

NATIONAL TRANSPORTATION SAFETY BOARD

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



August 20, 2018

MATERIALS LABORATORY FACTUAL REPORT

Report No. 18-066

1. ACCIDENT INFORMATION

Place : West Creek, New Jersey
Date : May 15, 2017
Vehicle : Stinson 108-2, N9366K
NTSB No. : ERA17LA182
Investigator : Heidi Kemner, AS-ERA

2. COMPONENTS EXAMINED

Remnant of an exhaust valve assembly

3. DETAILS OF THE EXAMINATION

On May 16, 2017, about 2030 eastern standard time, a Stinson 108-2 was substantially damaged during a forced landing near West Creek, NJ. The private pilot received minor injuries. According to the pilot, the engine began to "shake," and when he turned the airplane, the engine lost power. Smoke filled the cockpit and the pilot noticed an "orange glow" under the floor boards near the firewall. The pilot initiated an emergency descent, during which the airplane struck trees and terrain. Examination of the wreckage by a Federal Aviation Administration (FAA) inspector revealed a breach in the top section of the engine crankcase. One of the components from the Franklin 6A4-165 engine were recovered and sent to the NTSB Materials Laboratory for additional examination.¹

Figure 1 shows a remnant of an exhaust valve from the engine, as received. Figure 2 shows the fractured exhaust valve assembly from the side with the fracture surface and from the retainer side, as received. In the as-received condition, the retainer and retainer keepers were still in place on the end of the valve stem. Underneath the retainer was a cylindrical area of dark-colored viscous material (Figure 3). This material was consistent with residue or contamination that built up during service in the cylinder valve bore.

The valve stem had fractured 3.00 inches from the valve retainer keeper grooves. The fracture was oriented approximately 90° relative to the direction of the stem. The

¹ The Franklin 6A4-165 was a six-cylinder, horizontally-opposed reciprocating engine with 335 cubic inch (5.5 L) displacement with 165 hp (123 kW) at 2,800 rpm. Franklin Engine Company was headquartered in Syracuse, NY until 1975.

fracture surface is shown after sectioning in Figure 4. The fracture surface exhibited a general dull dark color, consistent with high temperature oxidation post-fracture. This oxidation obscured many of the underlying fracture features, although some areas that were relatively less damaged exhibited features that could be examined. There was no indication of local gross plastic deformation on the stem adjacent to the fracture surface. The stem thickness was measured in multiple places along the stem as 0.388 inches.

As annotated in Figure 4, the fracture surface exhibited features consistent with multiple fracture modes. The majority of the fracture surface exhibited features consistent with crack arrest marks having progressed from the outside of the valve stem inward. A thin strip of the fracture surface exhibiting rougher features was present between the areas exhibiting crack arrest marks (see Figure 5).

The fracture surface was successively cleaned using acetone and Alconox cleaner.² The fracture surface section was then examined using a scanning electron microscope (SEM). While the majority of the fracture surface exhibited a layer of oxidation that obscured fracture features, some portions were cleaned substantially to reveal the underlying features.

Figure 6 shows a typical area in where the outer oxide had been removed. The underlying surface exhibited fatigue striations, consistent with fatigue crack propagation. The nature of these striations was consistent with crack propagation inward from the outer surface. The features in the center strip on the fracture surface exhibited dimple rupture, consistent with tensile overstress, as typified in Figure 7. All of these fracture features were consistent with fracture of the exhaust valve stem by reverse bending fatigue crack propagation. When the fatigue cracks had propagated deep enough, the remaining middle cross section of the valve succumbed to tensile overstress.

Distinctive features on the edges of the fracture surface indicative of fatigue crack initiation sites could not be ascertained due to the extensive corrosion and damage around the periphery. Figure 8 illustrates a typical area of this damage. Smearing, consistent with post-fracture contact was present. In addition, portions of the outer surface of the stem near the fracture surface had spalled off (Figure 8b). Some of this edge material was examined in the SEM, as shown in Figure 9. The outer layer of the valve stem surface exhibited a faceted fracture surface, exhibiting a porous interior. These features were consistent with brittle fracture of an outer oxide layer.

Transverse and longitudinal cross sections of the valve stem were mounted, polished, and etched. Figure 10 shows a typical portion of the stem microstructure. The microstructure consisted of ferrite and tempered martensite, along with second phase stringers in the longitudinal direction, consistent with manganese sulfide (MnS). This microstructure was consistent with those typical of alloy steels. The composition was examined using energy dispersive x-ray spectroscopy (EDS). The composition was found to be consistent with an alloy steel.

² Alconox is a powdered cleaning detergent, containing primarily sodium bicarbonate and sodium alkylbenzene sulfonate, manufactured by Alconox, Inc., White Plains, NY.

The surface of the valve stem was examined in both longitudinal (Figure 11) and transverse (Figure 12) cross section. In all cases, the surface of the stem exhibited an 0.003 to 0.005 inch thick, undulating surface layer of non-metallic material. This surface oxide exhibited cracks that were oriented in random directions, including 90° to the valve stem longitudinal direction. When examined using EDS, the material was found to be consistent with iron oxide. In addition, high levels of lead (Pb) and bromine (Br) were present. These elements were consistent with constituents in combustion compounds derived from the tetraethyl lead additives added to avgas aviation fuel.

Erik M Mueller
Materials Research Engineer



Figure 1 – The remnant of the exhaust valve, still affixed to the retainer, as received.

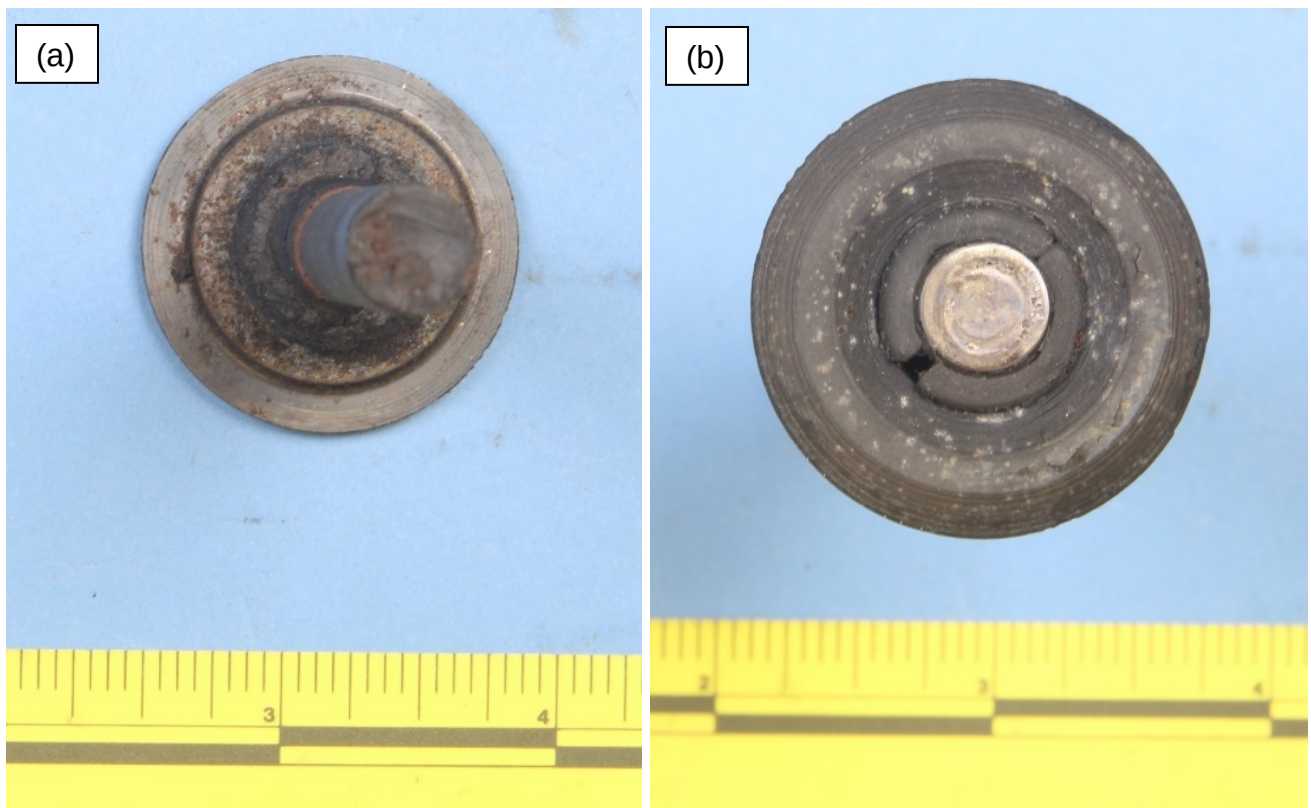


Figure 2 – The fractured valve assembly viewed from (a) the stem fracture surface and (b) the top rocker face with the retainer and keepers still attached, as received.



Figure 3 – The underside of the retainer on the exhaust valve, showing contamination buildup.

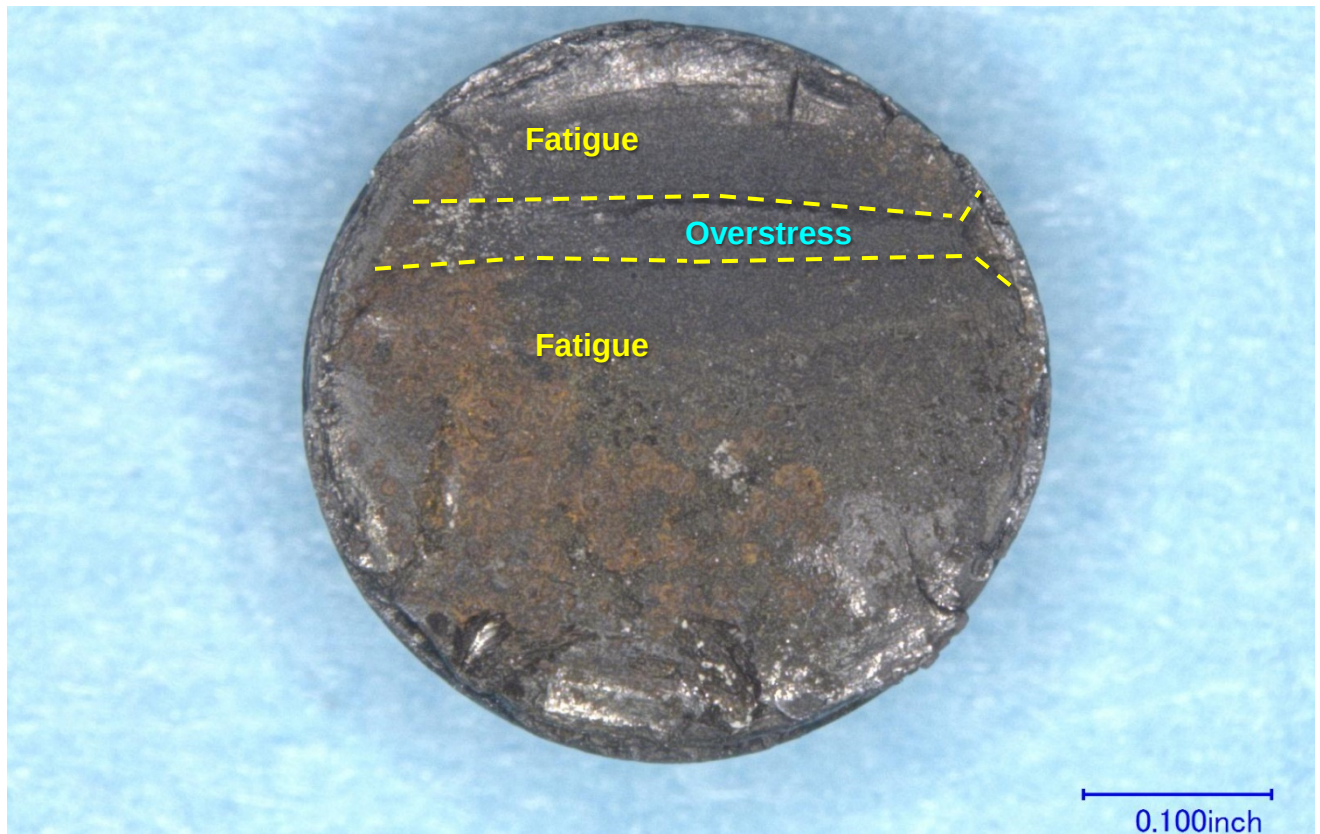


Figure 4 – View of the stem fracture surface after sectioning.

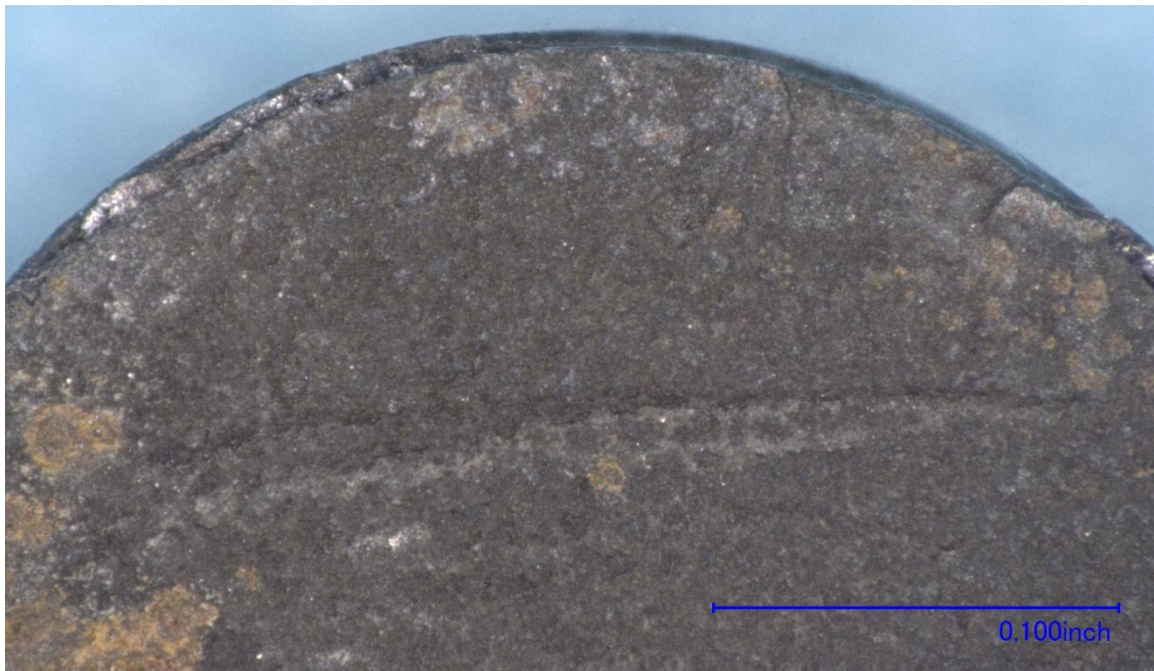


Figure 5 – Closer view of the portion of the fracture surface opposite Figure 5a, showing the middle ridge area on the fracture surface.

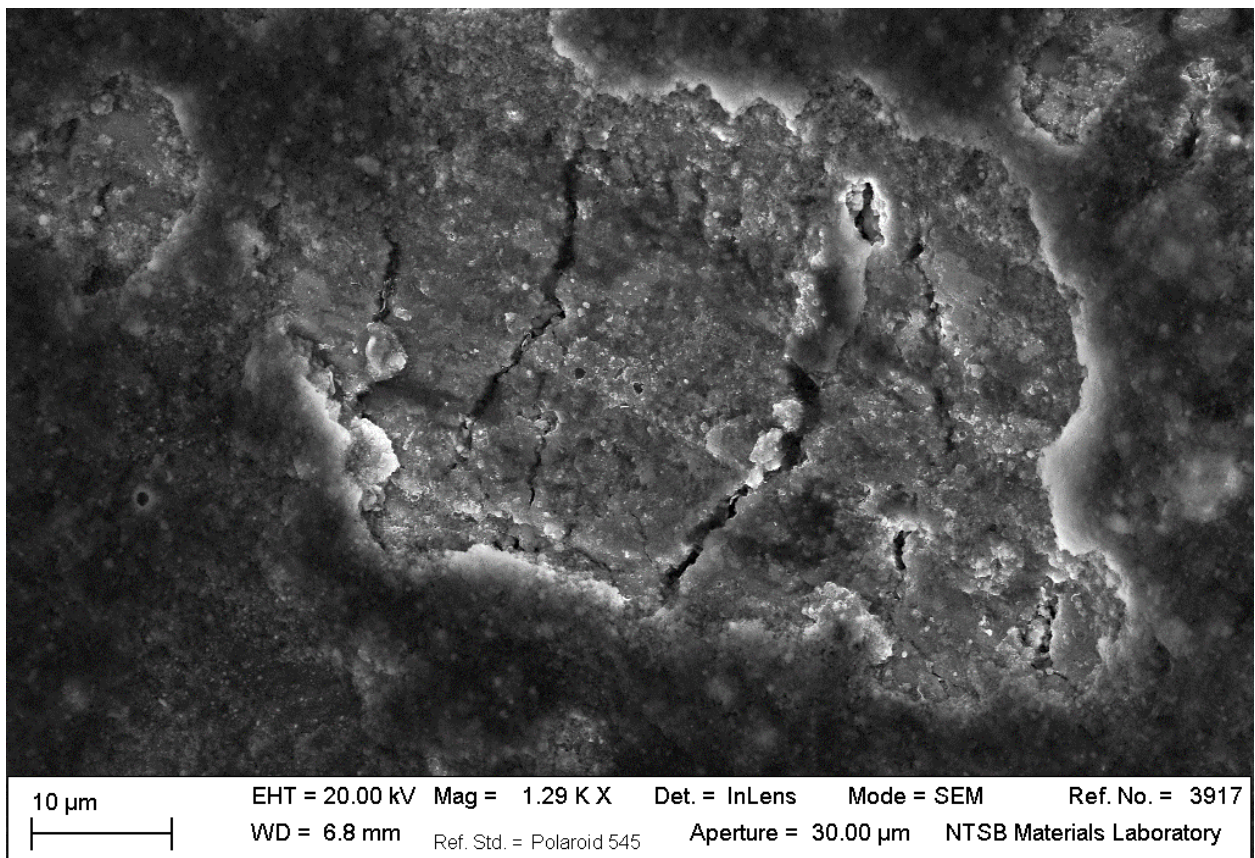


Figure 6 – Secondary electron (SE) micrograph of corroded fatigue striations where the outer oxide spalled.

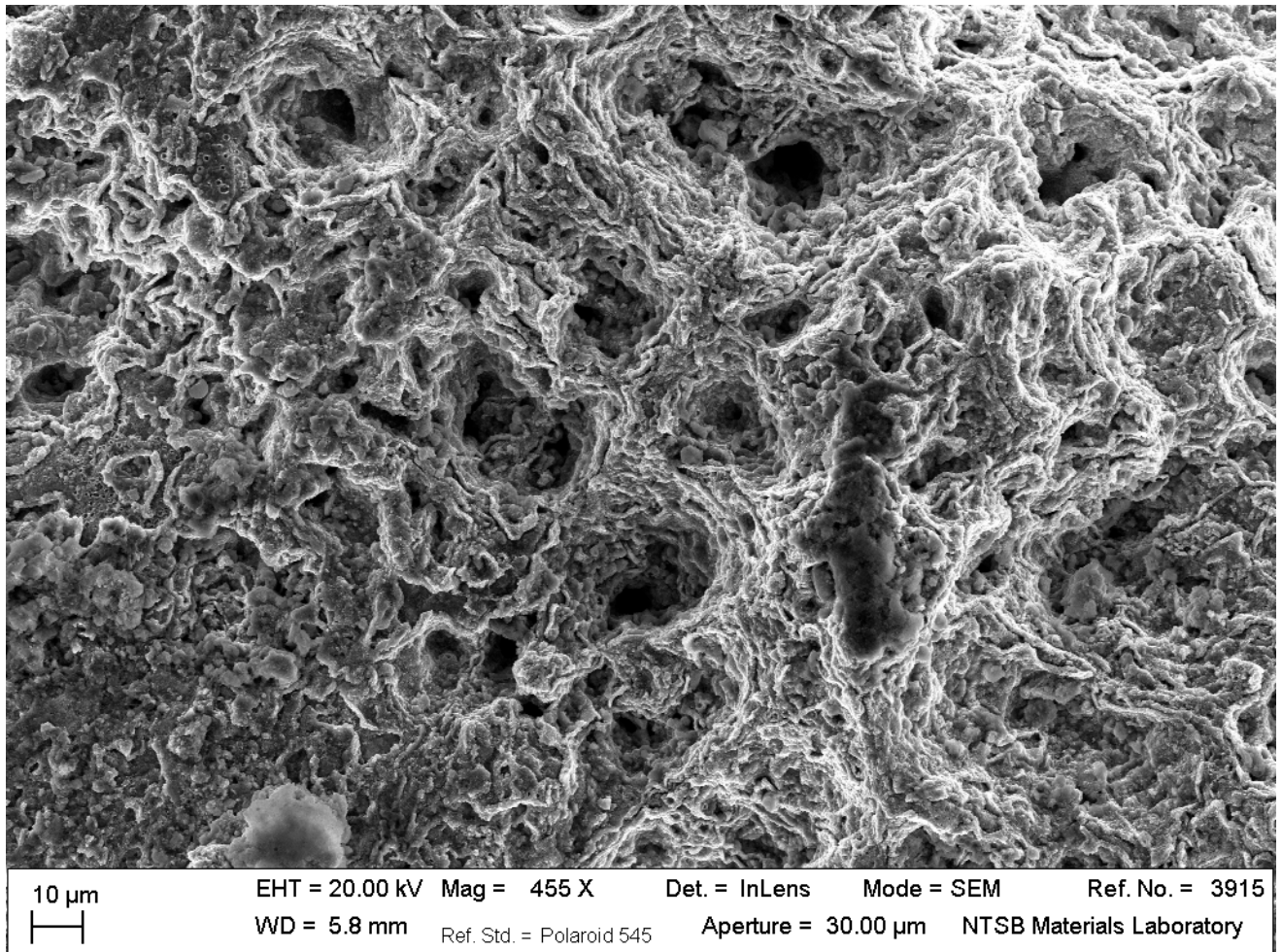


Figure 7 – SE micrograph showing oxidized dimple rupture features on the center strip portion of the fracture surface.



Figure 8 – The area consistent with the fatigue crack initiation site(s) viewed from (a) the fracture surface and (b) the side, showing outer material loss.

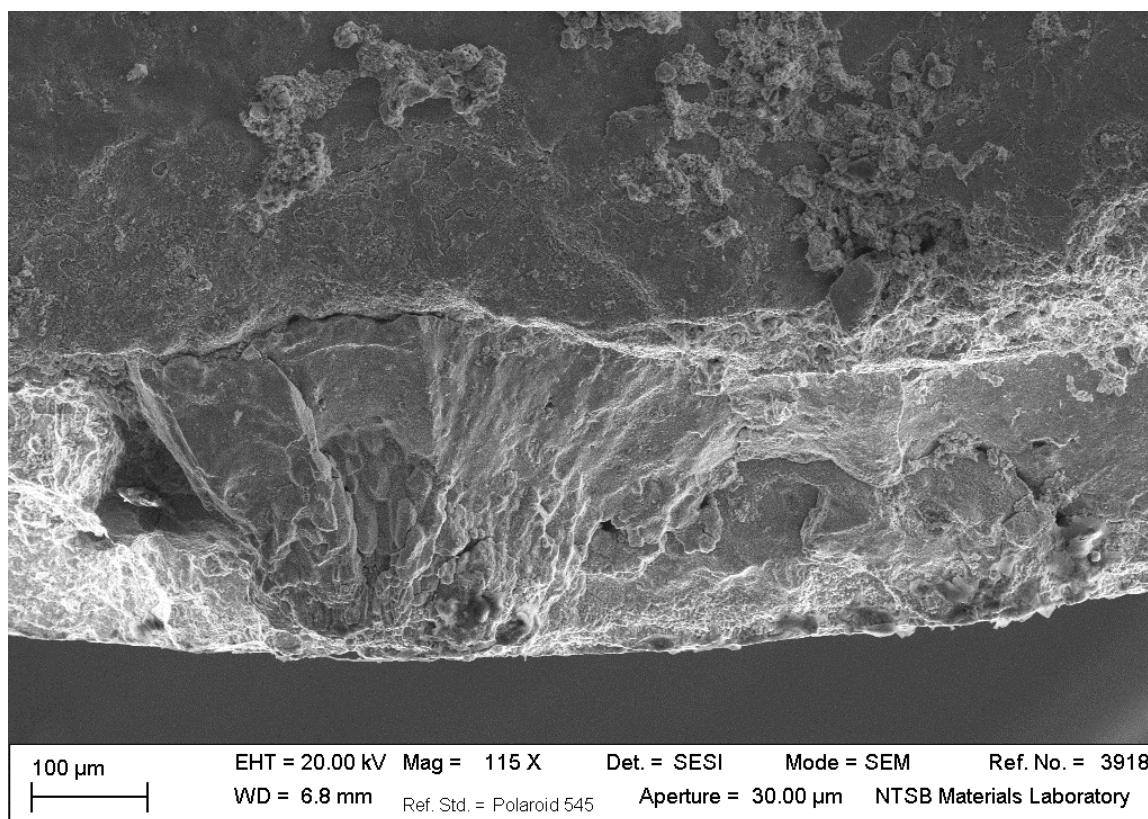


Figure 9 – SE micrograph showing the edge of the fracture surface, with fractured corrosion product.

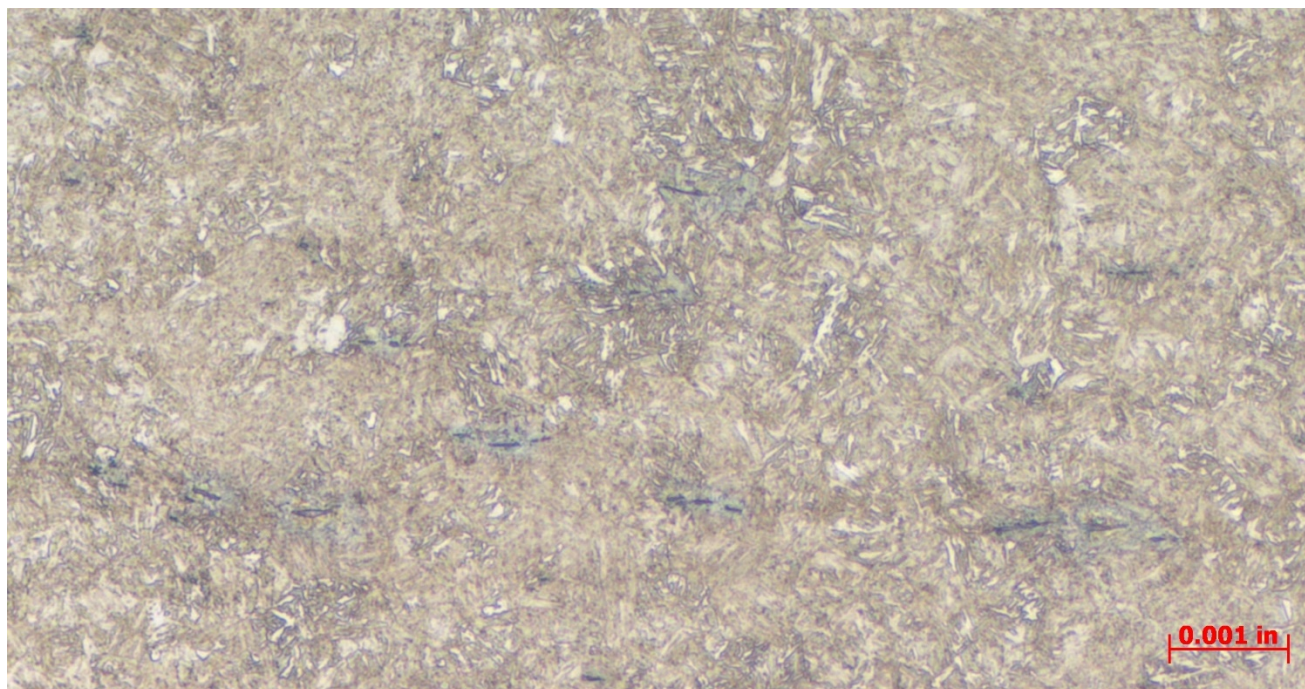


Figure 10 – Bright field (BF) optical micrograph showing a typical area of the valve stem microstructure (longitudinal cross-section), showing a tempered martensite microstructure with MnS stringers (~500X, etched 2% Nital).

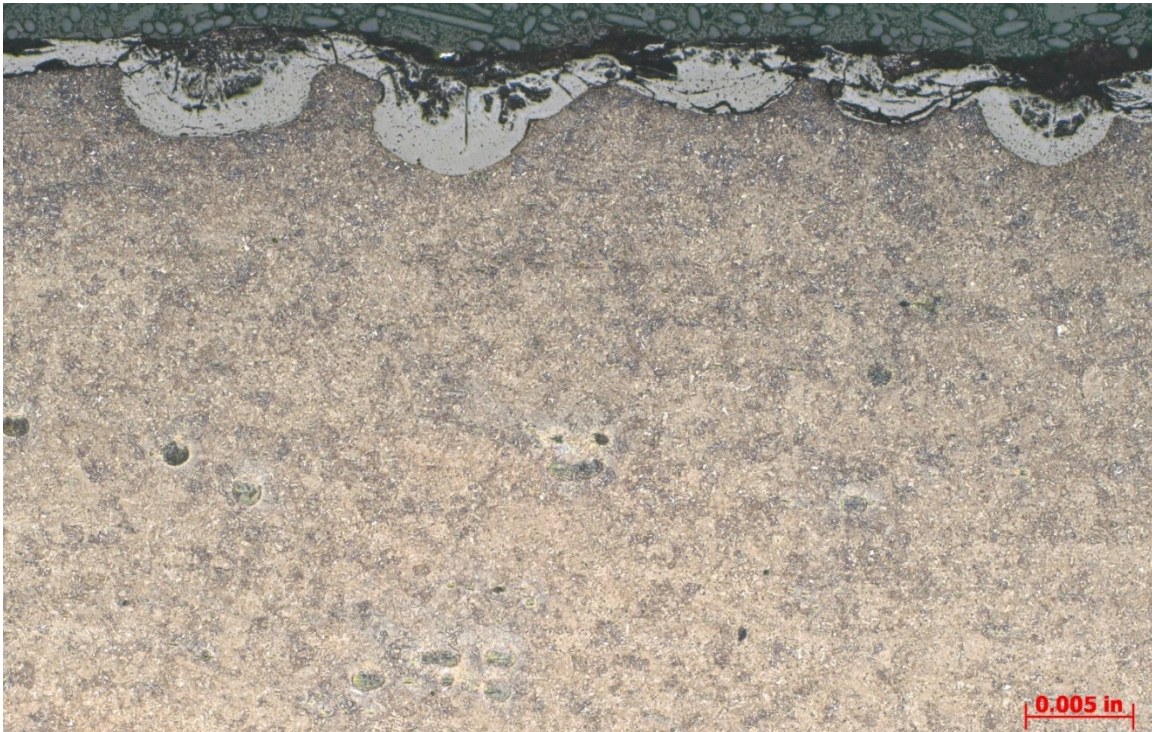


Figure 11 – BF micrograph of a longitudinal cross section of the valve stem surface, showing undulated corrosion product (~100X, 2% Nital).



Figure 12 – BF micrograph of a transverse cross section of the valve stem near the fracture surface, showing surface oxidation (~200X, 2% Nital).