

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

September 22, 2021

**Attachment 2 –Honeywell No. 1 Engine (P36058C) Materials Laboratory
Analysis Report**

POWERPLANTS

CEN20LA215

BACKGROUND

Two (2) TPE331 engines were torn down at Product Integrity (PI) in support of a NTSB accident investigation. The engines had been removed from the left and right sides of the same aircraft. The left engine was identified as ESN P36058C. The right engine was identified as ESN P36235C. Note that only the hardware from the left engine was submitted for evaluation. Analysis of the hardware from the right engine was reported in ERS-ASYS-PENG-MA-0000801.

PROBLEM STATEMENT

Perform non-destructive evaluations of the separated coupling shaft and starter shaft to determine the modes of separation. Filter the submitted magnetic plug and analyze the collected debris.

SUMMARY/CONCLUSIONS

- The separation of the coupling shaft was the result of torsional overload. Overload dimples were observed to be elongated in the counterclockwise direction (forward looking aft (FLA)) which indicated that the aft section separated as a result of torsional loading in the clockwise direction, relative to the forward section.
- The separation of the starter shaft could not be determined due to secondary smearing and damage of the fracture features.
- Debris collected from the magnetic plug was suggestive of steel similar to 9310 or 4340, stainless steel similar to 17-4PH or 15-5PH, debris suggestive of an aluminum alloy, and debris rich in copper.
- See Findings.

PART NAME:	Coupling Shaft
PART NUMBER:	894119-1
PART L/N:	9828
MODEL/PROGRAM:	TPE331
MODEL/PROGRAM S/N:	P36058C (Left Engine)
OPERATING TIME:	Not Reported
OPERATING CYCLES:	Not Reported
MATERIAL:	H11
MATERIAL SPEC:	AMS6487
SUPPLIER:	Not Reported
SUPPLIER P/N:	Not Reported

Findings

After takeoff, the right wing of the airplane dipped until the airplane nosed down to the ground in Sioux Falls, South Dakota. The coupling shaft (P/N 894119-1), a piece of the separated starter shaft (P/N not provided), and debris collected from the left engine S/N P36058C magnetic plug were submitted for analysis. Investigation of the right engine S/N P36235C from the same aircraft was reported in ERS-ASYS-PENG-MA-0000801.

Coupling Shaft Separation

The coupling shaft (Lot Number 9828) from the left engine S/N P36058C had separated approximately 0.582" from the aft end (Figure 1). The fracture surface of the separation was oriented normal to the shaft axis and was flat in appearance. Wear was observed adjacent to the shoulder of the shaft (Figure 2). Contact/wear patterns were observed on the loaded side of the gear teeth from the aft end of the coupling shaft (Figure 3).

The fracture surface of the coupling shaft was examined in the scanning electron microscope (SEM) and is shown in Figure 4. Examination revealed that most of the fracture features were obscured by smearing and secondary damage. In some areas, overload dimples elongated in the counterclockwise direction (forward looking aft (FLA)) were observed, which indicated that the aft section of the coupling shaft had separated as a result of torsional loading in the clockwise direction relative to the forward section (aft looking forward (ALF)). The specified direction of rotation of the shaft was counterclockwise FLA.

Energy dispersive X-ray (EDX) analysis of the coupling shaft produced a spectrum indicative of the specified H11 tool steel material (Figure 5).

No additional work was performed on the coupling shaft from the left engine S/N P36058C per customer request.

Starter Shaft Separation

The starter shaft had separated approximately 0.689" from the forward end (Figure 6). Wear was observed on both sides of the gear teeth.

The fracture surface of the starter shaft was examined in the SEM and is shown in Figure 7. The finer fracture features of the starter shaft could not be determined due to smearing and secondary damage of the fracture surface. The specified direction of rotation of the shaft was clockwise ALF.

EDX analysis of the starter shaft produced a spectrum suggestive of a steel similar to 4140 (Figure 8). Note that the specified base material of the starter shaft was not reported.

No additional work was performed on the starter shaft from left engine S/N P36058C per customer request.

Debris Analysis

The as-received condition of the submitted magnetic plug from left engine S/N P36058C is shown in Figure 9A. The magnetic plug was flushed using Flash 142 mineral spirits and captured onto an 8 micron filter patch. The collected debris was cleaned with toluene and dried. The weight of the debris was measured to be 28 mg.

SEM analysis of the collected debris is shown in Figures 9B-C. EDX analysis of the larger metallic particles were suggestive of a steel similar to 4340 or 9310 (Figure 10A). The smaller metallic particles were suggestive of a stainless steel similar to 17-4PH or 15-5PH, as determined by EDX analysis (Figure 10B). Debris rich in copper (Figure 10C) and debris suggestive of an aluminum alloy (Figure 10D) were also detected amongst the debris, as determined by EDX analysis.

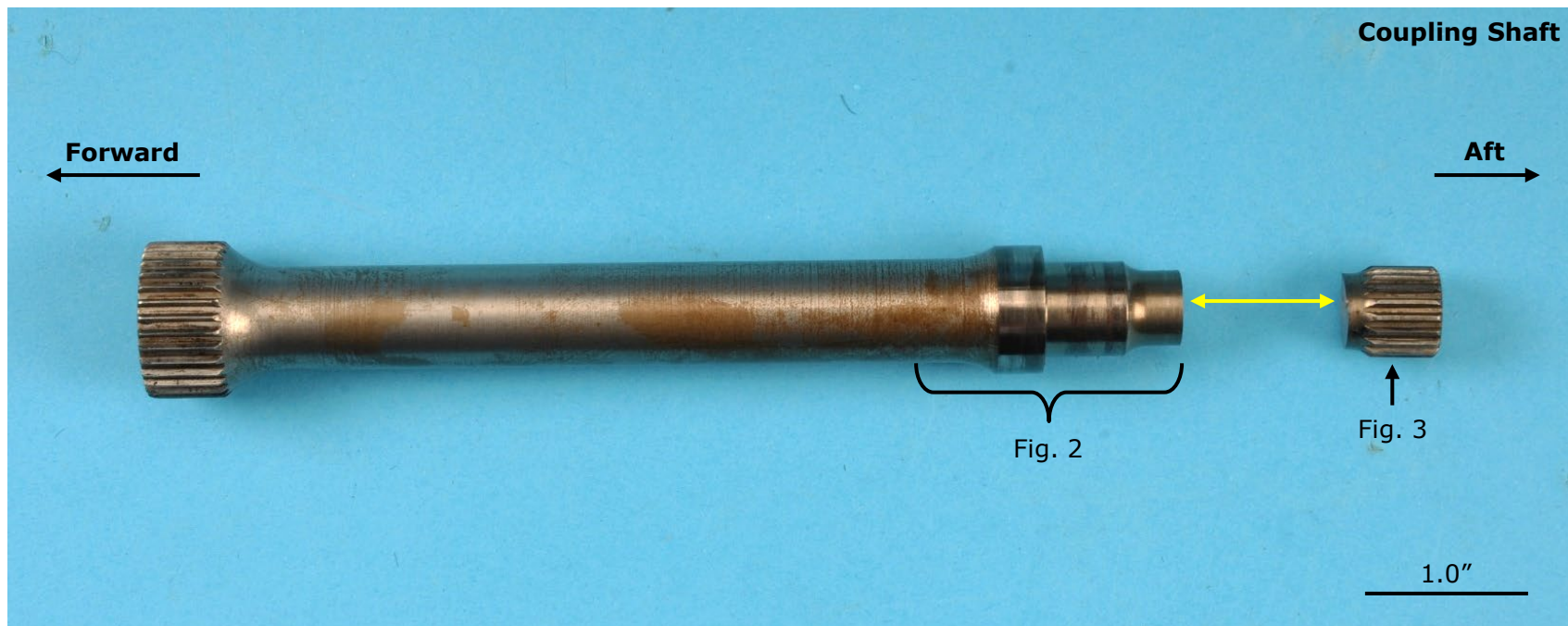


Figure 1.

Overall image showing the as-received condition of the separated coupling shaft (Lot Number 9828) from TPE331 engine S/N P36058C (left engine). The coupling shaft had separated near the aft end (yellow double-sided arrow). Close up images of the shaft are shown in Figures 2-3, as indicated.

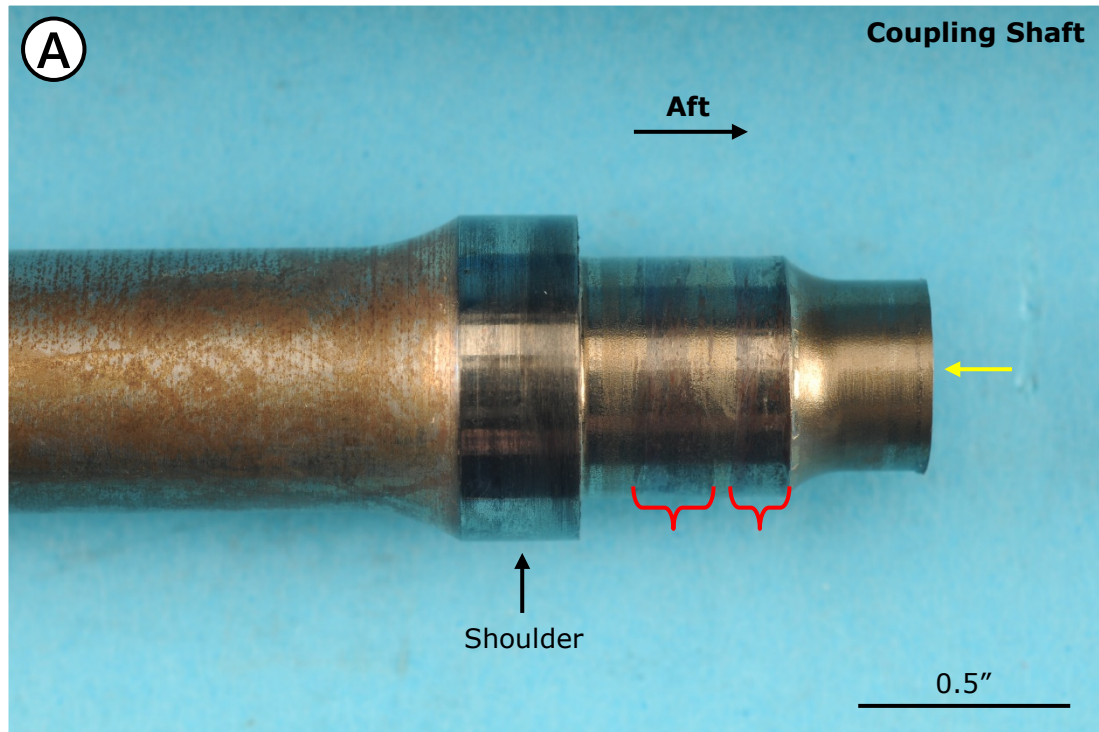
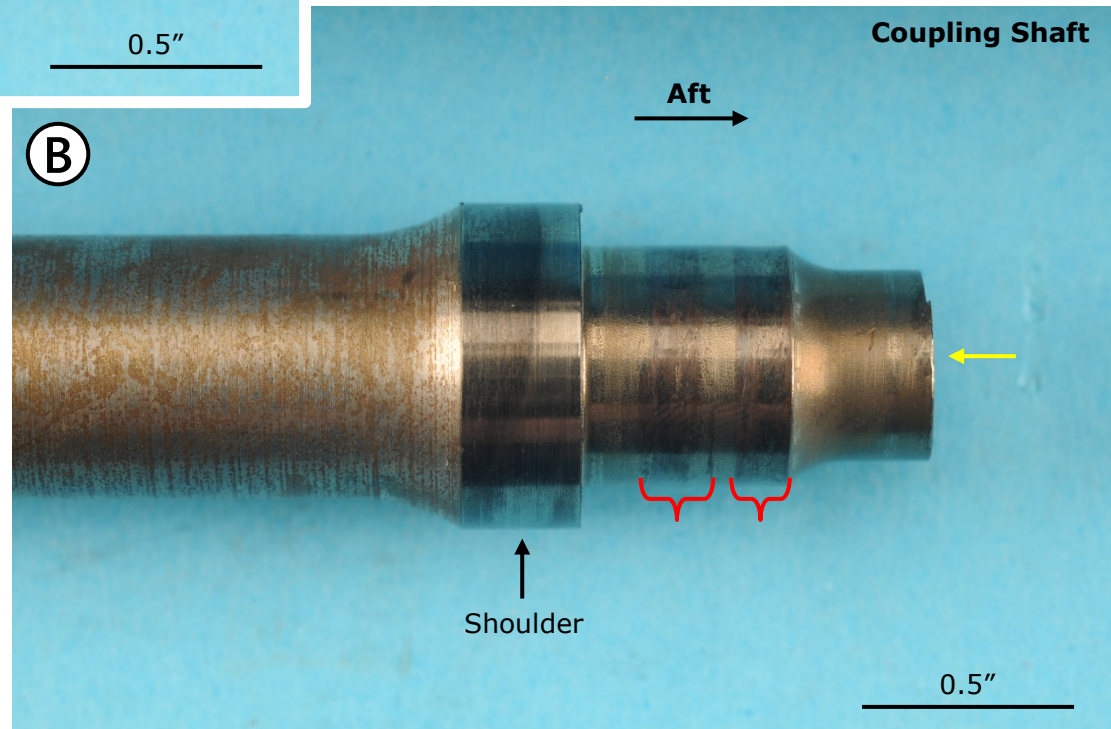


Figure 2.

(A-B) 180° views of the aft end of the coupling shaft (reference Figure 1). Non-uniform wear was observed aft of the shoulder (red brackets). The yellow arrows identify the fracture surface.



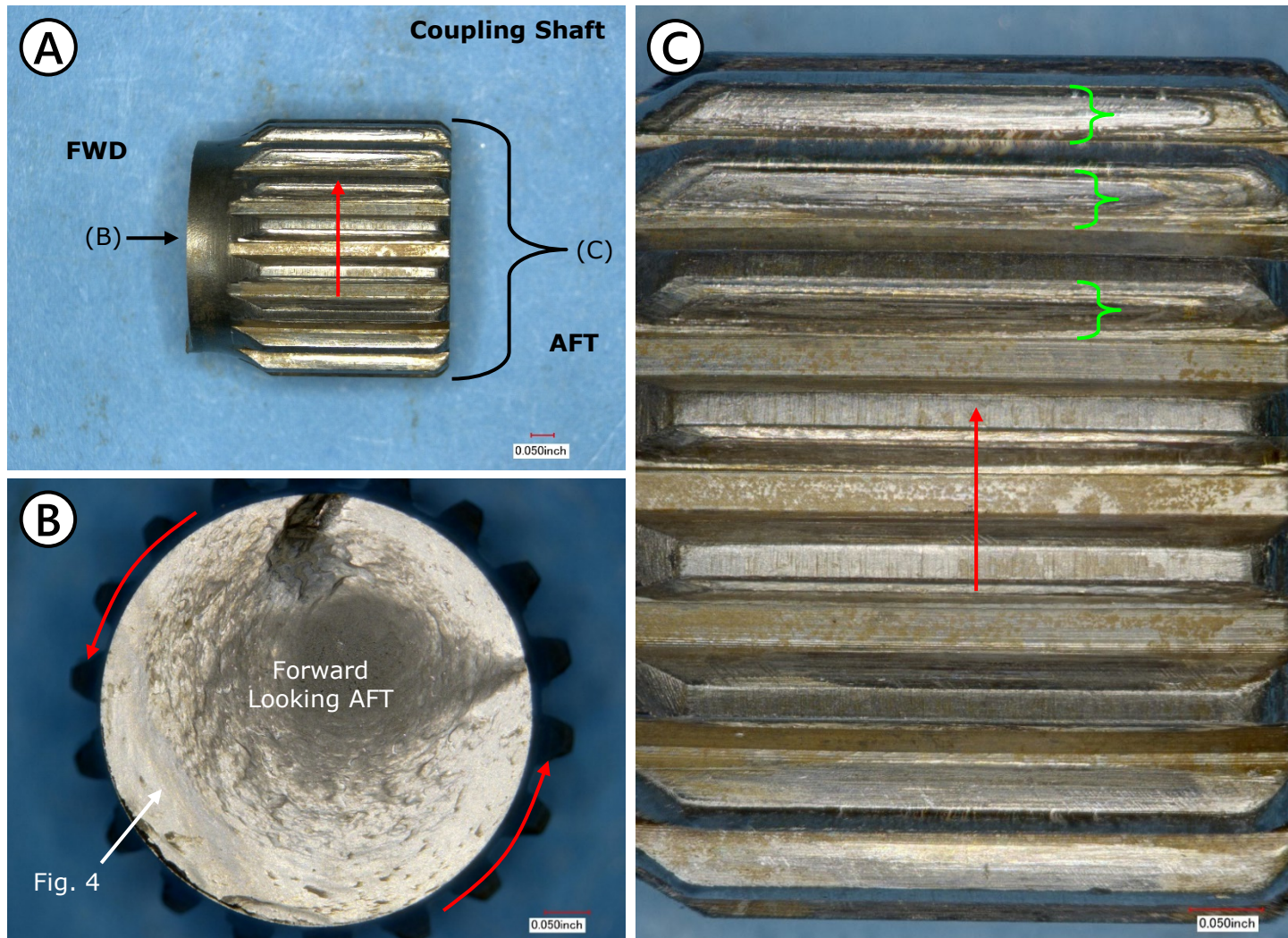
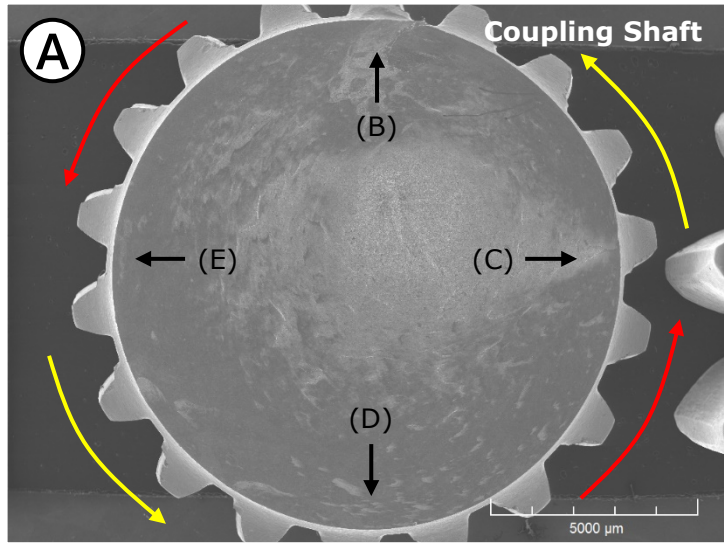
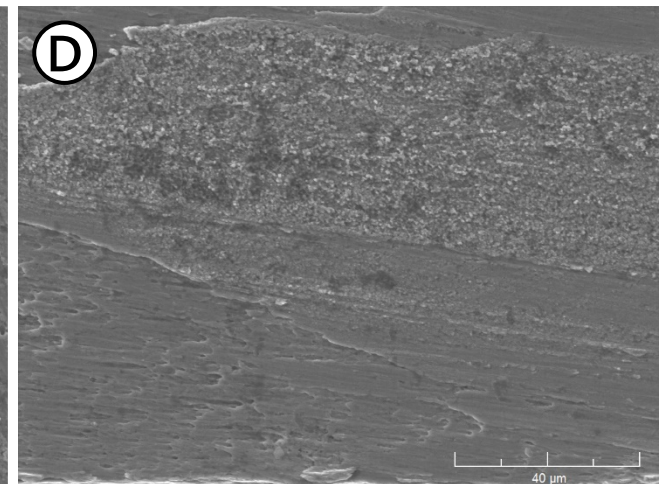
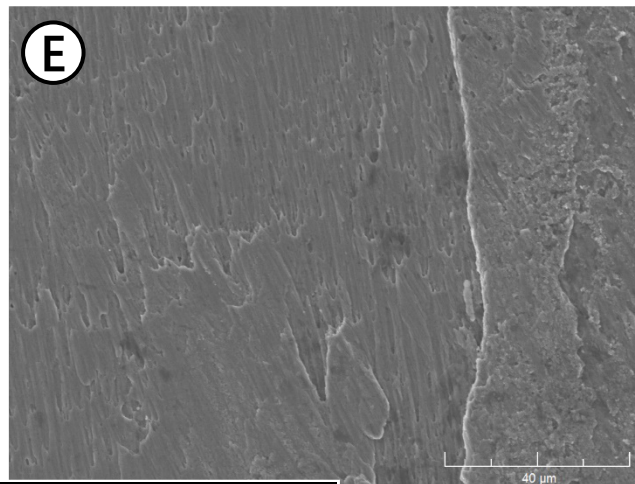
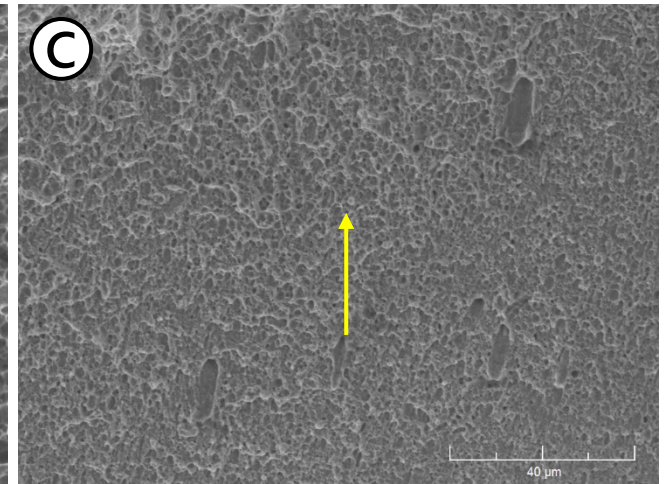
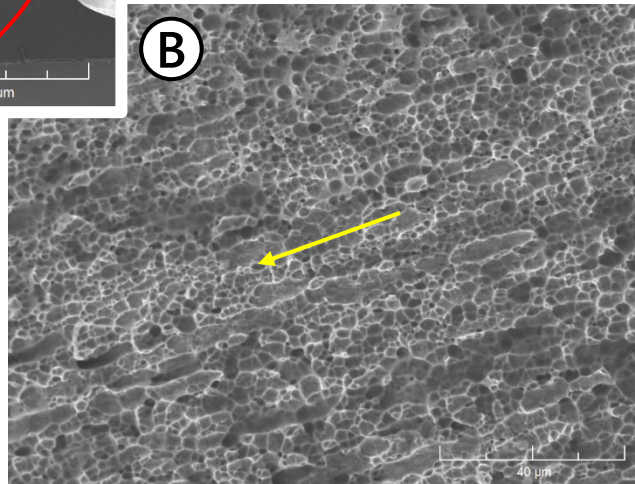


Figure 3.

(A-C) Digital microscope images of the separated coupling shaft (reference Figure 1). The red arrows indicate the specified direction of the shaft rotation within the engine (counterclockwise forward looking aft (FLA)). Wear was observed on the loaded side of the gear teeth (green brackets in (C)). Scanning electron microscope (SEM) images of the coupling shaft fracture surface are shown in Figure 4.

**Figure 4.**

(A-E) Secondary electron (SE) SEM images showing the fracture surface on the aft section of the separated coupling shaft (reference Figure 3B). Fracture features indicative of torsional overload were observed in some locations, as indicated by the elongated dimples in the counterclockwise direction as shown in views (B-C); however, most of the fracture features were obscured by smearing and secondary damage (reference views (D-E)). The yellow arrows in (A-C) indicate the direction of rotation with respect to the mating fracture surface. The red arrows in (A) indicate the specified direction of the shaft rotation within the engine (counterclockwise FLA).



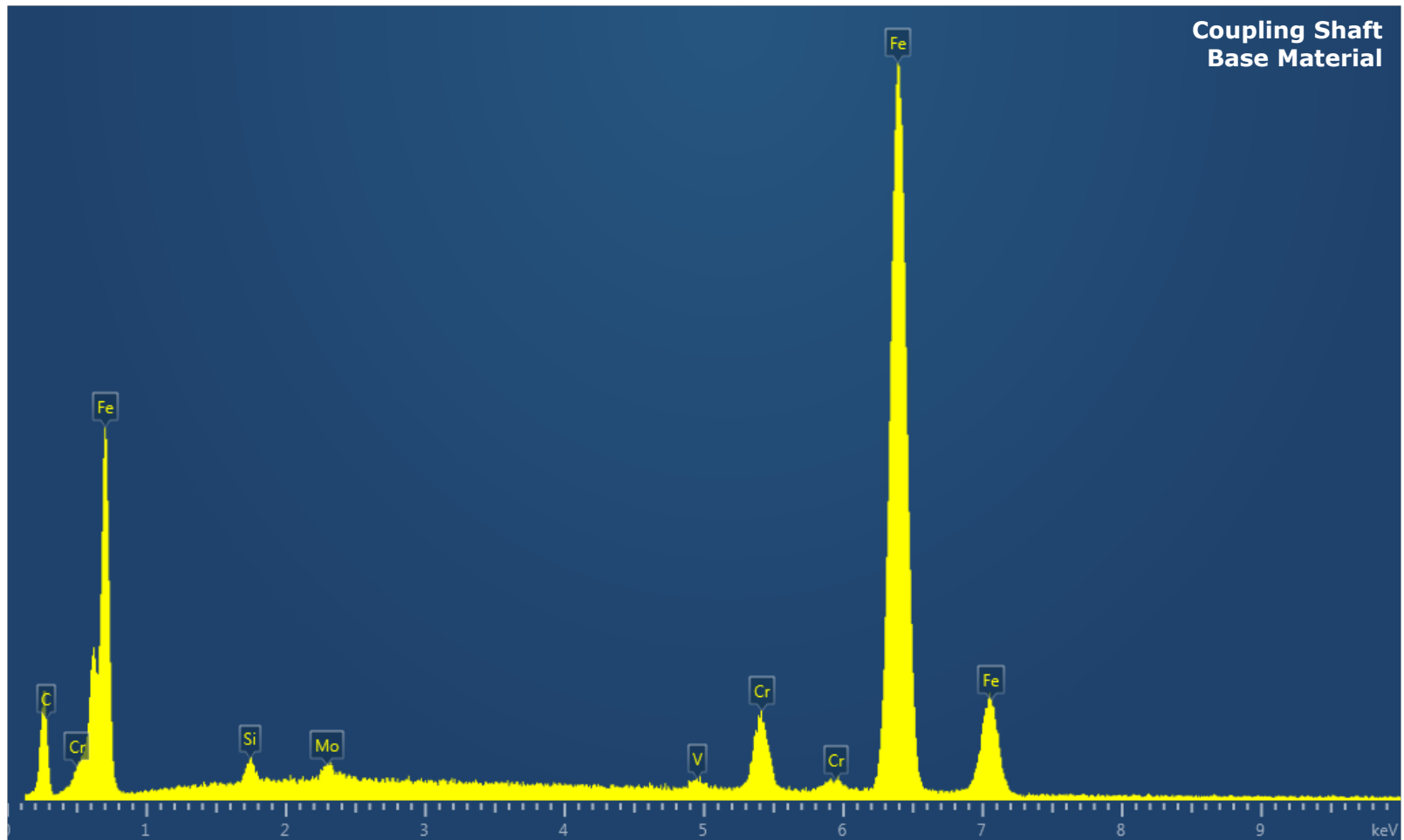


Figure 5.

Representative energy dispersive X-ray (EDX) spectrum generated from analysis of the coupling shaft base material. The spectrum was indicative of the specified H11 material.

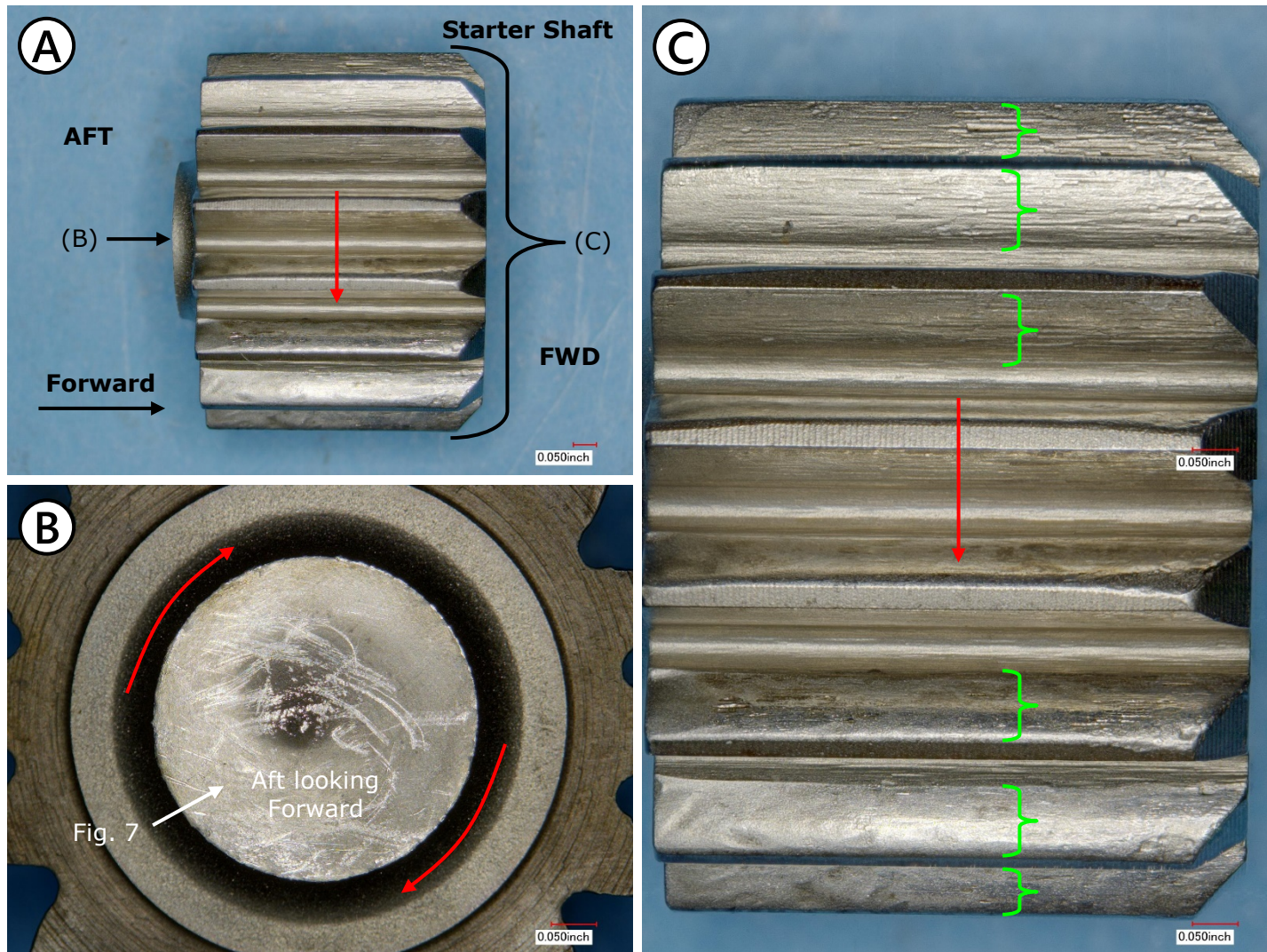


Figure 6.

(A-C) Digital microscope images of the separated starter shaft (P/N not provided). The red arrows indicate the specified direction of the shaft rotation within the engine (clockwise aft looking forward (ALF)). Wear was observed on both sides of the gear teeth (green brackets in (C)). SEM images of the starter shaft fracture surface are shown in Figure 7.

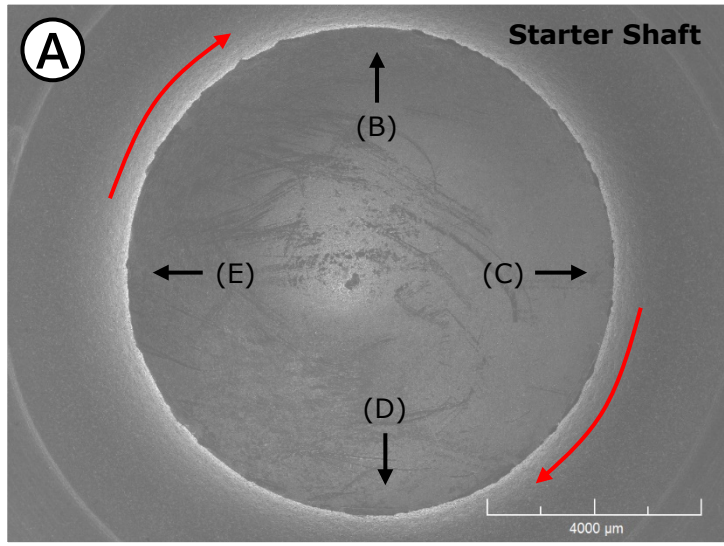
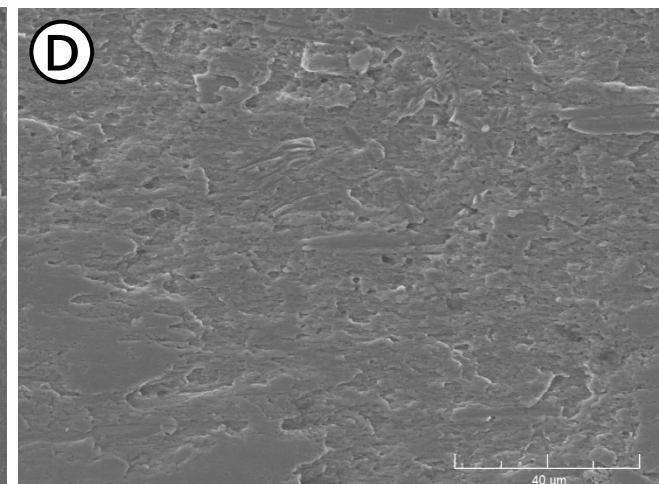
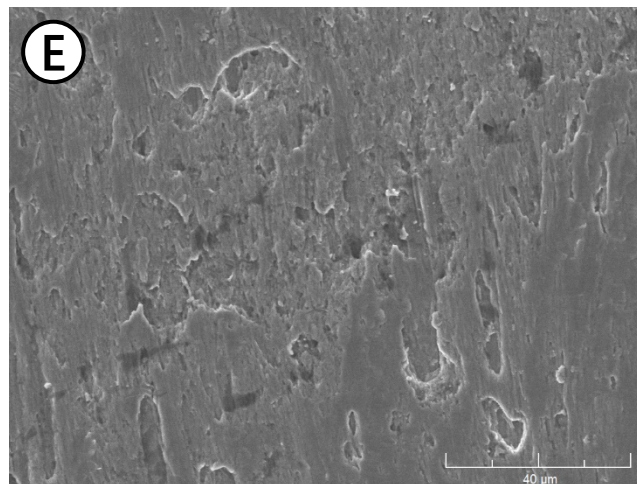
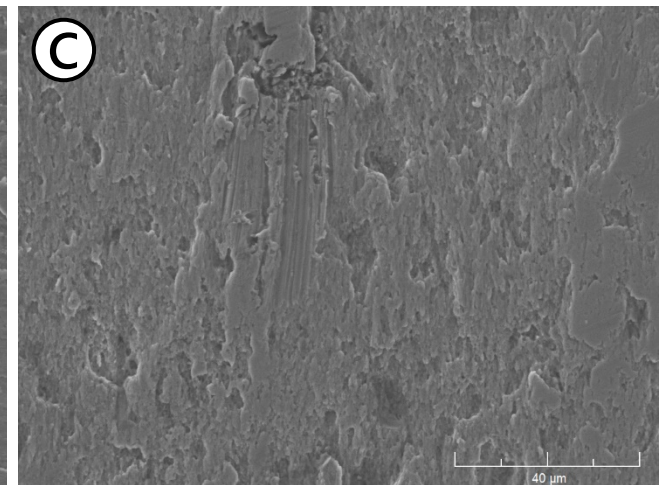
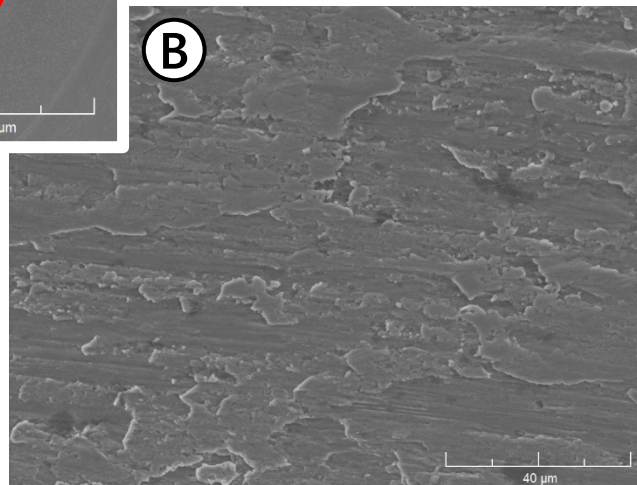


Figure 7.

(A-E) SE SEM images of the starter shaft fracture surface (reference Figure 6B). The finer fracture features could not be determined due to smearing and secondary damage of the fracture surface. The red arrows in (A) indicate the specified direction of the shaft rotation within the engine (clockwise ALF).



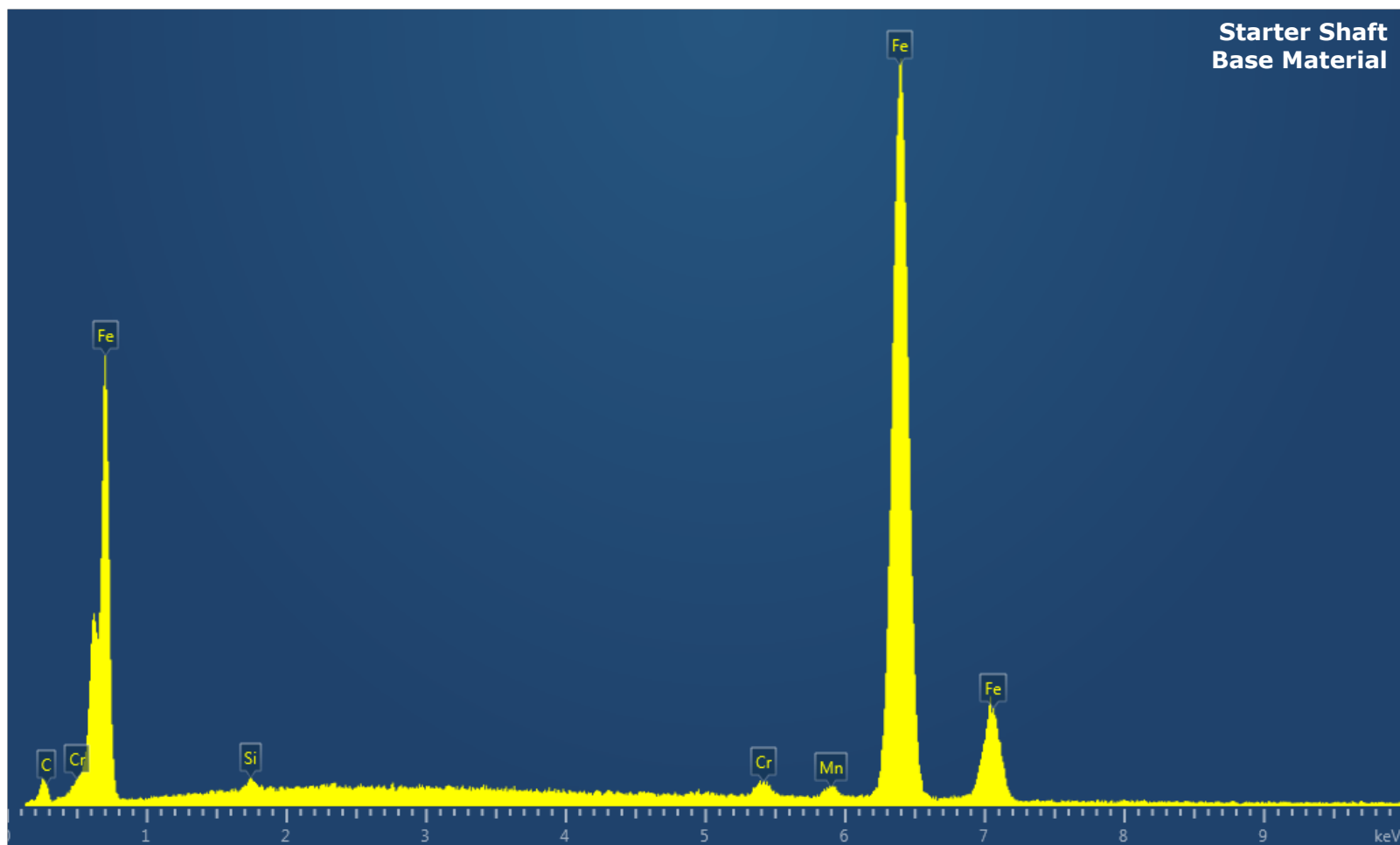


Figure 8.

Representative EDX spectrum generated from analysis of the starter shaft base material. The spectrum was suggestive of a steel similar to 4140. Note that the specified base material of the starter shaft was not reported.

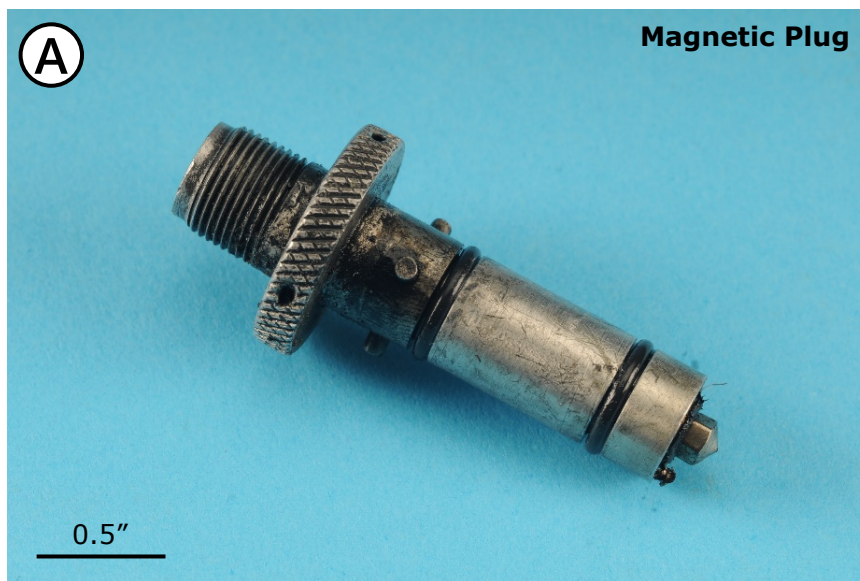
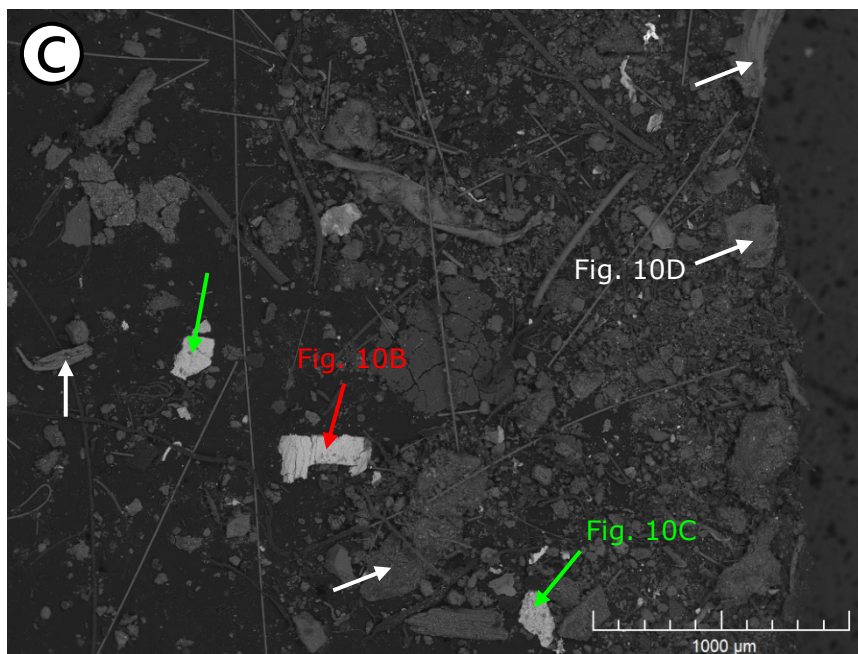
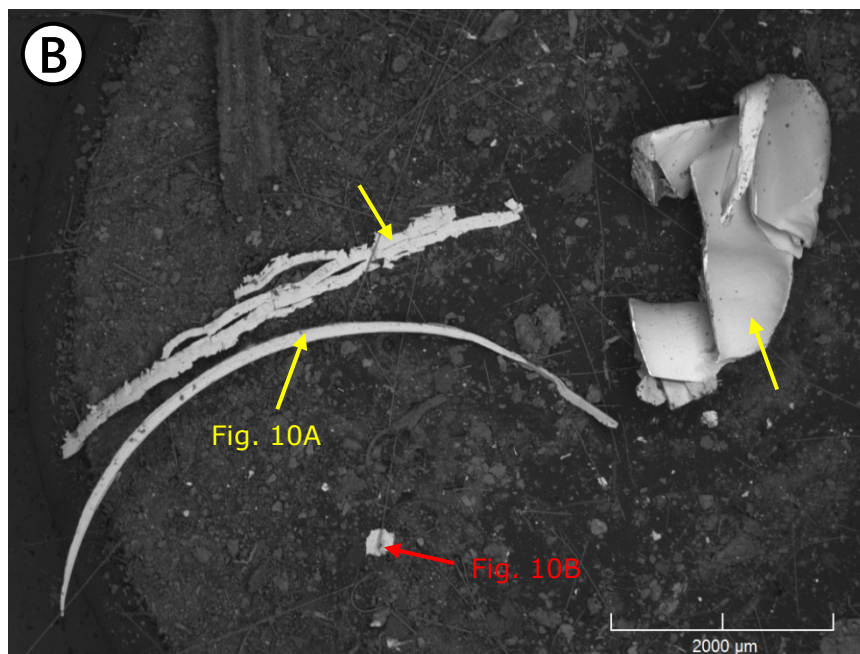


Figure 9.

(A) Macro image showing the magnetic plug in the as-received condition. (B-C) Backscattered electron (BSE) SEM images showing representative debris collected from the magnetic plug. EDX analysis of the debris identified by the yellow, red, green, and white arrows are shown in Figure 10, as indicated.



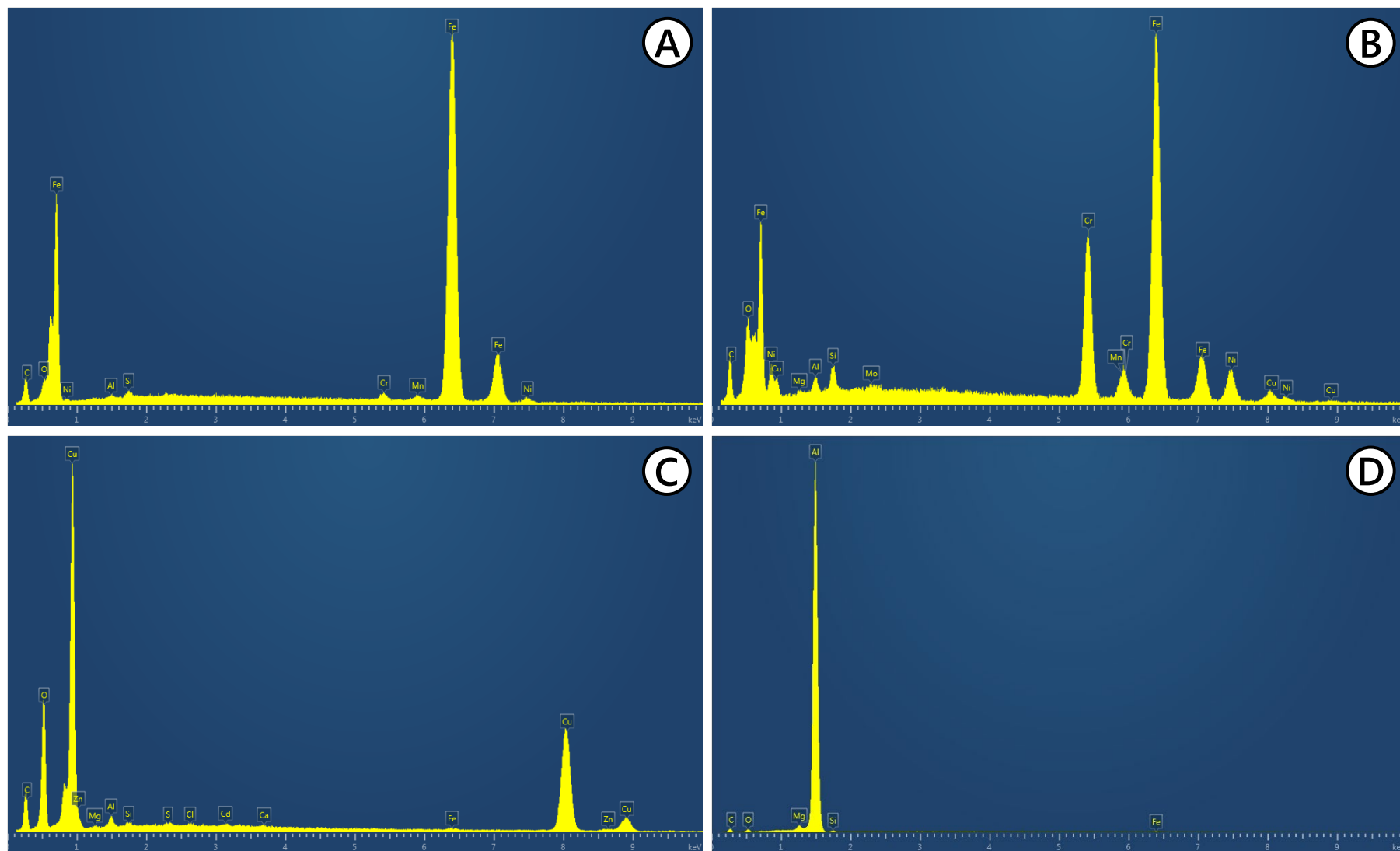


Figure 10.

(A-D) Representative EDX spectra generated from analysis of the debris collected from the magnetic plug identified by the yellow, red, green, and white arrows in Figures 9B-C. The spectrum in (A) was suggestive of a steel similar to 9310 or 4340. The spectrum in (B) was suggestive of a stainless steel similar to 17-4PH or 15-5PH. The spectrum in (C) was rich in copper with lower concentrations in other elements. The spectrum in (D) was suggestive of an aluminum alloy.