Structural Stress Analysis
Tested vs. Predicted

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Use of strain gauges provides correlation for numerical Finite Element Analysis, and helps to identify real world stresses not always predicted with ideal analysis models. The following case study documents the work performed on the foundation for an A-Frame structure on the aft end of a supply vessel.

The connection of the support arm of the A-Frame structure to the hinge structure at the base of the Frame had experienced a number of weld cracks over a relatively short operational lifetime. A Finite Element Analysis (FEA) was commissioned to evaluate the structure, and determine if the design was adequate for the intended operational service. The results of the initial FEA indicated relatively low levels of stress in the connection of the support arms to the hinge structure, and were not indicative of the types of cracks that had been observed in the structure.

To provide further insight into the stresses in the A-Frame, a series of strain gauges were installed on the upper and lower flanges of the support arms. On each arm, strain gauges were located along the inboard and outboard edges of each flange to capture potential bending effects in both directions. The strain measurements were recorded as the A-Frame swung through a 90 degree

Figure 1 – A-Frame Initial FEA Stress Results

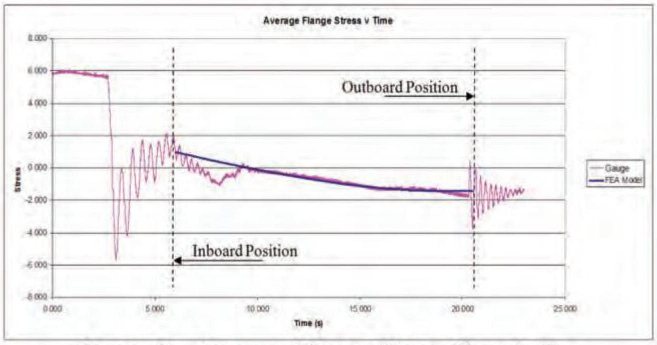

Figure 2 – Average Flange Stress Correlation

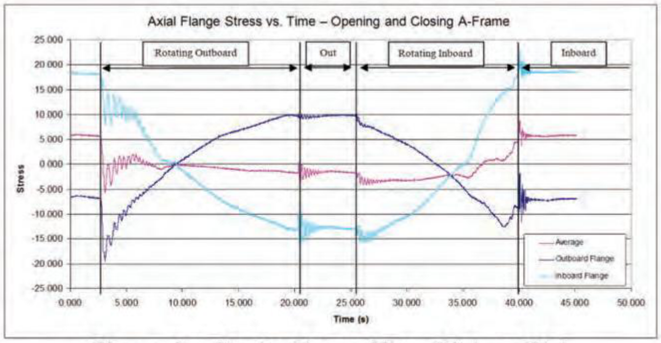

Figure 3 – Strain Gauge Time History Plot

arch from the inboard position, to the outboard position, and back.

The initial stress correlation showed excellent agreement between the FEA predicted stress and the average stress results for both the upper and lower flanges. (Stress averaged between the inboard and outboard gauge locations). The good correlation of the average stress results of both the upper and lower flanges indicated that the FEA model was a good representation of the overall stiffness, the fore and aft bending, and the overall stress present in the structure during the operation of the A-Frame. However, a comparison of the inboard and outboard stain gauges results identified a significant discrepancy between the FEA and real world stress results. A plot of the stress time histories from the inboard, outboard, and average strain gauges is shown in Figure 3.

As shown in Figure 3, there is a significant difference in the inboard and outboard strain gauge results, with the two results inversely proportional to one another, indicating that the stress results are likely the results of a transverse bending in the structure. The initial FEA model results showed fairly uniform stress results across the width of the upper and lower flanges, and did not correlate well with the results of the strain gauges.

The initial FEA model was based upon ideal geometry, and included perfect alignment of the structure and the axis of rotation of the hinges supporting the port and starboard support arms. In the real structure, construction tolerances and distortion from the welding during fabrication had introduced imperfections within the structure, and the axis of rotation for the port and starboard hinges were no longer aligned. As a result, the port and starboard A-Frame support arms were rotating in non-parallel planes, but the cross bar connecting the tips of the support arms ensures the tips of the support arms maintained a constant distance from one another, and resulted in large horizontal bending loads when the A-Frame was rotated inboard and outboard.

To correlate with the strain gauge results, imperfections were introduced into an updated FEA model with various levels of misalignment between the two hinges. The models were kinematically solved to investigate the effect of hinge alignment on horizontal bending within the structure, and a FEA model was developed that provided good correlation with the observed stress results in way of the gauge locations. Once the model was tuned to match the known stress results in way of the gauge locations, the FEA model could then be used to evaluate the effect of the horizontal bending loads on the stresses throughout the structure, including in way of the connections to the hinge structure where cracking had been previously observed. The results of the misalignment study were then used to determine appropriate alignment tolerances to avoid overstressing the local A-Frame, hinge, and supporting structures details.

The Author

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