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Procedia Technology 24 (2016) 364 – 371

Procedia Technology

International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015)

# 3D simulation of residual stress developed during TIG welding of stainless steel pipes

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**Abstract**

This paper deals with the effects of weld parameters on residual stress developed during TIG welding of pipes. Circumferential TIG welding is widely used in industries such as piping, oil refineries, power stations, etc. The 3D numerical simulation ANSYS code is used to predict the residual stress distribution developed during circumferential TIG welding. Due to non-uniform distribution of plastic and thermal strains in and around the weld pool, large amounts of residual stresses and deformations are present in all welded structures. The simulated results are validated using experimental results available in the literature. The effects of welding current and pipe thickness on residual stress and temperature fields at different locations were assessed.

Peer-review under responsibility of the organizing committee of ICETEST – 2015

*Keywords:*TIG welding; residual stress; simulation; numerical code.

## 1. Introduction

Welding is a reliable and efficient metal joining process used in almost all industries. Welded joints are extensively used in the fabrication industry, including ships, offshore structures, steel bridges, aerospace and pressure vessels. Steel pipes have been in widespread use for the engineering applications such as nuclear power plants, underground pipelines, etc.

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Peer-review under responsibility of the organizing committee of ICETEST – 2015
doi:10.1016/j.protcy.2016.05.049

*1.1. Literature Review*

In 1946 Rosenthal developed a relation for both line and point moving sources. In 1969 Pavelic introduced Gaussian form of distribution which is used by many researchers and has been using the same because of its simplicity and accuracy of such an assumption. Later John Goldack et al.[1] introduced a double ellipsoidal heat distribution model. Sabapathy et al. [2] developed a modified double ellipsoidal heat distribution model.

Ueda and Yamakawa[3] used 2D finite element analysis to calculate the welding residual stresses for the first time. They analyzed the effect of geometry configuration on residual stress and compared the results with X-Ray diffraction method. Many others also proposed FEM models to predict residual stresses. R A Owen et al.[4] presented a comparison among neutron diffraction, X-ray diffraction, synchrotron X-ray diffraction and Finite element model results of residual stress developed during welding of aluminium alloy AA2024.

Dean Deng et al.[5]developed a 3D FE model for simulating residual stresses during multipass welding of a pipe. The distribution of residual stress in welded pipe structures depends on several factors such as structural dimensions, material properties, heat input, number of weld pass and welding sequence, etc. Afzaal M. Malik et al. [6] analyzed the residual stress fields in circumferentially arc welded thin-walled cylinders. In order to reduce the computational time and cost, most of the researchers choose the axisymmetric models. Brickstad and Josefon[7] employed 2D axisymmetric model to simulate circumferential welding of stainless steel pipe up to 40 mm thick in a non-linear thermo-mechanical finite element analysis.

In the present study, a three dimensional finite element model is developed to simulate the temperature fields and residual stress fields developed during welding of pipes. The model is validated using the experimental results presented by Dean Deng et al.[5].

## 2. Physical modeling

A pipe with outer diameter of 114.3 mm, thickness of 6mm, and a total length of 800 mm as shown in fig.1 is considered for the analysis. The welding direction is as indicated in fig.1(a). The meshed model of pipe is shown in fig. 1(b).The material used is SUS304 stainless steel and it's mechanical and thermal properties with varying temperature are shown in fig.2.

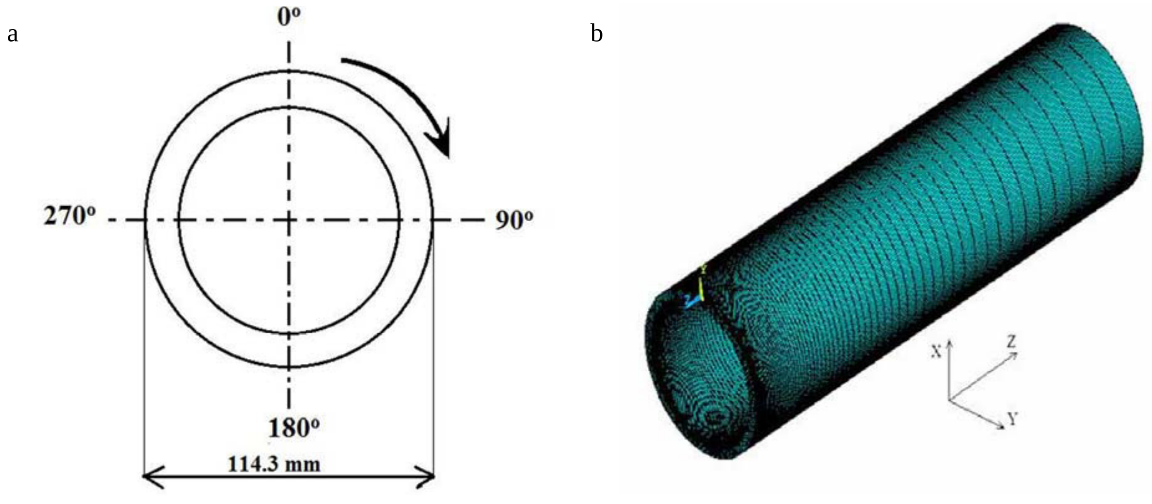


Fig.1.(a) dimensions of pipe and welding direction: (b) 3D finite element model of pipe

In this study, two pass TIG welding with an inter-pass temperature of 50°C is used. The welding conditions for the two passes are as shown in table 1.