

NATIONAL TRANSPORTATION SAFETY BOARD

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



February 14, 2017

MATERIALS LABORATORY FACTUAL REPORT

Report No. 17-019

A. ACCIDENT INFORMATION

Place : Santa Paula, California
Date : May 28, 2016
Vehicle : Moore VariEze, N80681
NTSB No. : WPR16FA118
Investigator : Tealeye Cornejo, ASI-WPR

B. COMPONENTS EXAMINED

Crankshaft with Camshaft Drive Gear Cluster and Main Bearings
Camshaft with Gear

C. DETAILS OF THE EXAMINATION

The as-received components are displayed in figure 1. The crankshaft was intact but discolored at several bearing locations. The crankshaft was steel stamped "N02EA902" on the flange perimeter along with timing marks. All three main bearings journals and cylinder 2 and 3 journals were darkened on the same side consistent with baked on oil from heating on one side of the nonrotating engine.

Nine consecutive gear teeth were fractured from the cam drive gear ring of the crankshaft gear cluster as shown in figure 2 (gear rotation clockwise). Large pieces of eight teeth were recovered from the oil sump along with some small pieces, as shown at the top of figure 2. Close examination positively identified the gear ring locations of 6 of the recovered gear pieces. Looking forward at the gear, the fractured teeth were numbered counterclockwise, as shown. The #1 tooth was also marked as one of the two location indexing teeth for the camshaft gear. Six teeth were fractured generally through base of the tooth and gear ring fractures liberated the remaining three teeth (4, 5 and 6).

Figure 3 displays a radial view of the fractured teeth with #1 and #9 identified. Magnified optical examination of the fractures after cleaning revealed fatigue progression beach marking on the fracture surfaces of teeth #1 #2 and #3. The remaining teeth fractures were overstress in nature.

As shown in figure 3, the fatigue progressed almost entirely through the cross sections of teeth #1 and #2. The fatigue in tooth #3 was about 25% of the section. In all three fractures, the fatigue initiated at the sharp forward-pressure face corners of the teeth. Scanning electron microscope imaging confirmed the fatigue initiation location as shown in figure 5 for teeth #1 and #2. Initiation was near the base of each tooth, about 0.025 inch outboard of the root diameters.

Magnified inspections found that the forward faces of teeth #1, #2 and #3 had been non-uniformly ground as exemplified by the face of the #1 tooth shown in the upper view of figure 6. Further inspections found similar grinding marks on most of the remaining gear teeth in the gear ring.

A transverse metallographic section was cut through four intact gear teeth opposite the fractured teeth. Etching the polished specimen with 2% Nital¹ revealed a microstructure typical of a carburized case on the gear tooth profiles. A typical area is shown in the upper view of figure 8 with indentations from a microhardness. Graphical results of the traverse is shown below. HRC 50 depth is about 0.032 inch with the depth at HRC 40 about 0.040 inch. Total case is over 0.050 inch.

A longitudinal cross section through a typical tooth with grinding on the forward face is displayed in figure 9. No significant microstructural changes were noted with the areas of grinding of the forward face (blue bracket) and inter-gear diameter (red bracket).

Joe Epperson
Senior Metallurgist

¹ 2% concentrated nitric acid and ethyl alcohol.

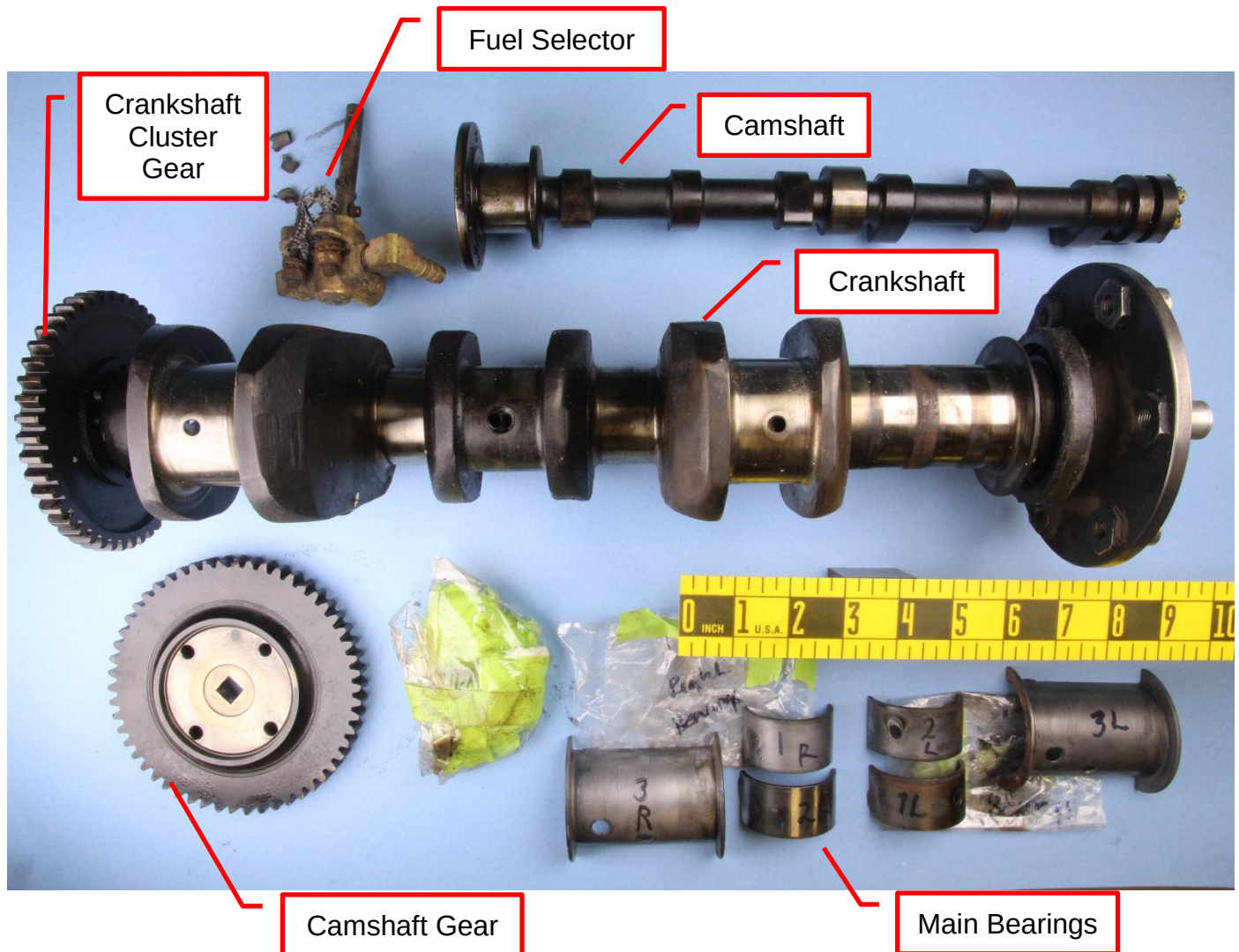


Figure 1. Overall view of the as-received components with label. The fuel selector valve was received with the engine components but not examined. Engine forward at right.

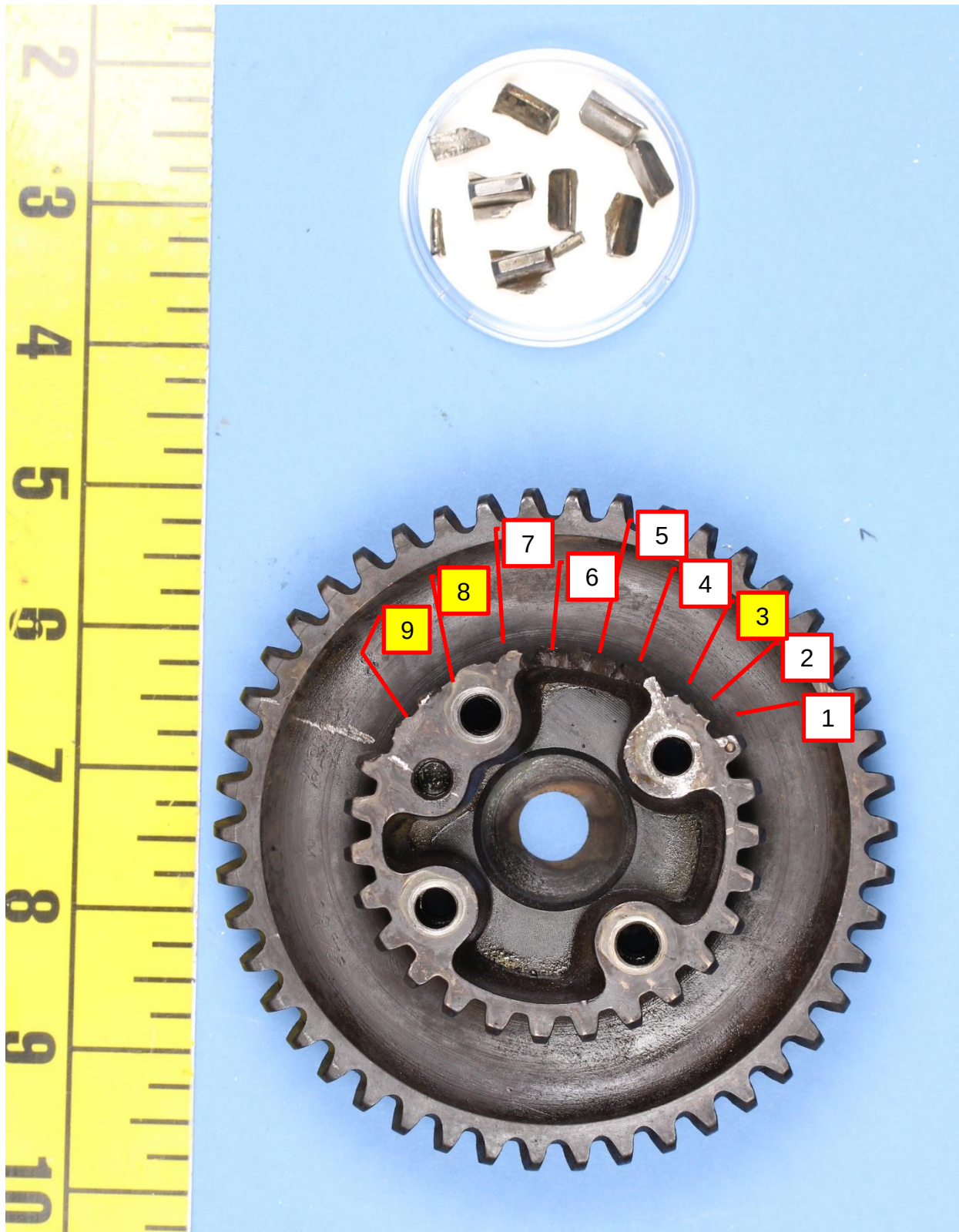


Figure 2. View looking forward at the cluster gear with recovered teeth at top. Fractured teeth on cam drive gear ring are numbered with yellow boxes indicating teeth not identified in the recovered ones. End of crankshaft still attached.

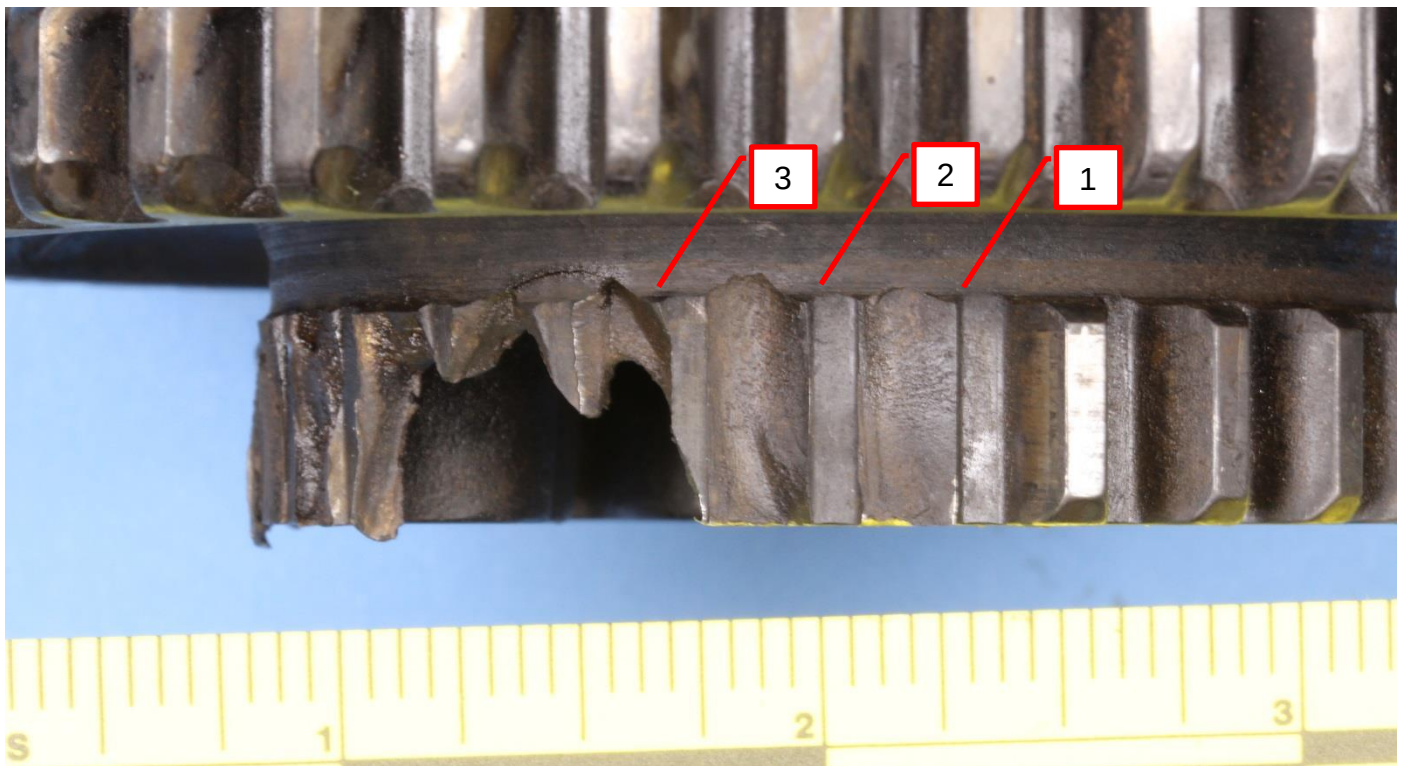
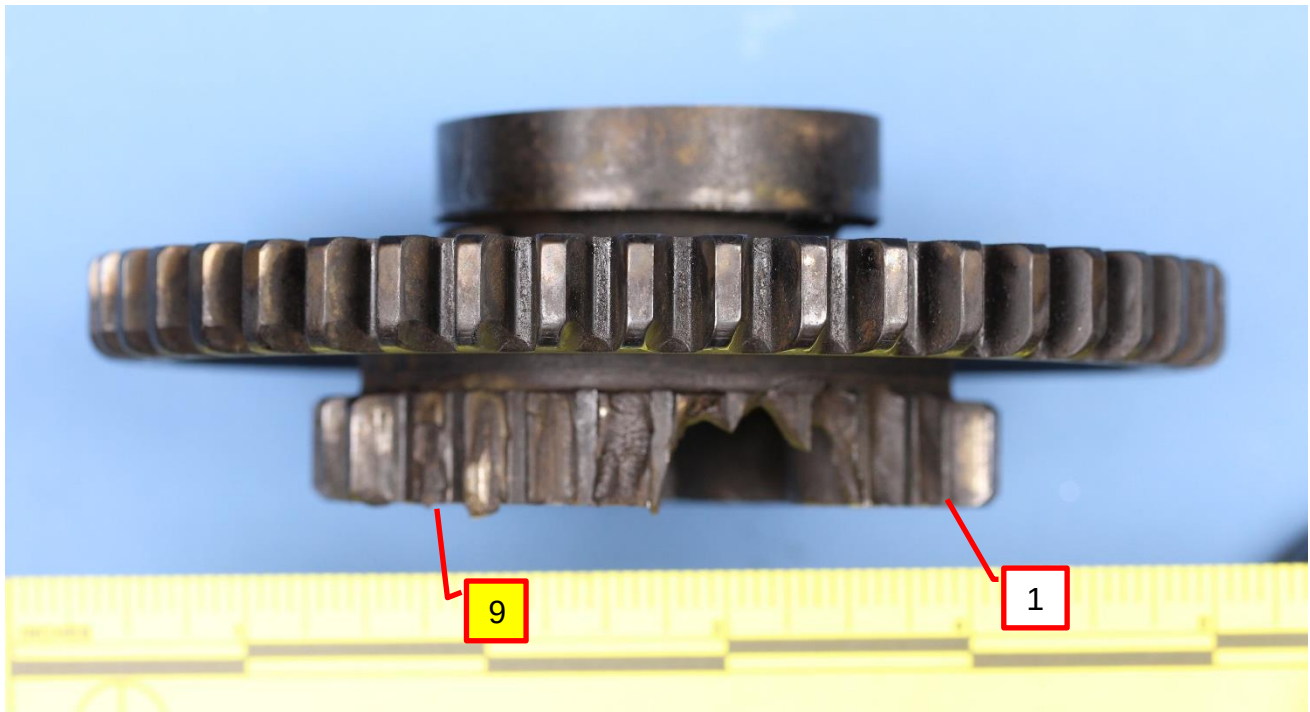


Figure 3. Radial view of the cluster gear looking at the area of fractured teeth on the cam drive gear ring. Lower view shows a closer view of the fatigue fractured #1, #2 and #3 teeth with lines pointing to origin locations.



Figure 4 Magnified views of the fracture faces on separated teeth #1 and #2 showing fatigue origins and beach marks. Progression was through almost entire cross section of each tooth.

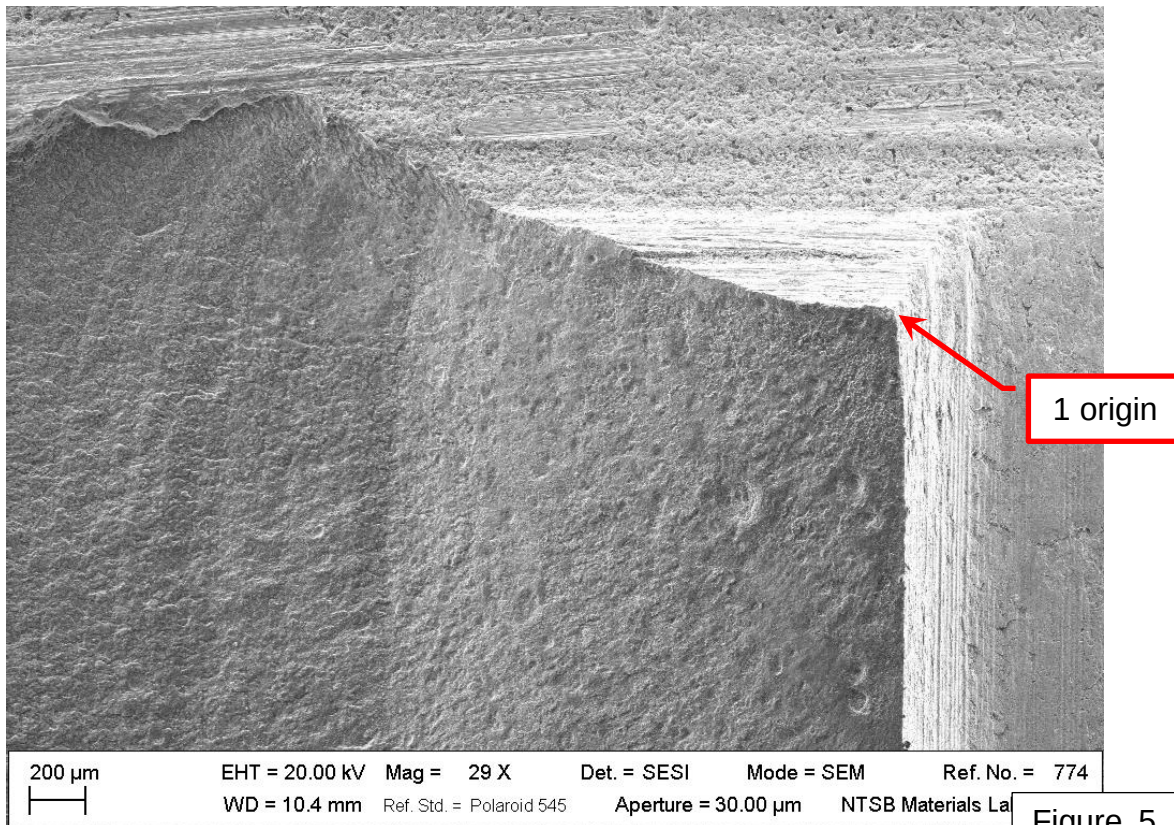
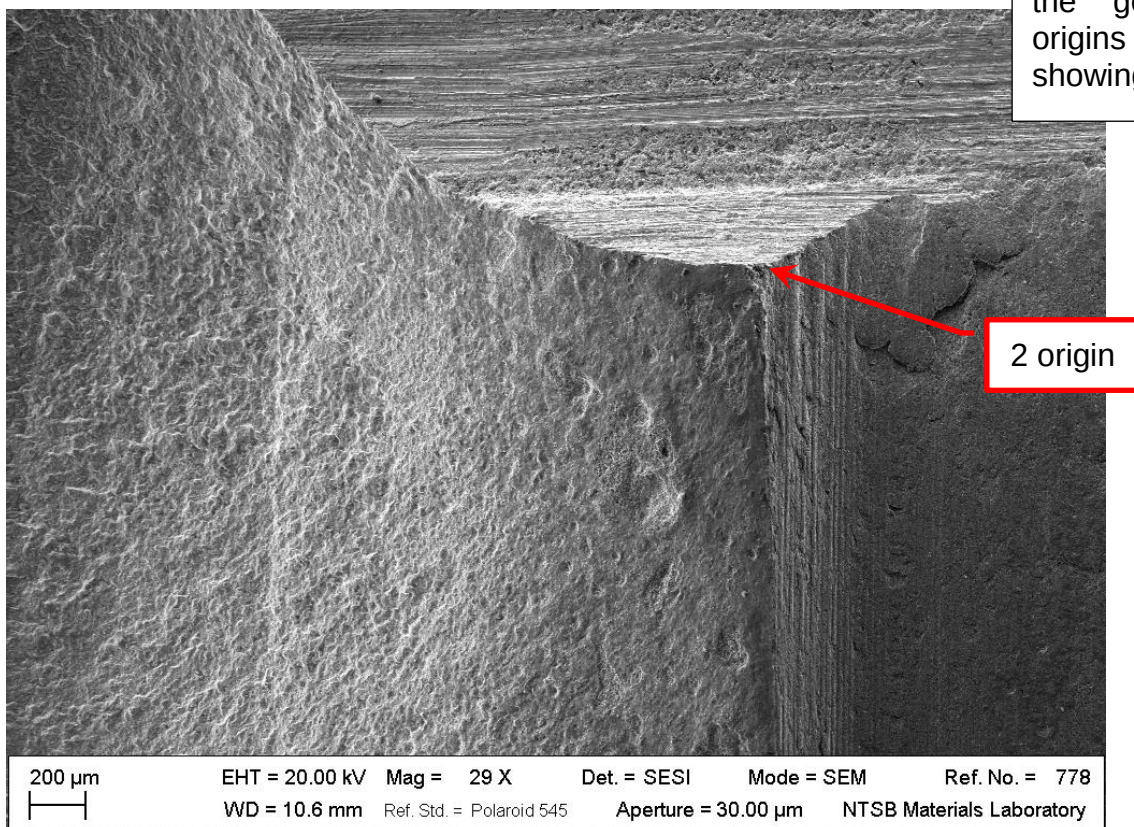


Figure 5. SEM views of the gear side fatigue origins on teeth #1 and #2 showing the sharp corners



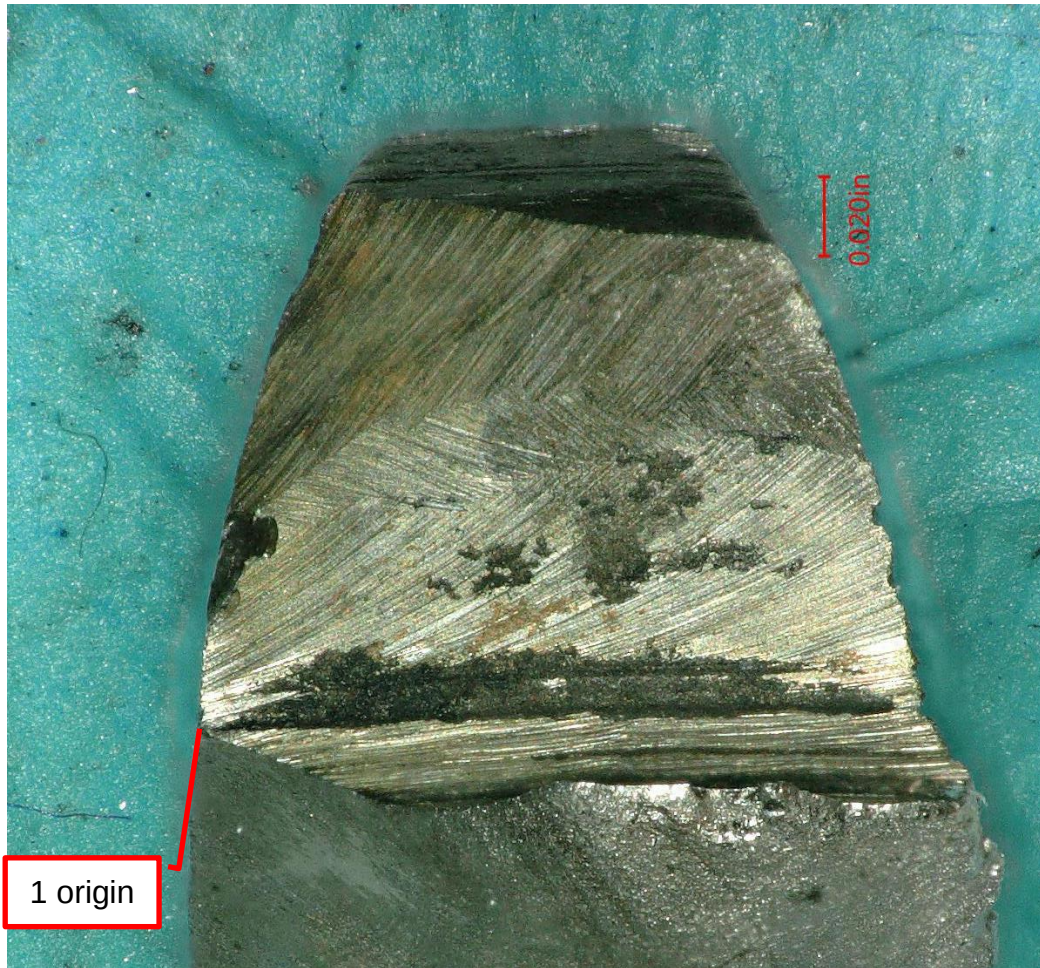


Figure 6. Optical views showing typical grinding on forward faces of teeth. Separated #1 tooth at top and a typical intact tooth below.



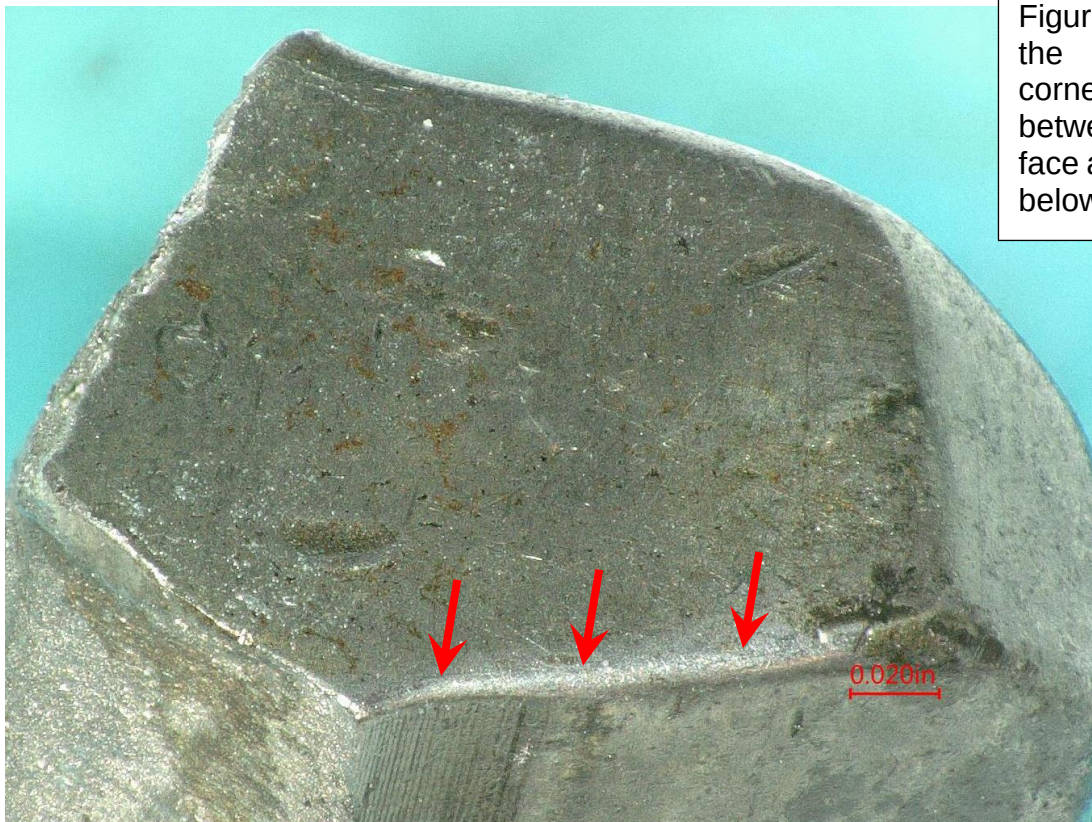
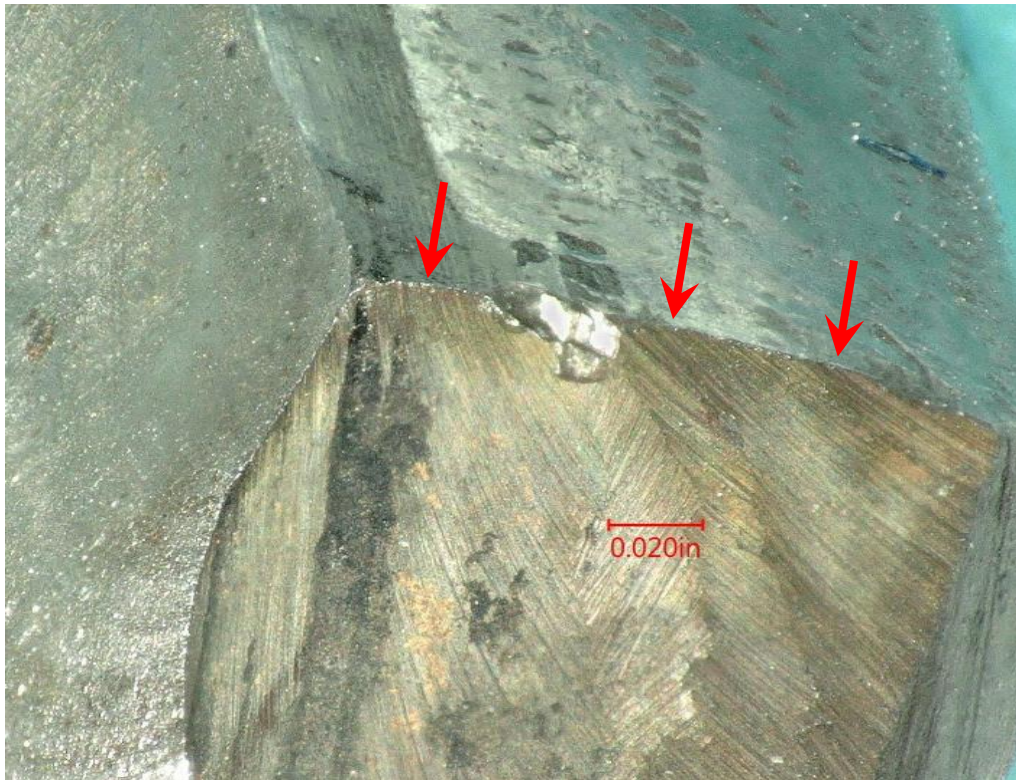


Figure 7. Views illustrating the differences in the corner shapes (arrows) between the forward tooth face at top and the aft faces below.

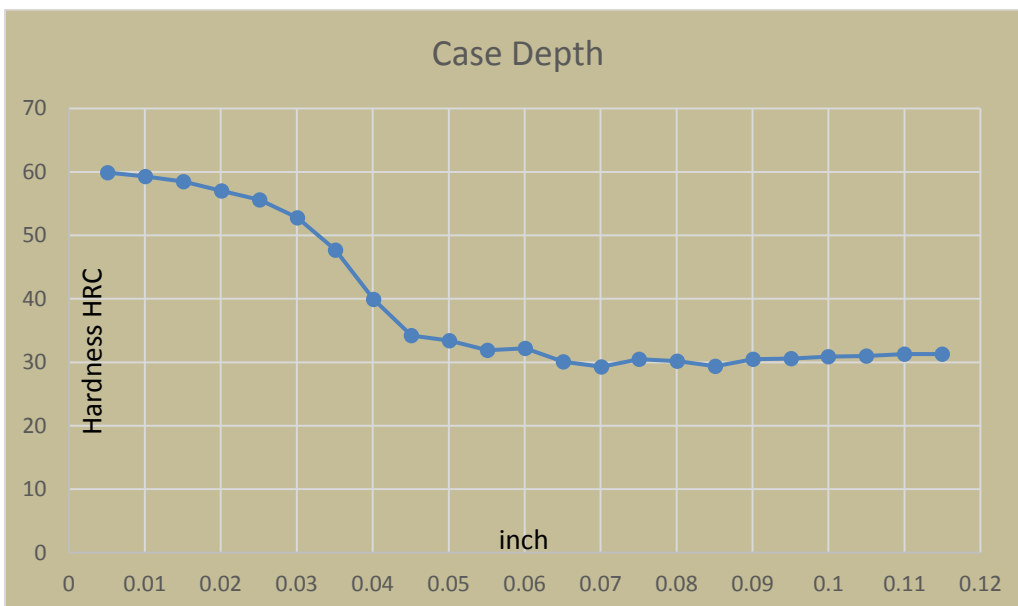
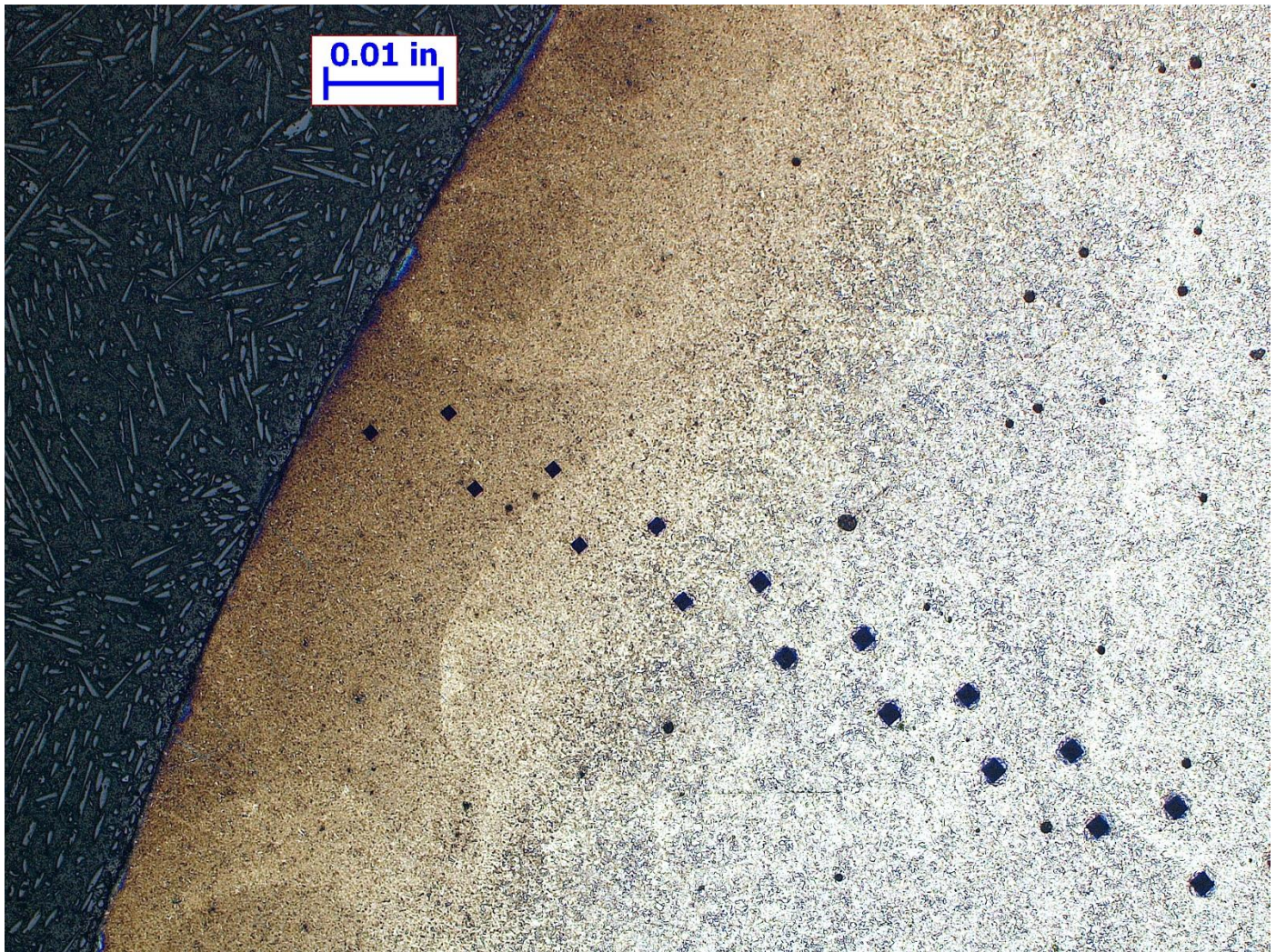


Figure 8. Optical micrograph, above, of a transverse section of tooth showing the carburized case and core microstructures. 2% Nital. Graph at left shows hardness profile through the case.

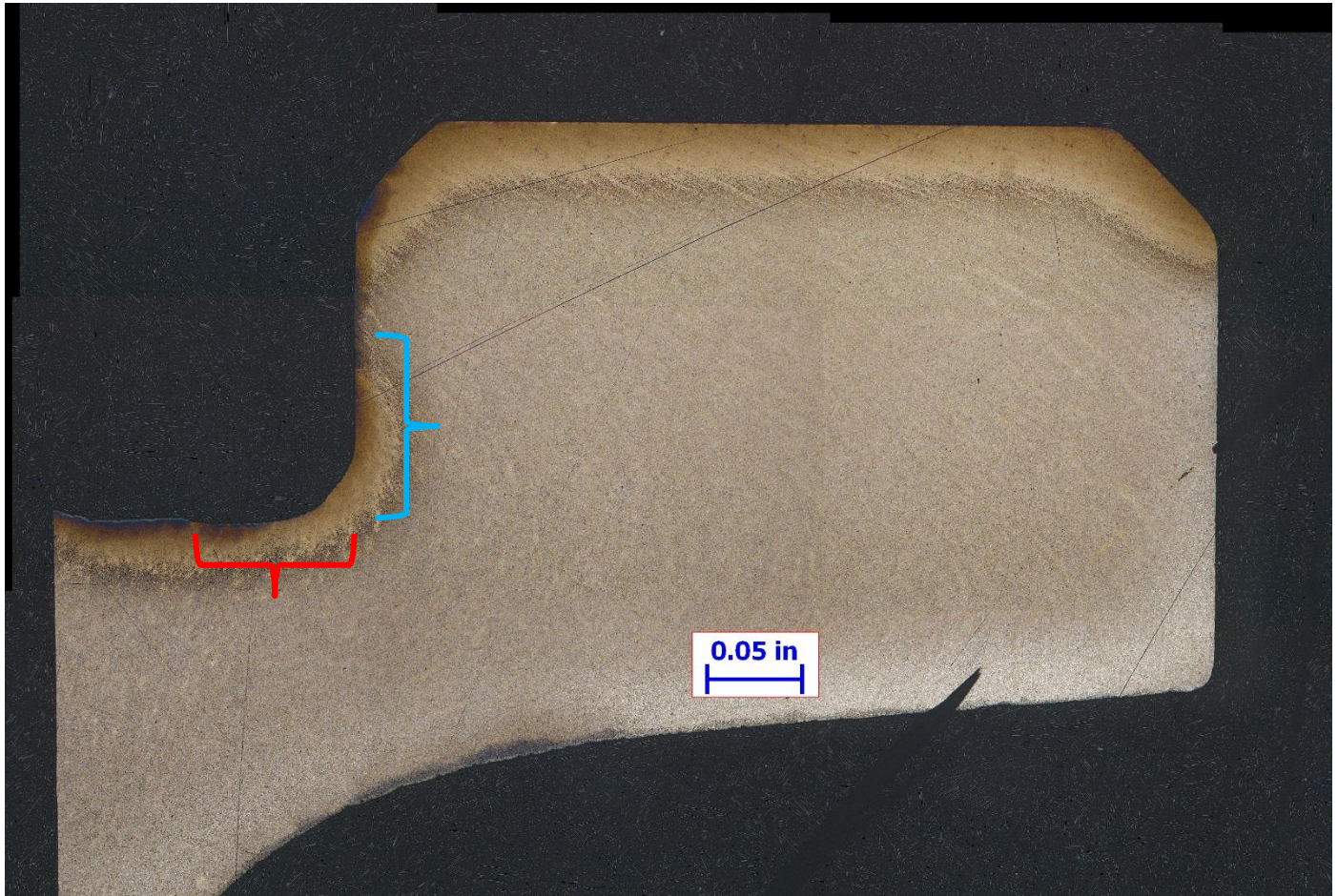


Figure 9. Longitudinal microsection through a typical tooth showing grinding on the forward face (blue bracket) and the connecting diameter (red bracket).