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# Metallography as a Microanalysis Tool during the Failure Investigation of the Starboard Solar Alpha Rotary Joint of the International Space Station

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In June 2007, Space Shuttle mission STS-117 delivered and installed two starboard truss segments to the International Space Station (ISS). The mission included installation of a 10-foot diameter Solar Alpha Rotary Joint (SARJ) used for rotation of the solar arrays in the direction of the sun. Three months after installation, mission control at Johnson Space Center observed vibration and electric current spikes near the SARJ, which resulted in the decision to park the SARJ in a safe position and to investigate the cause. A remote failure analysis was performed at the Kennedy Space Center using three unidentified debris samples that were collected from the starboard SARJ during an STS-120 extra-vehicular activity (EVA). This presentation will show how metallography was used to characterize the microstructure of the fragments during the failure investigation, which also included stereomicroscopy, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), and laser confocal microscopy. Metallography was used as a microanalysis tool during the failure investigation in order to better characterize the source and microstructure of the spalled fragments.

Initial SEM analysis was performed by leaving the fragments on the sampling tape while utilizing the SEM variable pressure (VP) mode and backscattered electron (BSE) detector. The debris ranged in size from sub-micron dust to fragments that were over 1 mm in length. Over 600 locations were analyzed via EDS and nearly all of the fragments were nitrided 15-5 precipitation hardened (PH) stainless steel, which indicated that the fragments were liberated from the starboard SARJ race ring.

Fractography was accomplished by removing several fragments from the sampling tape, placing them on a conductive tape, and utilizing the SEM in high vacuum mode for improved resolution. The fracture surfaces on the fragments consistently displayed elliptical-shaped regions that suggested crack initiation with evidence of apparent arresting of crack propagation, as shown in Fig. 1. BSE imaging with atomic contrast located bright and dark regions at the initiation sites that were determined to be niobium (Nb) carbide precipitates and manganese sulfide (MnS) inclusions.

The specimens were prepared metallographically in order to examine the cross sectional microstructure. During the initial analysis, two larger fragments were hot mounted in conductive epoxy resin and a third fragment was cold mounted in a two-part resin. Real-time radiography was utilized to locate the fragment specimen in the metallographic mount and provide orientation and progress during grinding. A nitrided 17-4 PH stainless steel bull gear exemplar was prepared for methodology and microstructural comparison. Typical hand grinding, polishing and chemical etching steps were carried out on both types of samples. The exemplar nitrided 17-4 PH stainless steel bull gear displayed a nitrided case, a distinct diffusion interface, and a martensitic core. In comparison, the SARJ fragments did not display an interface and did not contain any of the martensitic core, indicating that the spalling was likely limited to the nitrided case [1].

Additional fragment samples were received after STS-123 for further investigation and two large nitrided 15-5 PH fragments were cold mounted for microstructural evaluation using a two-part resin. Cross-section samples were examined as-polished and after a slow rocking etching technique with a diluted nital solution. Etching revealed the nitrided case layer microstructure, remnant white layer with fingers extending into the case, and transgranular secondary microcracking. The additional SARJ fragments did not display a martensitic core microstructure or case-core interface, further validating that the spalling was limited to the nitrided case [2].

It was determined that failure of the fragments was due to contact stress fatigue with subsurface initiation. The cracks initiated at hard, non-metallic inclusions and propagated parallel to the outer surface before spalling off of the surface of the race ring due to contact stress fatigue [3]. The data was used by the SARJ team to ultimately determine root cause [4].

References

[1] Lubas, D.L., "STS-120 International Space Station (ISS) Starboard Solar Alpha Rotary Joint (SARJ) Debris Analysis," Internal report KSC-MSL-2007-0499, (2007).

[2] Wright, M.C., "International Space Station (ISS) Expedition 16 Starboard Solar Alpha Rotary Joint (s-SARJ) Debris Analysis," Internal report KSC-MSL-2008-0099, (2008).

[3] Wulpi, D.J., *Understanding How Components Fail*. ASM International. 1985. p. 199.

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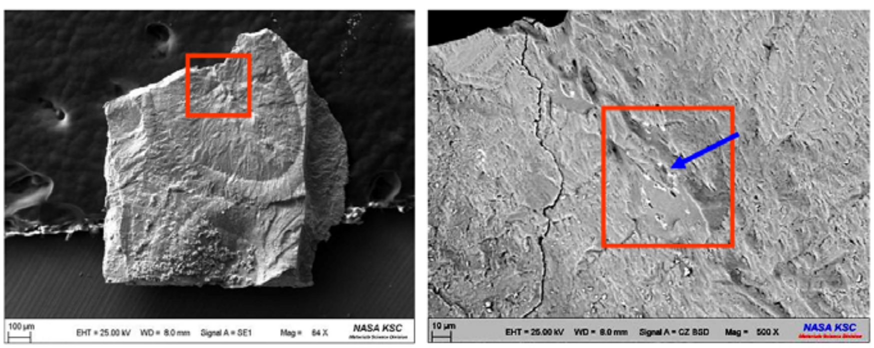

FIG. 1. SEM image of a fragment in secondary electron (SE) mode (left) and a higher magnification BSE image of the boxed area showing atomic contrast (right). This area appears to be the fracture initiation site and the elliptical feature suggests crack arresting. The light constituent is primarily Nb, and the dark constituent is MnS (arrow). Original magnifications: 54X (left), 500X (right).


FIG. 2. Nitrided 15-5 PH fragments cross sectioned and etched to reveal the case layer microstructure and transgranular secondary microcracking. No martensitic core microstructure or case-core interface was observed. Etchant: diluted nital. Original magnification: 100X

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