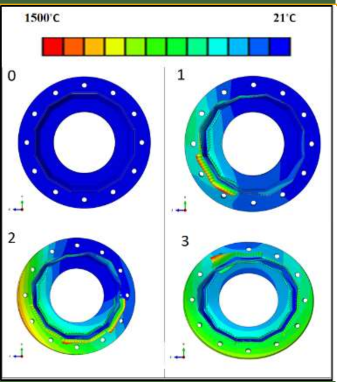
Optimizing the Geometric Configuration and Manufacturing process of High Mast Illumination Poles

Elucidating the root causes of weld toe cracks generated during the manufacturing process of high mast illumination poles (HMIPs)



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PI: Dr. Arturo Montoya (UTSA)

Dr. Adolfo Matamoros (UTSA)

A high-fidelity model that accounts for the cumulative effect of welding and hot-dip galvanizing was developed to determine the residual stresses and deformations induced during the manufacturing process of high mast illumination poles (HMIPs) with a TxDOT pole-to-base plate connection detail. The plug-in Abaqus Welding Interface (AWI) in Abaqus was used to model the welding of the base plate to the pole. The welding stress results were used as initial input to the galvanizing analysis. A parametric study was conducted to quantify the variation in the residual stresses and plastic strains induced during the welding and galvanizing of HMIPs due to changes in welding and galvanizing practices. The results revealed that the cumulative effects of the different processes involved in the manufacturing of HMIPs contribute to the formation of galvanizing cracks in HMIPs. Increasing the dipping submersion speed during galvanizing and lowering the torch temperature magnitude during welding resulted in fewer zones prone to cracking. Moreover, altering the angle of inclination effect did not have a significant impact on the results. This model's development could serve to identify variations in the manufacturing practices that will reduce the extensive inspection procedures conducted post-galvanizing to identify weld toe cracks.

Background

Post-galvanizing inspections have reported cracks in HMIPs, particularly at the toe of the welded connection between the pole and the base plate. These flaws impose a risk to the public as they can propagate during service due to cyclic wind loads. Most research efforts up to date have concentrated on understanding the factors that contribute to the propagation of galvanization flaws once the HMIP is under service. The effects of pole shape on fatigue performance of high-mast lighting towers subject to wind loads have been investigated through experimental tests. Researchers have also made efforts to track the mechanical behavior of HMIPs during the galvanizing process. However, the hot zinc bath's high temperatures limit the stress, strain, and deformation measurements that can be recorded during galvanizing.

Experimental studies have been complemented with numerical simulations to quantify the response of HMIPs during galvanization, and the stress demands when the poles are in service and subject to wind-induced fatigue loads. Nonetheless, as each of the fabricating stages, i.e., cold working, welding, and hot-dip galvanizing, induce residual stresses in the steel, the crack formation phenomenon cannot be solely attributed to the galvanizing process. Thus, numerical models that capture the cumulative effects of both the welding and the galvanizing fabrication processes in HMIPs are needed to approximate the strain and stress demands during their manufacturing.

Project Summary

This research work focuses on developing a better understanding of the root causes of weld toe crack in HMIPs by capturing the cumulative effects of both welding and galvanizing. This research objective was achieved by developing a three-dimensional finite element analysis capable of simulating the welding and galvanizing of HMIP and performing a parametric study. The welding and galvanizing parameters were varied to determine their influence on the crack formation phenomenon occurring post galvanizing. These variables' effects on the likelihood of cracks developing during galvanizing were quantified by comparing the resulting residual stresses and equivalent plastic strain magnitudes generated during the simulations.

Status Update

In this study, finite element modeling was used to analyze the response of the HMIPs under thermomechanical loading conditions. A high-resolution finite element (FE) model that can simulate the thermo-mechanical response of HMIPs throughout its manufacturing process, both welding and galvanizing, including dipping,

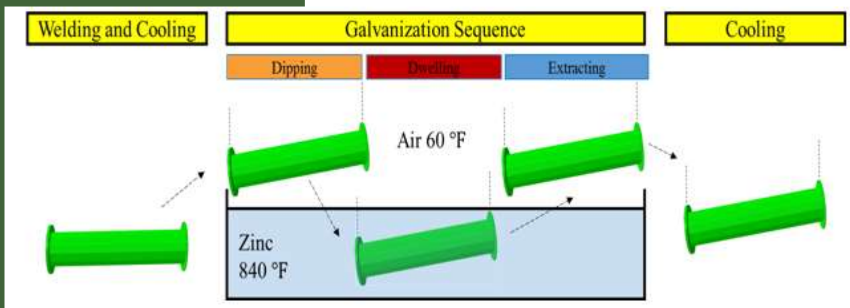

Figure 1. Cumulative Simulation sequence

dwelling, extraction, and cooling, was developed. The cumulative stress results were compared against simulations that only considered the galvanizing process. A parametric study was then conducted to quantify the variation in the residual stresses and equivalent plastic strain resulting after the galvanizing of HMIPs. The control variables of the study were speed, angle of inclination, and torch magnitude.

The results revealed that the cumulative effects of the different processes involved in the manufacturing of HMIPs contribute to the formation of galvanizing cracks in HMIPs. Also, increasing the dipping submersion speed during galvanizing and lowering the torch temperature magnitude during welding resulted in fewer zones prone to cracking. Altering the angle of inclination effect did not have a significant impact on the results.

Future simulations performed with the approach developed in this study will serve to identify geometric configurations that make HMIPs less vulnerable to damage during their manufacturing, evaluate the likelihood of crack for the types of connections details used by the different state department of Transportations, and propose modifications to the welding and galvanizing procedures to minimize the residual stresses induced during these processes.

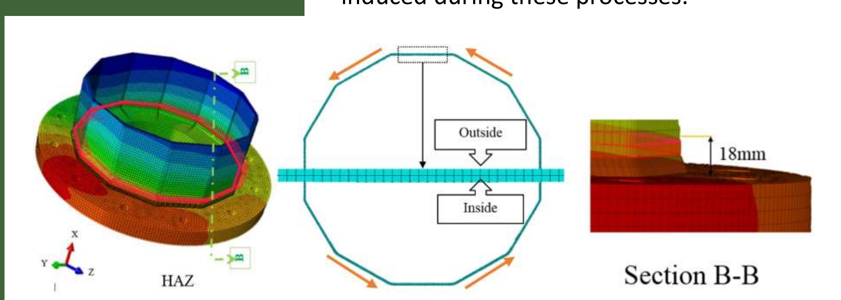

Figure 2. Radial path for extracting results

Impacts

This work addresses several FAST Act reseach priorities, including promoting safety, improving durability, extending the life of transportation infrastructure, and preserving the existing

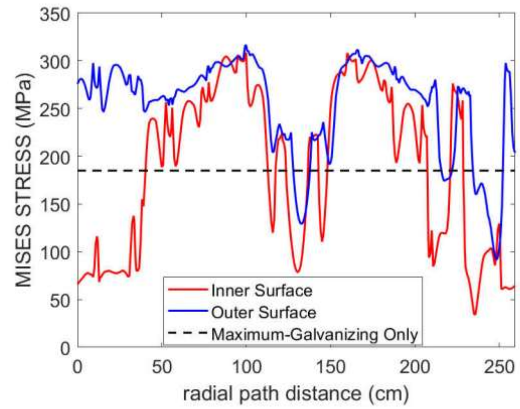

Figure 3. Comparison of simulation with cumulative results (welding and galvanizing) versus a simulation only accounting for galvanizing

transportation system. An in-depth understanding of the residual stresses generated during the manufacturing process of HMIPs can be used for preventing HMIP failures during service. The findings and tools developed in this project could also minimize the costs associated with detailed inspections of welded connections and maintenance and repair of cracks that manifest while the HMIPs are in service. Finally, it could prevent the financial losses incurred every time a damage connection is found and ensure the safety of the traveling public.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

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