper support was coated with silver tinted paint. A sample of this silver tinted paint was removed from the upper support and cleaned in soap solution. EDS spectrum of silver paint contained a major elemental peak of aluminum and minor peaks of silicon, oxygen, and iron.

Figure 14 shows the lower face of the upper support after it was cleaned by immersion in a commercial degrease solution. The attachment bolt remained lodged in the upper support after cleaning. Examination of the bore of the exposed through-holes revealed no evidence of fretting damage. The diameter of the each exposed through-hole measured approximately 7.95 mm, as specified in the Messier-Dowty engineering drawing for the upper support. The upper support showed no evidence of other cracks.

Frank P. Zakar
Senior Metallurgist



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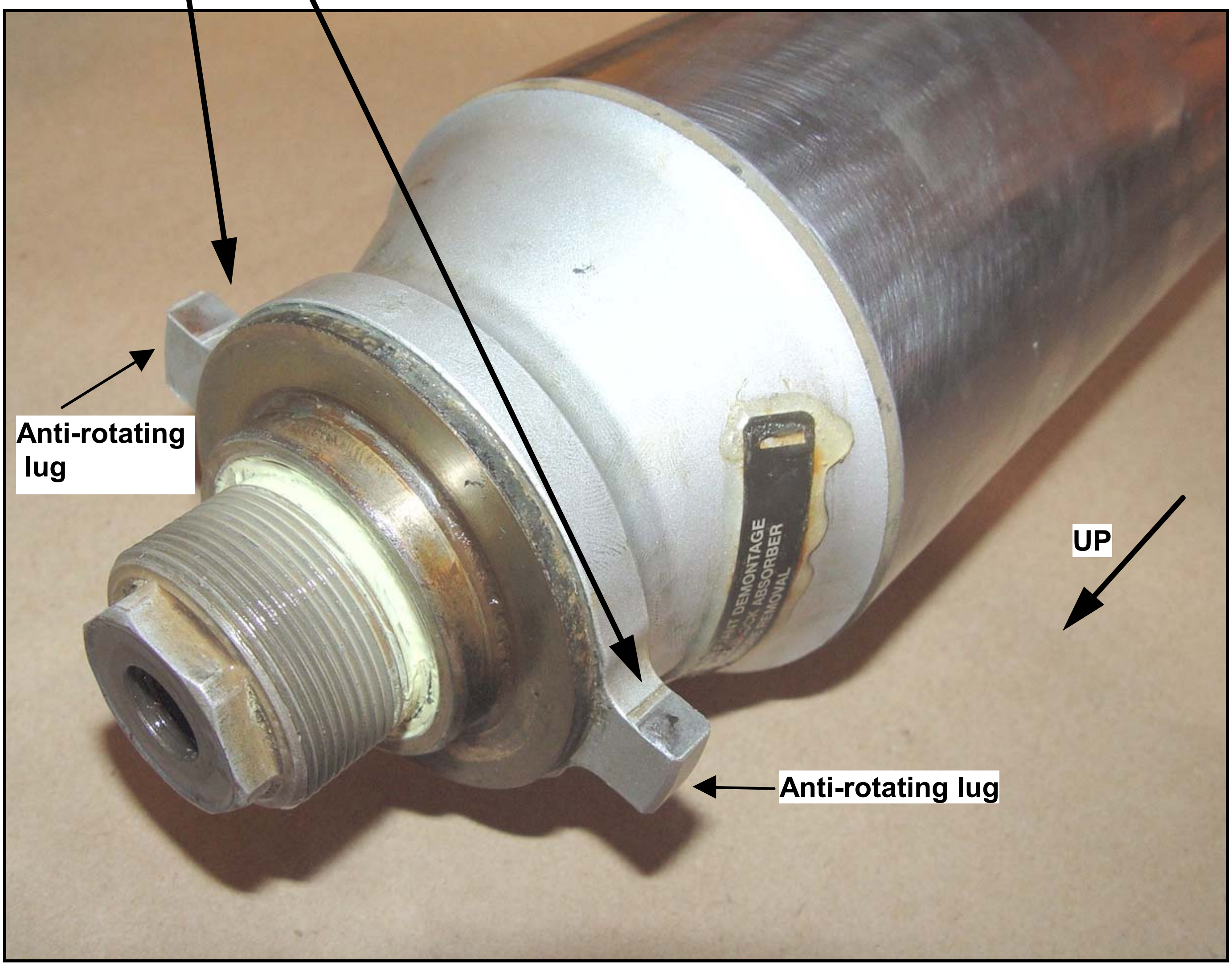

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Figure 1. View of the disassembled inner cylinder assembly from the nose landing gear (top photograph) with safety cap that was attached after disassembly and close-up view of the upper end of the inner cylinder showing anti-rotating lugs (bottom photograph).

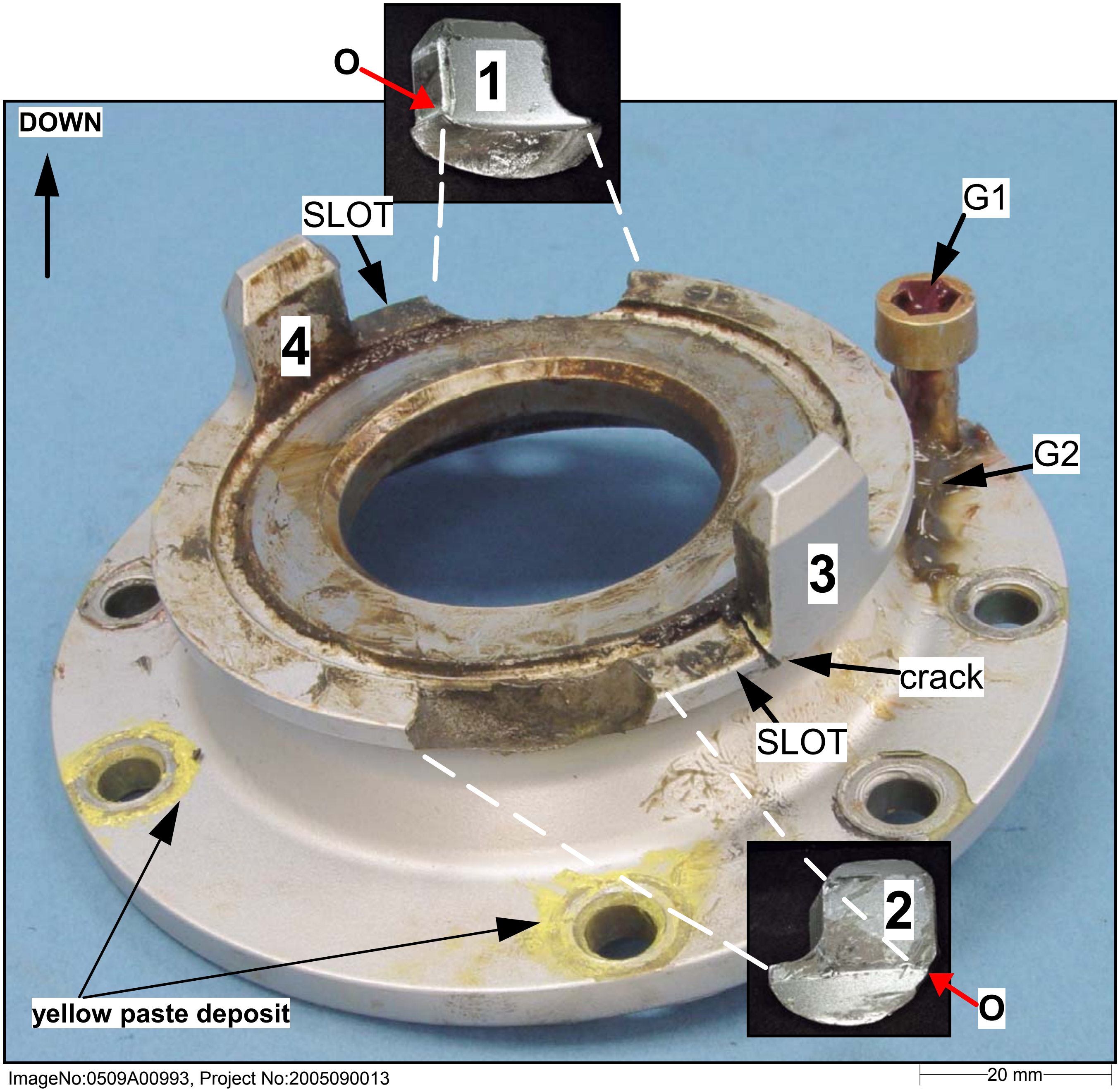
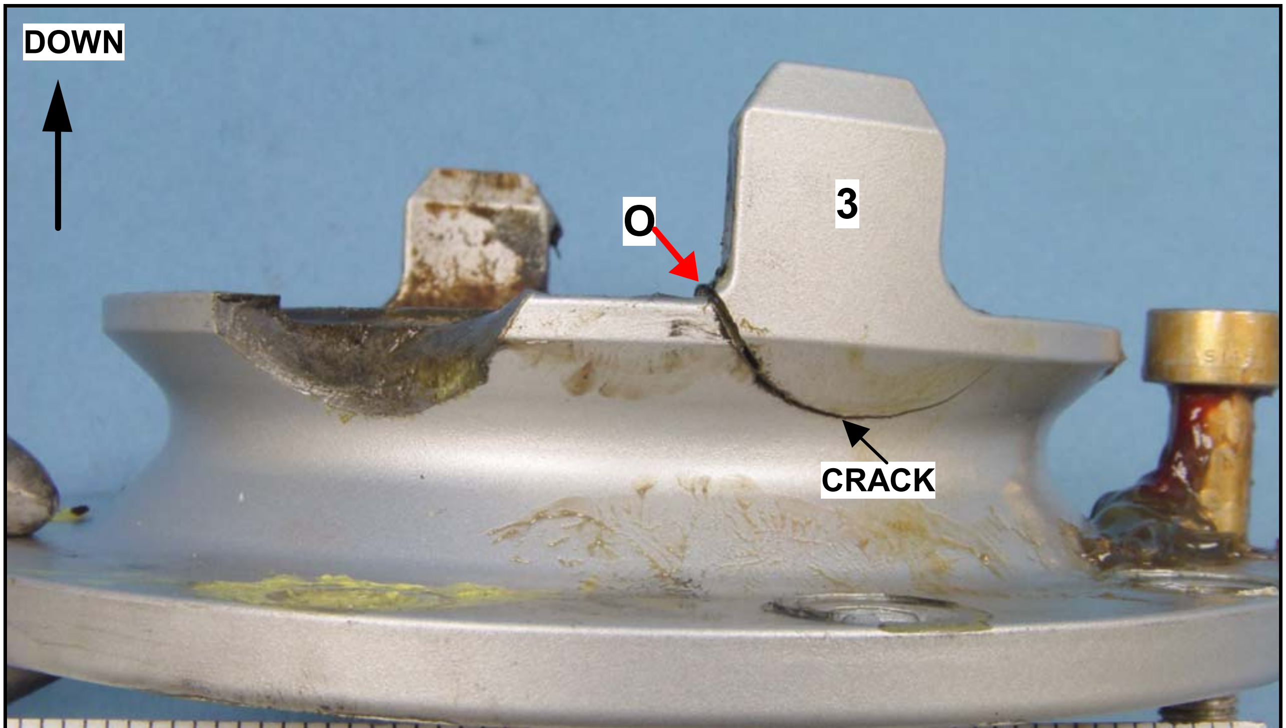


Figure 2A. View of the upper support and relative postion of fractured lug pieces "1" and "2". Fatigue origins are indicated by arrow "O". When the nose landing gear is in the assembled condition, anti-rotating lugs from the inner cylinder are inserted into corresponding slots on the upper support (located between lugs "2" and "3" and between lugs "1" and "4"). Fractured lug pieces "1" and "2" are shown in this figure after they were immersed in a commercial degrease solution.

ImageNo:0509A00979, Project No:2005090013 50 mm

Figure 2B. View of the top side of the upper support.



ImageNo: 0509A00996, Project No:2005090013 20 mm

Figure 3. Side view of the upper support showing lug "3" that contained a crack at the base. Arrow "O" indiates the location of the fatigue crack.

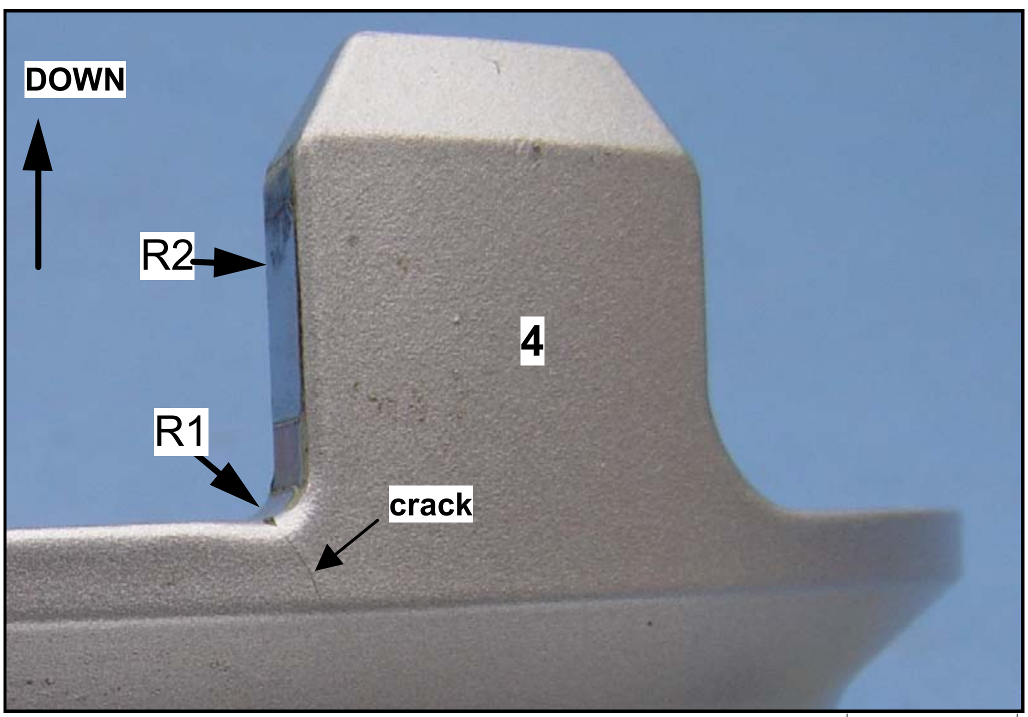


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Figure 4. View of lug "4" showing a crack that emanated from the radius at the base.

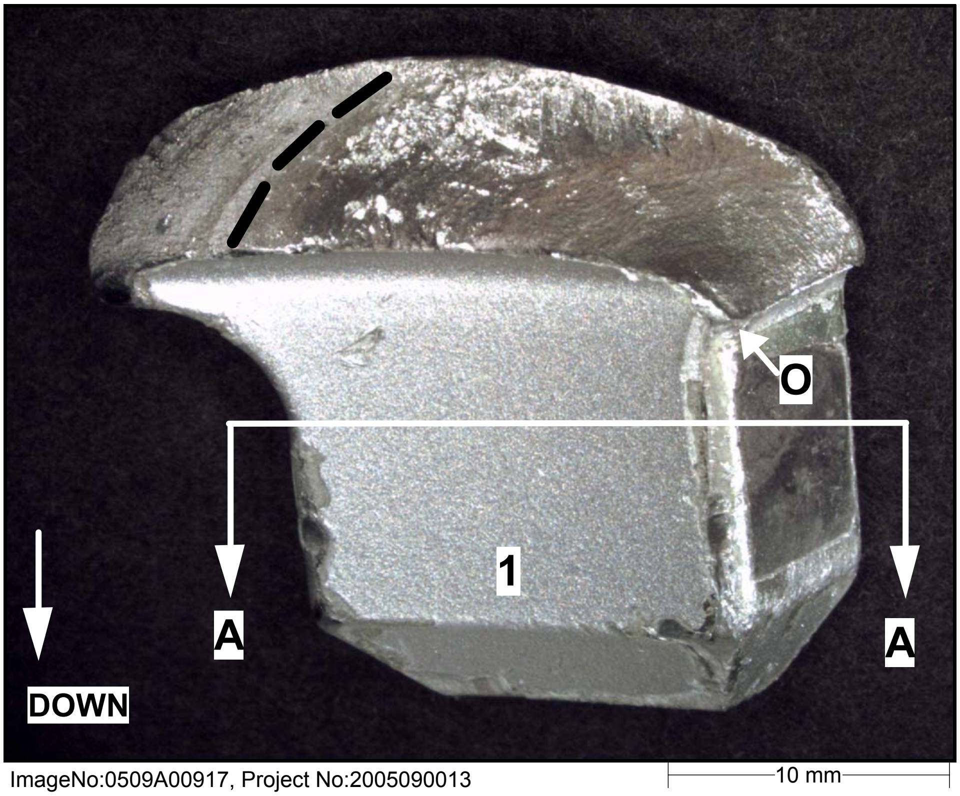

Figure 5. View looking at the inner diameter face of fractured lug "1". The fracture face contained a fatigue crack that emanated from the fillet radius at the base of the lug in the area indicated by arrow "O".

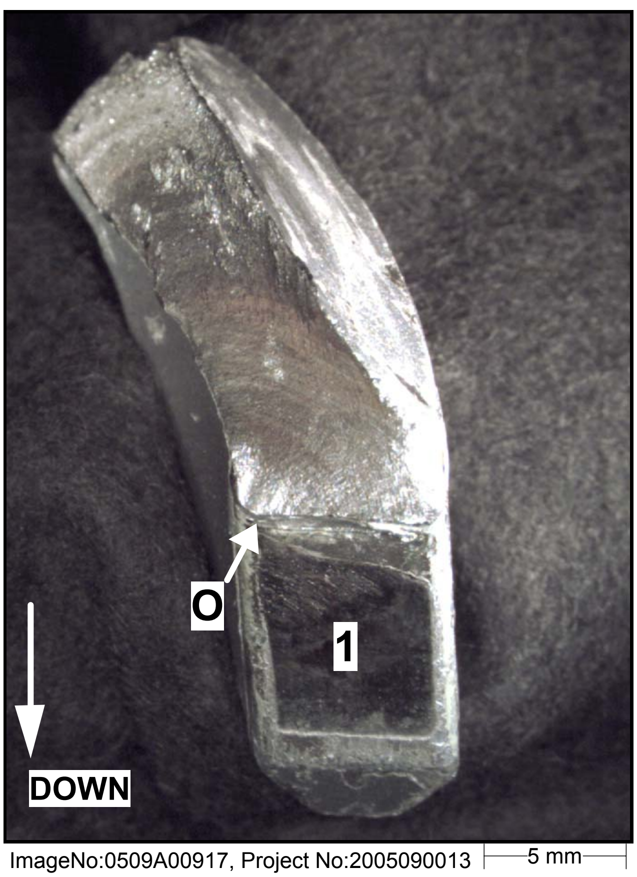

Figure 6. Another view of fractured lug "1" and the fatigue origin area indicated by arrow "O".

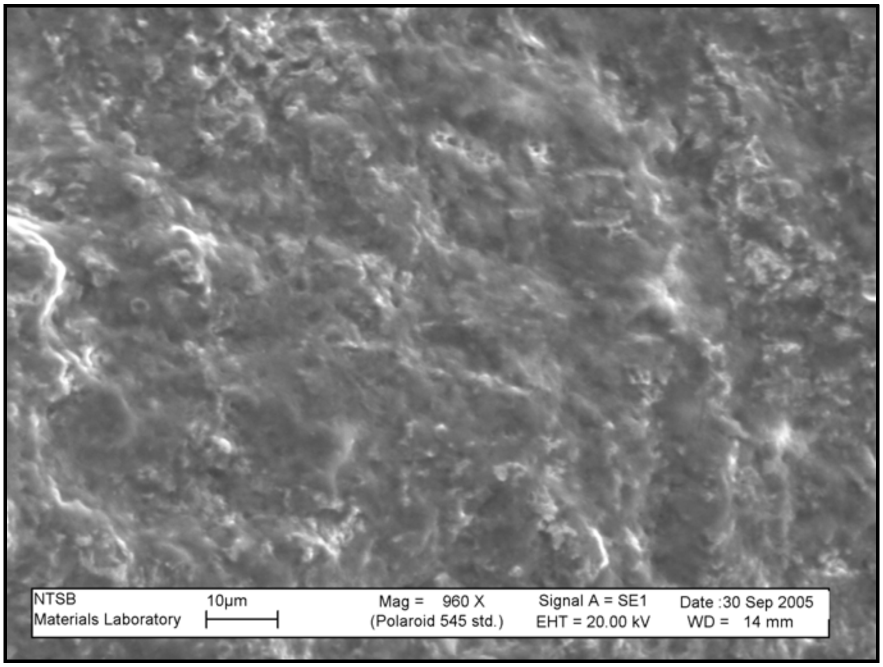

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Figure 7. SEM image of the black-brown oxide deposit on the fracture face of lug "1"

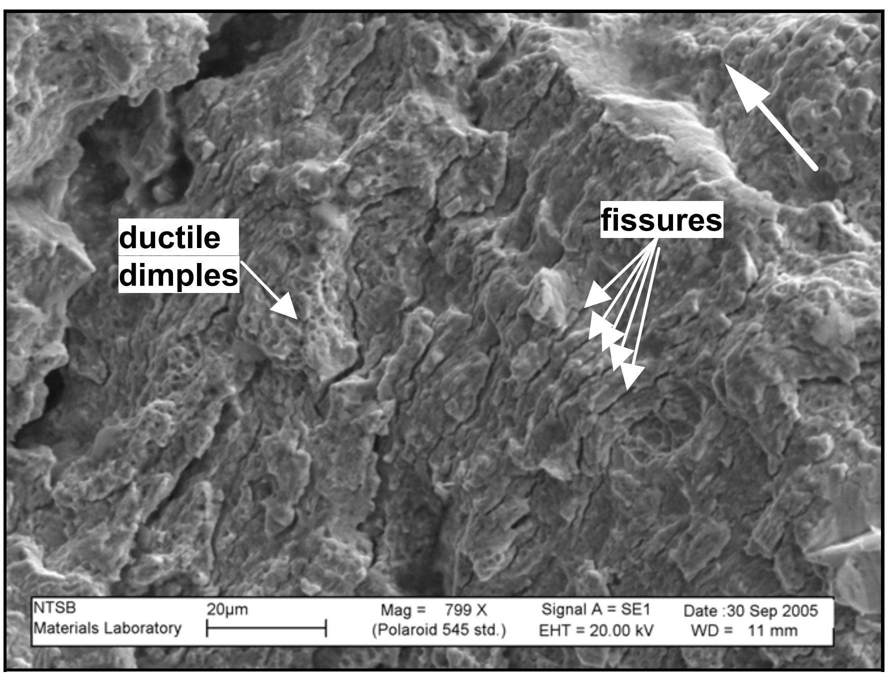

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Figure 8. SEM image of the fracture face of lug "1" showing fracture features that were found outside and adjacent to the black-brown oxide region. This image shows fatigue crack features (parallel fissures) mixed with ductile dimple features. Arrow shows general direction of fatigue propagation.

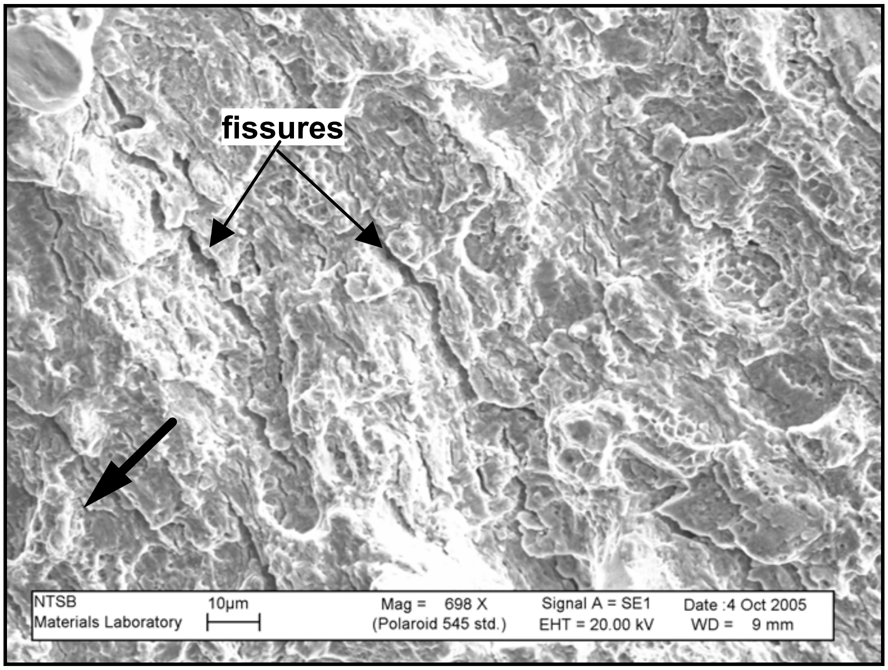

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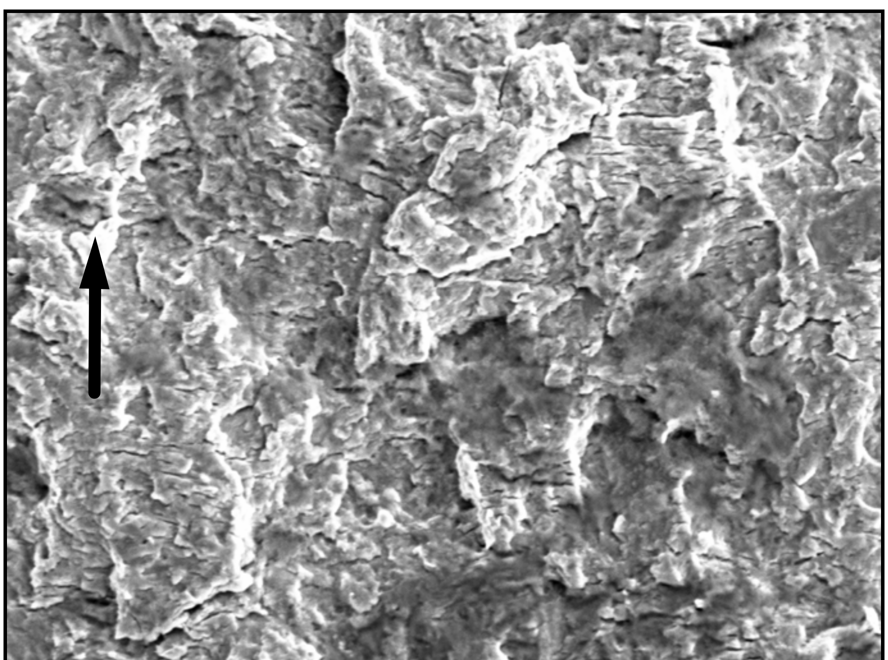
Figure 9. SEM image of the fracture face of lug "1" showing fracture features that were found near the terminus of the fracture. The fracture in this region contained mixed fatigue crack features (fissures) and ductile dimple features. Note that the distance between the fissures in this image was greater than those found in figure 8. Arrow shows general direction of fatigue propagation.



ImageNo: 0510A00161, Project No:2005090013 20 µm

Figure 10. SEM image of the fracture face from lug "1" in the black-brown iron oxide region after electrolytically cleaning, showing exposed fatigue crack features. Arrow shows general direction of fatigue progagation.

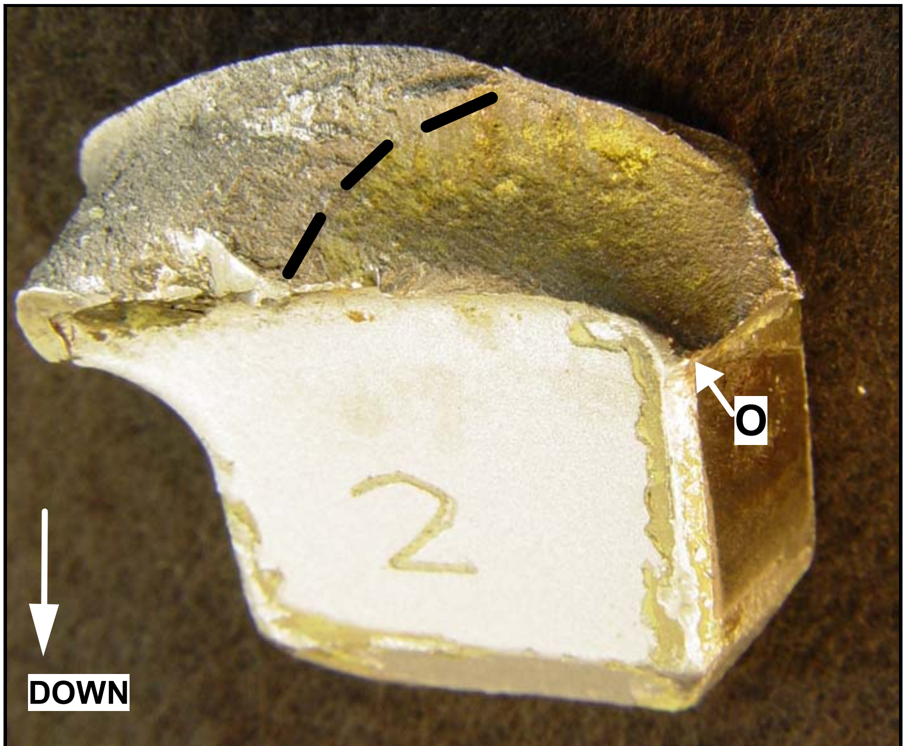


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Figure 11. View looking at the inner diameter face of fractured lug "2". The fracture face contained a fatigue features that emanated from area indicated by arrow "O".

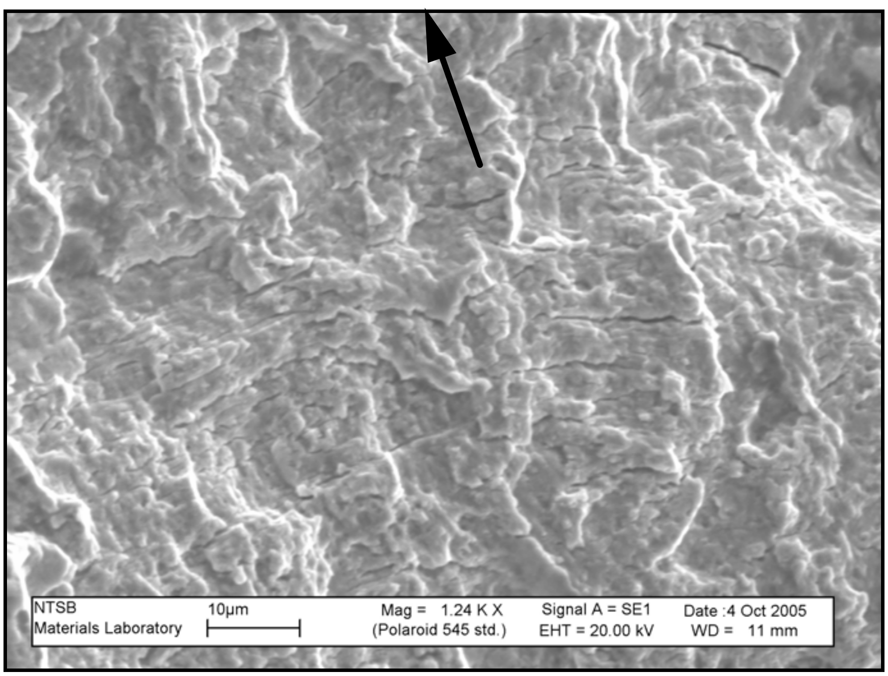

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Figure 12. SEM image of the fracture face of lug "3" showing fatigue crack features that emanated from the fillet radius in the area indicated by arrow "O" in figure 11. Arrow shows general direction of fatigue propagation.

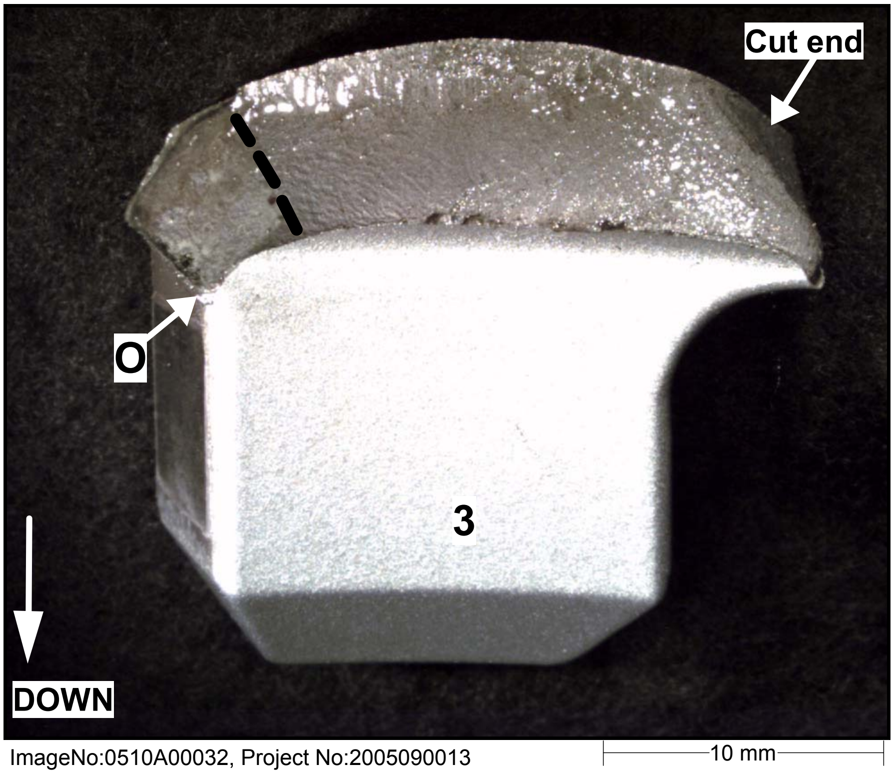


Figure 13. View looking at the inner diameter face of fractured lug "3". The fracture face contained a fatigue features that emanated from the area indicated by arrow "O".

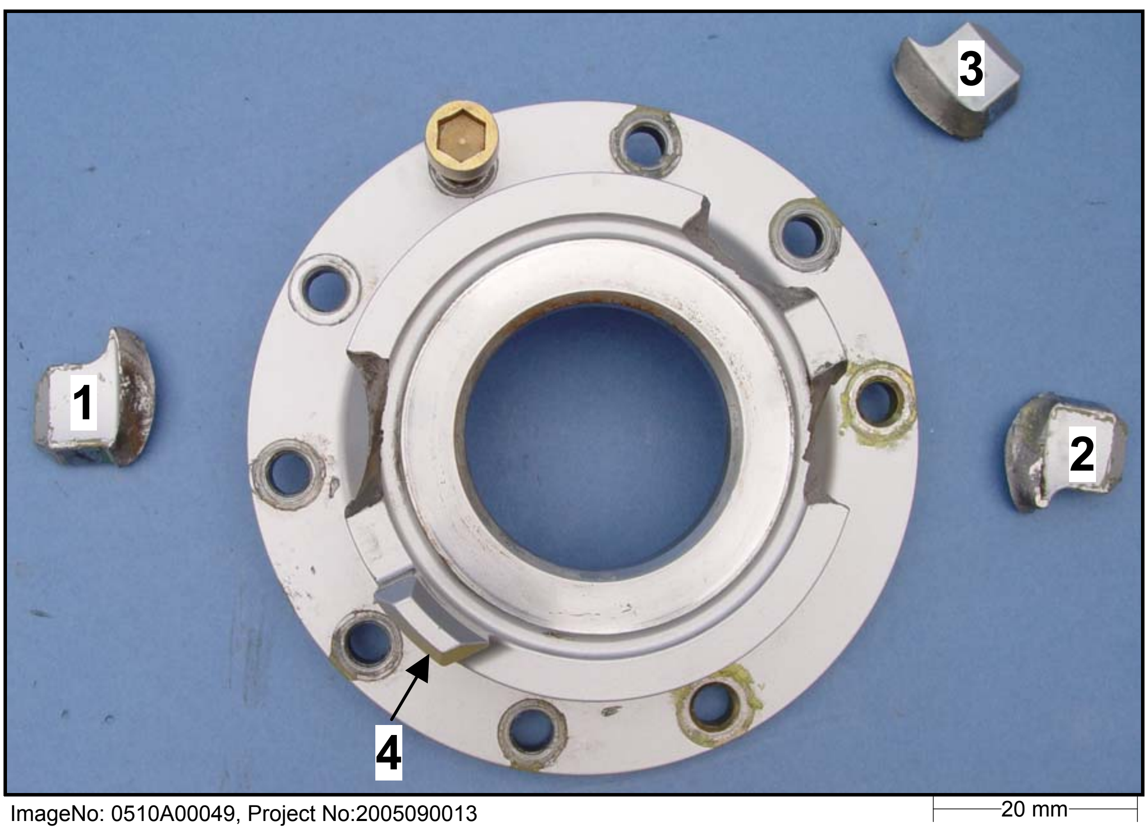
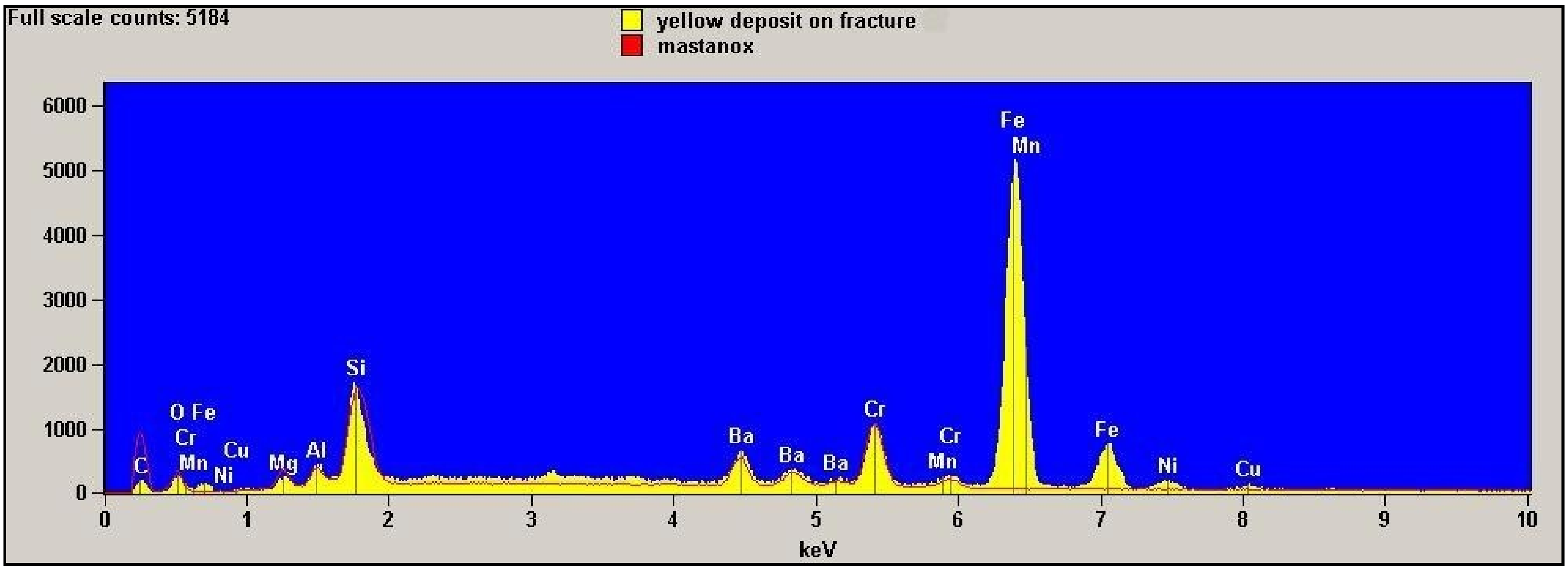


Figure 14. View of the bottom face of the upper support after cleaning and lugs positioned next to their respective mating fractures.

ATTACHMENT 1.

X-ray Energy Dispersive Spectroscopy Spectrum of yellow deposit that was found on the fracture face of lug "2" (shown as a solid yellow spectrum) and Mastinox (shown as an overlapping red line).



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