Experimental and Numerical Simulation of Girth Welded Joints of Dissimilar Metals in Clad Pipes

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The welding of two dissimilar materials was carried out in-house with the aid of a tungsten arc weld having dynamic measurement of temperature profiles in the vicinity areas of the welding track using high-temperature thermocouples. A previous comparison of the simulated and measured transient temperatures versus finite element simulation is shown. Stress analyses of the pipe were carried out using finite element analysis (FEA) simulations with two different clad thicknesses. Results of thermal analysis show a close match, and laboratory tests reveal occurrences at the welded joints, the fusion zone and the heat-affected zone (HAZ); the result of stress analysis also shows good agreement when validated with neutron diffraction experimental results.

INTRODUCTION

In joining technology, welding is one of the vital techniques used to make continuous pipelines in industry. The thermal and mechanical loading in the process has a profound impact on the integrity of the pipeline over its service life. An accurate and thorough assessment is needed on the associated residual stress and its effect on the structural properties of the pipeline.

One of the novelties of this research is the understanding of the welded joints’ temperature responses, as demonstrated by positioning high-temperature thermocouples at strategic points on the welded joints to capture the transient temperature response at different points. It is not enough to assume that the distribution of heat through the weld metal will depend on the distance from the thermocouples to the heat source only; the temperature profile must actually be studied to uncover any peculiar trends.

The second impact of this research is the treatment of dissimilar materials through the implementation of a cladded layer. Previous experimental works have been carried out on the welding of single-layer pipes, but very little work has been carried out on cladding. Cladding is carried out mainly for the purpose of increased strength after which other qualities such as enhanced corrosion resistance can follow. Since two metals of different chemical constituents are welded together, we study the properties of the newly formed weld joint in terms of its chemical composition, strength, corrosion resistance, etc. (Total Materia, 2006; Kah et al., 2014).

The heat-affected zone (HAZ) also has an impact as it addresses a gap in knowledge. Since welding is carried out on two dissimilar materials, there is the need to investigate what occurs in the HAZ of the welded joint because the chemical component of the HAZ is altered via high weld temperatures. There is also a need to understand the location of the weakest point of burst because if a structure is to fail, the failure begins at that point.

The thermal properties of the inner and outer surfaces of the pipe are clearly defined and described in the next section of this paper. The finite element analysis (FEA) software considers the transient temperature variations and obtains close agreement with the experiment. We note that the friction between the two layers has not been considered—we define a frictionless contact between the two layers because we consider the relative motion between the two layers to be negligible; friction, however, can be considered in future research.

The thermal analysis in cladded girth welded joints was carried out using three-dimensional (3D) finite element analysis in Abaqus. Results of the transient temperature curves have been generated for the different cladding thicknesses (stainless steel and mild steel).

Welding of the two dissimilar materials was also carried out in-house with the aid of a tungsten arc weld with dynamic measurement of temperature profile in the vicinity areas of the welding track using high-temperature thermocouples. A comparison of the measured temperature with the simulation outcome shows good agreement. Laboratory tests were also carried out to reveal the occurrences at the fusion zone (FZ) and the HAZ of the welded joints.

In the thermal model, it was observed that the distribution of heat in the HAZ was maximum at the heat source position and minimum at the start and end points, indicating that heat was trapped in the middle region, which is responsible for the fluctuations in the heat distribution in these zones (Inspectioneering, 2016). It has therefore been deduced that the heat was retained within the welding spool for approximately 10 seconds in the middle region of the weld prior to cooling. The distribution was also considered in the final output as a result of the cavities present within the model (Lampman, 2001; Goldak and Akhlaghi, 2005; Youtsos, 2006; Qureshi, 2008).

Convection is the major procedure for transmission of heat from the weld strip to the immediate environment, whereas the...