

NATIONAL TRANSPORTATION SAFETY BOARD

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



December 30, 2014

MATERIALS LABORATORY FACTUAL REPORT

Report No. 14-013

A. ACCIDENT INFORMATION

Place: Lake Park, Georgia.
Date: December 10, 2012.
Vehicle: Diamond DA 40, N840DS.
NTSB No.: ERA13FA083.
Investigator: Todd Gunther.

B. COMPONENTS EXAMINED

1. Elevator trim cable, separated end.
2. Exemplar swage tensile test samples.

C. DOCUMENTS REVIEWED

1. Diamond Aircraft Industries drawing DAI-9027-38-01 revision 3, titled Bowden Cable-Trim.
2. DURA¹ drawing 1-6662020R03 00 revision a, titled Trimmzug T5, DAI-9027-38-01.
3. VOFA² drawing 1020001-009R3403 revision 3, titled Gew. -Gleitbolzen M5.
4. Vofa-Werk³ drawing 1350151R0401 revision a, titled Seele Type 5.

D. DETAILS OF THE EXAMINATION

The as-received portion of the elevator trim cable assembly showing the separated swage bolt is depicted in figure 1. A closer view of the separated area is shown in figure 2. The aircraft manufacture, Diamond Aircraft Industries (DAI), supplied drawing DAI-9027-38-01 (document 1 in section C) which contained DURA drawing 1-6662020R03 00. DAI also supplied DURA drawing 1-6662020R03 00 (document 2 in section C), VOFA drawing 1020001-009R3403 (document 3 in section C), and Vofa-Werk drawing 1350151R0401 (document 4 in section C) and a translation of notes on the drawings.

Accident trim cable examination

The separated ends of the accident trim cable are depicted in figure 2, with the bolt and the core cable identified. The core cable consists of the cable strand with a plastic

¹ DURA Automotive Systems GmbH, Dusseldorf, Germany part of DURA Automotive Systems Inc. Auburn Hills, MI.

² VOFA Group, Dusseldorf, Germany, part of DURA Automotive Systems.

³ Vofa-Werk Xavier Vorbruggen GmbH, Dusseldorf, Germany, part of DURA Automotive Systems.

coating⁴ that is removed in the area where the bolt is swaged onto it. The fractured swaged end of the bolt is identified.

Examination of the cable strand revealed twelve outer wires that were clean and exhibited bands of deformed material along their outermost surfaces. A closer view of the cable strand is illustrated in figure 2. The strand contains nineteen wires in the configuration of 7 inner wires and 12 outer wires (e.g. 7 x 12, 19-wire strand). Via micrometer, the average strand outside diameter is about 0.142 inch (3.6 mm). Measured by digital microscopy, the average wire diameter is about 0.027 inch (0.7 mm). The outer wires are wound in a right lay⁵. Drawing 1350151R0401 indicates that the strand had a diameter of 3.5 mm (0.138 inch) and consists of nineteen zinc-coated wires, each with a diameter of 0.7 mm (0.027 inch). The drawing also illustrates and specifies a left lay.

The ball end and the nut were removed from the bolt and measurements revealed that the bolt satisfied the dimensional requirements in drawing 1020001-009R3403. The drawing specified the bolt material as DIN 1.4305 (compositionally equivalent to UNS S30300) and drawing 1-6662020R03 00 specifies the bolt material as stainless steel. A closer view of the fractured swaged end is illustrated in figure 3. The swaging tool pressed five flat regions equally spaced around the circumference. Ribs of extruded material are formed between the flat swaging jaws. The fracture occurred along a rib of extruded material between the swaging jaws. Brown-colored deposits are present in the fracture as indicated in figures 3 and 4.

As show in figure 2, the swaged area was cut from the bolt and was then cut lengthwise 180° to the crack to reveal the inside of the swage. As noted, a small lab fracture was created to part the two halves. The inner surface of the bolt swage area adjacent to the fracture is illustrated in figure 5 where circumferential lines consistent with a drilling operation and helical impression marks consistent with contact with the cable wires is identified. External views of the swaged are shown in figures 6 and 7.

As identified in figure 5 (see also figures 3 and 4), the deposit in the crack was evaluated by scanning electron microscopy (SEM) and standardless semi-quantitative energy dispersive spectroscopy (EDS). The EDS spectra, as shown in figure 8a, revealed the presence of carbon, oxygen, iron, zinc, magnesium, aluminum, silicon, phosphorous, sulfur, chlorine, potassium, calcium, chromium, manganese, and nickel. An SEM image is shown in figure 8b.

The fracture surface of the swage area (see figure 5), was examined by SEM and a typical scanning electron fractograph is shown in figure 9a. For comparison a scanning electron fractograph of the lab fracture region is shown in figure 9b. In both instances, the fracture micro-mode is microvoid coalescence (MVC) due to overstress. The longitudinal orientation of stringers within the fracture surface are consistent with a resulfurized steel such as UNS S30300.

⁴ Drawing 1350151R0401 specifies the coating as Ultramid® B5, a general purpose grade, high-viscosity thermoplastic polymer produced by BASF.

⁵ Lay is the wire direction of twist along the length of the strand.

As identified in figure 5, the inside surfaces of the bolt swage area exhibited helical impression marks (e.g. grooves) consistent with permanent deformation from contact with the cable wires (see figure 10.) In some of the helical impression grooves, flakes of zinc electroplating from the cable strands were present as shown in figure 10b. EDS analysis (figure 10a) revealed that the flakes are zinc. In many regions of the inside surfaces of the swage, white-colored salts were present in the helical impression grooves as shown in figure 11. EDS analysis (figure 11a) indicates that the white salts are composed largely of zinc and oxygen, consistent with zinc corrosion product.

Exemplar swage joint tensile tests.

At NTSB request, DURA, through DAI, performed five tensile tests on cable and bolt samples that had been assembled in accordance with the production specification. For the test the bolt samples were identified as 1, 2, 3, 4 and 5 and are illustrated in figure 12 with the swaged ends identified. The force to cable pull-out is shown in table 1. According to the manufacturer, the cable assembly (including the swaged area) is rated for 2000 N (about 450 lbf.) In each instance, the swaged region of the bolt developed a longitudinal crack as shown in figures 12 and 13. In all instances the cracks developed along the extruded rib between the flat regions of the swage (see figure 3 for example.) Similar to the inner surface of the accident swage, the inner surface of the tensile test swages exhibited helical impression marks consistent with contact with the cable wires as shown in Figure 14. SEM analysis of each fracture revealed that the crack occurred in overstress with a microvoid coalescence fracture mechanism. An example of a typical scanning electron fractograph is shown in figure 15.

Table 1 Tensile failure strength of the exemplar swage assemblies

Sample number	Failure strength (N)	Failure strength (lbf)	Fracture location	Fracture mechanism
1	4302	967	Extruded rib	MVC
2	3667	824	Extruded rib	MVC
3	3999	899	Extruded rib	MVC
4	3758	845	Extruded rib	MVC
5	3873	871	Extruded rib	MVC

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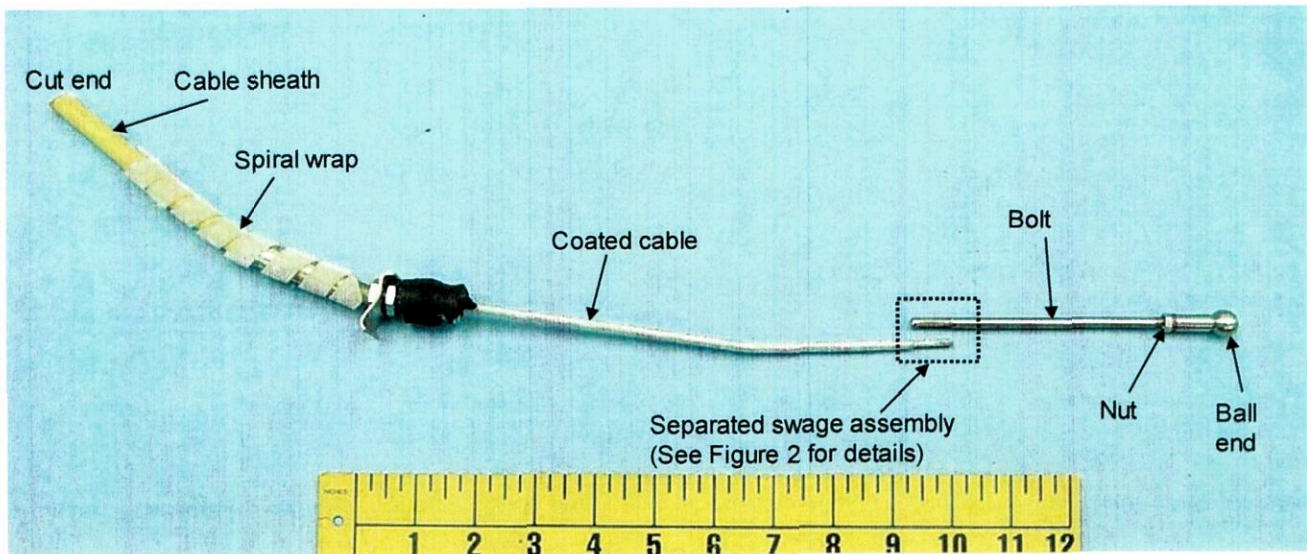


Figure 1 Overall image of the as-received accident elevator trim cable with the separated bolt and ball end identified.

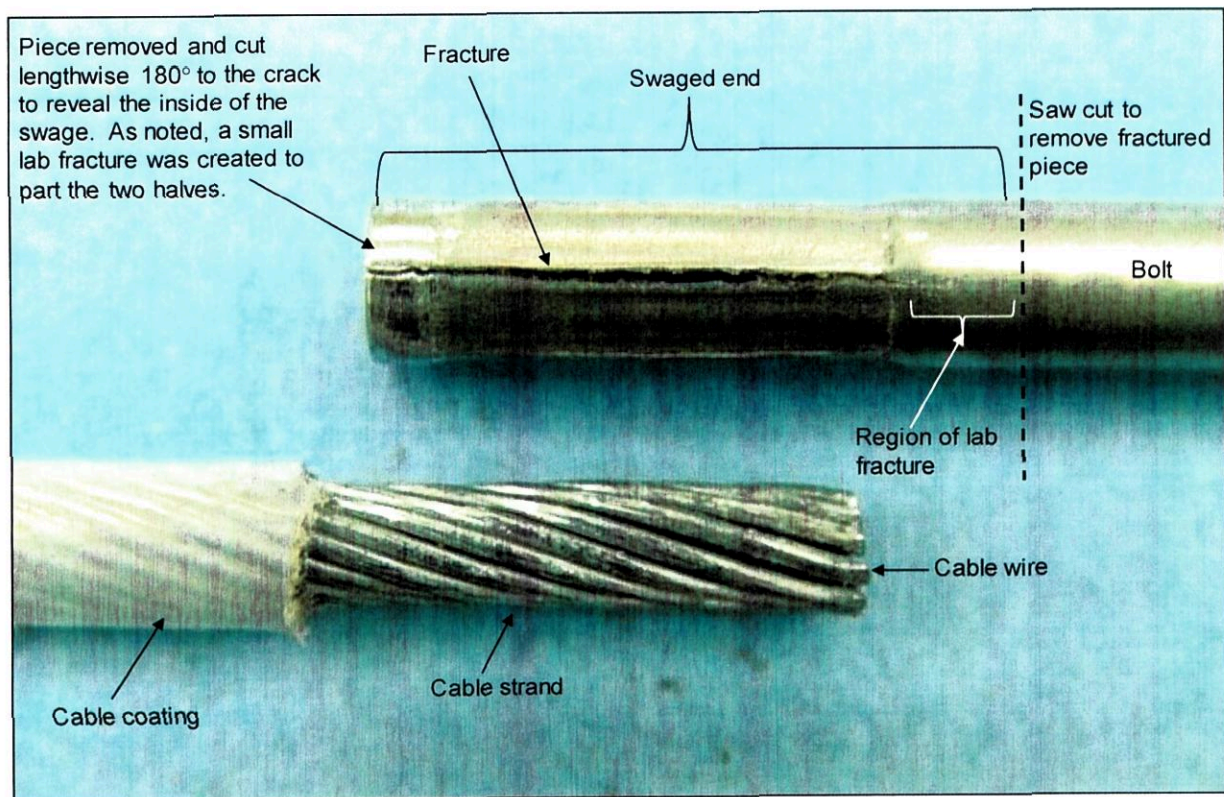


Figure 2 Closer view of the separated cable and fractured swaged area on the bolt. Locations of sample cutting are indicated.

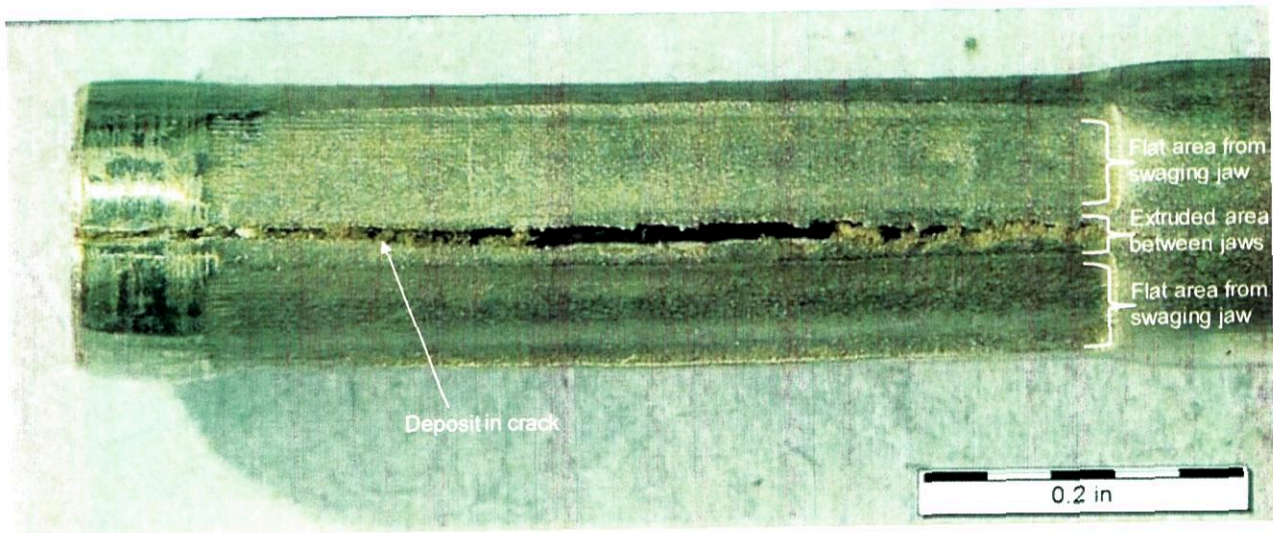


Figure 3 Closer view of the crack on the accident swaged bolt and the presence of a brown-colored deposit in the crack.

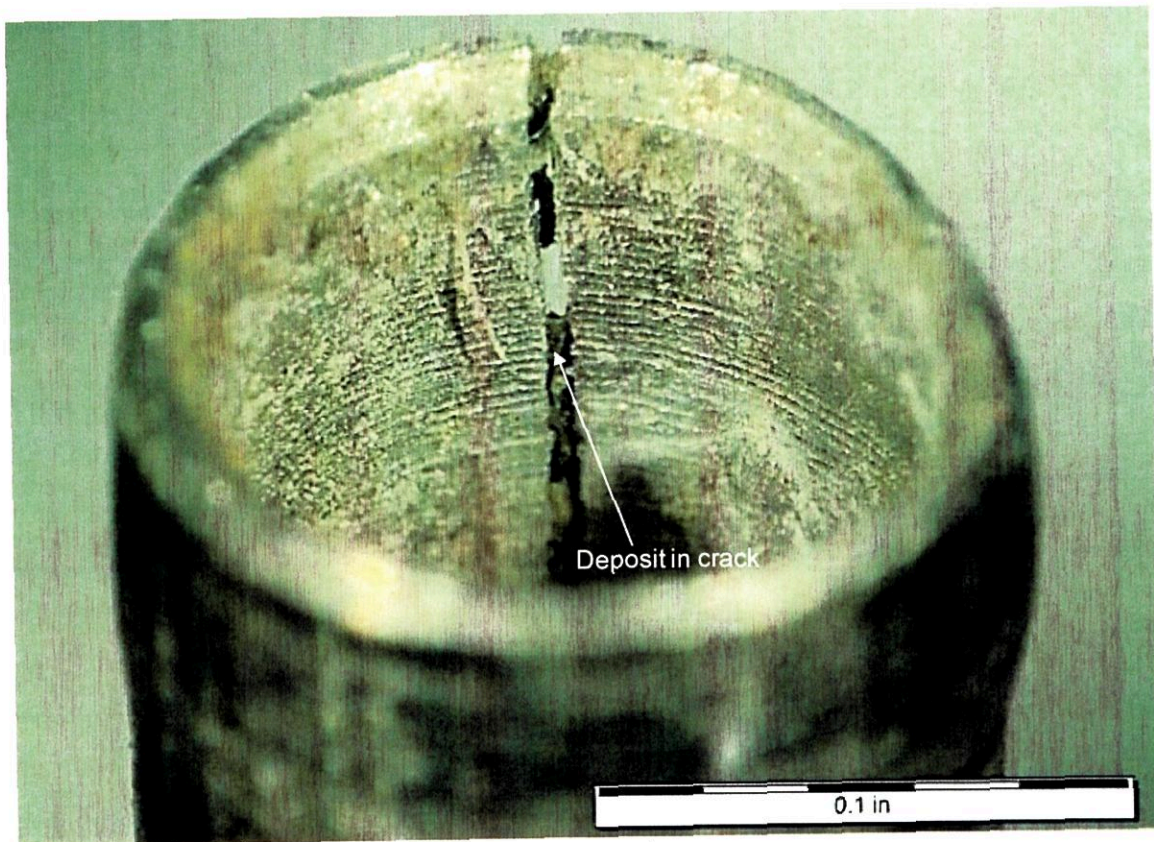


Figure 4 View from the inside of the crack on the accident swaged bolt and the presence of a brown-colored deposit in the crack.

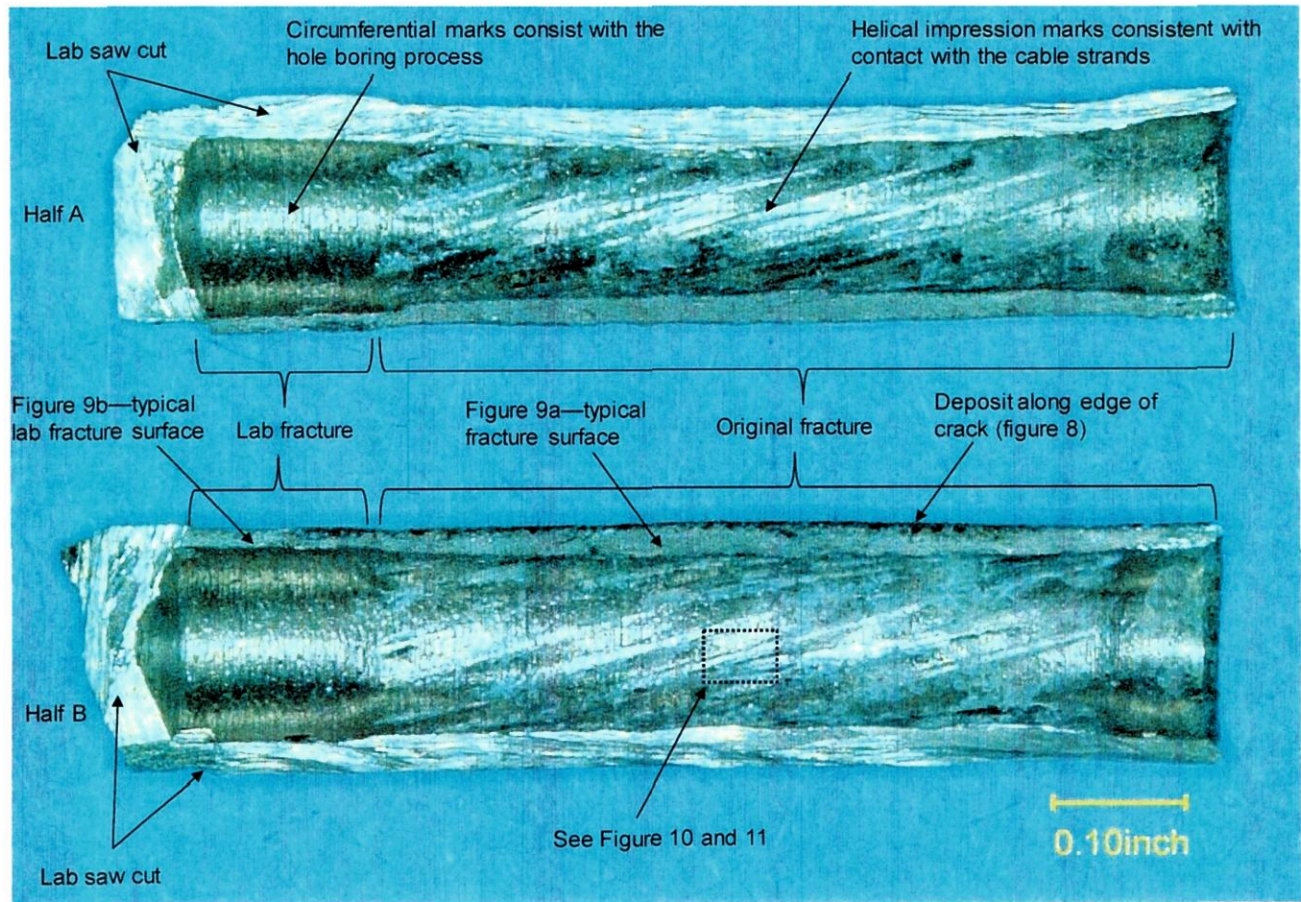


Figure 5 View of the inner surfaces of both halves of the swaged-portion of the bolt after cutting.

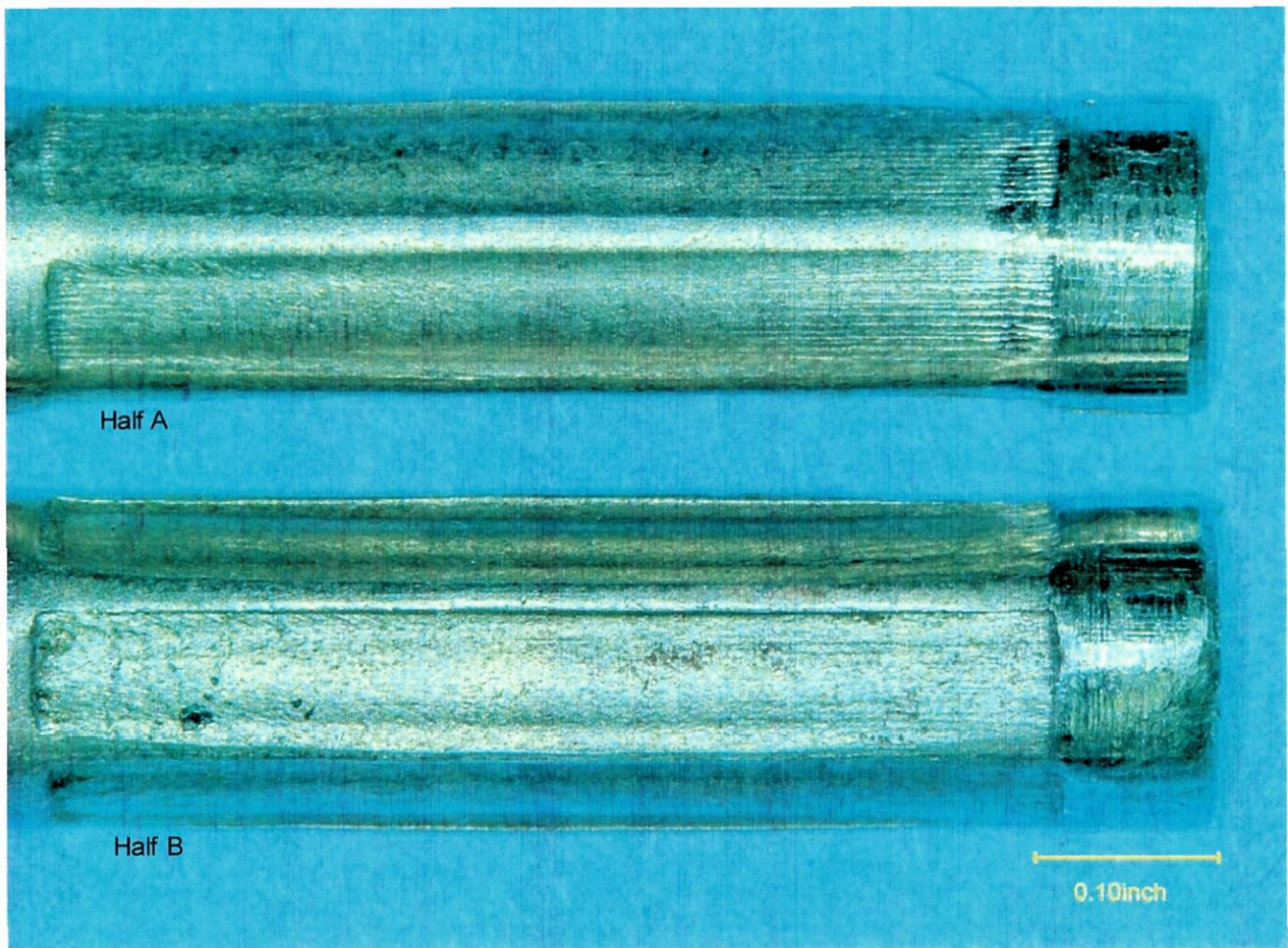


Figure 6 View of the outer surfaces of both halves of the swaged-portion of the bolt after cutting.

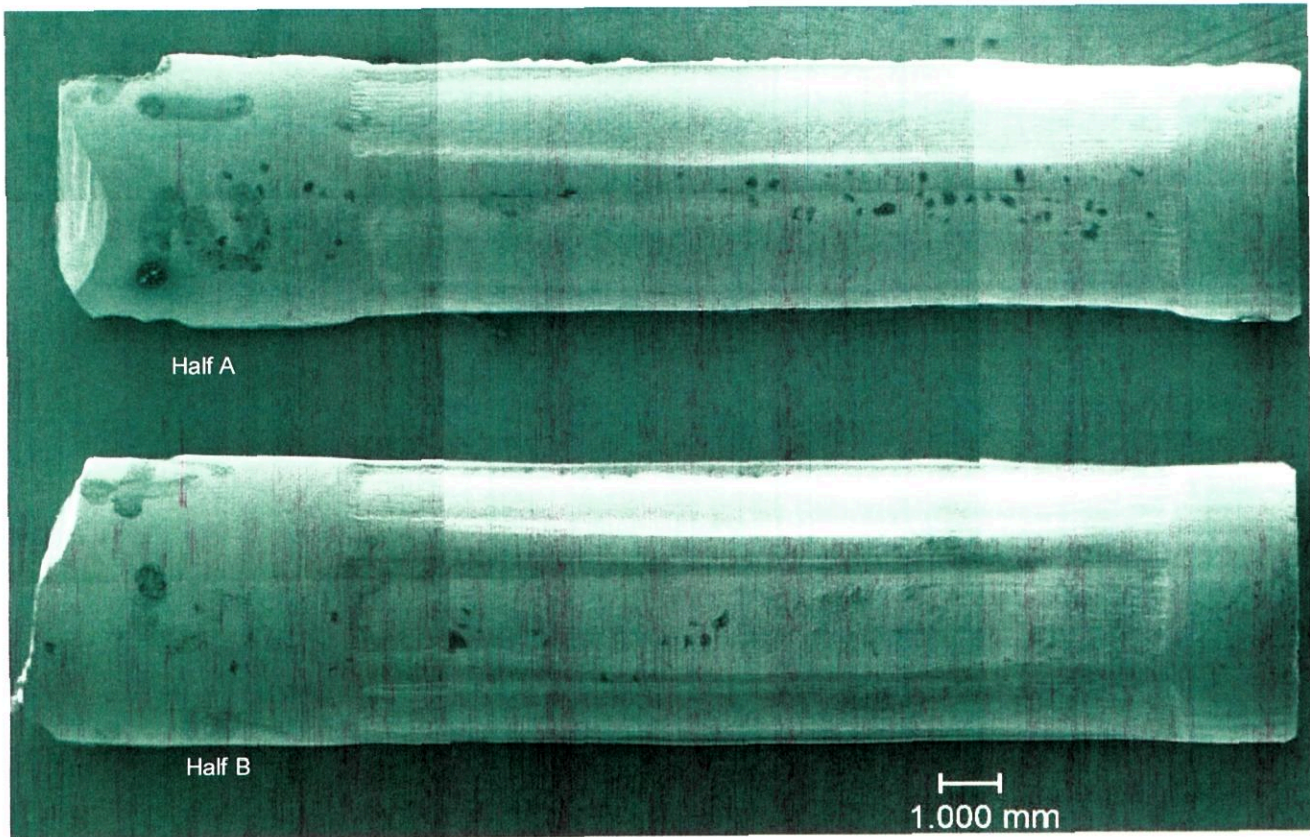


Figure 7 SEM image of the outer surfaces of both halves of the swaged-portion of the bolt after cutting.

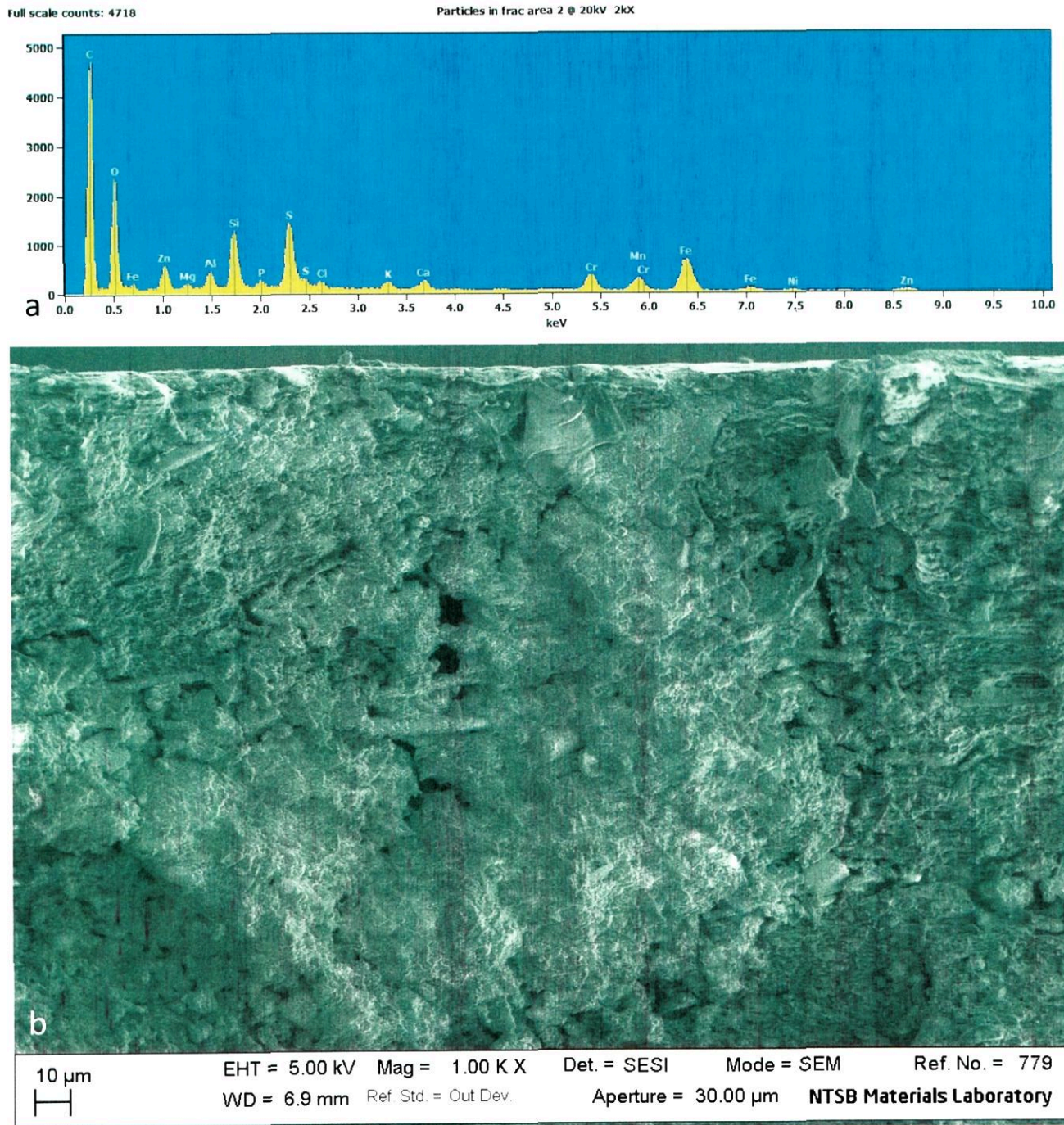


Figure 8 View (a) is an EDS spectra of the brown-colored deposit in the crack of the separated swaged assembly. View (b) is an SEM image of the brown-colored deposit in the crack of the separated swaged assembly.

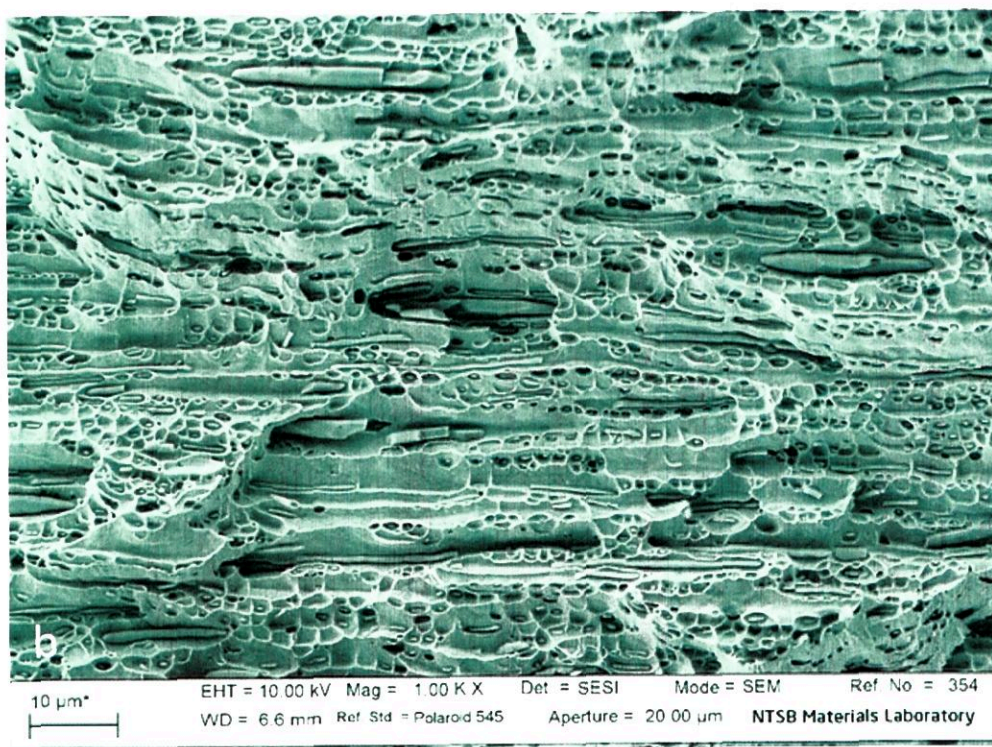
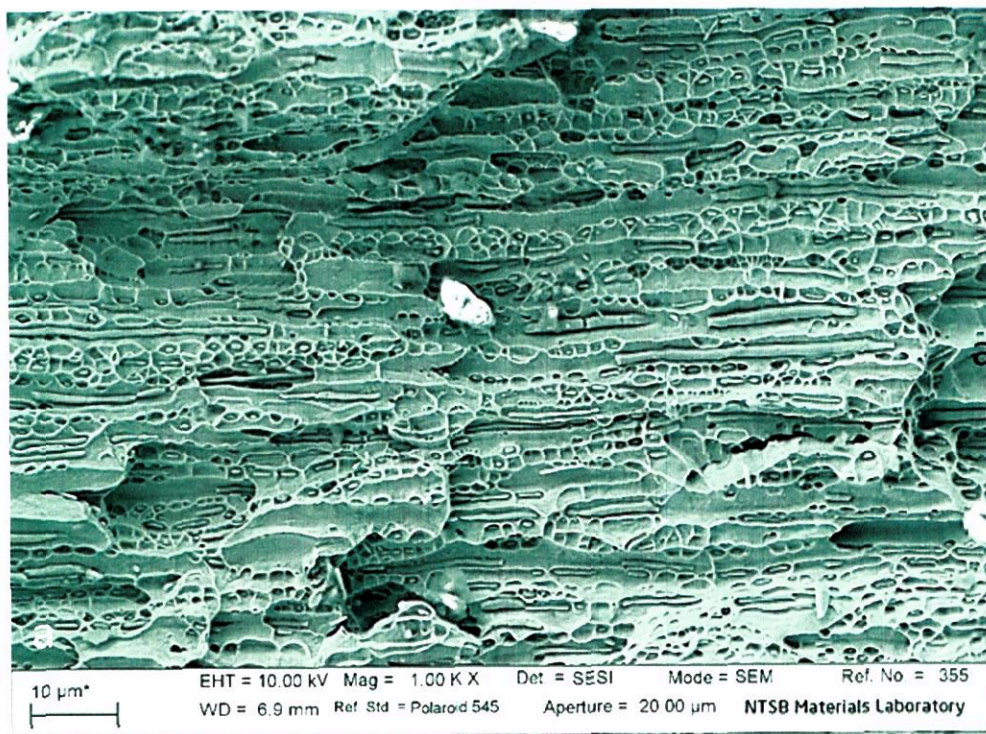


Figure 9 View (a) is an SEM fractograph of the crack in the swaged assembly. View (b) is an SEM fractograph of the lab fracture created in the swaged assembly when it was opened up.

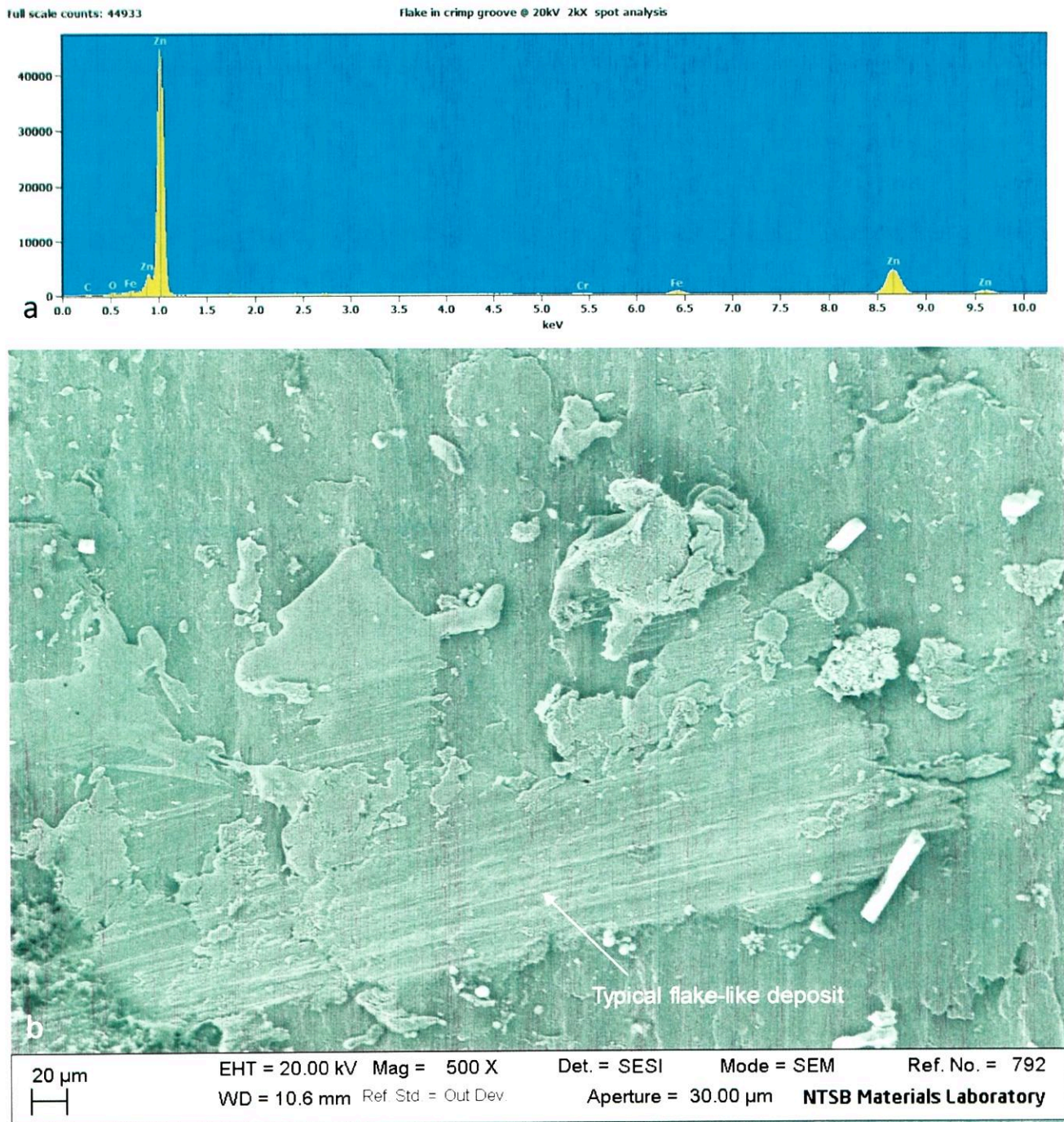


Figure 10 View (a) is an EDS spectra of a flake-like deposit in a helical impression groove. View (b) is an SEM micrograph of a flake-like deposit in a helical impression groove.

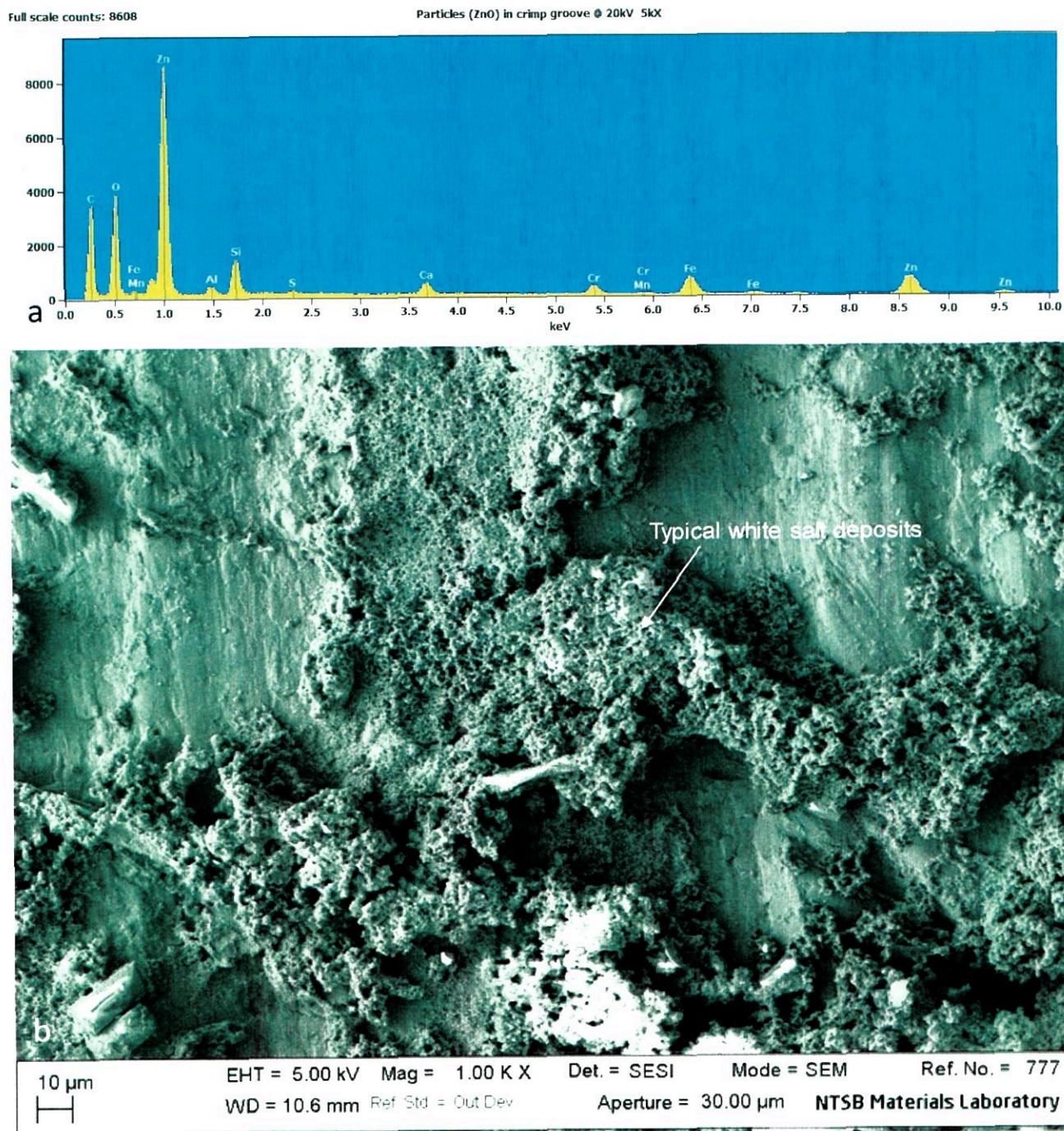


Figure 11 View (a) is an EDS spectra of white salt deposits in a helical impression groove. View (b) is an SEM micrograph of white salt deposits in a helical impression groove.

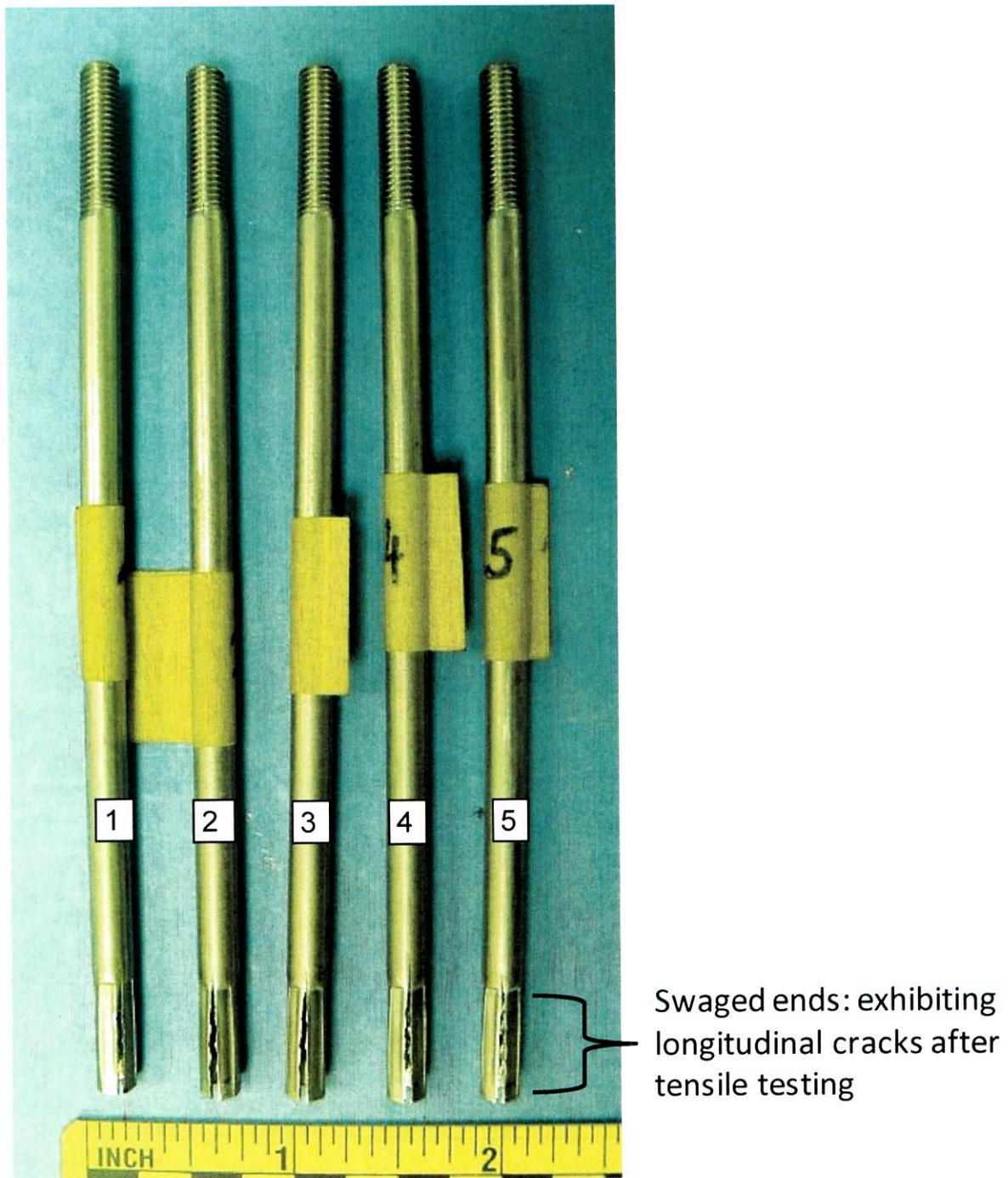


Figure 12 Image of the five exemplar test samples after tensile testing.

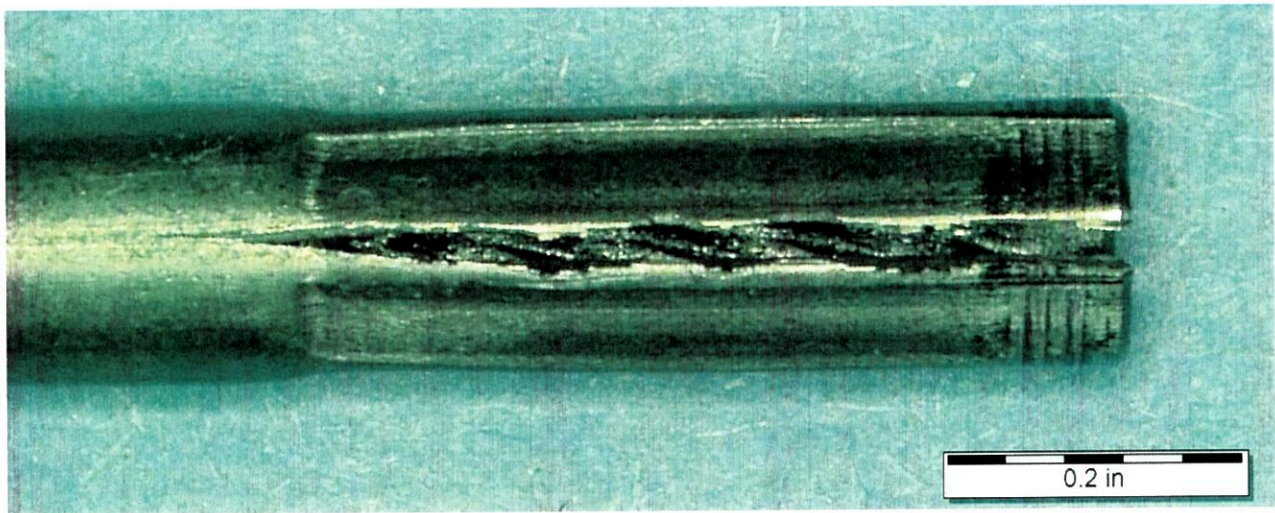
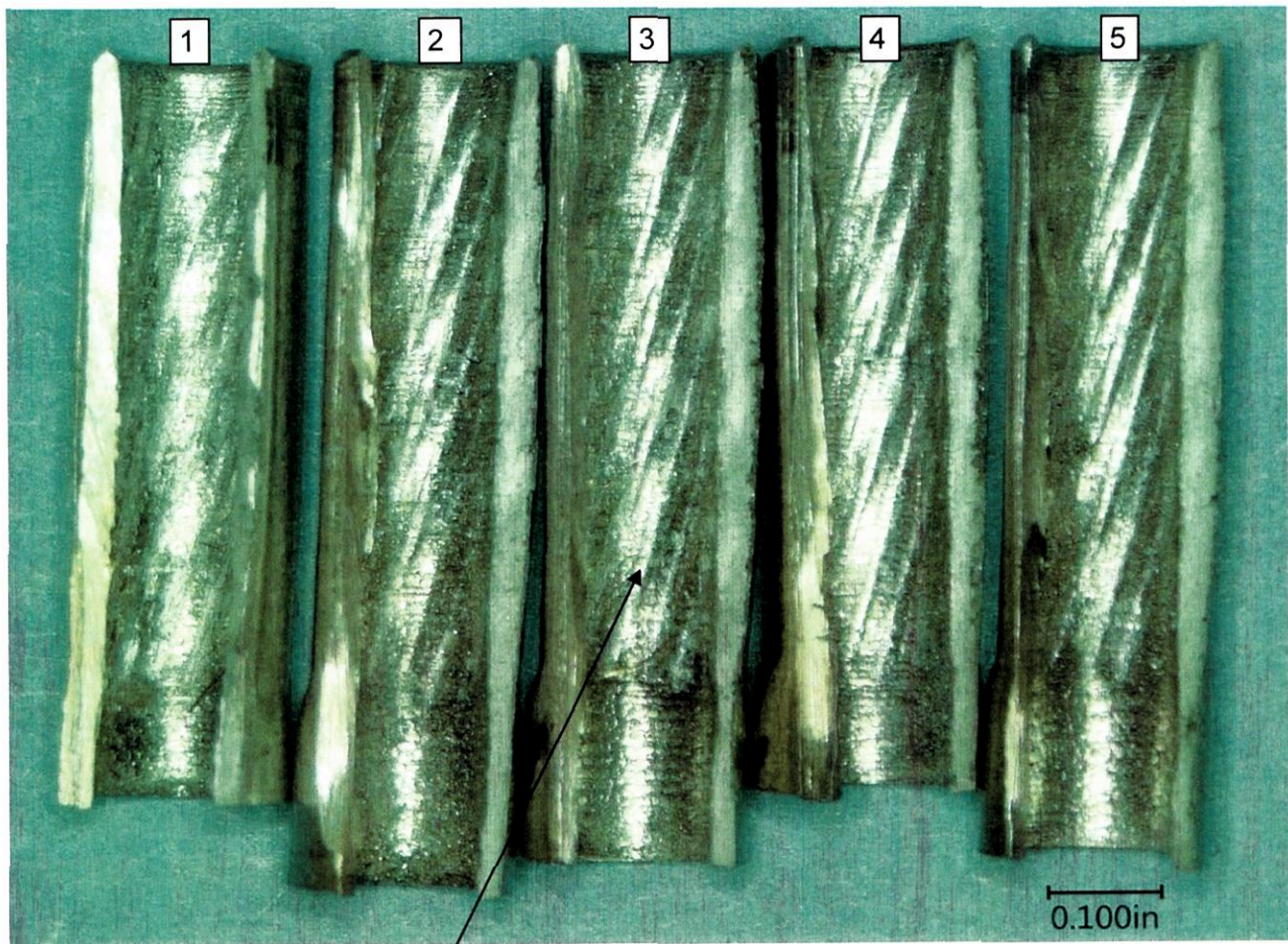


Figure 13 Example of a longitudinal fracture along the extruded rib in one of the exemplar tensile test samples.



Typical helical impression marks consistent with
contact with the cable wires

Figure 14 The inner surfaces of the swaged portion of the exemplar tensile test samples. The samples identification numbers are indicated.

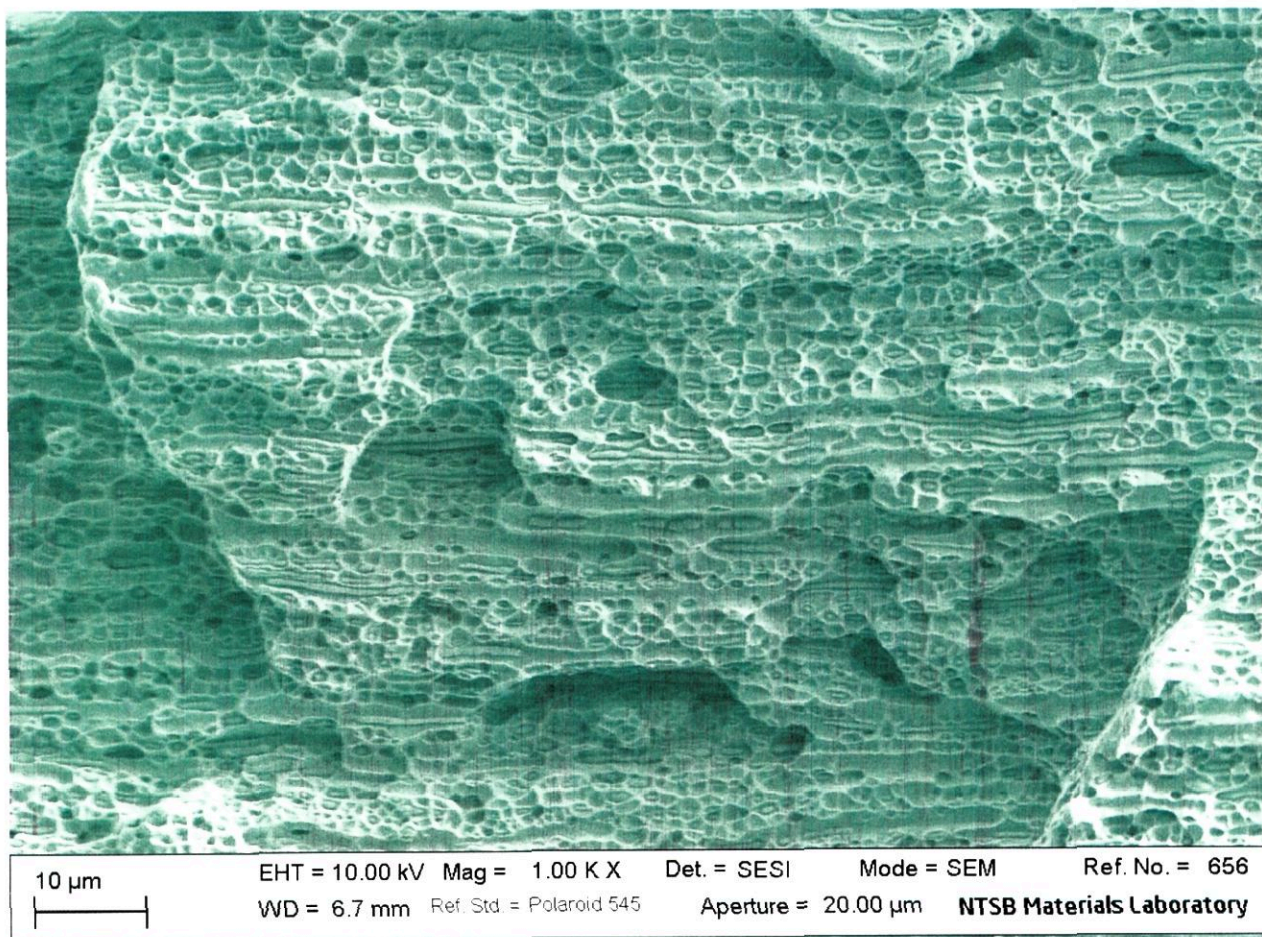


Figure 15 Scanning electron fractograph of the longitudinal fracture surface on exemplar test sample 4.