

NATIONAL TRANSPORTATION SAFETY BOARD

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



May 13, 2015

MATERIALS LABORATORY FACTUAL REPORT

Report No. 15-040

1. ACCIDENT

Place : Beverly, MA
Date : May 21, 2014
Vehicle : Bell 206L-4, N55SL
NTSB No. : ERA14LA248
Investigator : Ralph Hicks, AS-ERA

2. COMPONENTS EXAMINED

Outer Combustion Case

3. DETAILS OF THE EXAMINATION

On May 21, 2014, about 1011 eastern daylight time, a Bell 206L-4 landed hard following a total loss of engine power during initial climb at Beverly Municipal Airport (BVY), Beverly, Massachusetts. The commercial pilot and one passenger were not injured, but the helicopter was substantially damaged. According to the pilot, the engine abruptly lost all power shortly after liftoff. The pilot attempted an autorotation to a taxiway, but chose to land in the grass adjacent to the taxiway when it became apparent the he would not make the taxiway. During the landing, the main rotor contacted the tail boom, severing it just aft of the horizontal stabilizer. The helicopter came to rest on the landing gear.

An inspector with the Federal Aviation Administration responded to the accident site and examined the wreckage. The engine inspection revealed that the combustion section outer case was ruptured in the elbow area. The engine for this aircraft was a Rolls-Royce M250-C30P.¹ The combustion case was removed for examination at the NTSB Materials Laboratory.

The combustion case is shown in Figure 1 and Figure 2, as received. The case contained a rupture aft of the left elbow shown in the figures. The rupture was manifested as case material protruding outward, with the mating fracture surfaces located along a horizontal butt weld line of the case (Figure 3). This fractured weld line was located where a wire mesh reinforcement patch was brazed to the case.

¹ The Rolls-Royce M250 series are turboshaft engines, originally manufactured by Allison Engine Company as the Model 250 series.

On the forward side of the case, were the following inscriptions that were consistent with having been vibroetched on the outside:

P/N 6899237-A
23030910
S/N 24358

Figure 4 shows one of the mating halves of the fracture surface along the horizontal butt weld of the case. The fracture extended into the braze joint around the left connecting flange and the butt weld of the center connecting flange. Much of the fracture along the flange joints outside the case butt weld exhibited a 45° slant consistent with overstress fracture. The fracture surface along the case weld exhibited a relatively flat orientation.

As shown in Figure 5 and Figure 6, the weld fracture surface exhibited crack arrest marks and ratchet marks consistent with progressive fracture. In the progressive regions, the fracture surface appeared dark with visible crack arrest marks, which were more visibly evident towards the periphery. The portions of the fracture surface outside the butt weld exhibited a brighter luster, but still exhibited crack arrest features (see Figure 7). Using a measurement standard for comparison, the thickness of the case was measured along the progressive regions of the fracture surface. As exemplified in Figure 8, the thickness of the case averaged 0.027 inches.

Examination of the opposite braze patch (right side Figure 2) revealed small cracks present on the outside surface (see Figure 9). These were consistent with smaller versions of outer surface defects observed on the braze patch from the fractured braze patch (compare with Figure 6).

One half of the fracture surface was sectioned away from the rest of the combustion case and was examined using a scanning electron microscope (SEM). As displayed in Figure 10, examination of the progressive portions of the fracture surface exhibited fatigue striations, consistent with fatigue fracture. The fatigue cracking originated along the weld line approximately halfway between the connecting flange joints. The fatigue regions consisted of relatively large striations with smaller striations overlapping—these fatigue features were consistent with spectrum loading.

Examination of this initiation area revealed the fatigue cracks started on the inside face of the case weld at multiple crack initiation sites (such as illustrated in Figure 11). No material defects, such as pores or inclusions were found at these initiation sites. At the end of the fatigue crack in the weld, features that appeared to represent transition to other failure modes (such as Figure 7) were also found to contain fatigue striations microscopically, as shown in Figure 12. Fatigue striations were present outside the main weld line. Outside the fatigue regions, dimple rupture, which was indicative of overstress failure, was observed (see Figure 13).

Examination of the exterior fractured braze patch revealed a region with pores, approximately 0.005 to 0.010 inches in diameter (see Figure 14). In areas where the braze material was well adhered to the case material, the fatigue cracking had

propagated through the interface into the braze material (Figure 15). In regions where there was a gap between the braze and the case, the braze material was more oxidized and the fracture features could not be discerned (Figure 16). The fracture surface of the braze filler in these regions contained smaller microcracks perpendicular to the fracture surface. Near the pores in the braze filler, these microcracks could be observed emanating from the pores (Figure 17). In addition, cracks were present on the exterior surface of the braze patch. However, neither the appearance of external surface cracks nor the interior microcracks were consistent with initiation of the fatigue crack on the interior of the case.

A portion of the case fracture surface was cross-sectioned, mounted, and polished for metallographic examination. Figure 18 shows a portion of the cross section. In backscattered mode, the braze material appeared lighter relative to the case material and wire mesh in the braze.² Like the fracture surface, the cross section of the braze filler contained multiple pores. These appeared light consistent with the braze material, whereas the wire mesh contrasted darker. Cracks were visible initiating from these pores. Gaps were found between the braze material and the case adjacent the fatigue fracture surface (see Figure 19). The mating surfaces of these gap exhibited backscattered electron contrast and chemical compositions consistent with oxidation. Gaps were also found adjacent to the wire mesh. Additional cracks were found perpendicular to the case and braze patch. Even in well adherent areas, cracks were found propagating into the case material, as shown in Figure 20. The interior surface of the case was not uniformly smooth, containing small crevices and gaps, as illustrated in Figure 21.

The chemical composition of the case and braze materials were inspected using energy dispersive x-ray spectroscopy (EDS). The case material was found to be consistent with Type 347 austenitic stainless steel. The composition of the wire mesh in the braze also was consistent with austenitic stainless steel. The braze material was consistent with silver-zinc-copper braze filler. The braze filler consisted of two phases—one silver rich (brightest in Figure 20) and one copper-zinc rich.

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² 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.

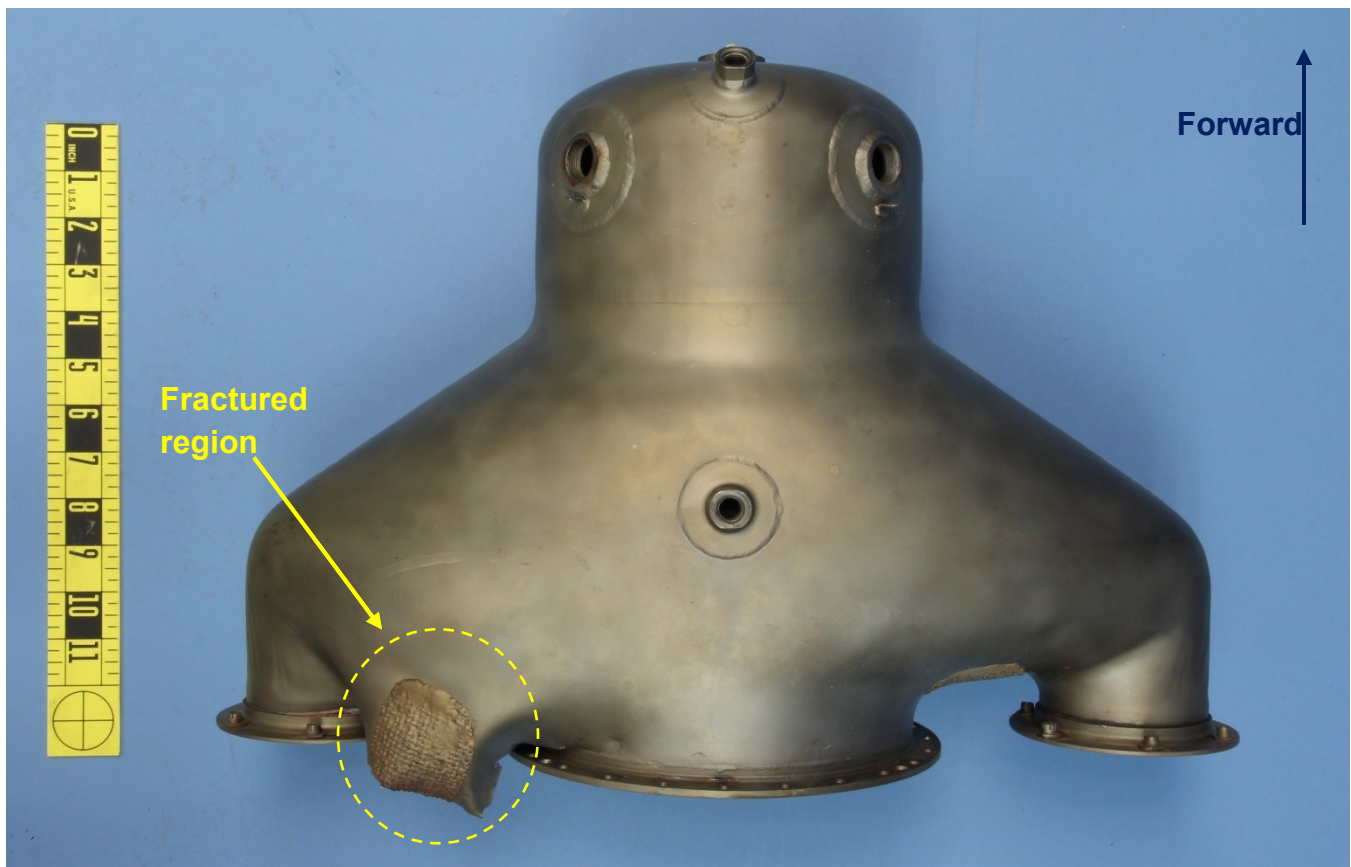


Figure 1 – The combustion case, as received. The breach was located on the lower left side.

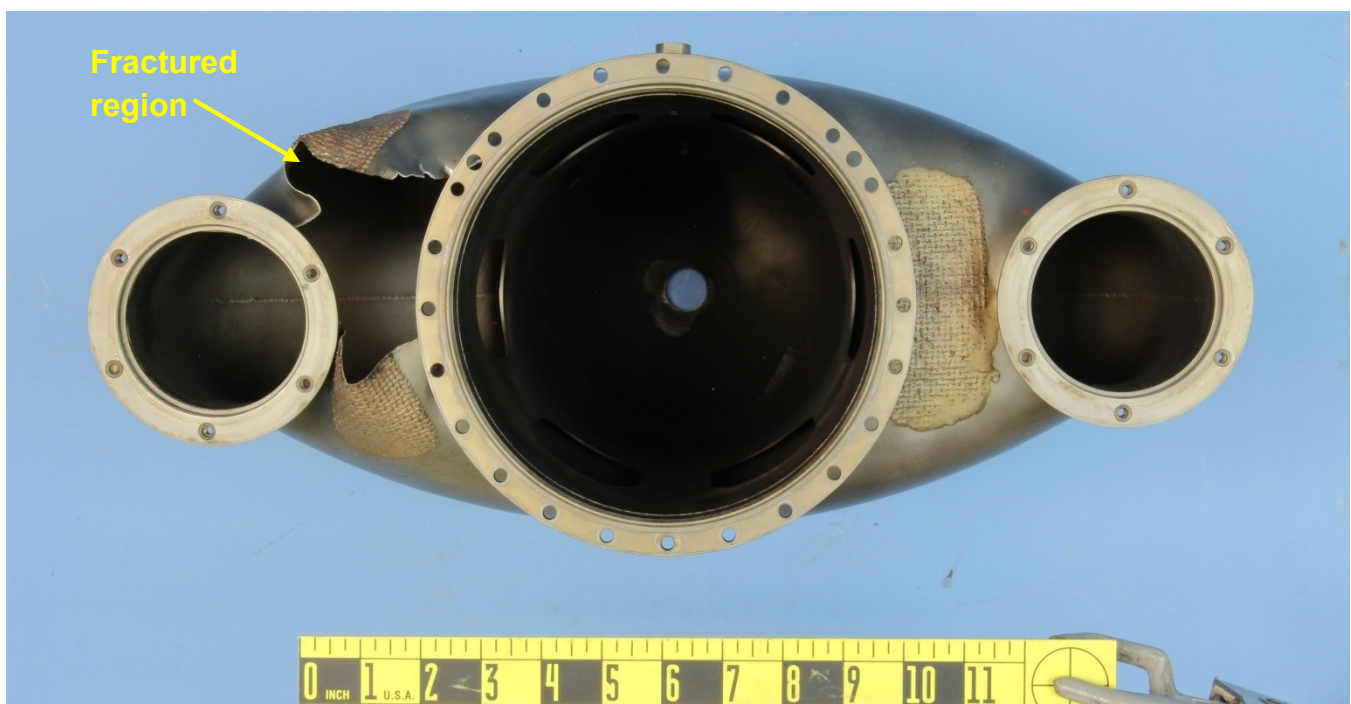


Figure 2 – The combustion case, as received, viewed from the aft side. The breach was located on the left side, where a braze reinforcement was placed. The right side braze reinforcement was intact.

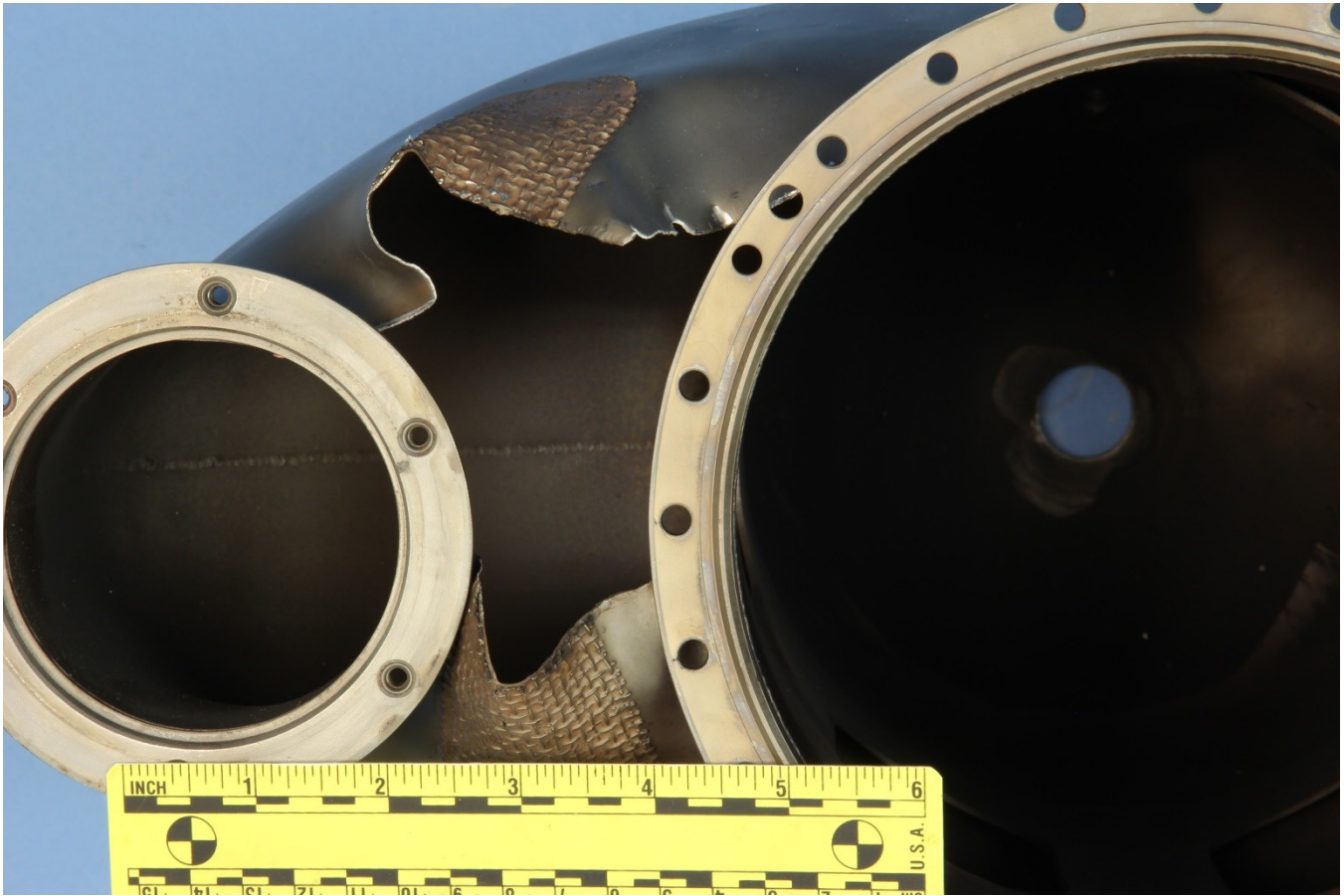


Figure 3 – A closer view of the fracture from Figure 2, showing tearing along the weld line through the braze patch, and secondary tearing from where the tear propagated along the joint with the connecting flanges.

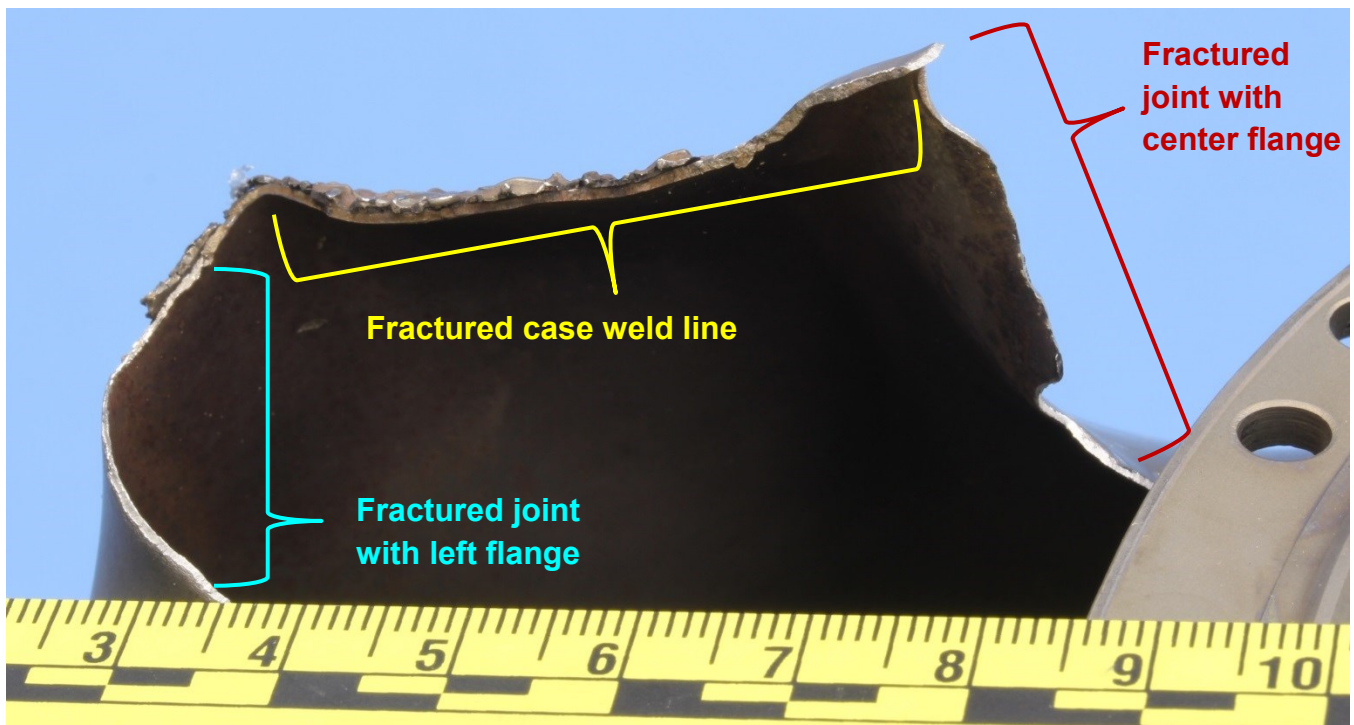


Figure 4 – One of the mating halves of the tear fracture, tilted to face the reader.

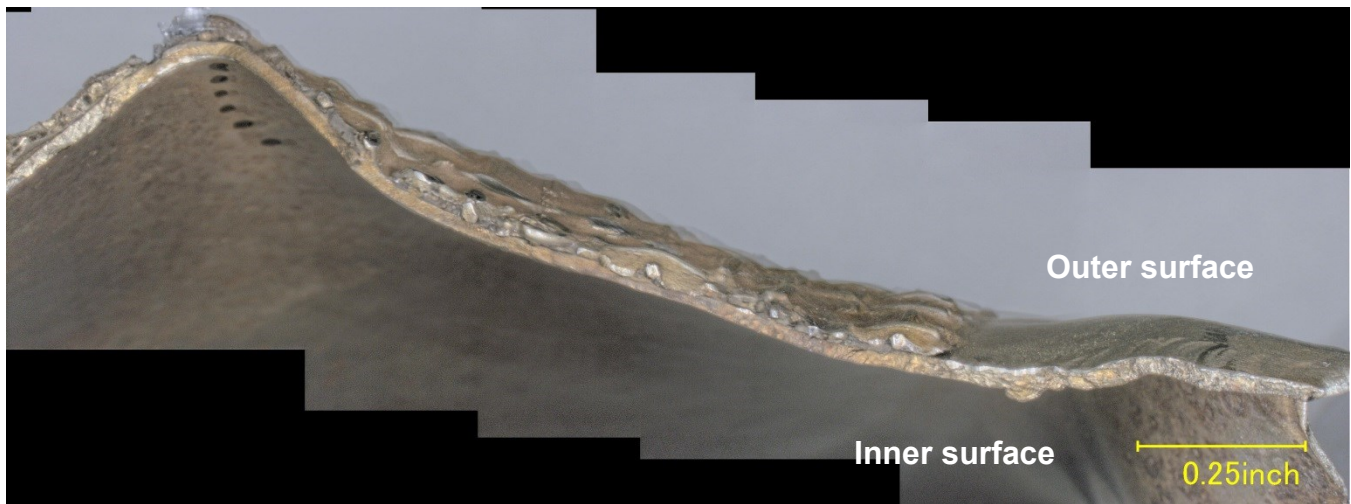


Figure 5 – Montage of the progressive portions of the weld tear fracture surface.

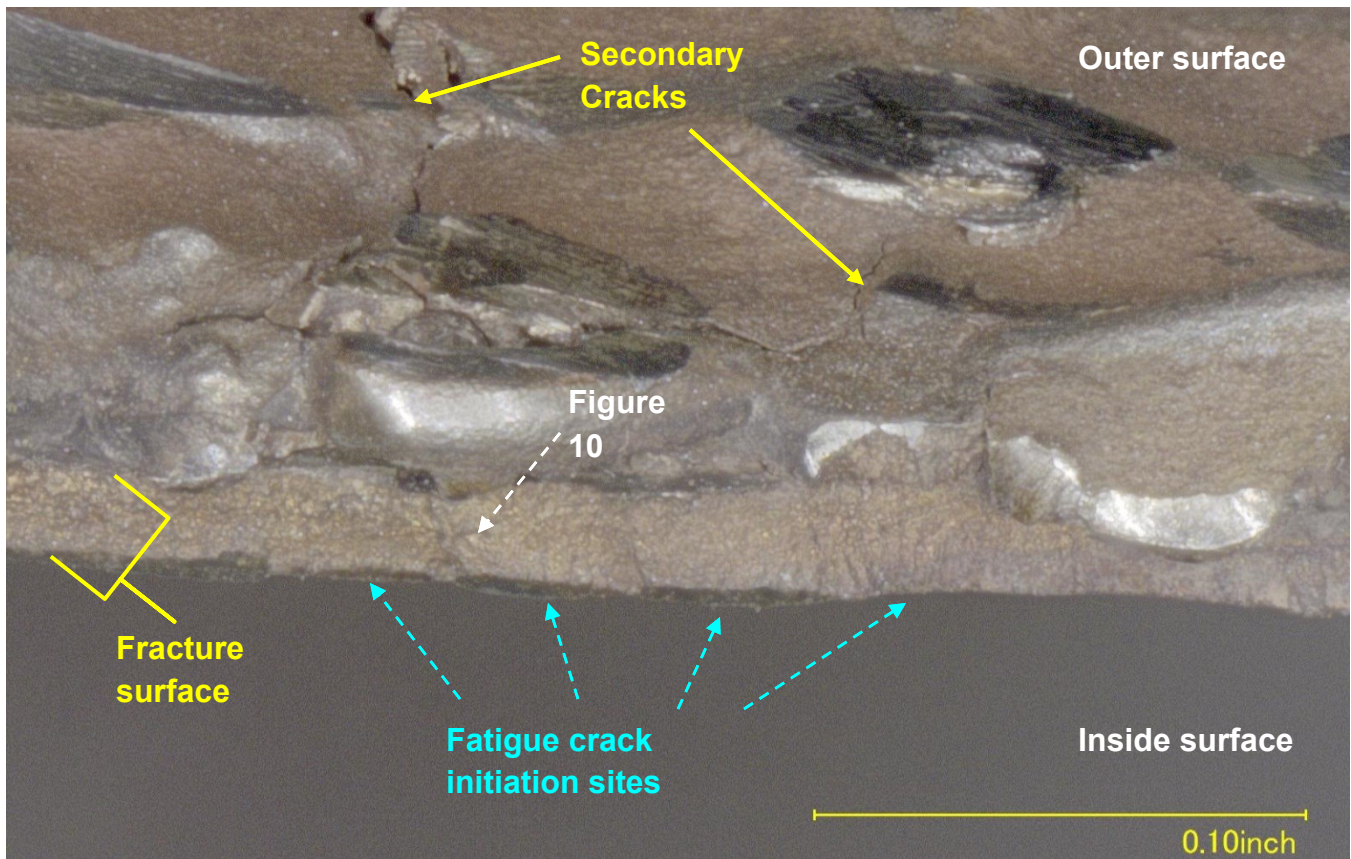


Figure 6 – View of the weld line fracture surface, at progressive crack initiation points (arrows). The braze reinforcement also contained an outer surface crack perpendicular to the fracture surface.

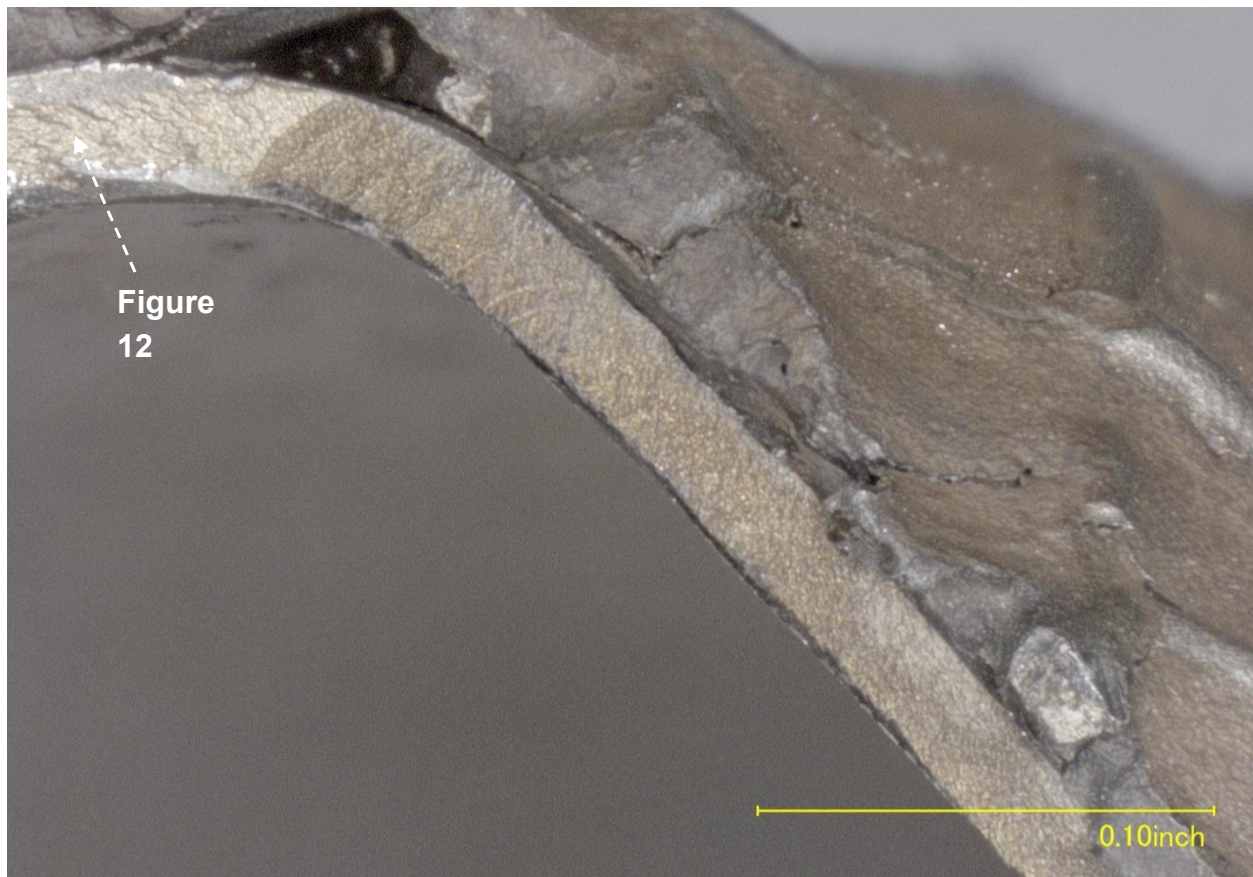


Figure 7 – Closer view of the fracture surface, as the progressive fracture transitioned from the case weld line to the braze joint with the left side connecting flange. The numbers refer to later figure locations.

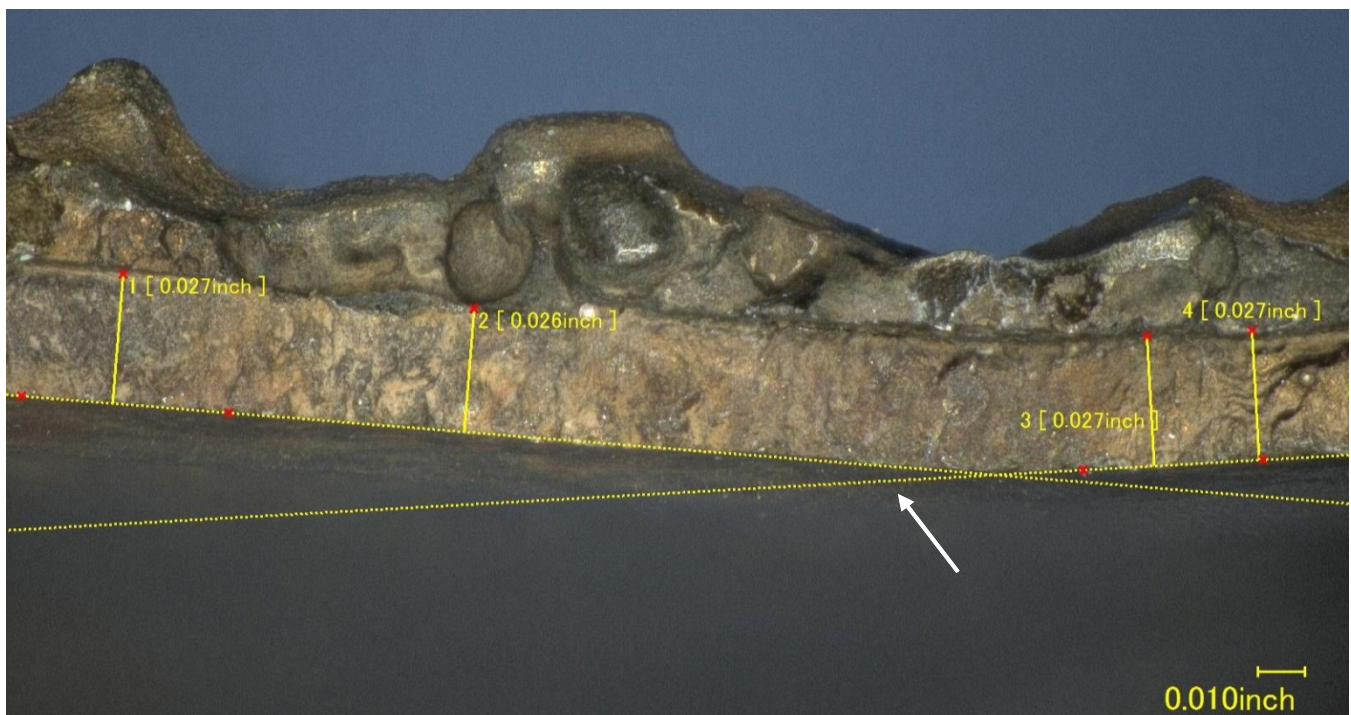


Figure 8 – One of the fatigue crack initiation points (white arrow) on the combustion case weld line, with case thickness measurements taken at four locations.

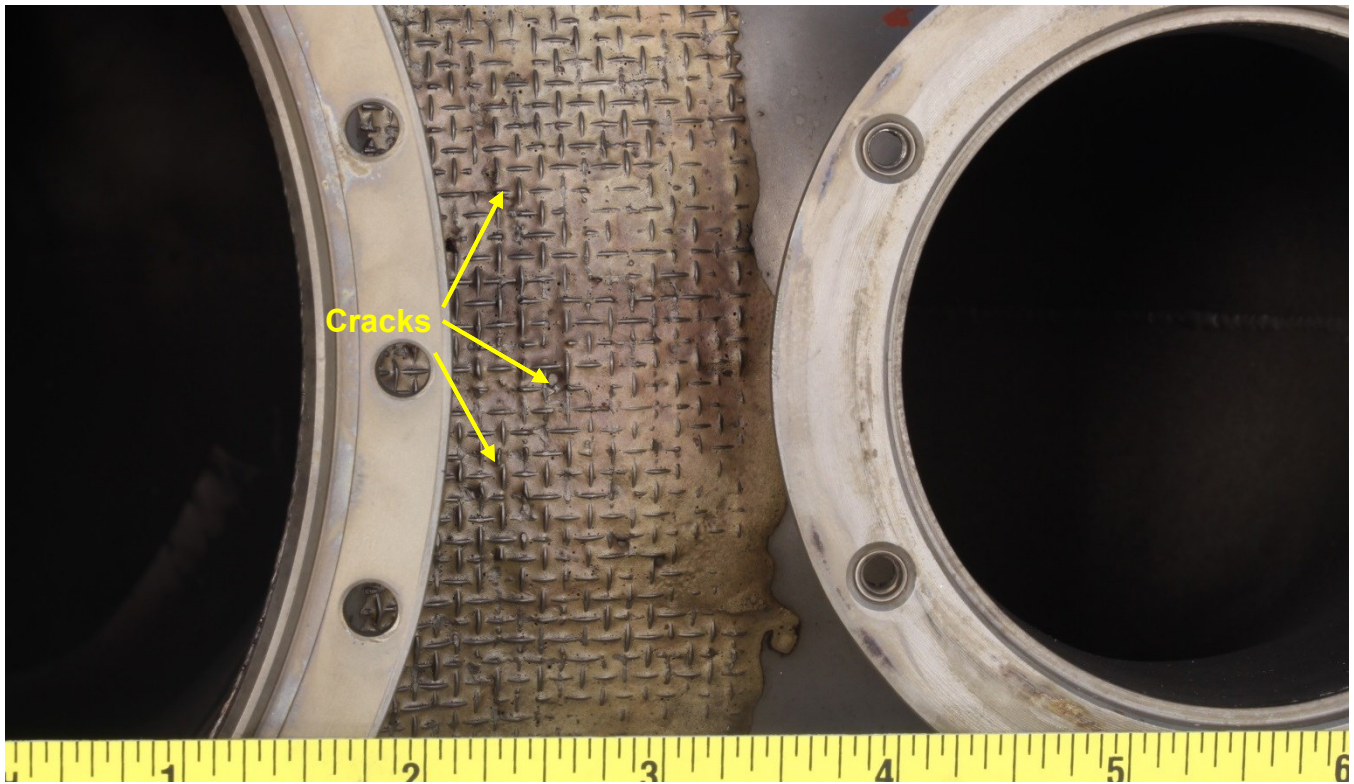


Figure 9 – Closer view of the right side braze reinforcement patch, showing small surface cracks visible from the braze side.

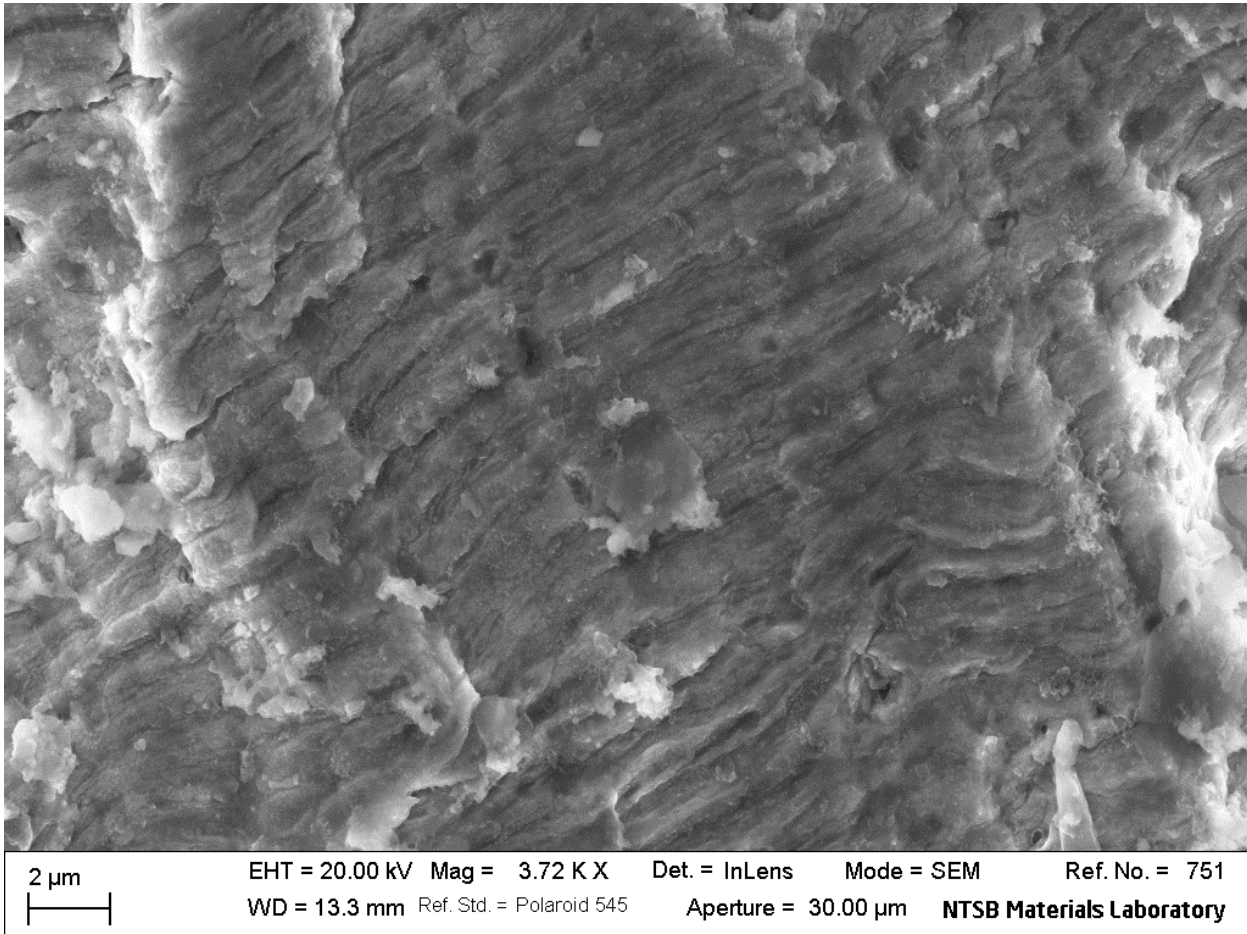


Figure 10 – Secondary electron (SE) micrograph of fatigue striations on the progressive portion of the fracture surface shown in Figure 6.

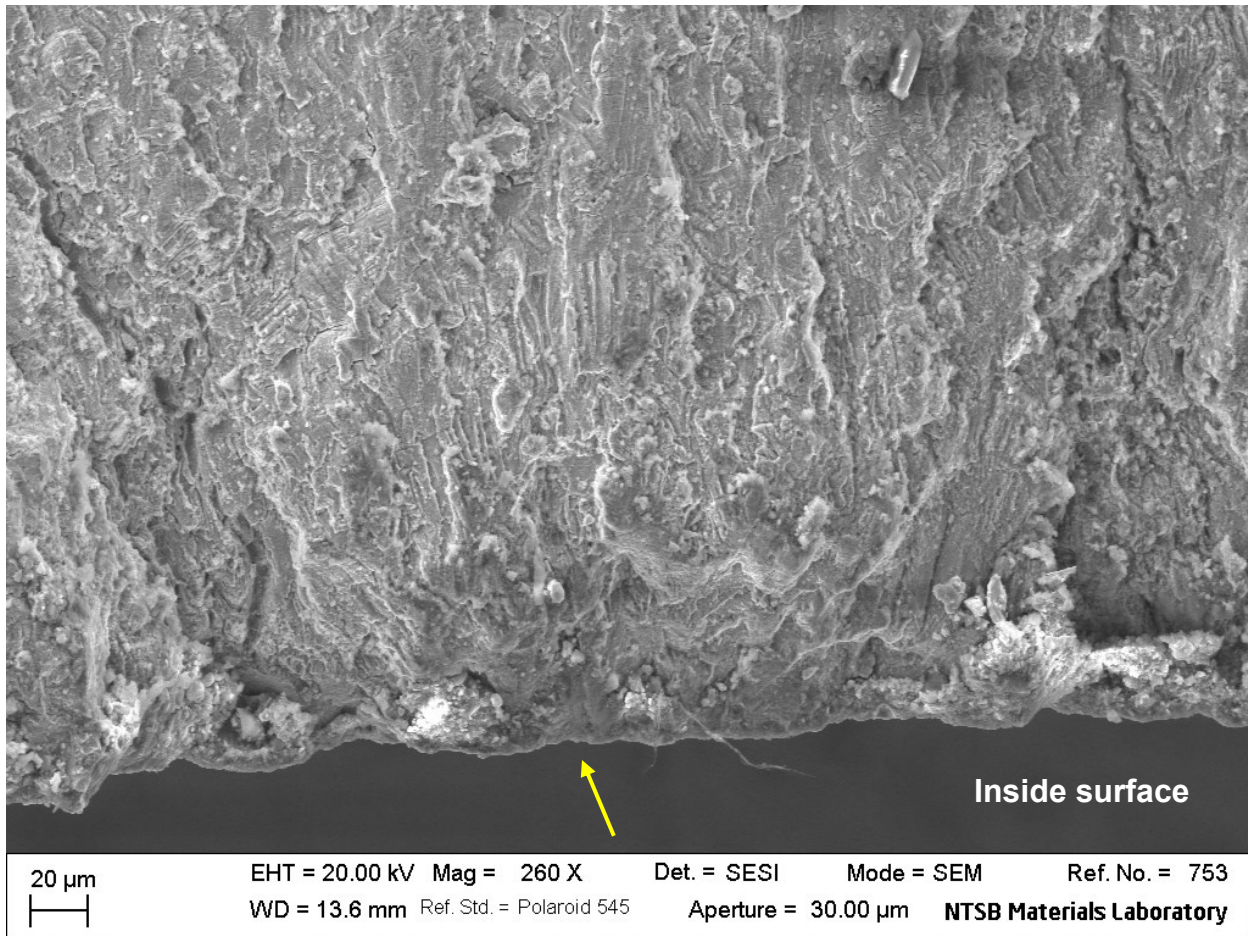


Figure 11 – SE micrograph of one of the fatigue crack initiation sites (yellow arrow) on the case weld fracture, location depicted in Figure 6.

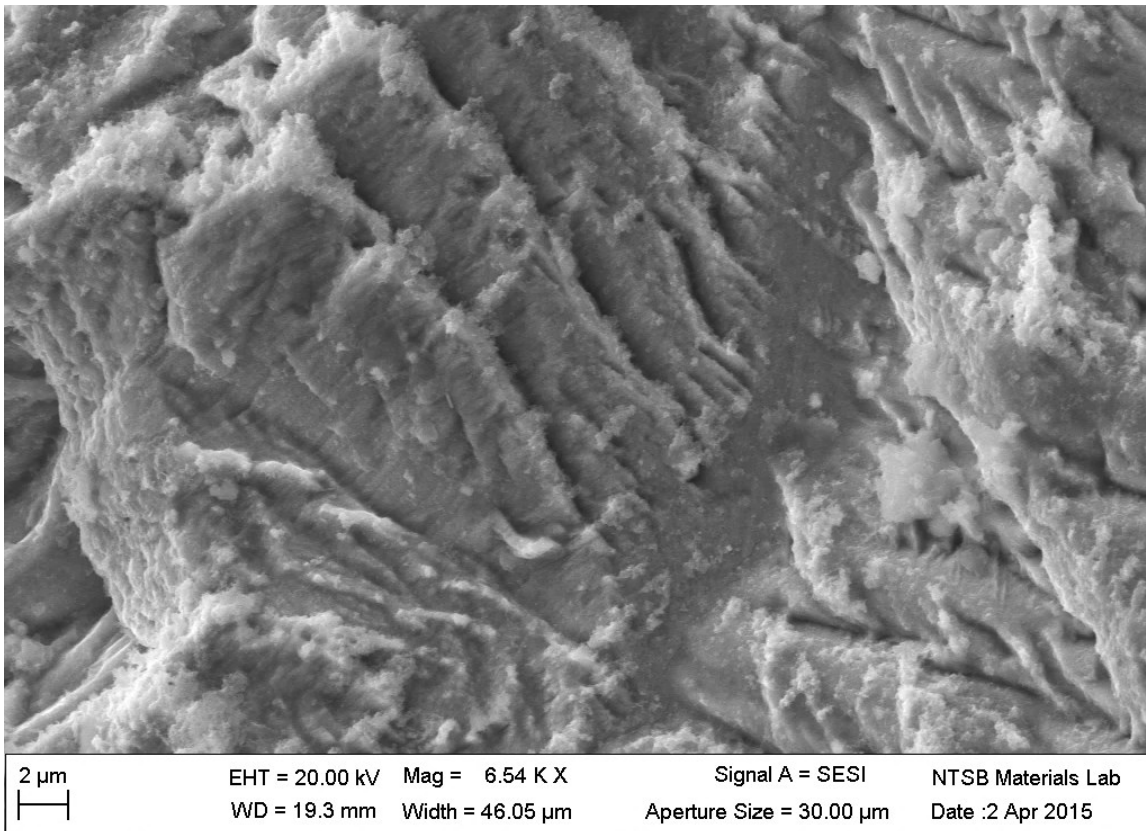


Figure 12 – SE micrograph of fatigue striations on the portion of the fracture surface located at a joint between the case and the left connecting flange, location depicted in Figure 7.

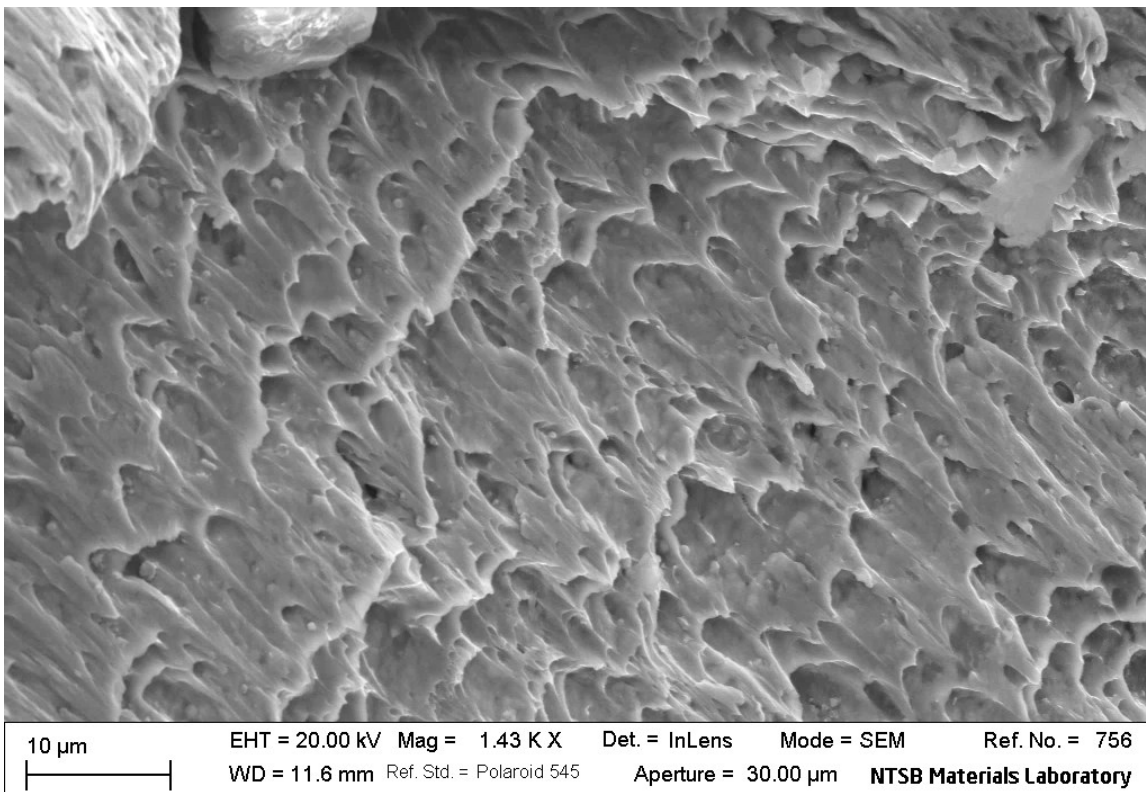


Figure 13 – SE micrograph of dimple rupture in the overstress regions outside of the fatigue regions on the case fracture surface (outside of Figure 7, left side).

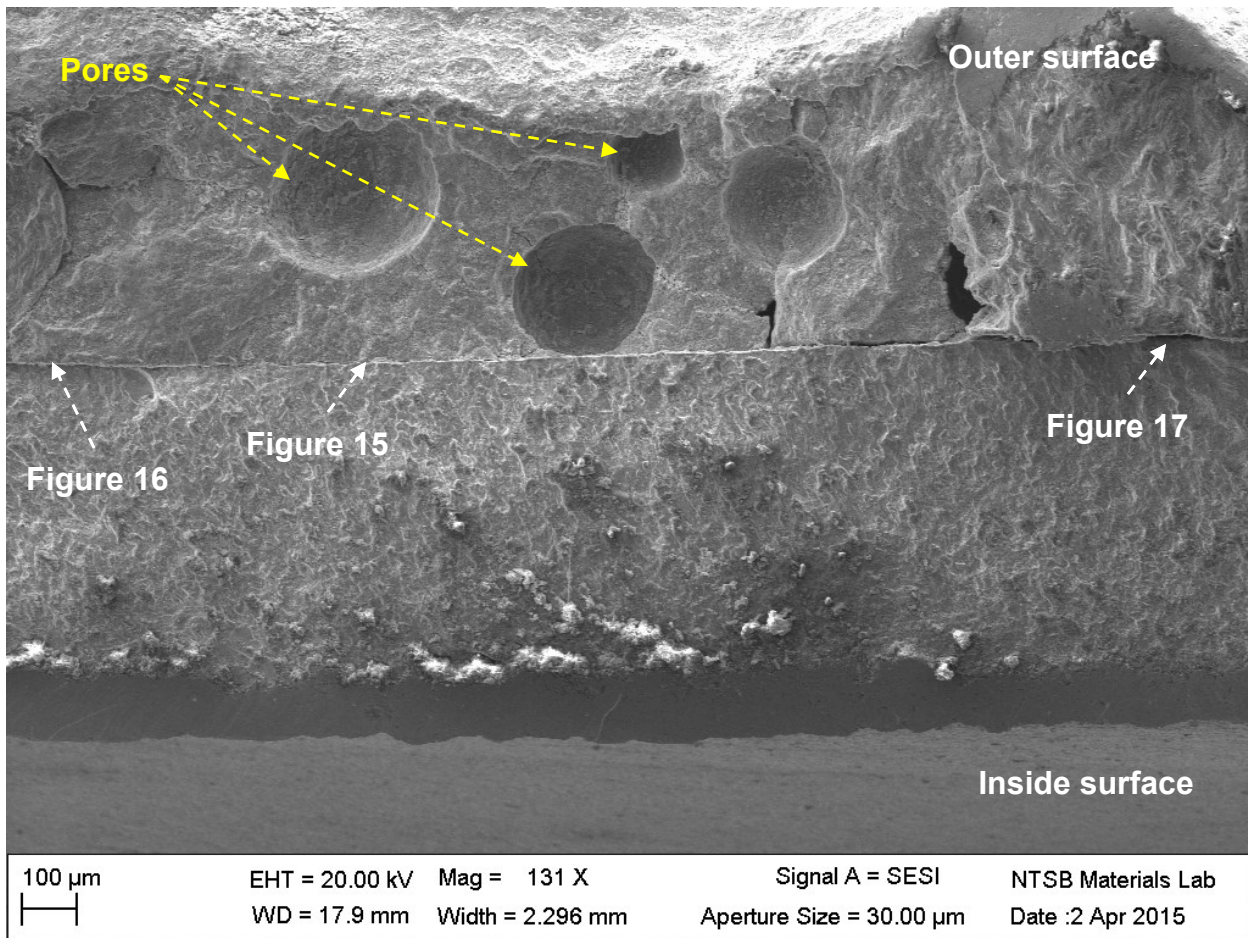


Figure 14 – SE micrograph of the weld line fracture surface, also showing the fractured outer braze layer that contained pores.

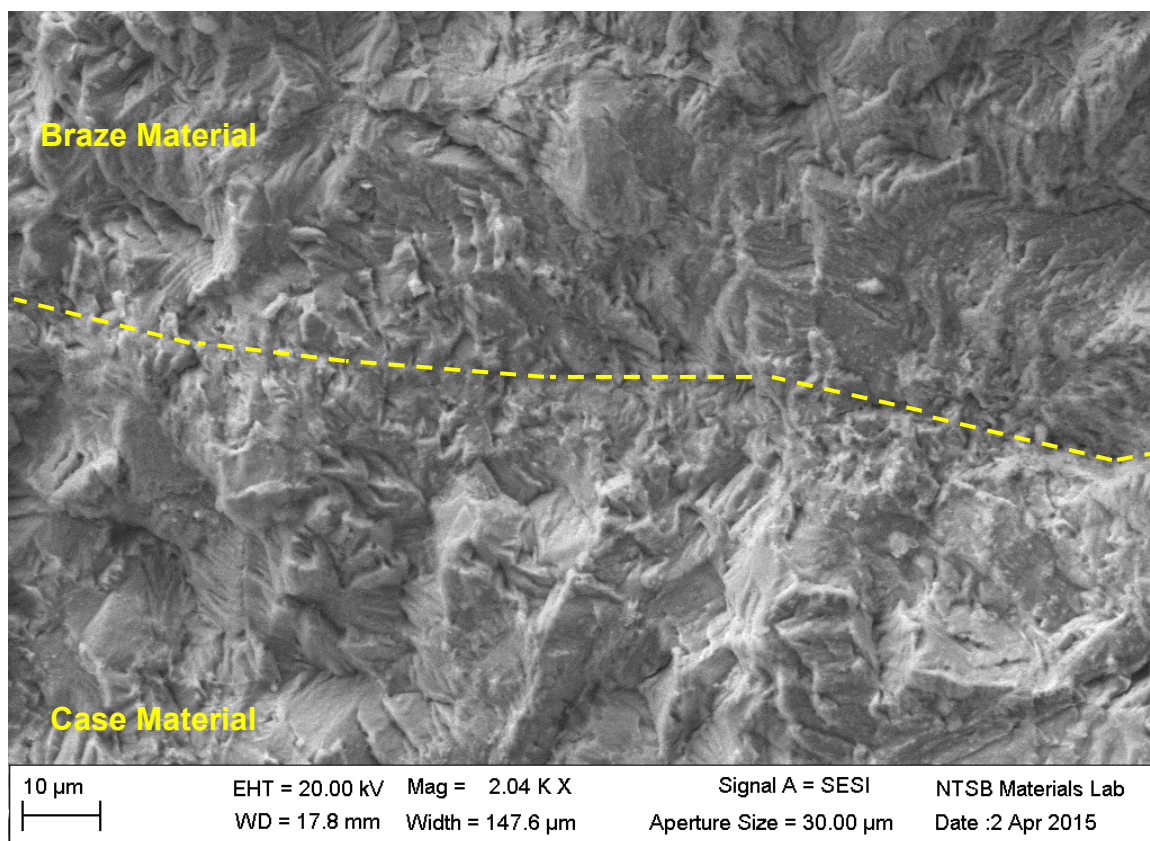


Figure 15 – SE micrograph of fatigue striations across a well-adhered interface between the case and braze material, location depicted in Figure 14.

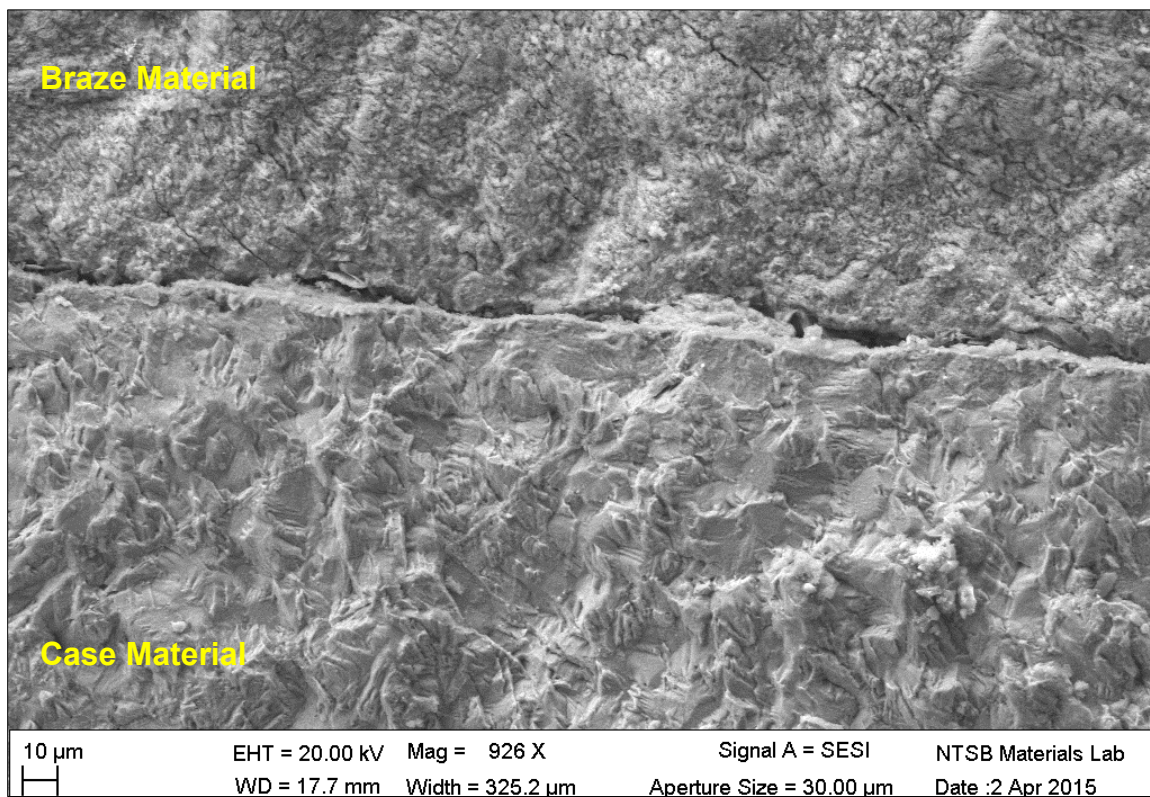


Figure 16 – SE micrograph of fatigue striations across a gapped interface between the case and braze material, location depicted in Figure 14.

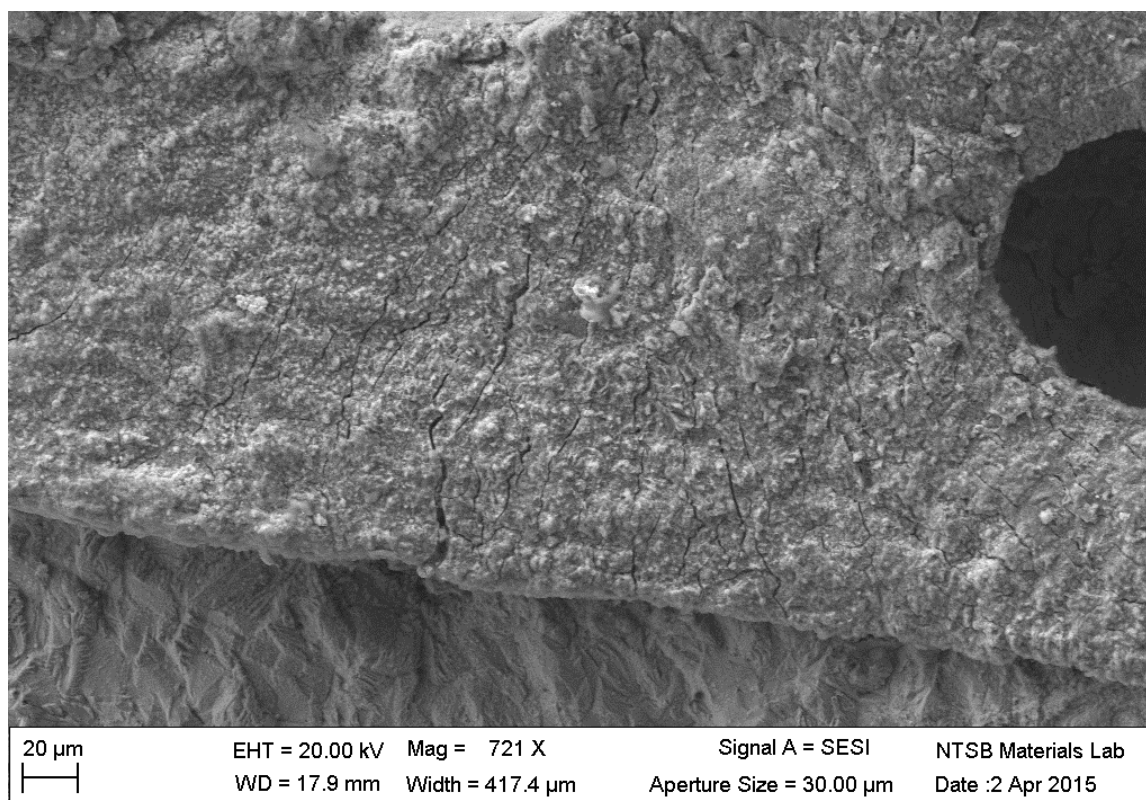


Figure 17 – SE micrograph of the braze fracture surface, showing small perpendicular cracks in the braze, location depicted in Figure 14.

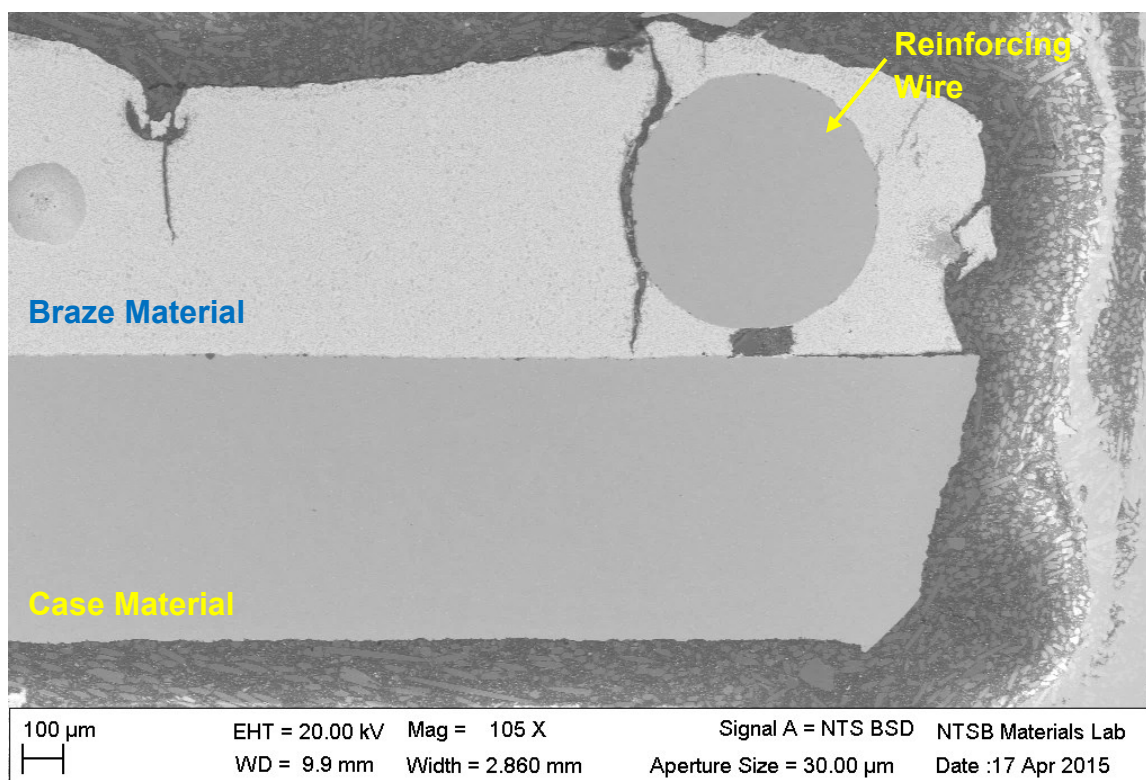


Figure 18 – Backscattered electron (BE) micrograph of a polished cross section of the braze reinforcement of the case, away from the fracture surface. Pores were visible in the braze, with cracks emanating from the pores and stainless steel wire reinforcement.

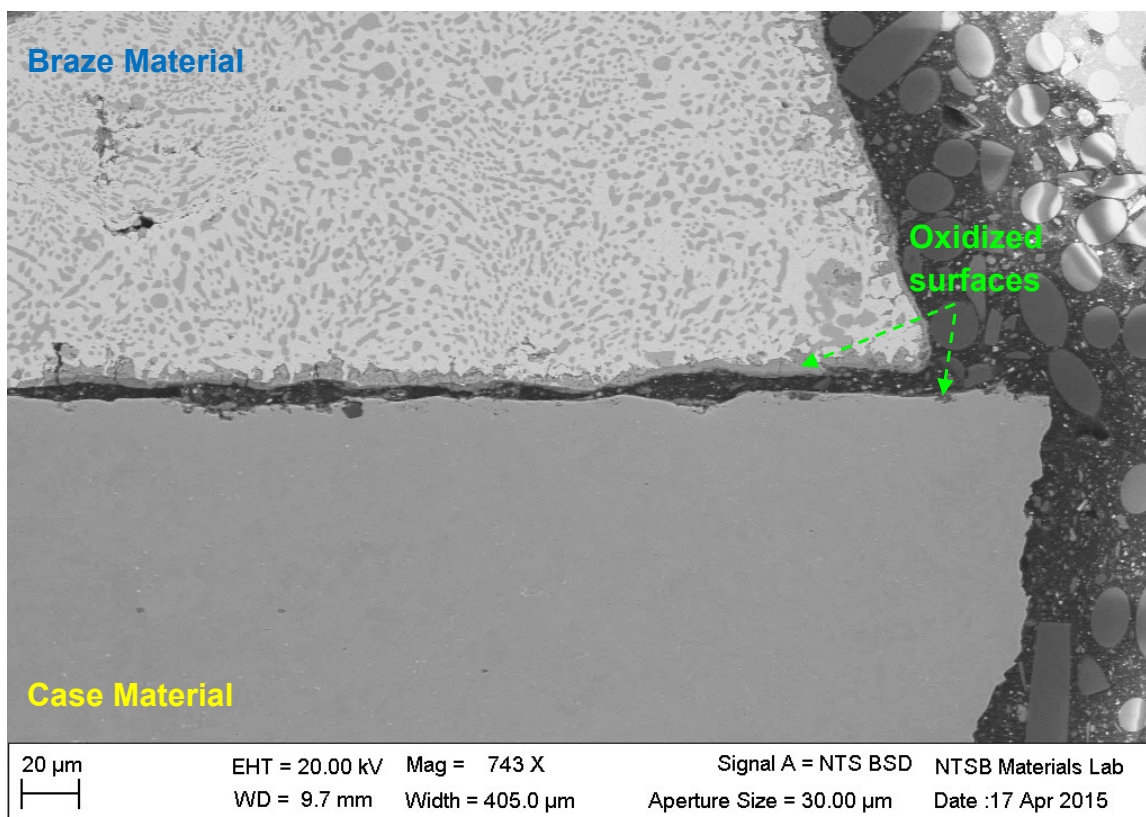


Figure 19 – BE micrograph showing an oxidized gap between the braze and the case materials.

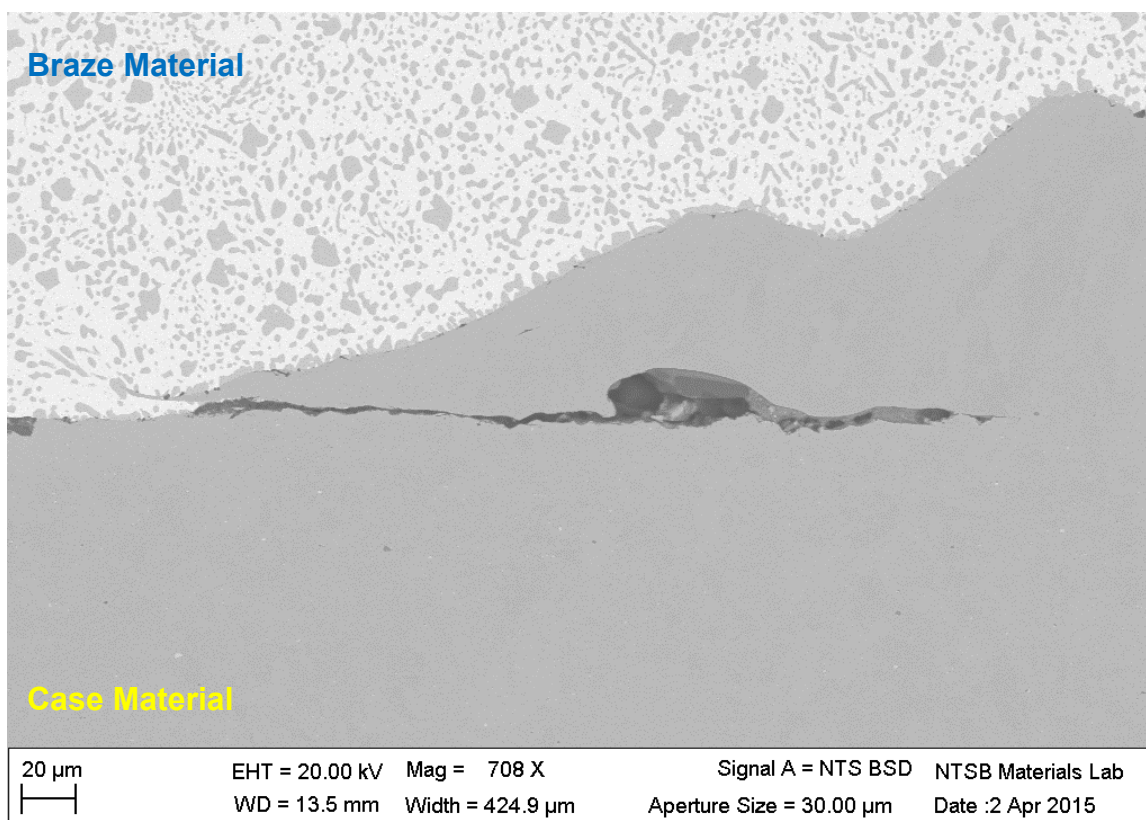


Figure 20 – BE micrograph of a crack in the case material emanating from the interface between the braze and the case.

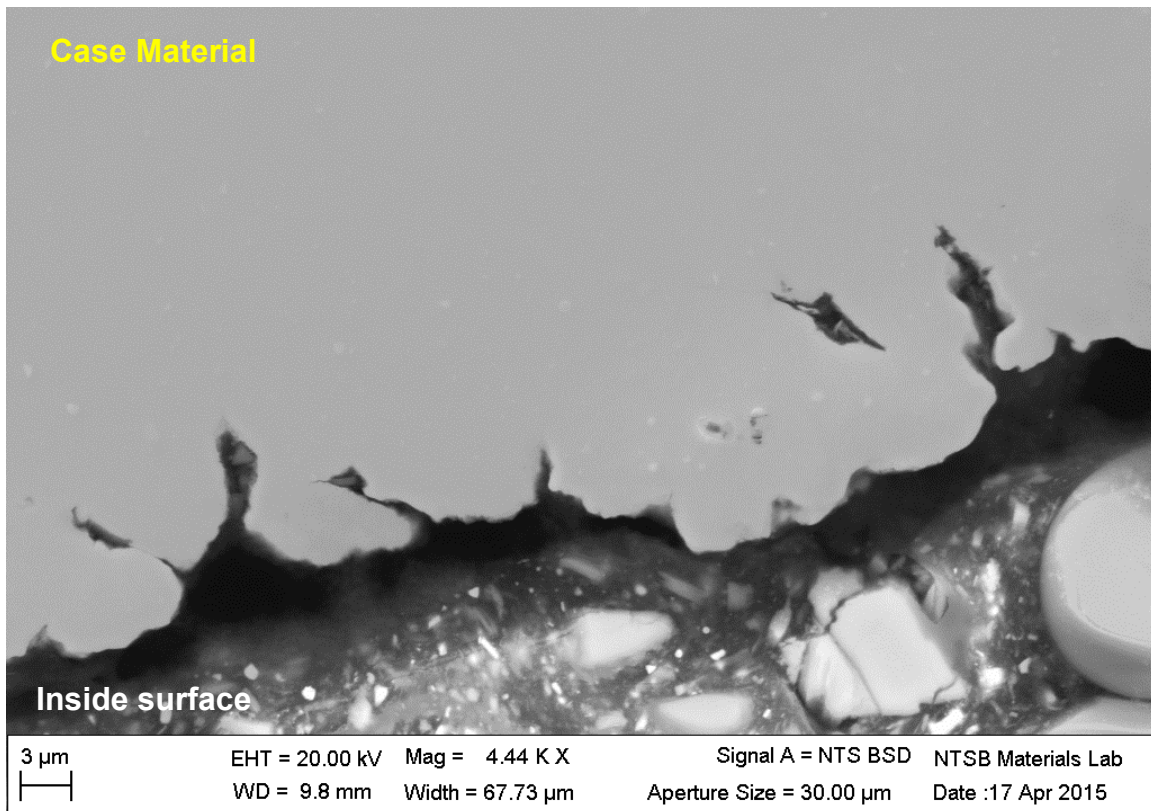


Figure 21 – BE micrograph showing a cross-section of the inside surface of the case, with small depressions along the inside surface.