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IMS Characterization of Materials and Microstructure through Metallography, Imagery Analysis, and Mechanical Testing – Fundamental and Applied Studies

Authors:
James E. Martinez[1], Christian DelaCruz[2], Spencer F. Day[2], Chad R. Carl[1], Jerry W. Buhrow[1], Charles E. Mccurry[2]

[1]NASA Kennedy Space Center, NE-L, [2]Jacobs Technology Consolidated Operations, Management, Engineering & Test (COMET) Contract

Title:

Surface Hardness Testing of Mobile Launcher 1 (ML-1) Vehicle Support Posts (VSP) Following Artemis I Launch Exposure

Abstract:

Following the successful launch of Artemis I on November 16th, 2022 (Fig 1), a surface hardness assessment was performed on the eight primary VSPs (Figs. 2, 3) located on the Zero Deck of the ML. This assessment was performed as part of an instrument investigation for strain gauges installed on VSP interior surfaces that had a "strange reaction". This report does not address the VSP strain gauge investigation, but rather VSP structural integrity for future service (Artemis II, III, …).

Surface hardness measurements were taken to assess the strength of the ASTM A148 steel castings to confirm thermal exposure from launch had not reannealed the VSPs. However unlikely, it is possible high temperature may have heated and tempered (reannealed) the VSPs, resulting in a change of built-in stresses. This loss in built-in stress may explain the change in off-set measured by the strain gauges.

Initial hardness measurements were made at two interior surfaces of VSPs near the strain gauges and the corresponding exterior surfaces (engine hole-facing). Field hardness measurements on the exterior, engine hole surface-facing surfaces for all eight VSPs ranged from 175 to 226 HB/P, well below the minimum hardness of 302 Brinell (HB). Opposing interior surface hardness measurements near strain gauges ranged from 264 to 358 HB/P. In all cases for flight VSPs, a drop in interior-to-exterior hardness ranging from 70 to 132 HB/P was measured.

Surface hardness measurements were then made on the two spare VSPs not exposed to launch temperatures for baseline comparison. These two spare VSPs had a drop in Brinell hardness from interior to exterior surfaces ranging from 3 to 17 HB/P. The large interior-to-exterior delta hardness for eight flight VSPs but not for the two spare VSPs suggests launch exposure temperatures softened the exterior surfaces, raising two questions: 1) Are the VSPs compromised for future use, and 2) How deep is the exterior surface softening effect?

To address concerns of low surface hardness values at non-critical exterior surfaces, additional field surface hardness measurements were taken at high-stress locations on VSP3: Both door jams, back radius, and internal left and right radius near the base. These values came in well above the required minimum hardness (317 to 365 HB/P).

For a more representative pre-launch versus post-launch surface hardness comparison, VSP Acceptance Data Packages (ADPs) were reviewed, and hardness measurements were made at the same eight original locations on VSP3 where hardness measurements were made at the foundry.

To determine the degree of softening, 1/8" of material was machined away at three exterior surfaces of engine hole-facing side (Fig. 4). A significant increase in surface hardness was measured ranging from 50 to 86 HB/P. Values at these three locations were still slightly below the required minimum hardness, so an additional 1/8" material was machined away, and hardness values were retaken. At the ¼" depth, hardness values increased to 321 to 324 HB/P. These values fall above the required minimum, concluding surface hardness testing.

Rationale for VSP continued use was reached with no restrictions during a Chief Engineering Review based on hardness values exceeding minimum at critical locations and subsurface locations for VSP #3.

Fig 1. Artemis I Launches from KSC Pad 39B

Fig 2. Mobile Launcher 1 Zero Deck Showing VSPs

Fig 4. VSP #3 Removed for Machining

Fig 3. Zero Deck Showing 7 VSPs Post Artemis I Launch