

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594



July 18, 2016

MATERIALS LABORATORY FACTUAL REPORT

Report No. 16-059

A. ACCIDENT INFORMATION

Place : Clermont, Florida
Date : March 12, 2016
Vehicle : EAB Sheehen Dane RV-8A, N838RV
NTSB No. : ERA16FA127
Investigator : Millicent Hoidal, AS-ERA

B. COMPONENTS EXAMINED

Superior Crankshaft, p/n SV40650A from a Superior XP-400 experimental engine.

Connecting Rods, p/n SV40450-1 Rev C with bearings SL13212A F and #2 and #4 main bearings, p/n SL16711A F.

C. DETAILS OF THE EXAMINATION

The crankshaft fractured at the forward radius of the #2¹ connecting rod journal as shown in the upper view of figure 1. The propeller flange of the crank was marked with part number SV40650 A ASSY and serial number 69521. It had reportedly accumulated 20 hours of service since new. The as-received connecting rods with bearings and #3 and #4 main bearings are displayed in the lower view of figure 1.

Visual examinations of the fracture surfaces revealed extensive beach markings and a finely textured surface indicative of fatigue progression from the vicinity of the forward radius of the rod journal, as shown in figure 2. The origin was rotationally located opposite the top-dead-center position of the piston. Higher magnification inspections established that the fatigue initiated at a single sub surface location, as shown in figure 3. The origin location measured 0.027 inch below the radius surface.

The aft fracture face was removed by an abrasive saw cut, transversely through the approximate center of the rod journal, then ultrasonically cleaned in acetone. Scanning electron microscope (SEM) viewing of the fracture surface also found markings consistent with fatigue progression from a subsurface location. However, SEM examinations also revealed extensive mechanical damage consistent with crack closure and crack face recontact that obliterated the fine details of the fracture, as shown in figure 4. The approximate origin location corresponds to a slight depression on the

¹ Superior numbers main and rod bearing from the front to the back of the engine.

fracture surface, see lower view of figure 4. Fracture features within the depression were also damaged.

Energy dispersive x-ray (EDS) spectra and maps of the origin location did not indicate an inclusion or chemical variations in the area. The EDS spectra of the crankshaft away from the origin was consistent with a low alloy steel containing chromium, molybdenum, nickel, manganese and vanadium as major alloy elements.

X-ray fluorescence spectrography² of several areas on the crankshaft including the #2 connecting rod journal were consistent with the material composition specified by EO251³ as indicated on the engineering drawing for the forging.

As previously noted the fatigue origin was rotationally located on the journal opposite the top-dead-center position of the piston. Longitudinally, the fatigue origin was under the forward radius of the #2 journal near the transition onto the journal surface, such that the majority of the radius remained on the forward cheek of the crankshaft as in figure 6. A small portion of the radius remain on the aft piece of the journal as shown in figure 7. The transition to the journal was smooth and tangent with no steps or abrupt changes. The #2 journal forward radius measured⁴ 0.1574 inch on the forward fracture face in the vicinity of the fatigue origin and 0.1621 inch on the aft piece of the journal away from the fracture.

A metallographic section was cut longitudinally through the #2 rod journal near the fatigue origin. The section was progressively polished to near the origin location. No inclusions or foreign material was noted at or near the origin location in any of the successive polish steps. The steel was very clean and only one inclusion was noted on one polish step anywhere in the sample.

The crankshaft was specified to be quench and temper heat treated to a hardness of HRC⁵ 33 to 38. Subsequently the journals and the majority of the crankshaft surfaces are to be nitrided⁶ to an effective case depth⁷ of 0.018 inch to 0.035 inch and a surface hardness of 83 HR15N⁸.

Etching the metallographic specimen with 2% Nital⁹ revealed the case and core microstructure as shown in the lower view of figure 8. Both case and core microstructures were tempered martensite with the case structure containing individual white etching iron nitrides and etching darker. Both typical of the specified heat

² Using a Thermo Scientific Niton XL3t-980 hand held x-ray fluorescence analyzer.

³ Superior Air Parts, Inc Engineering Order. Steel, Forgings, Crankshaft, Electro Slag Remelted. Rev F 1/16/2008.

⁴ Using an Opticom Qualifier 14B optical comparator by OGP (Optical Gaging Products).

⁵ Hardness Rockwell C scale.

⁶ Hardening process by which nitrogen is diffused into the surface to form a harder surface layer.

⁷ Case depth determined by microhardness measurements at HRC 40.

⁸ Superficial hardness using a diamond cone indenter and a 15 kgf total load.

⁹ 2% concentrated nitric acid in ethanol.

treatments. No iron nitride surface layer or networks were visible. Visually, the total case appeared to be about 0.025 inch deep.

Effective case depth was determined by four micro hardness traverses on the metallographic specimen. The hardness data are presented in the graph contained in figure 9. The effective case depth, measured at HRC 40, was between 0.018 inch and 0.023 inch meeting the drawing's specifications. Core hardness was measured on a cut section through the #2 rod journal. The 5 measurements averaged HRC 35.7 satisfying the drawing requirements.

The main and rod journal diameters and the fillet radii were measured optically¹⁰ in the top-dead-center (TDC) to bottom-dead-center (BDC) plane. The data are presented in the following tables. The journal diameters were measured near the forward radius and near the aft radius and each fillet was measured at TDC and BDC. Resulting in two measurements for each feature. Out of tolerance areas are indicated by gray shading.

Table A Journal Diameters (inches)								
Rod Dia.	#1	#1	#2	#2	#3	#3	#4	#4
2.124/2.125	2.124	2.124	NM	2.123	2.123	2.122	2.124	2.123
Main Dia	#1	#1	#2	#2	#3	#3	#4	#4
2.375/2.376	NM	NM	2.375	2.375	2.374	2.374	2.374	2.377

Table B Journal Fillet Radii (inches)								
Fillet Radius 0.140/0.156 all	#1	#1	#2	#2	#3	#3	#4	#4
Rod FWD	0.160	0.153	0.147*	0.155	0.153	0.155	0.156	0.153
Rod AFT	0.153	0.150	0.150	0.152	0.150	0.151	0.151	0.153
	#1	#1	#2	#2	#3	#3	#4	#4
Main FWD	NM	NM	na	na	0.148	0.124&	0.152&	0.144
Main AFT	na	na	0.171	0.173	0.149	0.144	na	na

- NM not measured
- * Fracture location on forward piece.
- & Damaged
- na Not applicable

As indicated by gray shading in the above tables, the majority of the dimensions were within tolerance and those that were out of tolerance were out by 0.001 inch or less.

¹⁰ QVI Spark MVP Computerized video based measurement system.

The as-received connecting rods and main bearings are displayed in the lower view of figure 1. The rods were ink stamped with part number SV40450-1 Rev C with rod bearing part number SL13212A F dated 09-14 FAA-PMA K-795. The main bearings were marked with part number SL16711A F, dated 01-15 FAA-PMA K-795.

The rods were generally in good condition. The #1 rod had heavy rub and heat bluing on the faces around the rod bearing. The corresponding cheeks on the crankshaft also showed rubbing damage and heat tinting. The #2 rod had light contact damage on one face and the other two rods did not have perceptible damage.

The received main bearings showed heavy rotational scoring and damage on the bearing surfaces. The bearings were also scored and rotationally damaged at the forward edges consistent with rearward movement of the crankshaft. The forward radius of the #3 and #4 showed matching damage. The rod bearings had light wear with some circumferential particle scoring.

Joe Epperson
Senior Metallurgist

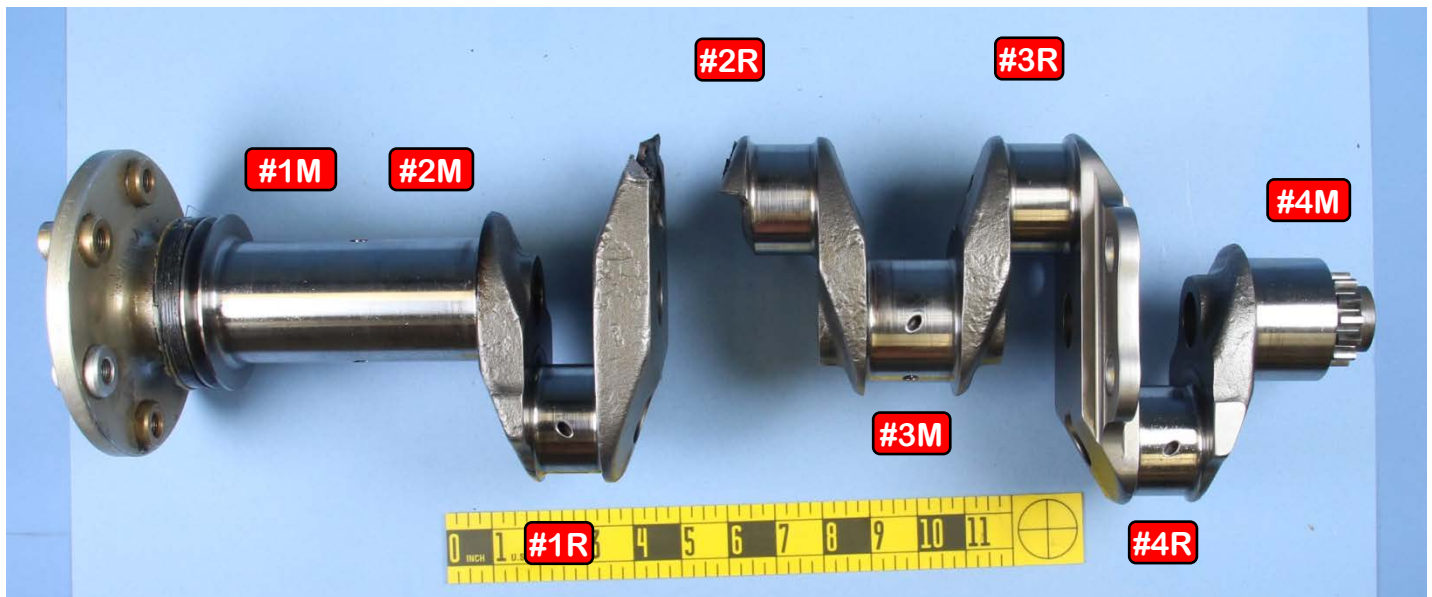


Figure 1. The as-received crankshaft at top and connecting rods and bearing below. Crankshaft fractured through the #2 cylinder rod journal. Journals and mains are labeled with position. Aircraft forward at left.

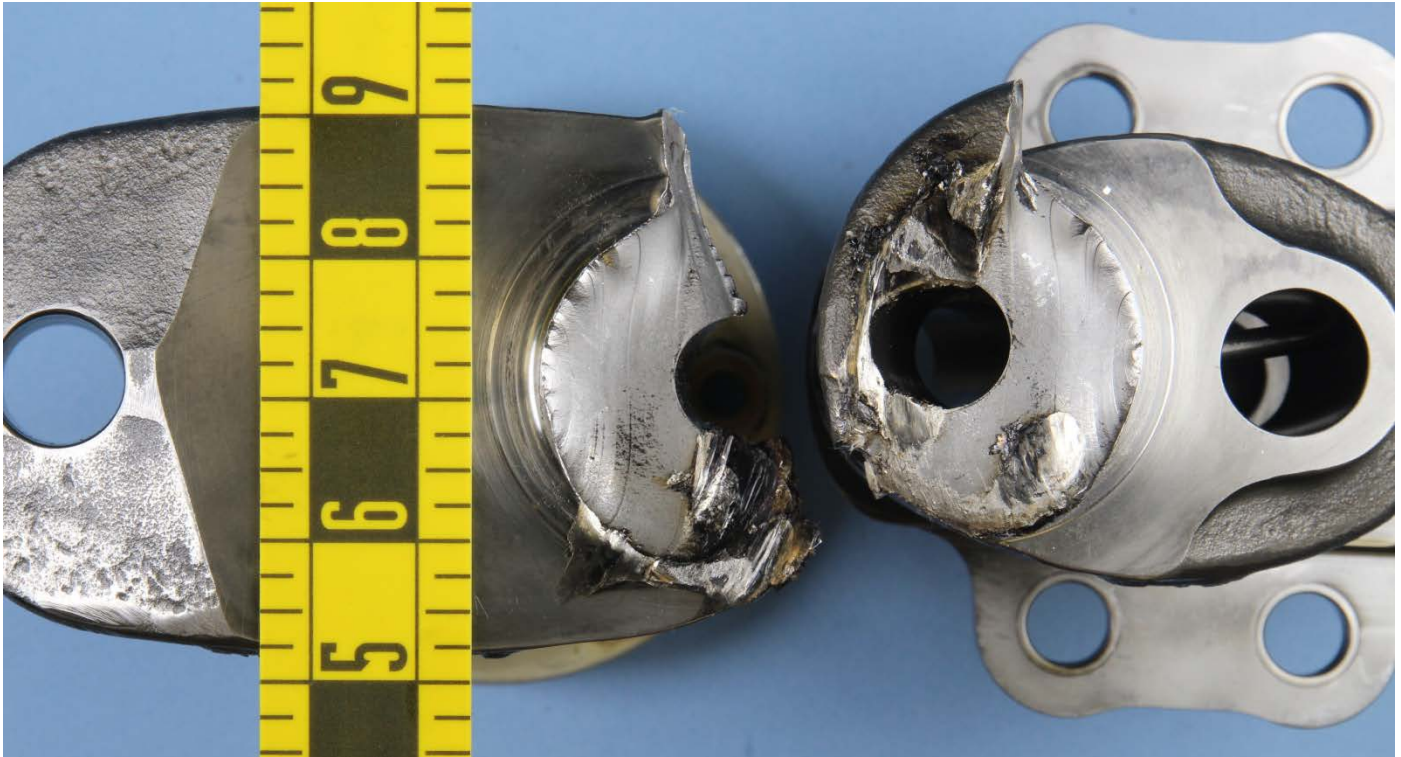


Figure 2. The fracture faces of the #2 rod journal showing fatigue features emanating from the area of the forward radius. Aft fracture face shown at left.

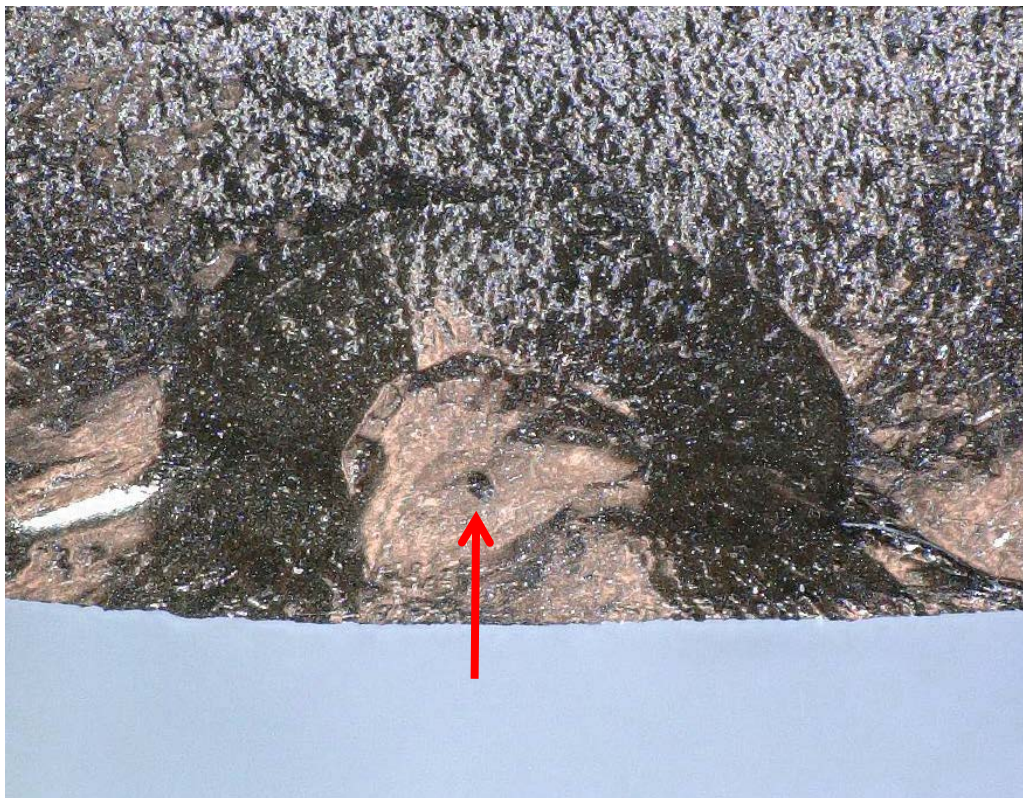
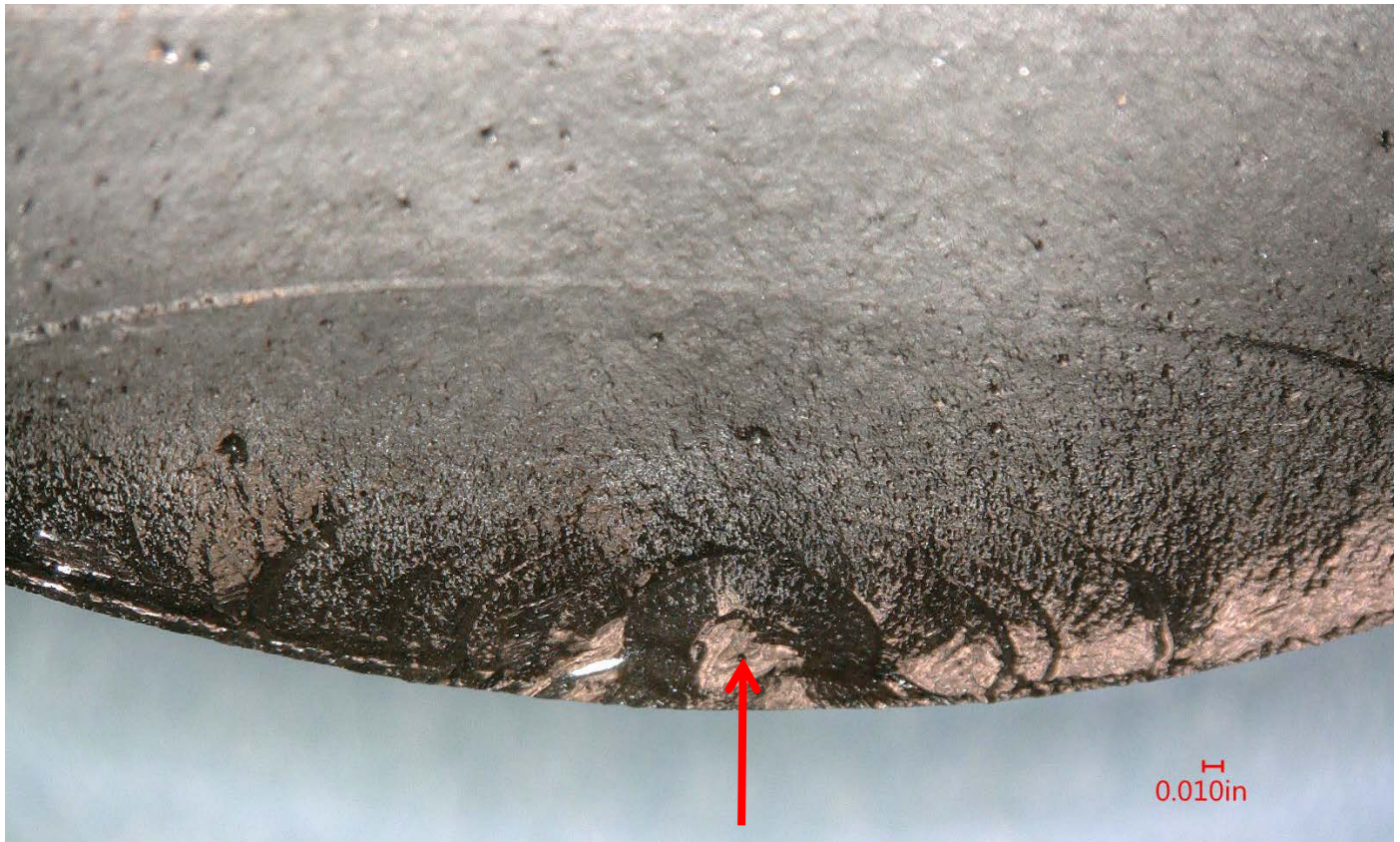


Figure 3. Optical views of the subsurface fatigue initiation (red arrow) and the beach marks expanding away from it.

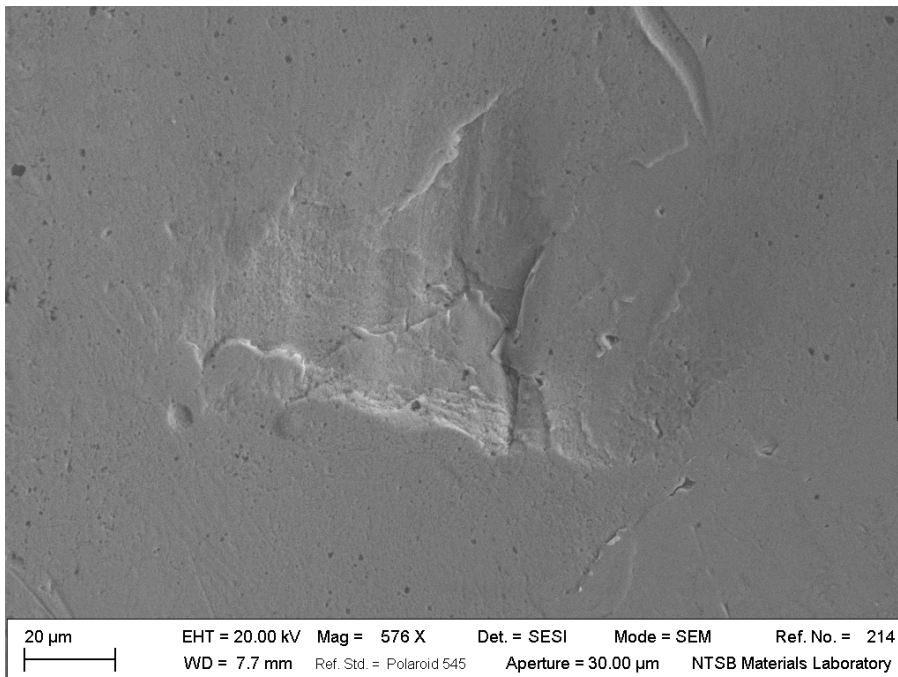
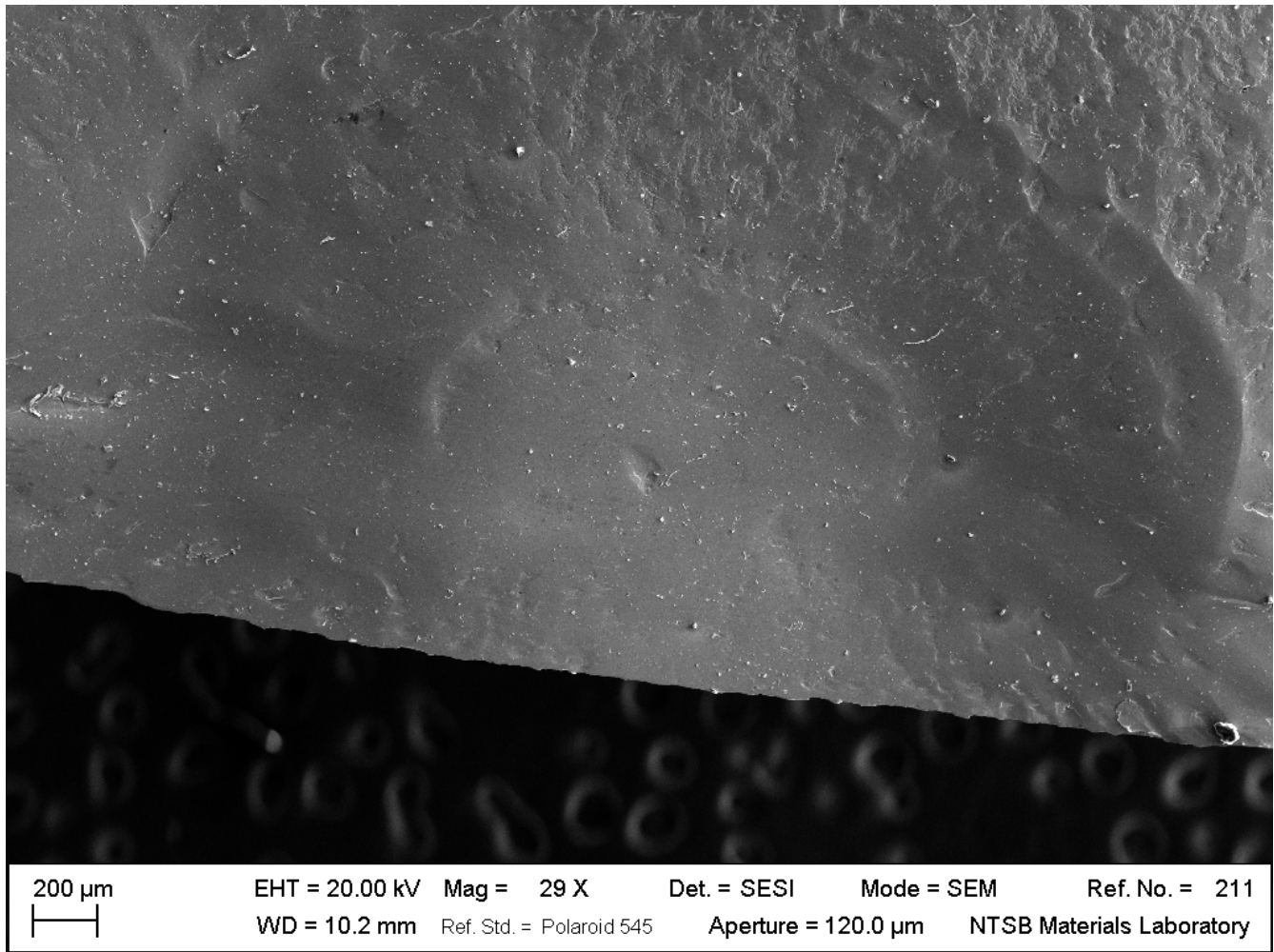


Figure 4. SEM views of the fatigue origin area at top showing the depression and extensive damage to the fine fracture details. Closer view of the depression at left.

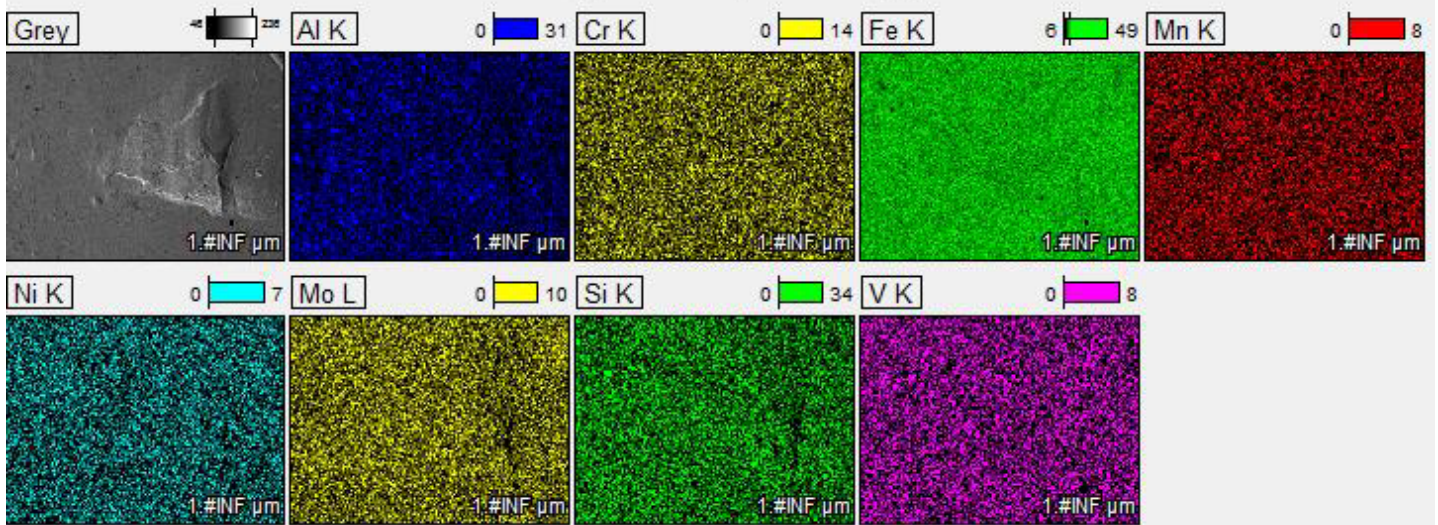
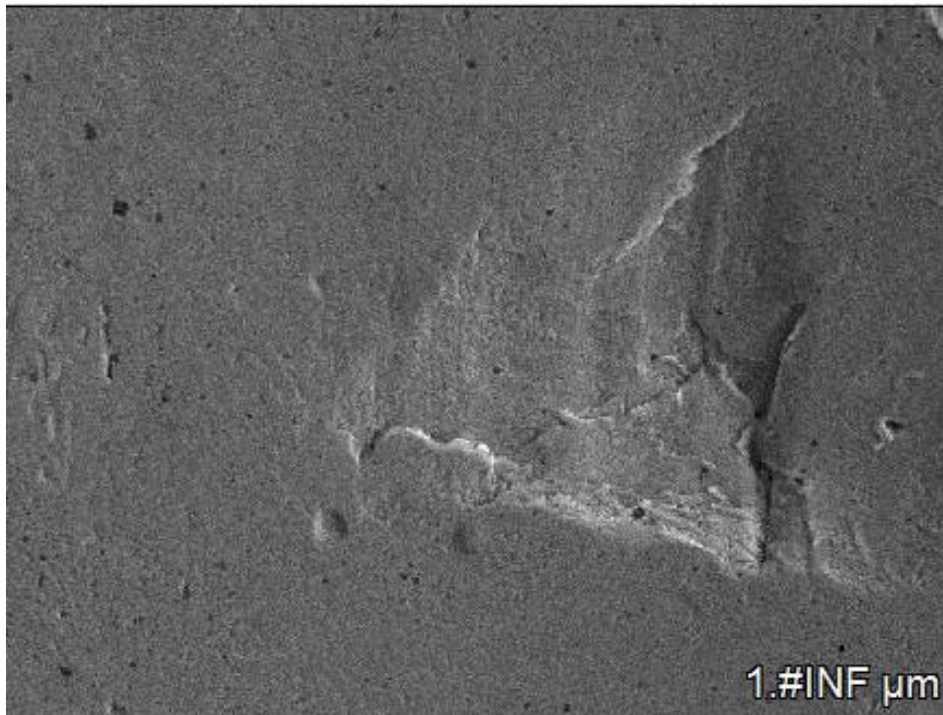
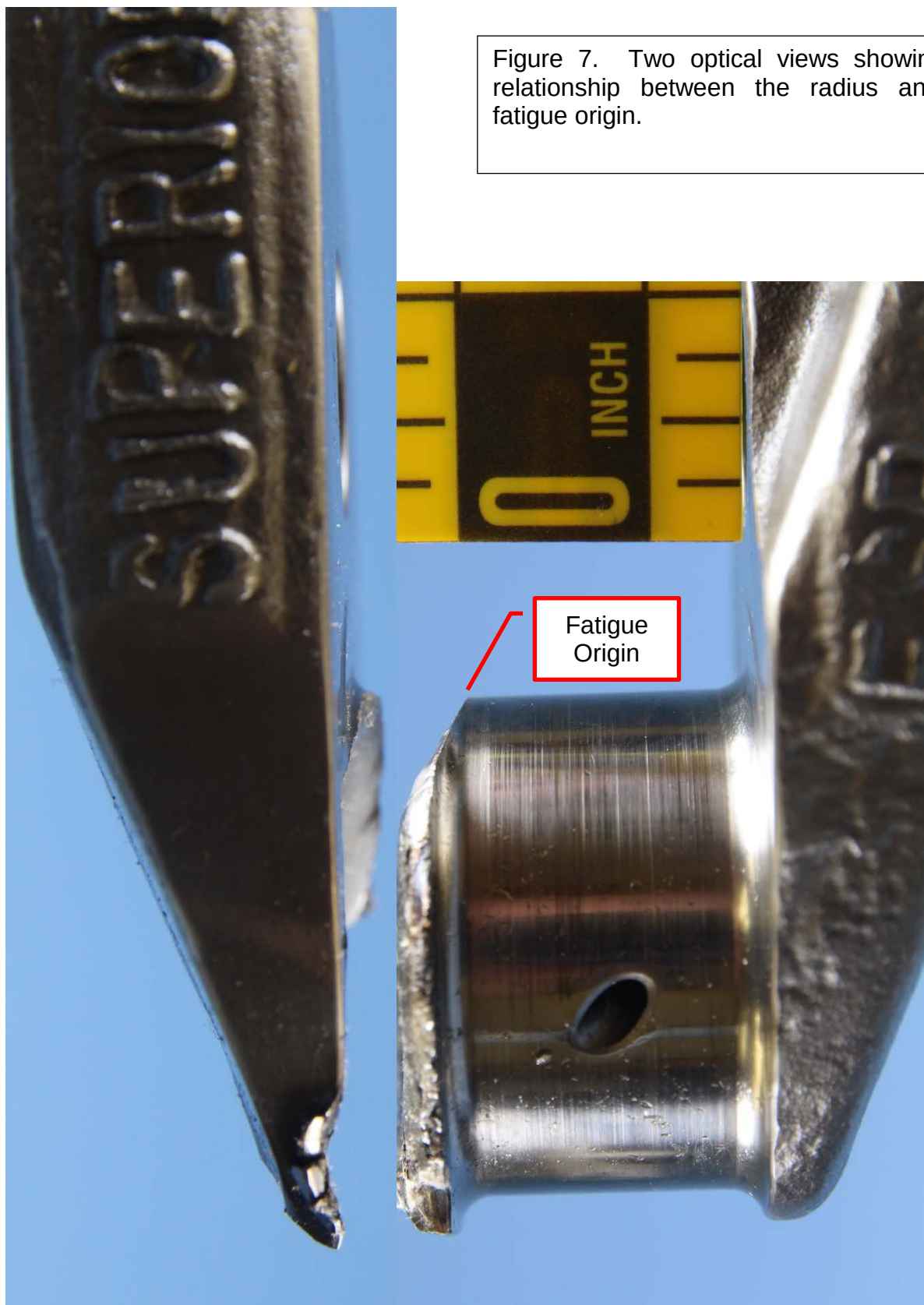
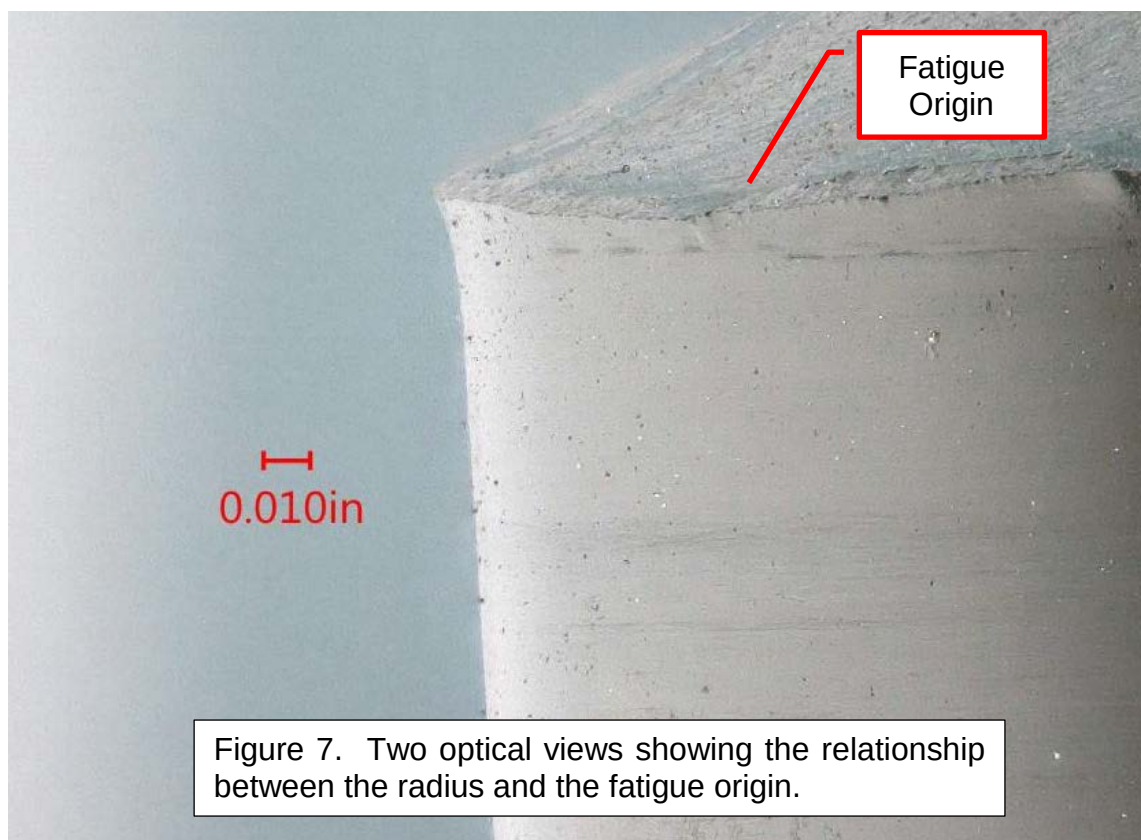


Figure 5. Energy dispersive x-ray maps of the depression and surrounding area showing no significant segregations of elements, aluminum, chromium, iron, manganese, nickel, molybdenum, silicon and vanadium.





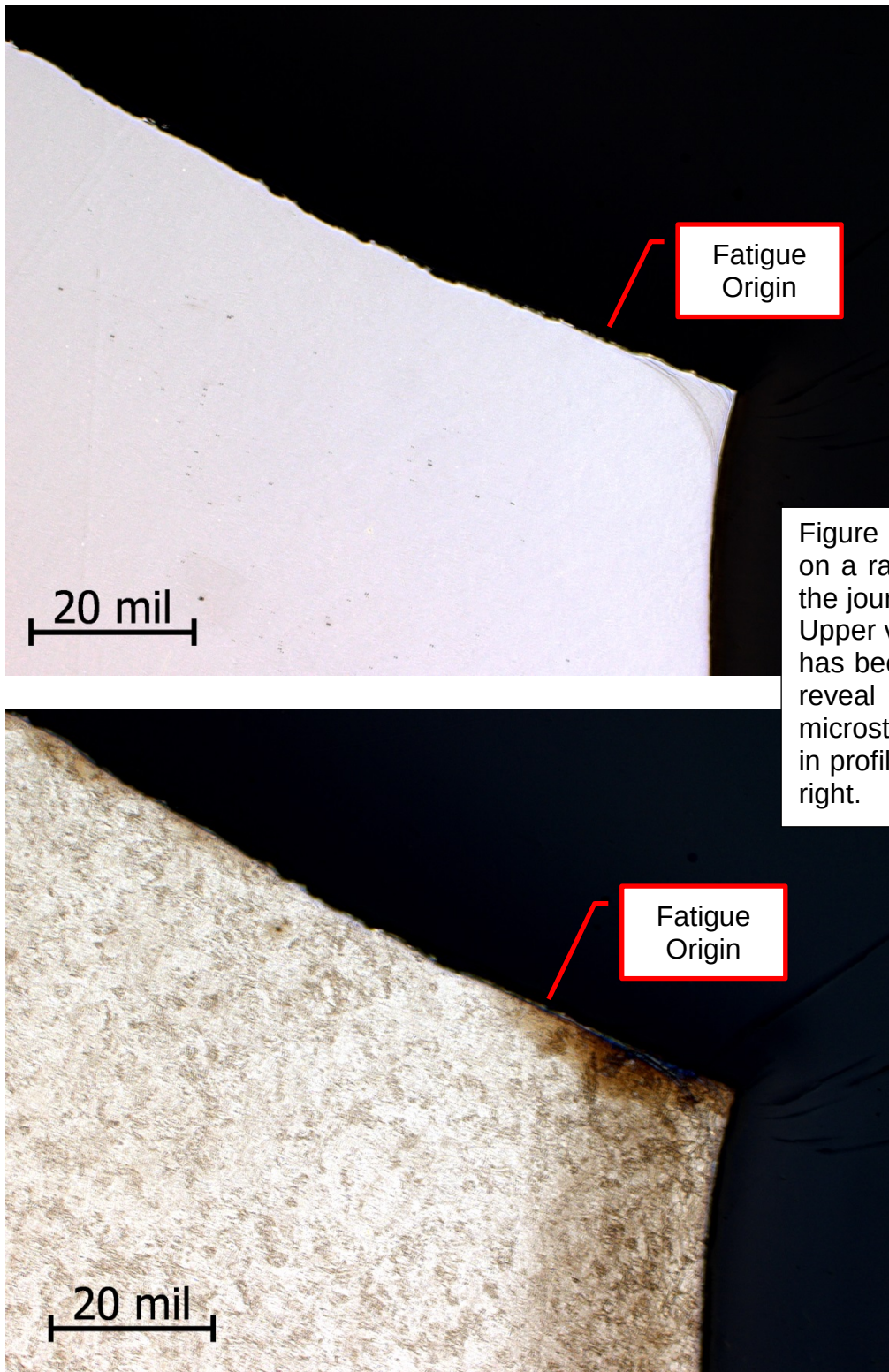


Figure 8. Metallographic images on a radial cross section through the journal near the fatigue origin. Upper view unetched. Lower view has been etched with 2% Nital to reveal the nitride case and core microstructures. Fracture surface in profile at top, journal surface at right.

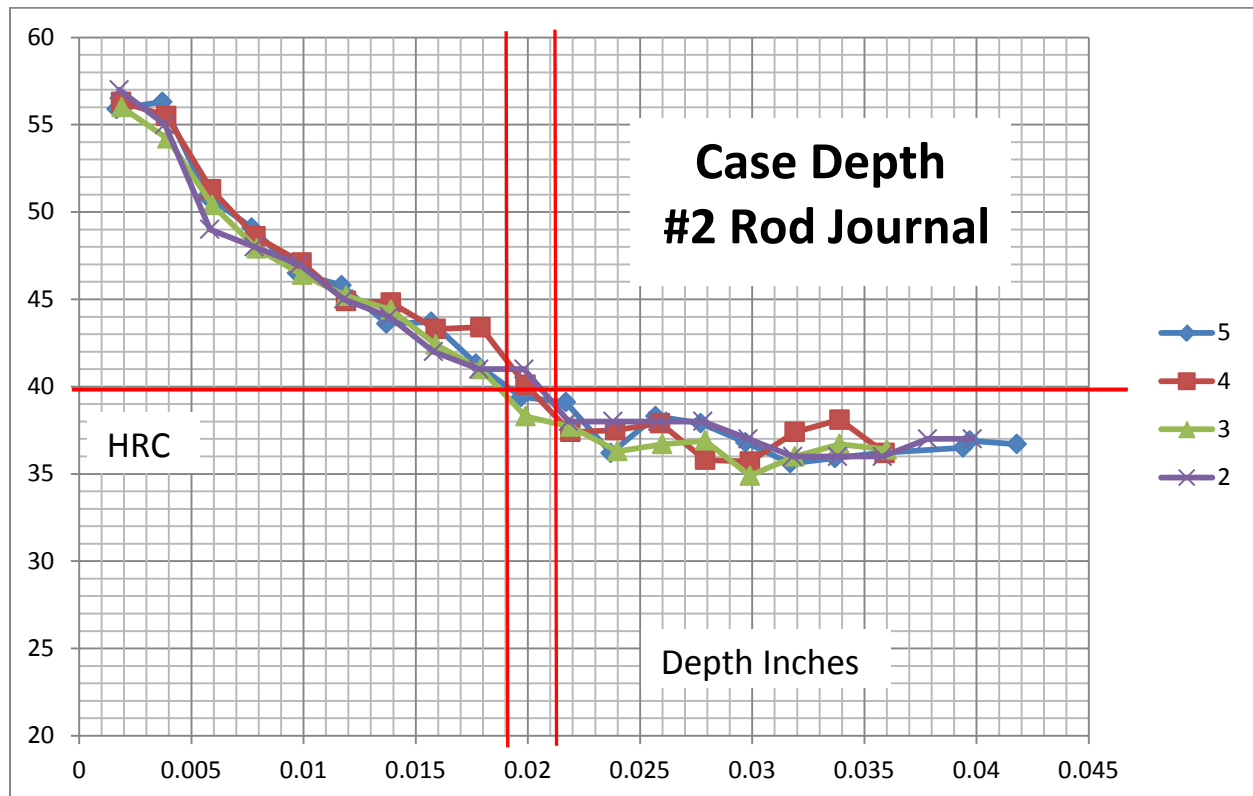


Figure 9. A graph showing four plots of microhardness versus depth below the journal surface. Case depth (vertical red lines) is defined as where the hardness drops to HRC 40 red horizontal line.