

NATIONAL TRANSPORTATION SAFETY BOARD

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



November 16, 2018

MATERIALS LABORATORY FACTUAL REPORT

Report No. 18-090

A. ACCIDENT INFORMATION

Place : Jacksonville, Alabama
Date : May 12, 2018
Vehicle : Beech BE35-A33, N486T
NTSB No. : ERA18FA146
Investigator : Ralph Hicks, AS-ERA

B. COMPONENTS EXAMINED

Exhaust system muffler heat exchanger.

C. DETAILS OF THE EXAMINATION

An overall view of the submitted muffler heat exchanger assembly is shown in figure 1. Cracks were observed in multiple locations including the forward left side shown in the left image in figure 1. On the heat exchanger portion of the assembly, the forward end flange and aft end flange were bent forward at the left side and the lower left side, respectively. The exhaust pipe attachment segments at the forward and aft ends of the muffler were bent to the right relative to the muffler axis. At the crack location on the left side forward end, the muffler end face was displaced forward at the outer circumference, exposing a crack opening from the interior to exterior of the muffler and heat exchanger as indicated with a bracket in figure 1.

The crack through the muffler wall and multiple cracks through the heat exchanger end flanges were located adjacent to the circumferential welds to the muffler end faces. The heat exchanger forward end flange had circumferential cracks at two locations including the location where the muffler wall was cracked on the left side shown in figures 1 and 2. Another crack through the forward end flange was located at the top of the assembly. The heat exchanger aft end flange had circumferential cracks located at the top and the lower left sides of the assembly, and the crack at the top side is shown in figure 3.

A crack was present in the muffler forward end face as indicated in figure 2. The crack was located adjacent to one of 3 welds for internal baffles attached to the end face next to the exhaust stack attachment tube. Three cracks were also present in the muffler aft end face adjacent to each of the 3 similar welds on the aft end face.

Crack fracture features were examined using an optical stereomicroscope. In the muffler wall crack at the forward left side, fracture features generally were covered with oxides and exhaust deposits across the thickness of the fracture. A close view of typical fracture features observed near the middle of the crack through the muffler wall is shown in figure 4. Near the ends of the muffler wall crack, light gray fracture features were observed as shown in figure 5, consistent with a relatively recent overstress fracture. The through-thickness oxidized portion of the crack in the muffler wall measured 3.35 inches long circumferentially.

Oxidized fracture features were also observed on the crack surfaces through the heat exchanger forward end flange shown in figure 2. The length of the oxidized portion of the crack at the left side of the end flange was 4.5 inches long. At the top of the forward end flange, the oxidized portion of the crack was 1.75 inches long.

At the aft end of the heat exchanger, the crack through the aft end flange at the upper side of the assembly (indicated in figure 3) was 4.25 inches long. The upper portion of the aft end flange had limited deformation, and crack surfaces were not exposed for examination. At the lower left side of the assembly, the heat exchanger aft end flange was deformed, and the crack fracture features were exposed. The fracture features through the thickness were covered in oxides, and the length of the oxidized portion of the crack measured 2.25 inch. At one end of the crack, light gray fracture features were observed consistent with a relatively recent fracture with no significant oxidation.

Some of the cracks in the muffler end faces such as the crack noted in figure 2 had a crack opening that allowed for examination under the optical stereomicroscope, and visible fracture features appeared to be covered with oxidation and exhaust deposits. The four cracks in the muffler end faces (1 in the forward end and 3 at the aft end) were each approximately 0.8 inches to 0.9 inches long.

To facilitate a further examination of the crack fracture surfaces at the forward left side of the muffler heat exchanger assembly, a bandsaw was used to separate the cracked segment of the heat exchanger forward end flange from the rest of the assembly. Next, a water-cooled abrasive saw was used to make two longitudinal cuts through the muffler end face and the muffler wall adjacent to the crack. A Dremel tool was used to make a transverse cut through the wall intersecting the longitudinal cuts to separate the wall piece with the crack from the remainder of the wall. The wall piece and the end flange piece were then encased in a metallurgical mount and polished.

Views of the polished cross-sections of the muffler wall forward and aft of the crack are shown in figures 6 and 7. The muffler wall aft of the fracture showed significant thickness variations associated with oxidation, and in one area aft of the crack, the wall was corroded nearly through the thickness in the plane of polish. As shown on the forward side of the fracture, the muffler wall showed branching intergranular cracks through the thickness at the fracture surface and through much of the thickness in areas forward of the fracture. Branching intergranular cracks were also observed on and adjacent to the fracture through the heat exchanger forward end flange shown in figure 8.

The polished cross-sections were etched using Vilella's reagent, and an overall micrograph showing the etched microstructure at the forward sides of the fracture is shown in figure 9. The fracture through the muffler wall occurred approximately 0.13 inch aft of the weld bead, and the fracture through the heat exchanger end flange occurred within 0.013 inch aft of the weld bead.

Areas of the muffler wall and heat exchanger forward end flange were sanded to expose fresh metal surfaces, and the exposed surfaces were analyzed using a Thermo Scientific Niton XL3t-980 x-ray fluorescence (XRF) alloy analyzer. The alloy analyzer identified the muffler wall material as type 309 stainless steel and the heat exchanger end flange material as type 321 stainless steel.

Matthew R. Fox, Ph.D.
Senior Materials Engineer

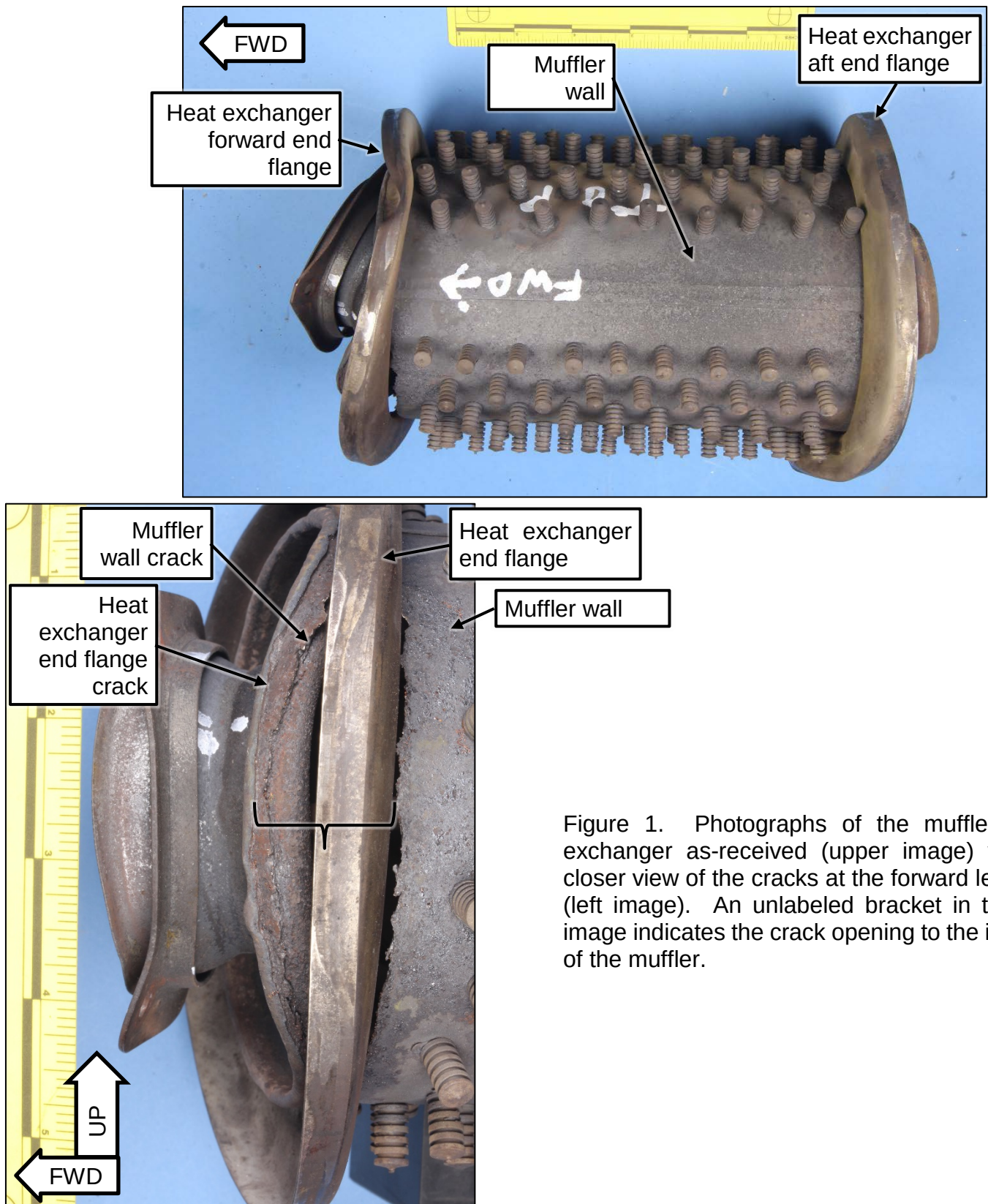


Figure 1. Photographs of the muffler heat exchanger as-received (upper image) with a closer view of the cracks at the forward left side (left image). An unlabeled bracket in the left image indicates the crack opening to the interior of the muffler.

Figure 2. View of the forward end of the heat exchanger muffler showing cracks in the shroud end flange and muffler end face.

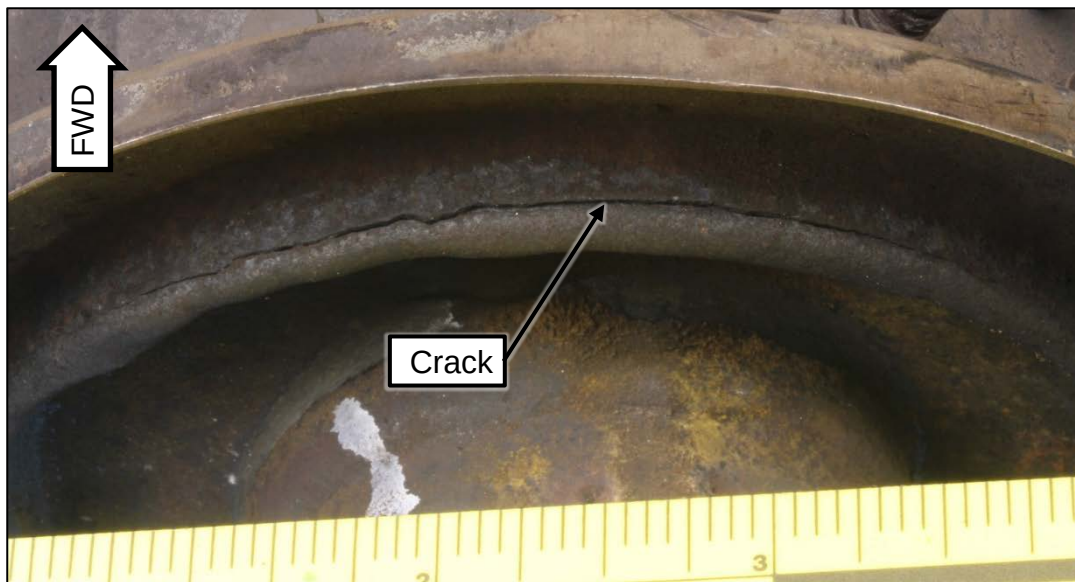
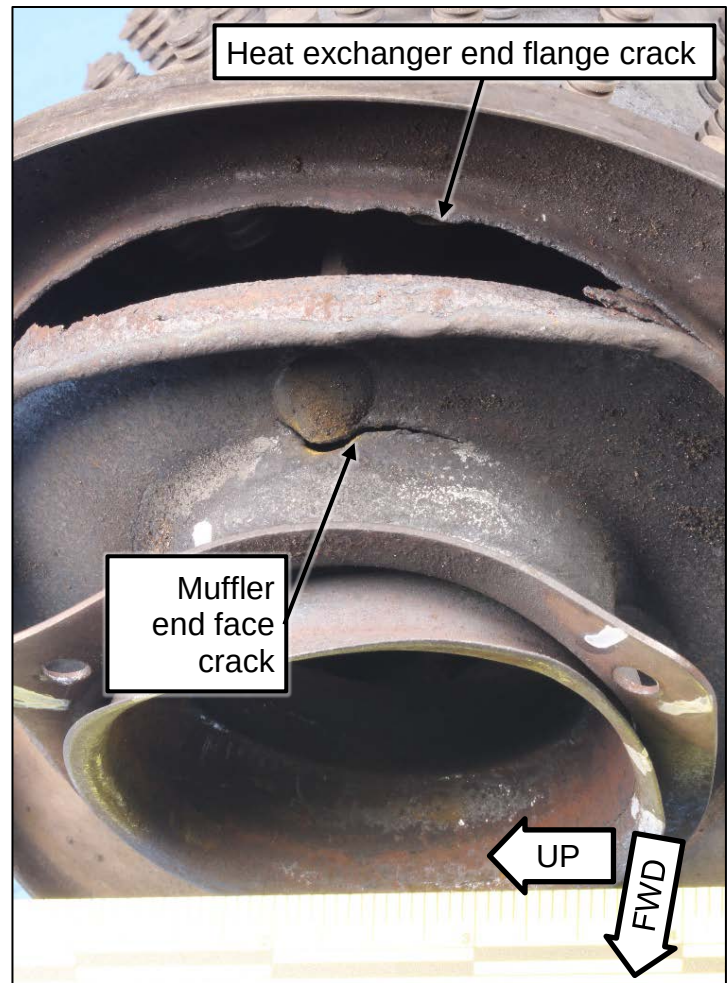


Figure 3. Crack in the aft shroud end flange adjacent to the weld at the top of the muffler heat exchanger.



Figure 4. Fracture surface near the middle of the crack in the muffler wall as viewed looking aft.

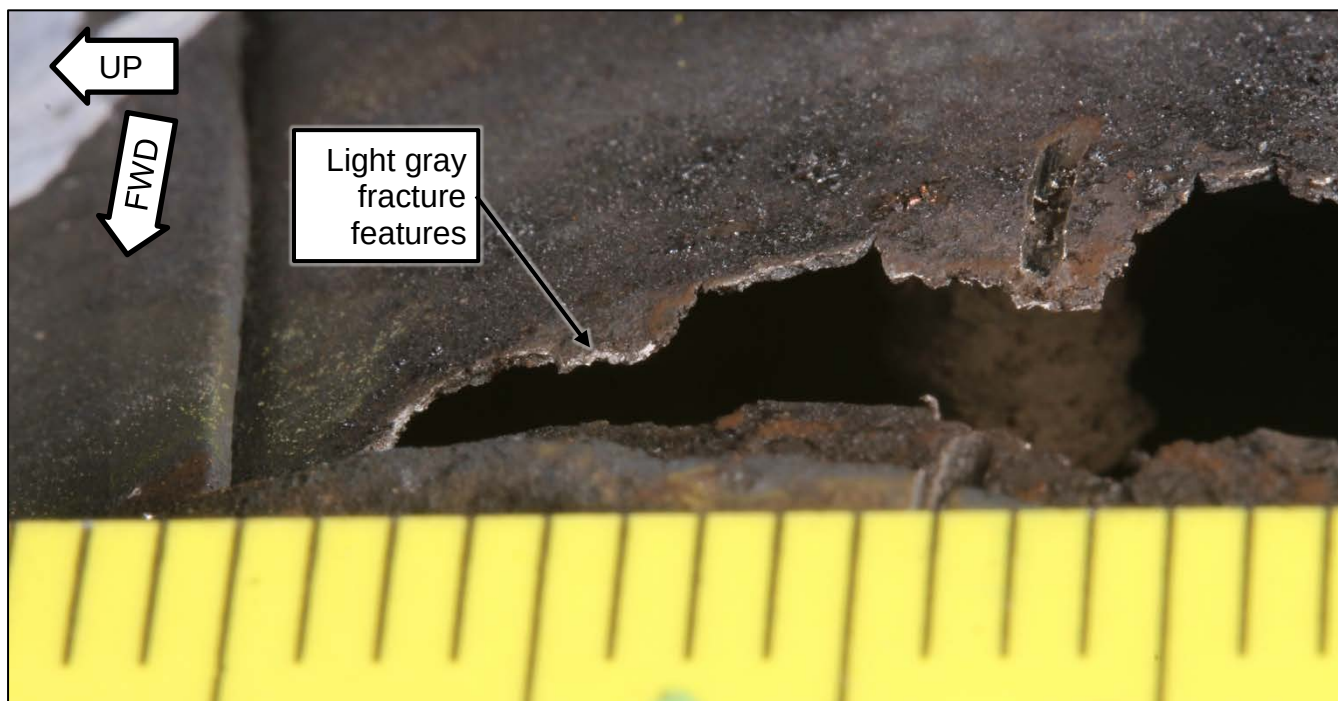


Figure 5. Fracture surface at the upper end of the crack in the muffler wall as viewed looking aft.

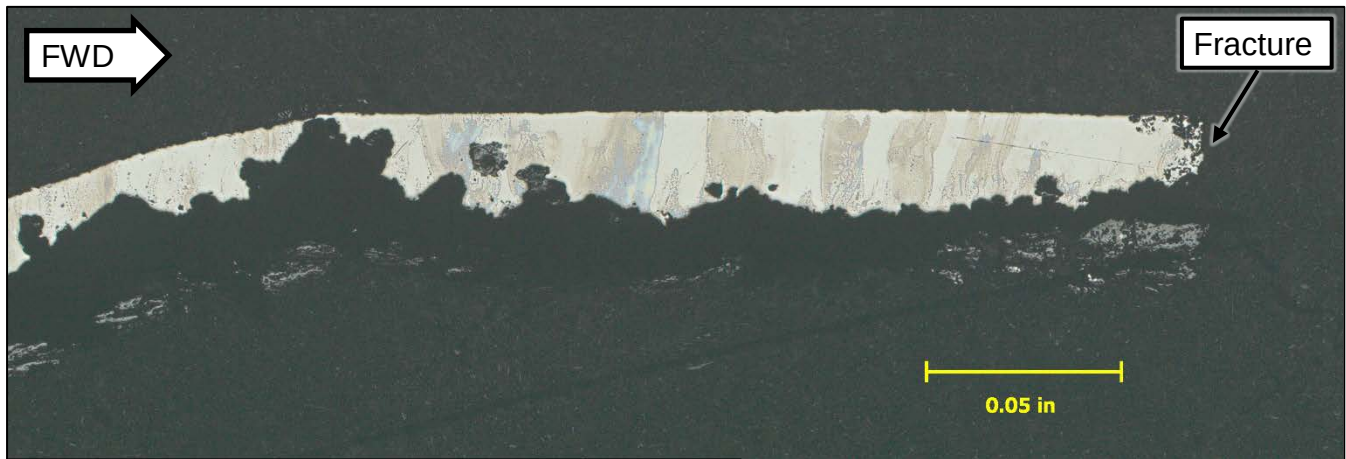


Figure 6. Brightfield optical micrograph of the as-polished cross-section through the muffler wall near the middle of the crack showing the wall cross-section adjacent to the fracture. Color variations on the unetched surface are due to staining from polishing and rinse agents that were retained in the oxides and deposits that later bled onto the surface during drying.

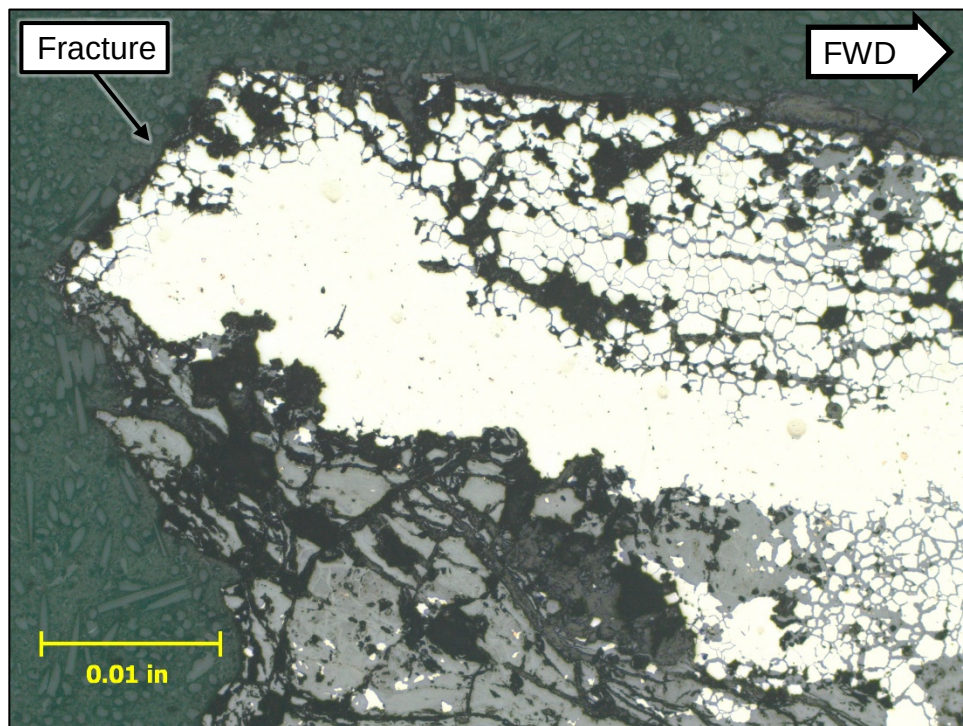


Figure 7. Brightfield optical micrograph of the as-polished cross-section through the muffler wall showing the cross-section forward of the fracture.

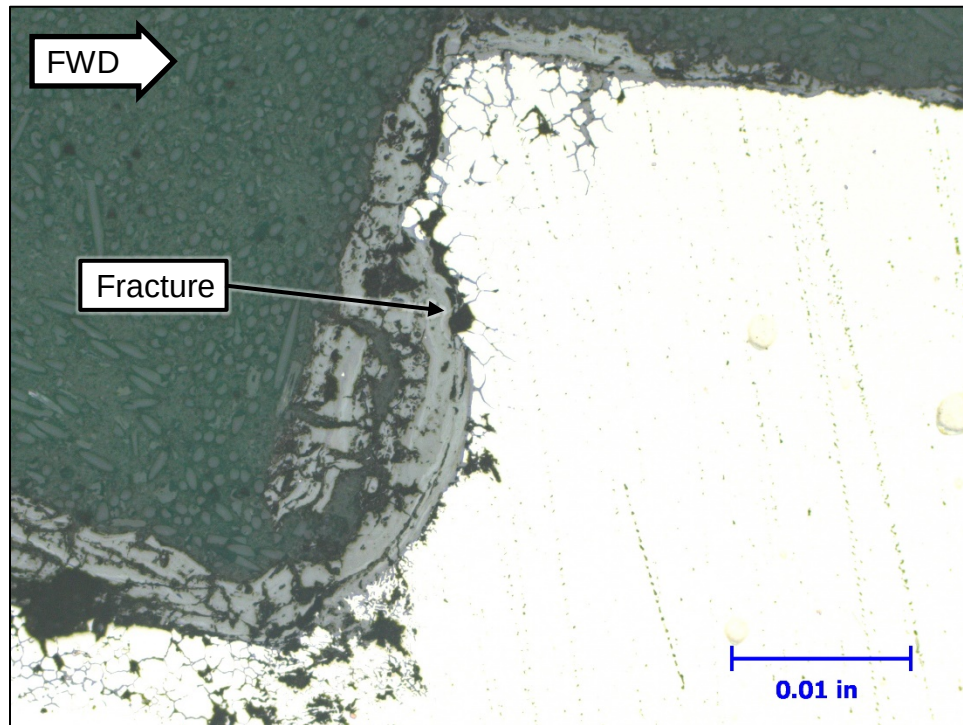


Figure 8. Brightfield optical micrograph of the as-polished cross-section at the forward side of the fracture through the shroud forward flange.

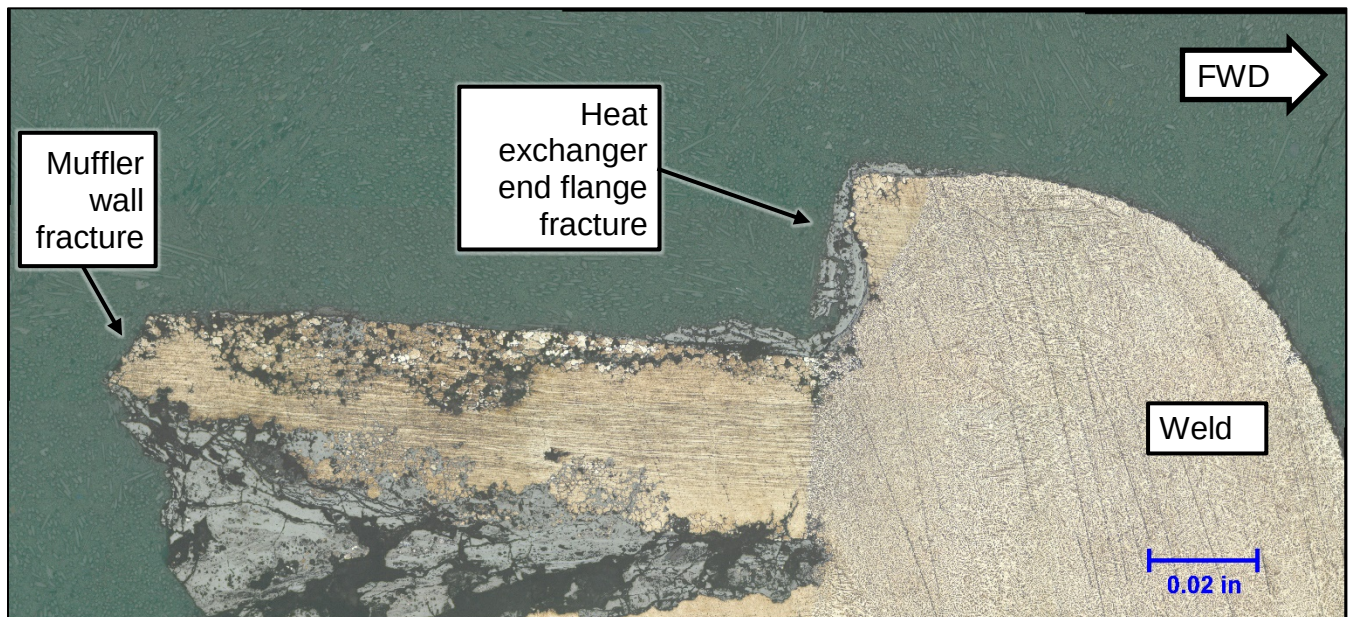


Figure 9. Brightfield optical micrograph of the polished cross-section forward of the cracks as etched with Vilella's reagent.