

NATIONAL TRANSPORTATION SAFETY BOARD

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



July 7, 2021

MATERIALS LABORATORY FACTUAL REPORT

Report No. 21-043

1. ACCIDENT INFORMATION

Place : San Juan, Puerto Rico
Date : June 2, 2020
Vehicle : Piper PA-23-250, N14181
NTSB No. : ERA20LA202
Investigator : Timothy Monville, AS-ERA

2. COMPONENTS EXAMINED

Portion of a ball screw and spring type joint assembly
Portion of a left engine throttle lever with fractured ball screw

3. DETAILS OF THE EXAMINATION

On June 2, 2020, about 1333 Atlantic standard time, a Piper PA-23-250 was substantially damaged when it was involved in an accident during takeoff from Fernando Luis Ribas Dominicci Airport (TJIG) in San Juan, Puerto Rico. The airline transport pilot and one passenger were fatally injured while another passenger was seriously injured. During the last takeoff attempt, a security video that captured the final portion of the flight depicted the airplane rolling left past 90° of bank, pitching nose down, and impacting the water north of the airport. The airplane was recovered for examination of the airframe and engines.

Two pieces from the left engine throttle connection from the airplane were received by the NTSB Materials Laboratory, as illustrated in Figure 1. The positions shown in Figure 1 do not correspond with the support positions on the aircraft prior to sectioning. The throttle connection assembly consisted of remnants of the throttle lever attached to a fractured ball screw (Figure 2) and a spring type joint assembly ball.

As illustrated in Figure 3, the ball screw assembly and throttle lever were joined by a threaded ball screw. This piece had fractured along the neck parallel with the outer shell surface at the opening on the bottom of Figure 3. The threaded portion of the ball screw was still affixed to the throttle lever by a washer and nut. The spherical head of the ball screw was held in place by the internal pressure of a spring and an adjusting screw, locked in by a cotter pin.

Figure 4 shows a closer view of the side of the fractured neck of the ball screw remnant, viewed from the arm side. As shown in this figure, as well as other figures in this report of the remnants in the as-received condition, all the surfaces were covered with flaky, dark brown compounds, consistent with iron oxide. The surfaces also exhibited brittle white compounds and dull gray material. These compounds were found to be consistent with salt deposits from exposure to marine environments.

To be examined, these remnants, and particularly the fracture surfaces, were cleaned using acetone in an ultrasonic cleaner. Figure 5 shows the same fractured neck of the ball screw, after cleaning. The fracture surface is visible, with a general orientation perpendicular to the neck direction. The fracture surface and neck were angled toward the direction of the throttle lever. On the opposite side, three semicircular cracks or tears were visible, parallel to the fracture surface and facing away from the throttle lever. These features were consistent with localized deformation from bending, with the tension side having been characterized by parallel cracks (facing the reader in Figure 5), and the compression side exhibiting localized buckling.

Figure 6 shows a planar view of the fracture surface from the threaded side of the ball screw remnant, as received. This figure demonstrated the degree of salt deposits and corrosion products present on the fracture surface. After cleaning, the fracture surface appeared as shown in Figure 7. The fracture surface was generally rough in texture, with a dull, gray luster. The periphery of the fracture surface appeared more reflective than the interior, with a flatter appearance. This area is demarcated with a dashed yellow circle in the figure.

This fracture surface in Figure 7 was examined using a scanning electron microscope (SEM). A typical area of an edge of the fracture surface is shown in Figure 8. Even after cleaning, much of the surface remained contaminated with post-fracture deposits—these compounds were nonconductive, which manifested as noise in the SEM micrographs.

In backscattered contrast, these compounds generally exhibited a darker color, consistent with salts and iron oxides.¹ Figure 9 is annotated to show these compounds, identified using energy dispersive x-ray spectroscopy (EDS). The salts contained Mg, Ni, Cl, and Br, along with other trace elements. The bare fracture surface exhibited a composition consistent with mild or carbon steel. The surface exhibited a high Cd content, consistent with a cadmium coating.

Looking again at the edge of the fracture surface, one can discern a contrast in fracture features between the outer and inner regions. Figure 10 shows a closer view of these different features, annotated with a dashed yellow line to highlight the transition. Figure 11 shows a typical view of the interior features. While damaged from removal of

¹ Backscattered electrons: SEM micrographs produced using backscattered electrons display contrast that is associated with the atomic numbers of the elements in the micrograph. Materials containing elements with higher atomic numbers visually appear lighter relative to other materials containing elements with lower atomic numbers.

the surface oxides and salts shown in Figure 6, the surface still exhibited a morphology consistent with dimpled rupture. These features were consistent with ductile overstress fracture.

The outer regions exhibited features typified in Figures 12 and 13. These showed the faceted flat characteristics of crystalline grains, consistent with intergranular fracture. The intergranular fracture was only present on the outer regions of the fracture surface. As illustrated in Figure 10, this outer region was approximately 0.004 inches (100 μm) in depth.

Figures 14a and 15a show the faces of the ball joint assembly shell as received, and Figures 14b and 15b show the same faces after cleaning with acetone. The side of the shell assembly with the ball screw fracture surface facing the reader is illustrated in Figure 16, as received. Like the mating surface on the throttle lever, this fracture surface was completely covered in corrosion compounds and salt deposits (see Figure 17).

After cleaning with acetone, the cotter pin was removed, and the ball joint assembly was taken apart. Figure 18 shows the interior components of the ball joint assembly, which consisted of the spring, bottom seat, fractured remnants of the ball screw head, and the adjusting screw. Figure 19 shows a closer view of the side of the ball screw, after disassembly and cleaning. The fracture surface was oriented perpendicular to the neck direction, located approximately 0.05 inches above the ball to neck transition.

Figure 20 shows the ball side fracture surface, after cleaning. Due to the degree of post-fracture contamination, the surface had to be repeatedly cleaned. The removal of the salts and oxides left much of the fracture surface damaged. However, selected areas did exhibit discernible fracture features that could be observed using a SEM. Figure 21 shows a typical area of the interior of the fracture surface, revealing dimpled rupture. Figure 22 shows a typical outer area of the fracture surface, exhibiting intergranular fracture features. These features were consistent with those of the mating fracture surface from the lever side.

The ball remnant was cold epoxy mounted under vacuum, then ground, polished and etched using 2% Nital solution.² Figure 23 shows a typical cross section through the exterior surface, revealing the surface Cd coating layer (exhibiting brighter contrast). In this figure, there was a shallow angled crack. However, no other cracks were observed, including along or near the fracture surface.

Along the surface of the spherical ball, areas of corrosion pitting were found, as typified in Figure 24. These pits did contain corrosion compounds, which contrasted dark in Figure 24. Using EDS, these corrosion compounds were consistent with iron oxides.

Figure 25 shows an optical cross section through the surface of the ball screw remnant after etching. The micrograph revealed a darker appearance at the surface,

² Nital is an acidic etchant mixture of 2% concentrated nitric acid in ethanol.

contrasting with the lighter interior regions. The dark-etched regions were consistent with a case hardening treatment, such as carburizing. Examination of the drawing for the spring type ball joint assembly (P/N 31747) stated that the ball screw was to be case hardened 0.005 to 0.007 inches deep.

Figure 26 shows a closer view of the core microstructure of the ball screw. This microstructure exhibited ferrite grains (lighter) with smaller darker areas of pearlite and limited martensite (brown). The microstructure also exhibited ellipsoid second phase particles, consistent with manganese sulfide stringers. A closer view of these particles using SEM and EDS revealed them to be manganese sulfide (MnS) with small amounts of Pb. These characteristics were consistent with a resulfurized leaded steel, designed for easier machinability.

The cross-sectional hardness of the ball screw was examined using an automated microindentation hardness tester per ASTM E384.³ The surface exhibited a hardness of 57 HRC (628 HV₅₀₀), whereas the core hardness averaged 77 HRB (142 HV₅₀₀).^{4,5} The depth of the case hardening was 0.0035 inches, consistent with those seen in the intergranular region on the fracture surface and the darker case-hardened region in the optical metallograph.

Overall, the fracture features, chemistry, and microstructure were consistent with bending overstress fracture of the ball screw. The outer intergranular layer was consistent with the harder, less ductile features distinctive of case hardening.

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Materials Research Engineer

³ ASTM E384 – *Standard Test Method for Knoop and Vickers Hardness of Materials*. ASTM International, West Conshohocken, PA

⁴ The two Rockwell hardness scales (B and C) are methods of reporting indentation hardness data. The HRC scale uses a conical diamond indenter and 150 kg major load, typically for harder metal alloys, and the HRB scale uses a 1/16-inch diameter ball indenter and 100 kg major load, typically softer metals alloys.

⁵ The Vickers hardness (HV₅₀₀) is an indentation hardness measurement unit. The test was done by applying a 500-gram load to a diamond indenter and measuring the size of the resulting impression. Higher numbers indicate harder materials.



Figure 1 – The pieces from the throttle connection, as received. Also included was an amount of dust and sand debris.



Figure 2 – The throttle lever, viewed from (a) the face with the threaded portion of the ball screw with the nut, and (b) the face with the fractured ball screw neck.

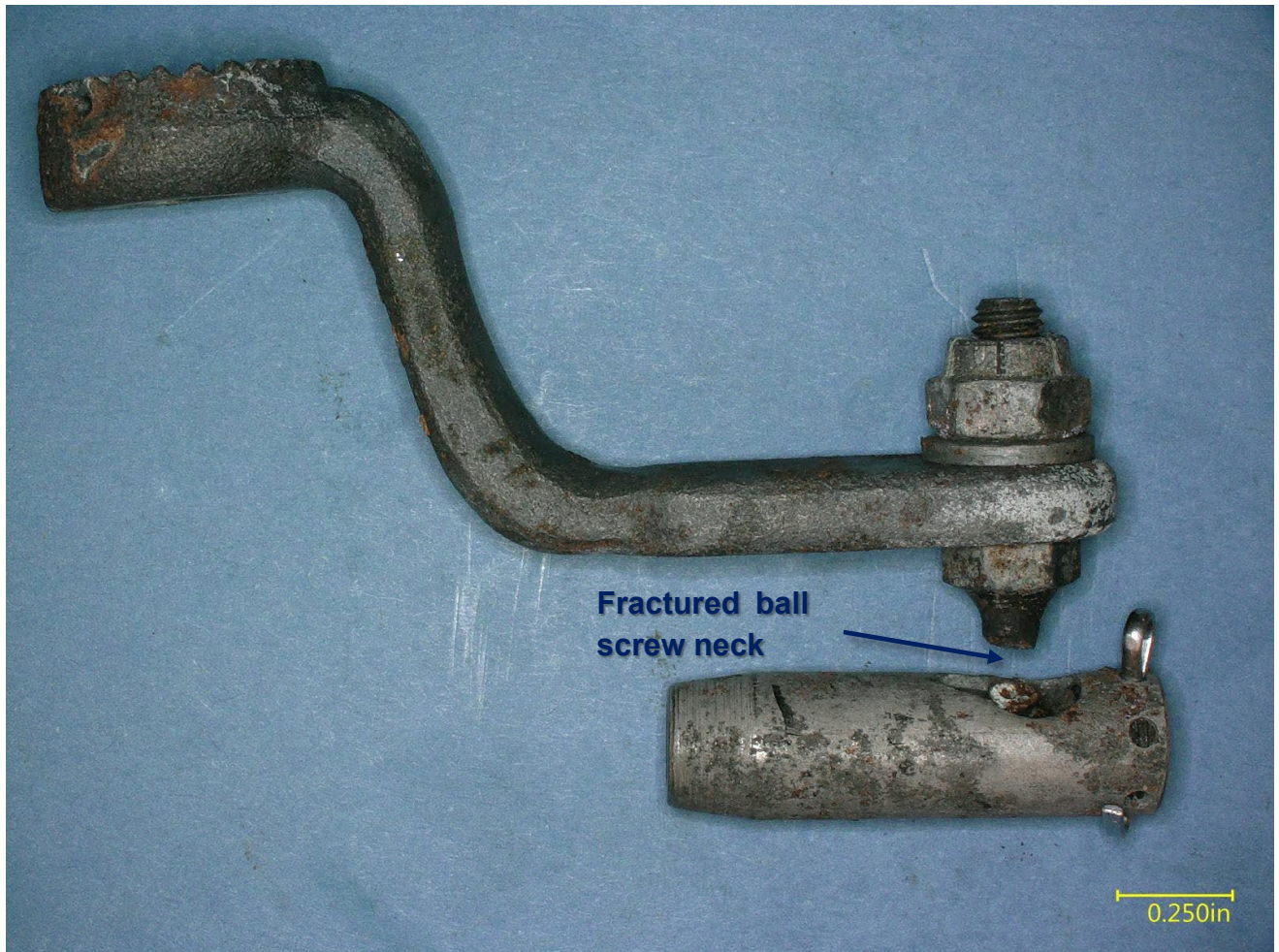


Figure 3 – Side view of the throttle lever and the ball joint assembly shell remnants, approximately positioned at the time of fracture of the ball screw.



Figure 4 – Side view of the fracture surface of the ball screw remnant, still connected to the throttle lever, as received.



Figure 5 – The ball screw neck fracture from Figure 4, after cleaning, showing parallel secondary cracks and a general deformation of the neck.



Figure 6 – View of the fracture surface of the ball screw neck from the throttle lever side, as received.



Figure 7 – View of the throttle lever side ball screw neck fracture surface, after cleaning. The dashed oval represents the different fracture regions on the surface.

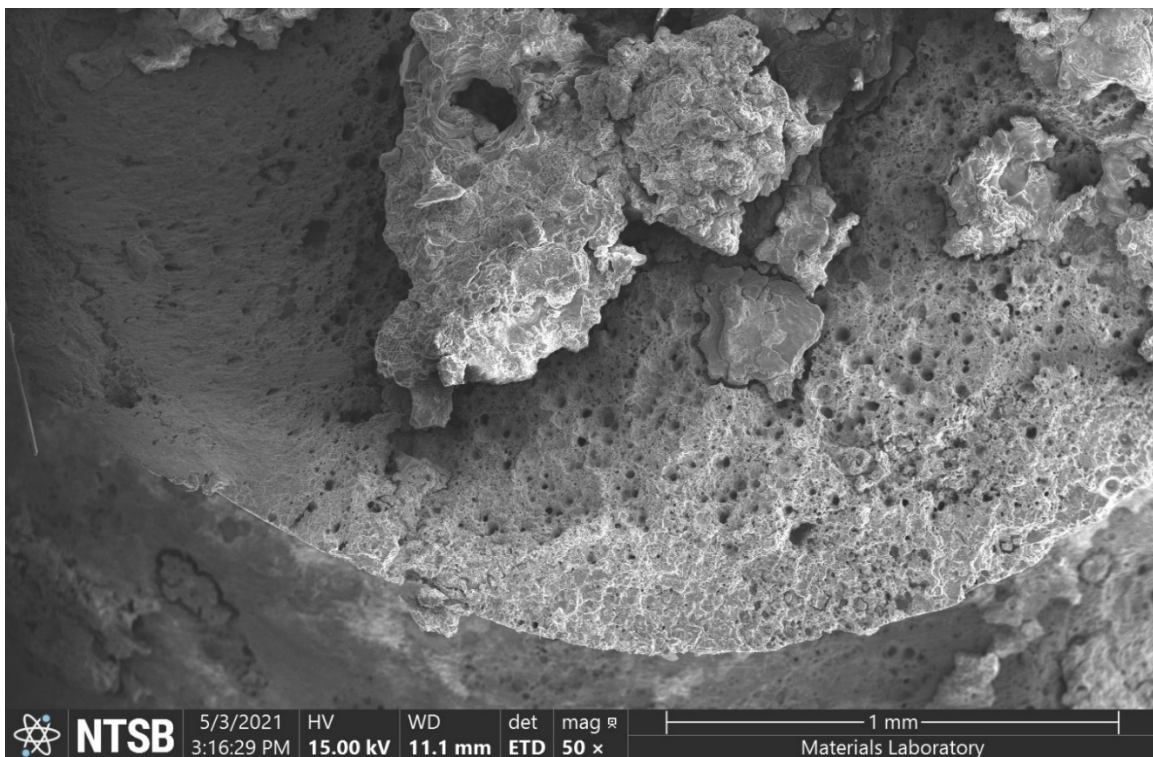


Figure 8 – Secondary electron (SE) micrograph of a portion of the neck fracture surface.

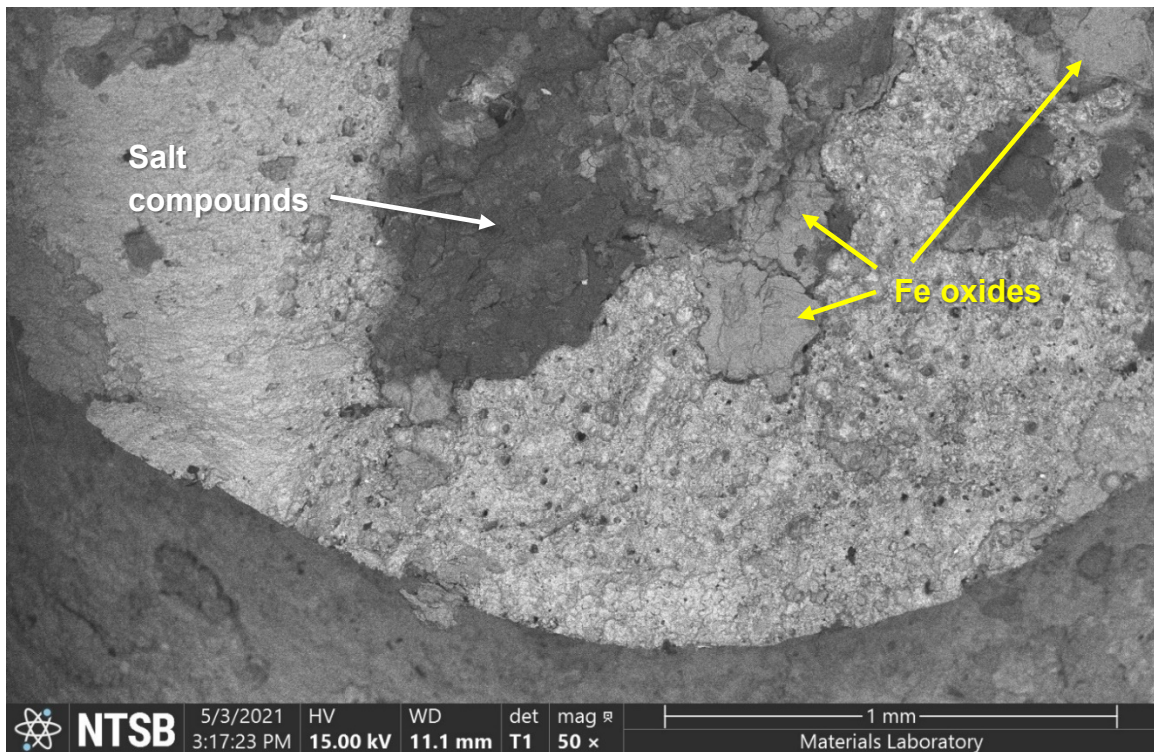


Figure 9 – Backscattered electron (BE) micrograph of a portion of the fracture surface in Figure 8.

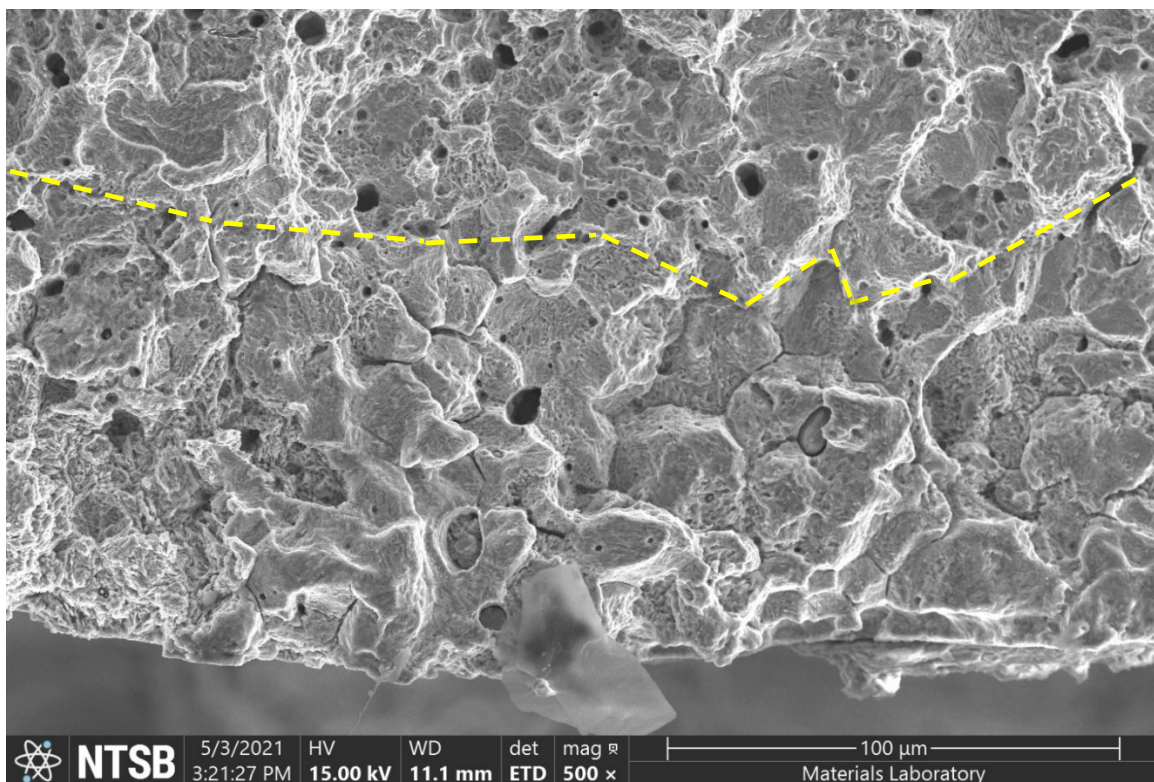


Figure 10 – SE micrograph of the edge of the fracture surface, showing two regions of different fracture features (dashed line).

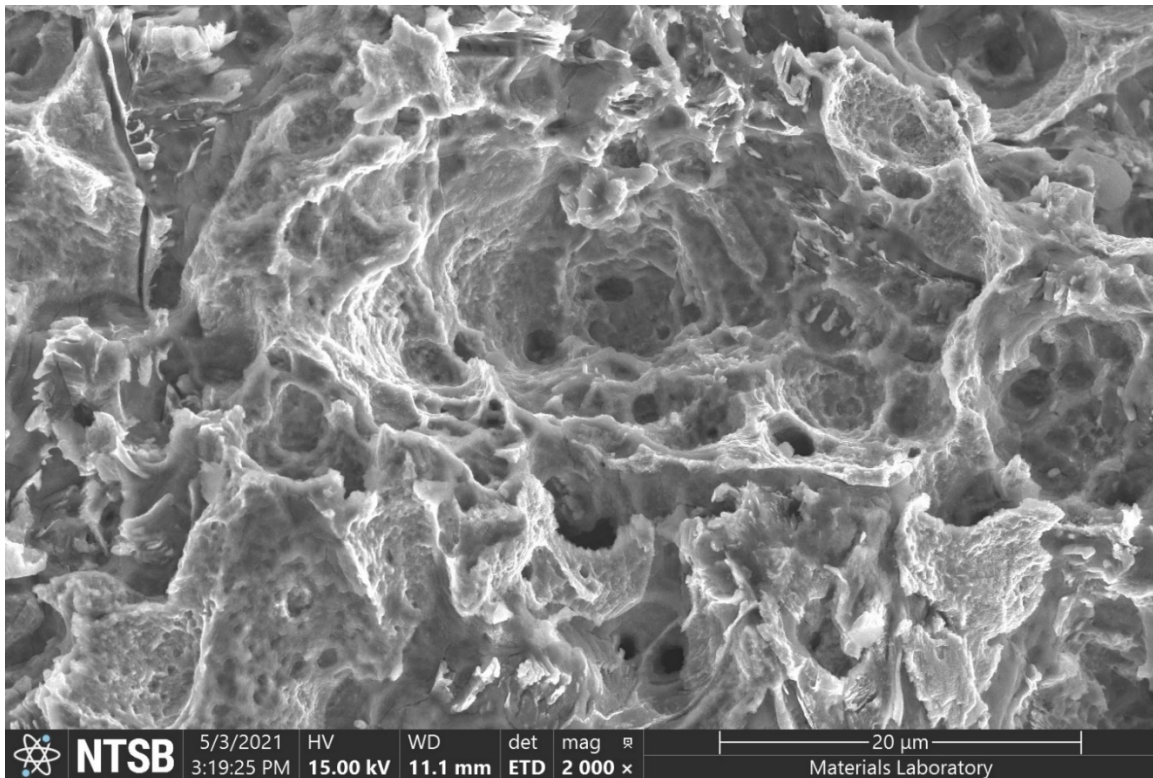


Figure 11 – SE micrograph of the inner fracture surface regions, showing dimpled rupture.

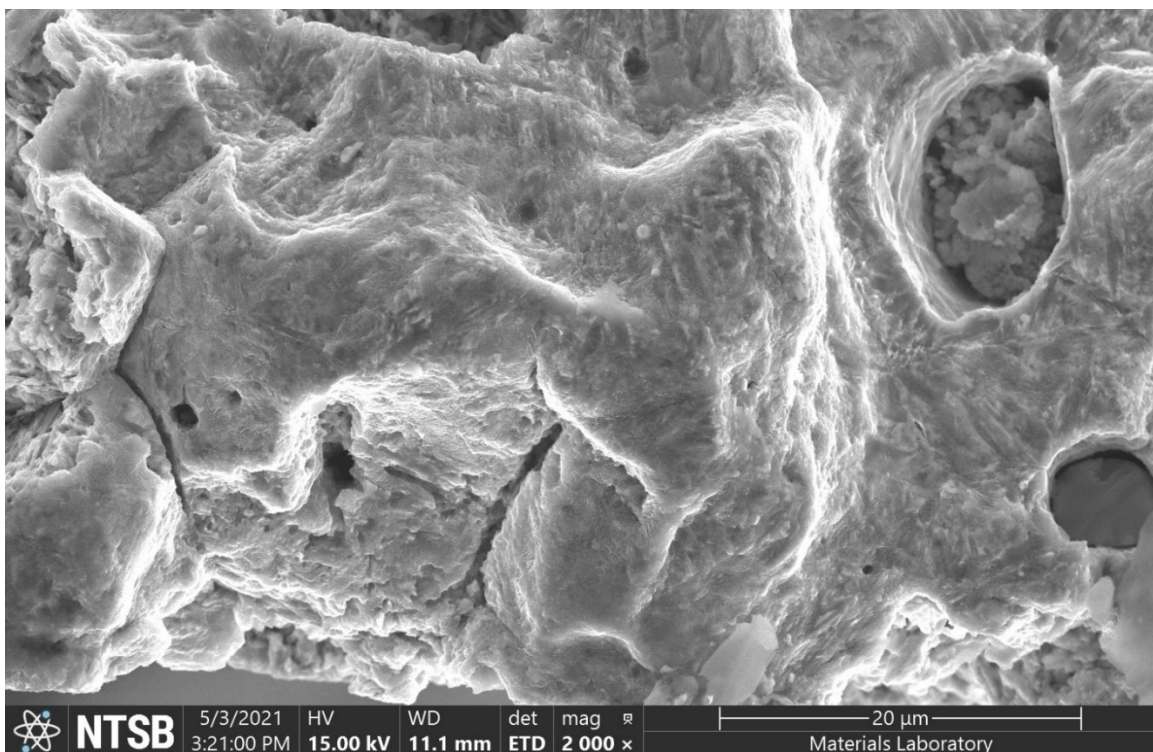


Figure 12 – SE micrograph of the outer fracture features, showing intergranular fracture.

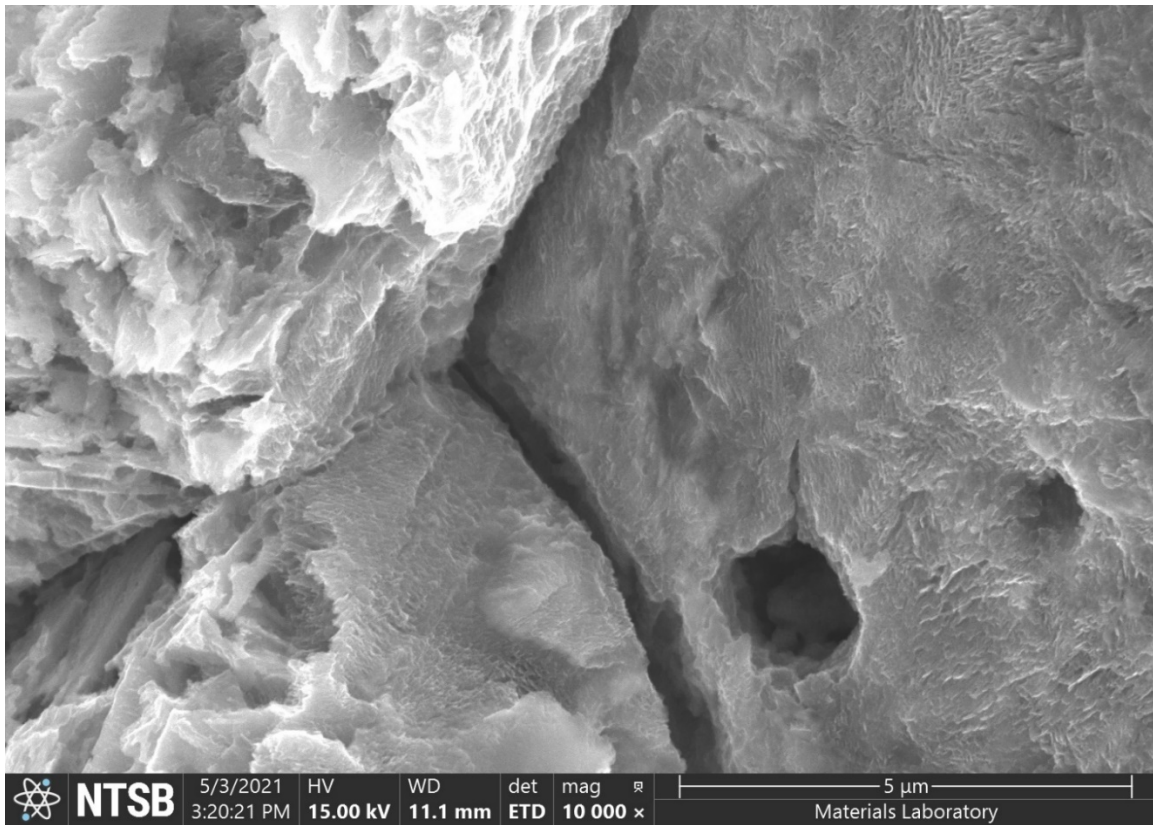


Figure 13 – SE micrograph of a closer view of the intergranular fracture in Figure 12.

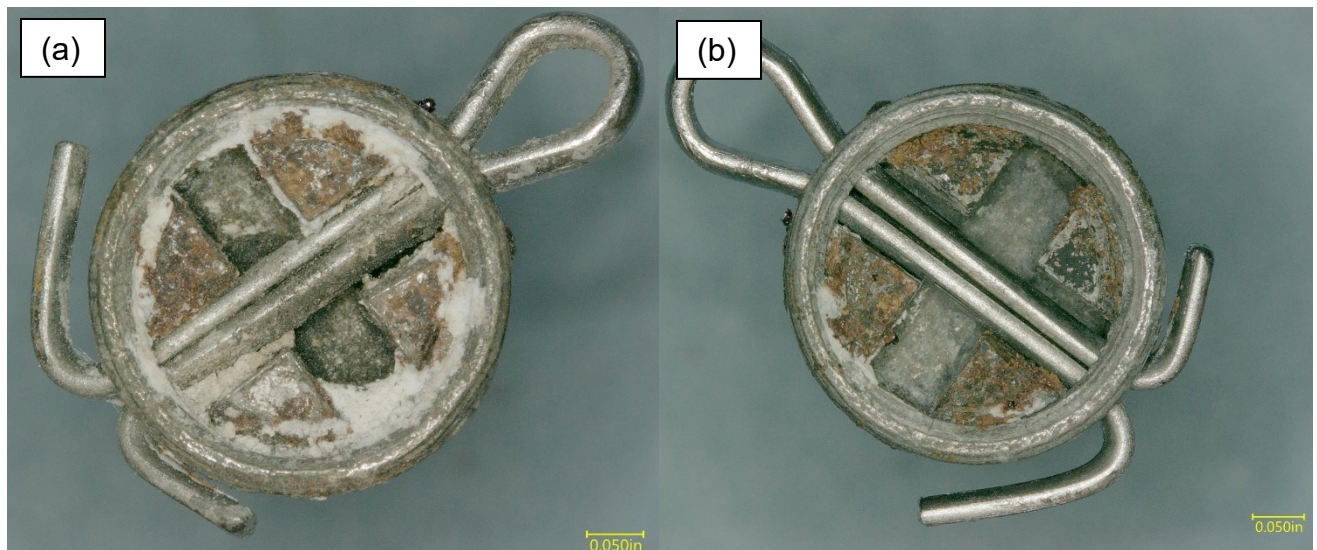


Figure 14 – View of the cotter pin side of the ball joint assembly remnant (a) before and (b) after cleaning.

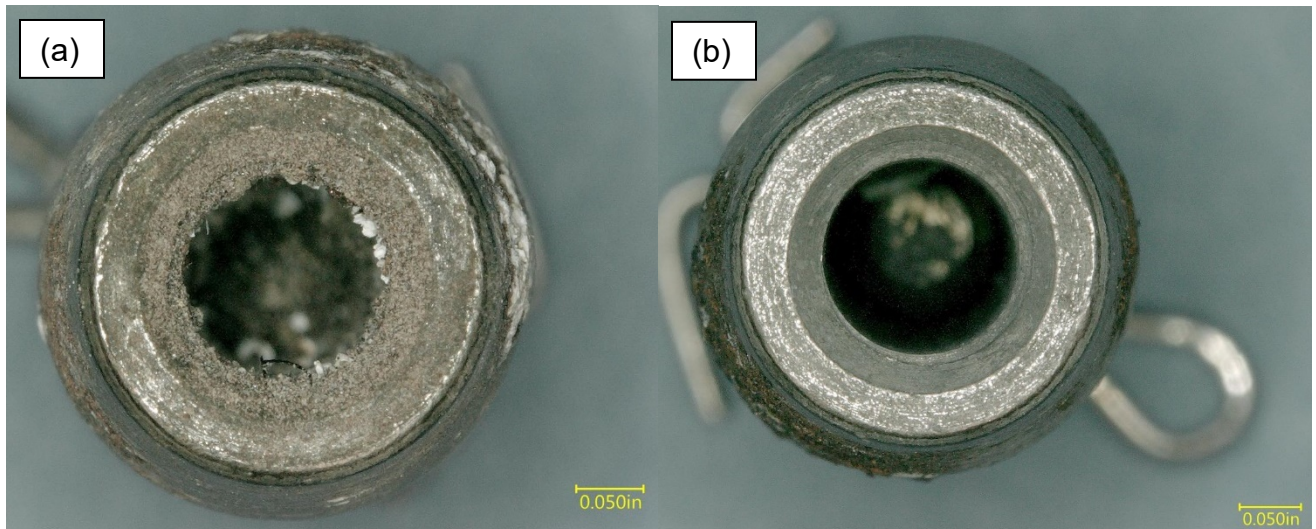


Figure 15 – View of the opposite side of the ball joint assembly from Figure 14, (a) before and (b) after cleaning.



Figure 16 – View of the ball joint assembly remnant and the ball screw neck fracture surface, as received.



Figure 17 – Closer view of the ball screw neck remnant fracture surface, as received.

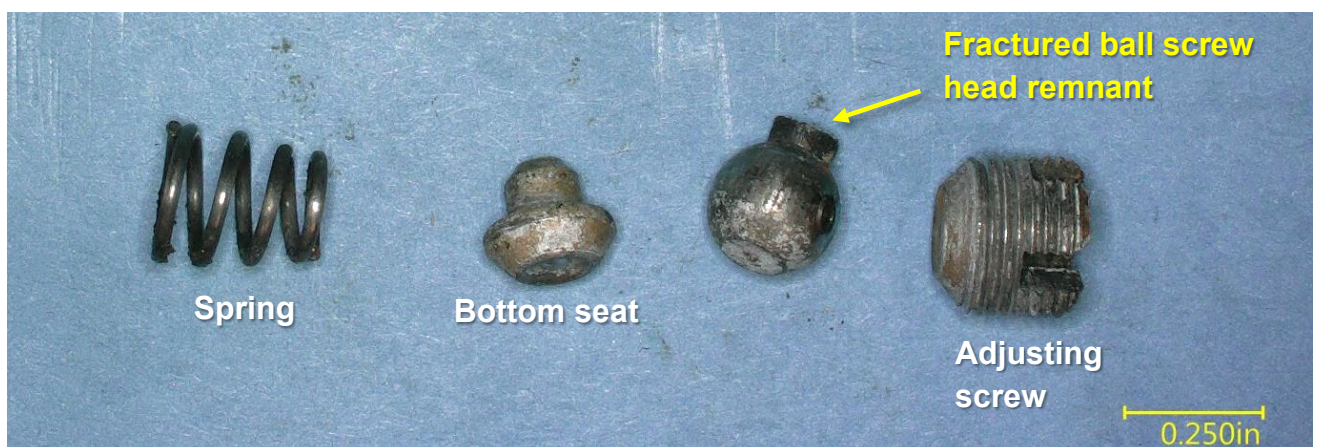


Figure 18 – View of the internal components from the ball joint assembly remnants after removal of the cotter pin and disassembly.



Figure 19 – Closer view of the head and fractured neck of the ball screw remnant from Figure 18, viewed from the side.



Figure 20 – View of the ball screw neck fracture surface from the head side, after cleaning.

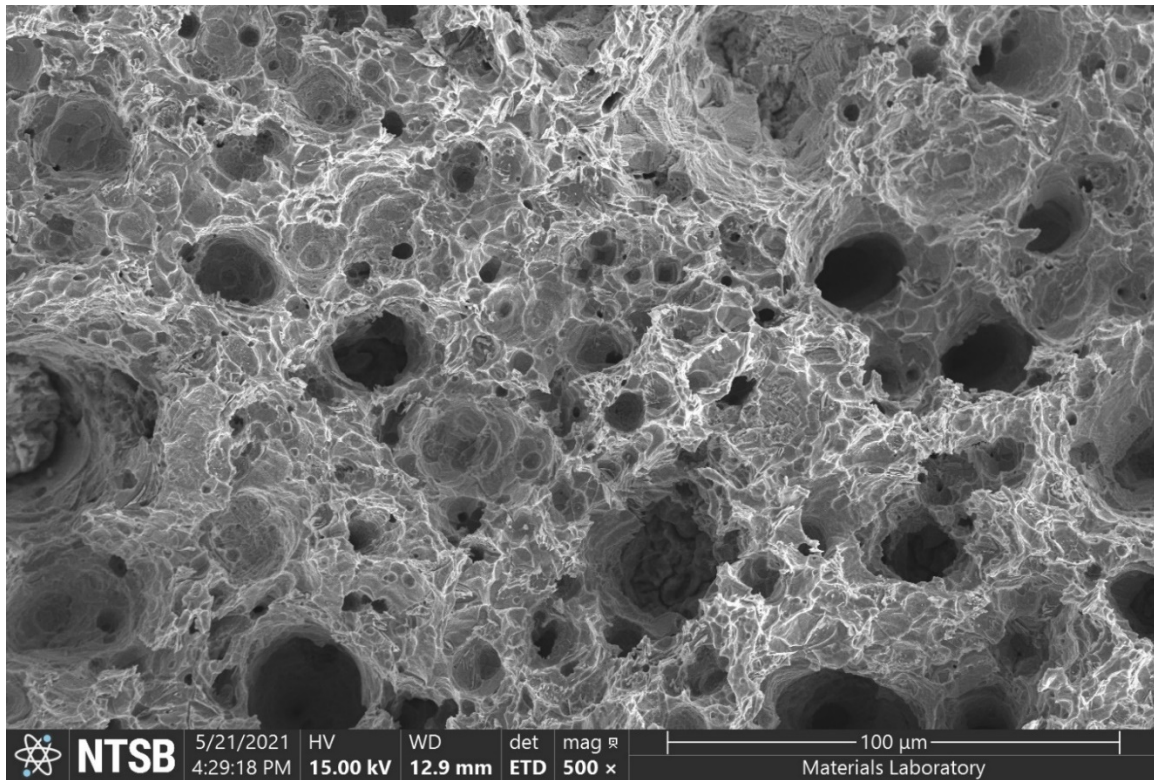


Figure 21 – SE micrograph of dimpled rupture from the neck fracture surface.

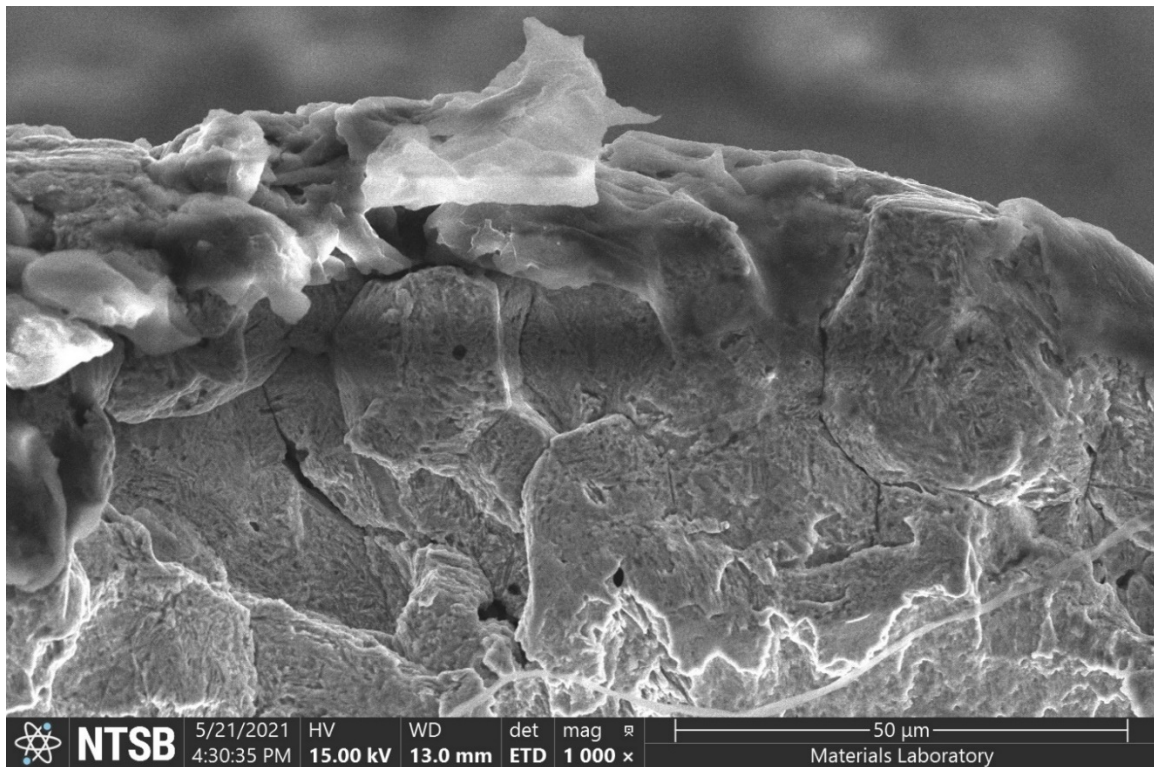


Figure 22 – SE micrograph of intergranular fracture from the neck fracture surface.

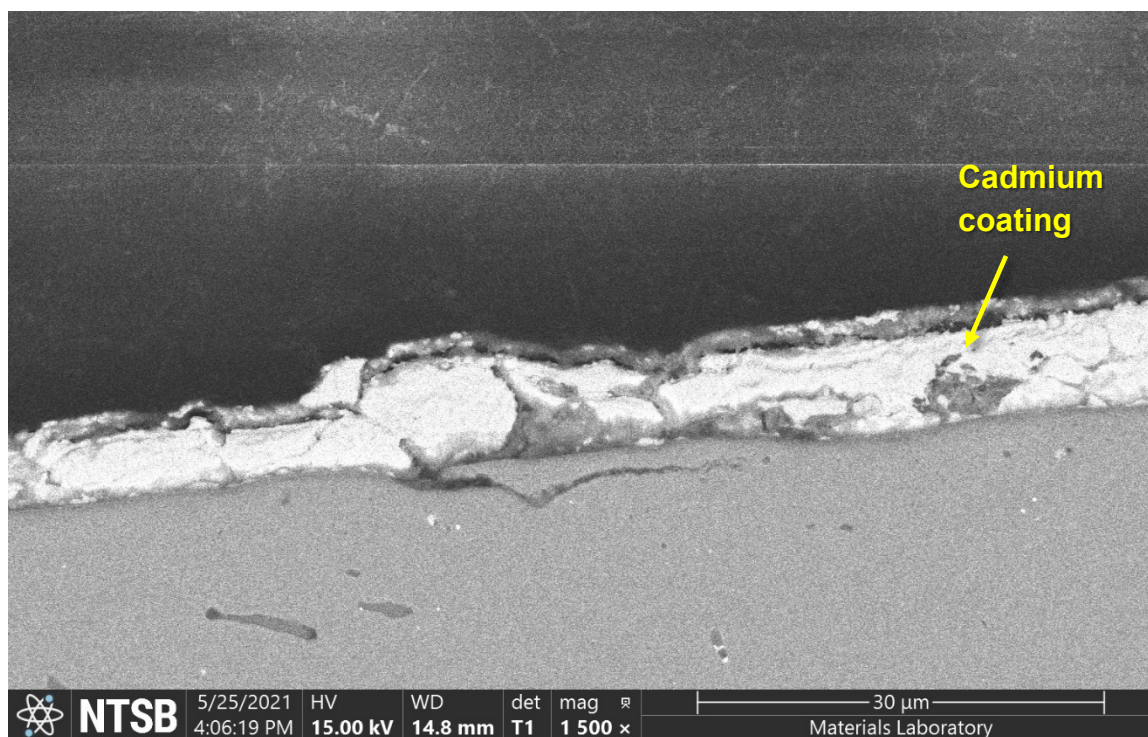


Figure 23 – BE micrograph of a cross section of the neck surface, showing the external cadmium coating and a shallow surface crack.

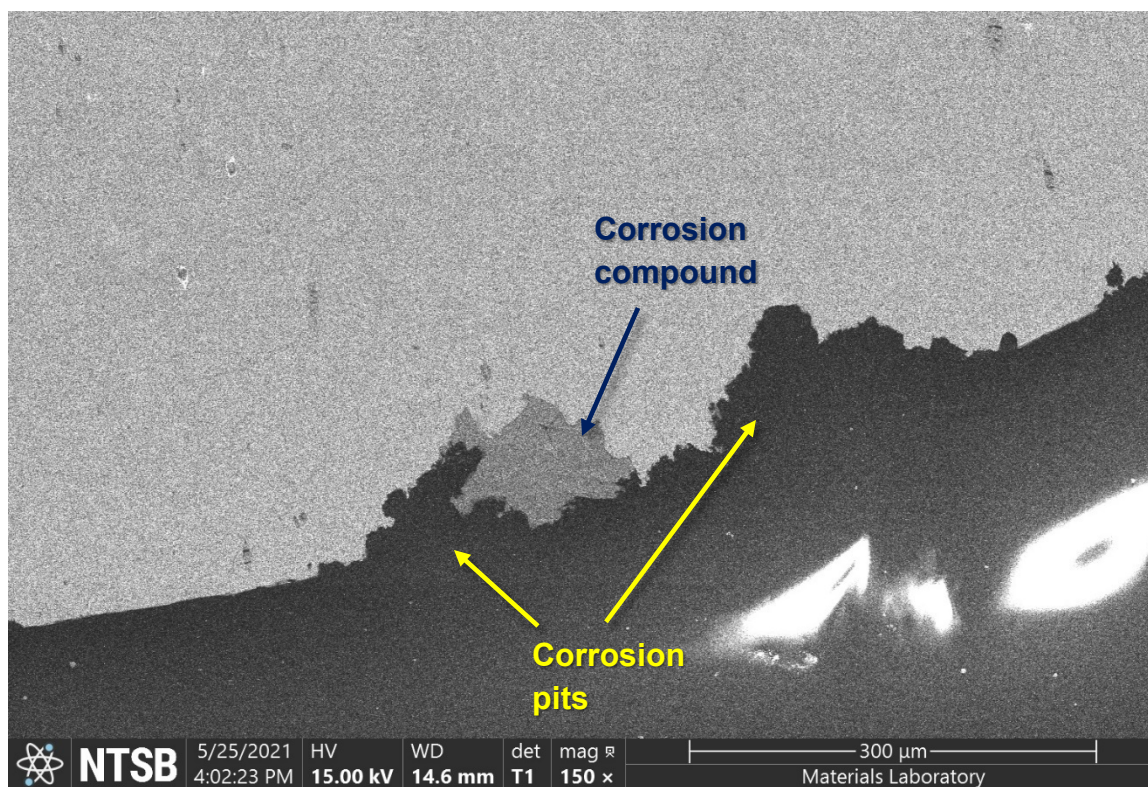


Figure 24 – BE micrograph of a corrosion pit on the neck surface with corrosion products.



Figure 25 – Bright-field (BF) optical micrograph of a cross-section through the surface of the fractured ball screw remnant. The darker areas were the carburized surface, with the core microstructure below (~200X, etched 2% Nital).

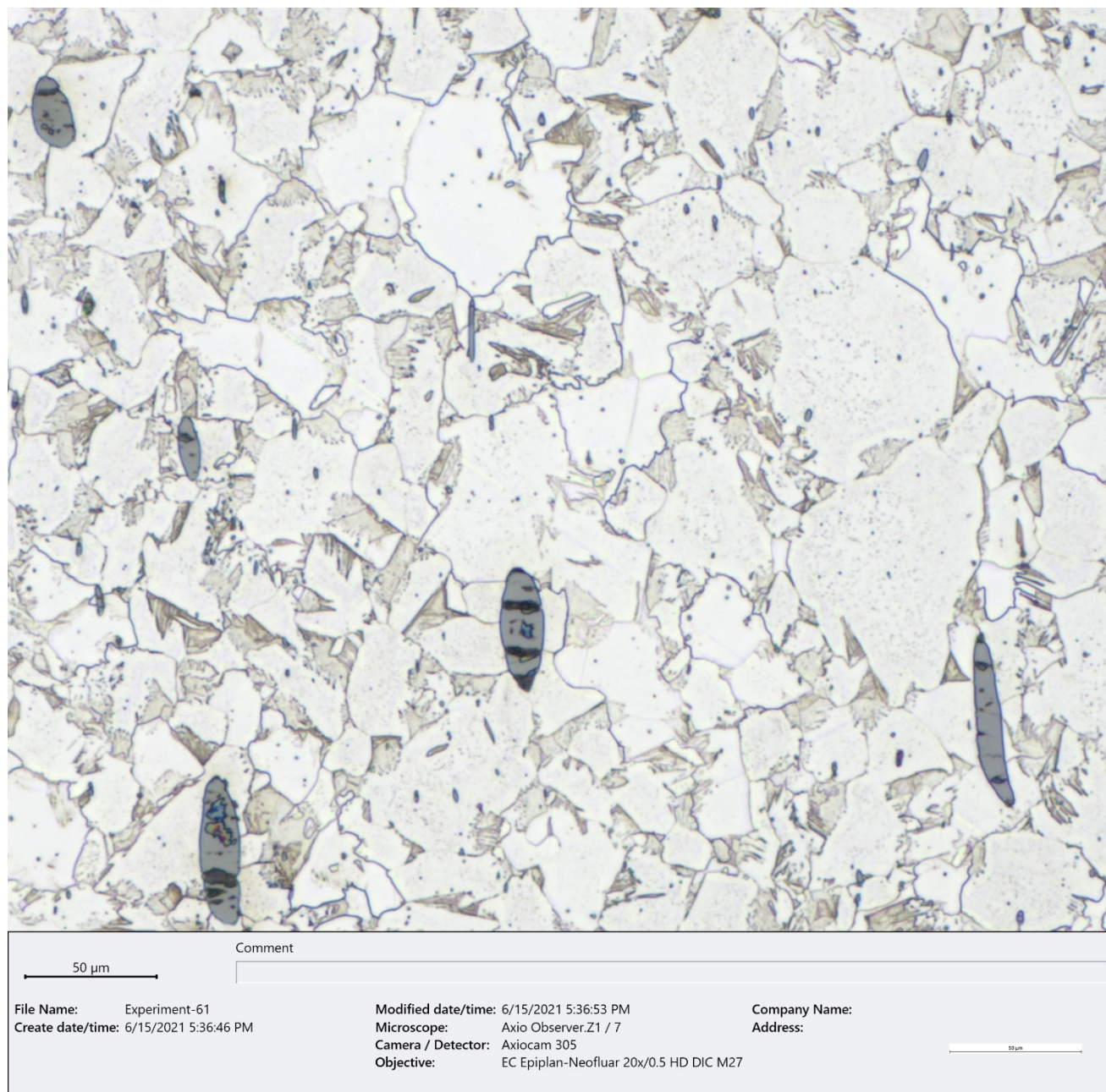


Figure 26 – BF optical micrograph of the core microstructure, showing the ellipsoid second phase particles (~500X, etched 2% Nital).

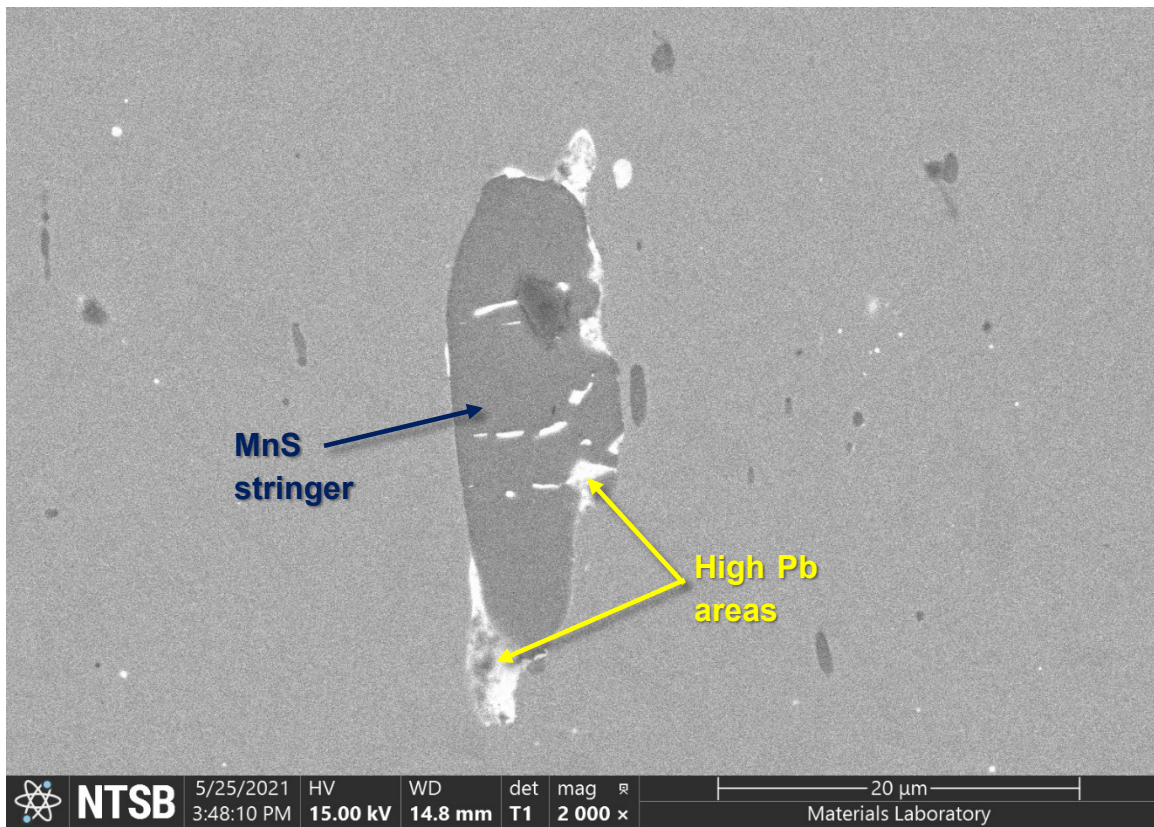


Figure 27 – BE micrograph of a second phase particle, consistent with a MnS stringer and Pb-based material.