

Technical Paper

Influence of welding speed and power on residual stress during gas tungsten arc welding (GTAW) of thin sections with constant heat input: A study using numerical simulation and experimental validation



A. Ravisankar, Satish Kumar Velaga, Gaurav Rajput, S. Venugopal*

Indira Gandhi Centre for Atomic Research, Department of Atomic Energy, Kalpakkam 603102, Tamil Nadu, India

ARTICLE INFO

Article history:

Received 30 July 2013

Received in revised form 26 October 2013

Accepted 13 November 2013

Available online 31 January 2014

Keywords:

Numerical simulation

Heat source fitting

Weld pool size

Temperature distribution

GTAW

Residual stresses

ABSTRACT

The temperature distribution and residual stresses for a GTAW circumferential butt joint of AISI 304 stainless steel using numerical simulation have been evaluated. For evaluation of weld induced residual stresses, the analysis of heat source fitting was carried out with heat inputs ranging from 200 to 500 J/mm to arrive at optimal heat input for obtaining proper weld penetration and heat affected zone (HAZ). For this chosen heat input, the influence of different weld speeds and powers on the temperature distribution and the residual stresses is studied. The heat source analysis revealed the best choice of heat input as 300 J/mm. The residual stresses on the inner and outer surfaces, and along the radial direction were computed. Increase in temperature distribution as well as longitudinal and circumferential residual stresses was observed with the increase in weld speed and power. The validity of the results obtained from numerical simulation is demonstrated with full scale shop floor welding experiments.

© 2013 The Society of Manufacturing Engineers. Published by Elsevier Ltd. All rights reserved.

1. Introduction

Gas tungsten arc welding (GTAW) is widely used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The circumferential butt joint is a common type of pipe joint in a variety of engineering applications such as oil and gas industries, nuclear, thermal power plants and chemical plants. The base metal and weld metal undergoes thermal cycles during the process of welding. These thermal cycles produce inhomogeneous plastic deformation, which results in the onset of the residual stresses in the weld metal. The presence of tensile residual stresses increases the susceptibility of the weld to fatigue damage, stress corrosion cracking (SCC) and fracture [1]. While manufacturing thin walled components these residual stress cause distortion of the component and make it difficult to control the dimensions of the components. Therefore, control of residual stresses and their distribution is important to avoid service failures and to ensure the dimensional compliance especially while welding thin walled sections. In order to control the residual stresses and their distribution a thorough understanding of the mechanism of development

and the influence of welding parameters on the generation and distribution of residual stresses are required. The measurement of temperature distribution and residual stresses in the regions adjacent to the weld during and after the welding process is of prime importance for understanding the distribution of residual stresses and the influence of process parameters on the distribution of residual stresses.

It is well known that industries in their urge to complete the fabrication to meet the production schedules resort to welding with higher speeds by giving more power inputs. The higher welding speed, higher power input and transient or unsteady state thermal behaviors are often encountered during welding of thin sections. In view of the above, modeling tools are often used for the estimation of temperature distribution and residual stresses in the regions adjacent to the weld during and after the welding process. Finite element (FE) analysis is a proven tool for accurate assessment of thermo-mechanical behavior in circumferentially joined thin-walled structures and is being used in the evaluation of thermal cycles and welding residual stresses [2]. A review of literature [2–20] reveals that a number of investigations have been undertaken by various authors through numerical analysis coupled with experimental validation to understand the residual stresses arising from the differential temperature distributions during welding. Thus, regions near the weld center are likely to undergo severe thermal cycles because of such high concentrated heat source,

* Corresponding author. Tel.: +91 4427487323; fax: +91 4427480356.

E-mail addresses: venu@igcar.gov.in, venusrini@hotmail.com (S. Venugopal).

which in turn generates residual stresses in the weld metal in the longitudinal as well as circumferential directions. Malik et al. [2] have evaluated the residual stresses on the inner and outer surfaces of cylinder for varying welding speeds with different heat input per unit volume. The above investigations reveal that the welding speed and power have strong influence on the distribution of residual stresses. Chin-Hyung Lee et al. [3] have carried out three dimensional FE analysis to estimate the residual stresses in circumferential welds of steel pipes with inside radius to wall thickness ratio ranging from 10.0 to 100.0. They have also illustrated the variation in residual stresses at different circumferential locations and the effects of diameter on residual stress distributions. Shim Y. et al. [4] considered a ramp heat input and included the effect of moving arc in their analysis. They also investigated the effect of various ramp times and observed that 20% of the actual heat input time is the best ramp time. Liang Wang et al. [5] have investigated the effect of laser travel velocities with constant power and the laser powers with constant velocity on the distribution of residual stress during laser welding of thin wall plates. In this study net heat input during welding process was also varied. Spina et al. [6] evaluated the effect of welding speeds on the weld profiles and distortion of the components during laser welding of AA 5083 sheets using numerical simulations. This study revealed that as the welding speed reduced the net heat input increased and vice versa. Brickstad et al. [7] used FE model to study the variation in weld heat inputs and the variation in the through-thickness of the weld and heat affected zone on the axial and hoop stresses for austenitic stainless steel pipe welds. Kazuo Ogawa et al. [8] investigated the residual stress in penetration nozzles by considering different nominal heat inputs and weld speeds at constant weld power for different weld passes. Chaowen Li et al. [9] carried out three dimensional finite element analyses of temperatures and stresses for increasing weld speeds with constant power on different samples. The above study reveals that increase in weld speed at constant power, increases the net heat input. Kermanpur et al. [10] studied the effect of variation in net heat input for a GTAW circumferentially butt welded pipes. The study revealed that increasing the heat input resulted in a wider weld pool along with a higher maximum temperature in the HAZ. Wu et al. [11,12] used different levels of heat inputs with different welding currents by keeping welding speed and voltage as constant for two different arc welding processes (double sided and plasma) in the numerical simulation. They also carried out numerical analysis to predict the temperature field and weld pool shape as a function of welding speed with constant laser power and current. Gery et al. [13] investigated the effect of variable welding speeds and energy inputs on the transient temperature distribution, shape and boundaries of fusion zone and HAZ. Dean Deng et al. [14] examined the influences

of heat input on the size of HAZ, welding residual stress and distortion during numerical simulation of electro slag welding process. Dean Deng et al. [15] performed four different cases of welding simulations with constant weld current, voltage and speed to clarify the influence of phase transformation on the residual stress and welding deformation. Farid Vakili-Tahami et al. [16] carried out welding simulations on T-shape fillet welding of AISI 304 stainless steel plates by considering the constant weld current, voltage and speed (i.e. constant heat input). Long et al. [17] predicted the temperature variations, fusion zone and heat affected zone as well as longitudinal and transverse shrinkage, angular distortion and residual stress for various welding speeds and plate thicknesses. Díaz et al. [18] carried out the comparative analysis of TIG welding distortions between austenitic and duplex stainless steels by considering two different net heat inputs for both the stainless steels. Jiang et al. [19] studied the effect of different welding heat inputs and layer numbers on residual stresses and deformation in repair welds of stainless steel clad plate. Yanhong Tian et al. [20] investigated the effect of heat input and welding speed on the temperature field, especially on the shape and dimensions of the weld pool. It can be observed from the above survey of literature that only limited investigations had been undertaken to study the effect of different conditions of weld speeds and powers with constant heat input on the variation in temperature distributions and residual stresses. Further, the information on the variation in longitudinal and circumferential residual stresses along the radial distance from the outer surface as a function of different weld speeds and powers with constant heat input is not available in the open literature. The relationship between weld speed and power versus residual stress and their distributions at constant heat input are important for the optimization of process parameters for welding of thin walled sections for achieving close dimensional tolerances in the products. The above mentioned relationships can be established, through FE modeling and these FE models can be used for optimizing the weld parameters for obtaining sound welds.

The objective of the present investigation is to estimate the temperature as well as residual stress distribution based on FE simulation during welding of AISI type 304 stainless steel by GTAW process for the purpose of optimizing the welding parameters for circumferential butt joint of circular sections of thin walled centrifugal extractors (CE) used for nuclear fuel reprocessing applications. Since the CE handle HNO_3 and rotate at about 3000 rpm the welds need to possess adequate penetration and the heat affected zone (HAZ) has to be as small as possible. For this study, circumferential welding of cylindrical components of 2.5 mm thick AISI 304 SS by GTAW process has been considered. The 2-D line diagram with boundary conditions for FE modeling is shown in Fig. 1.

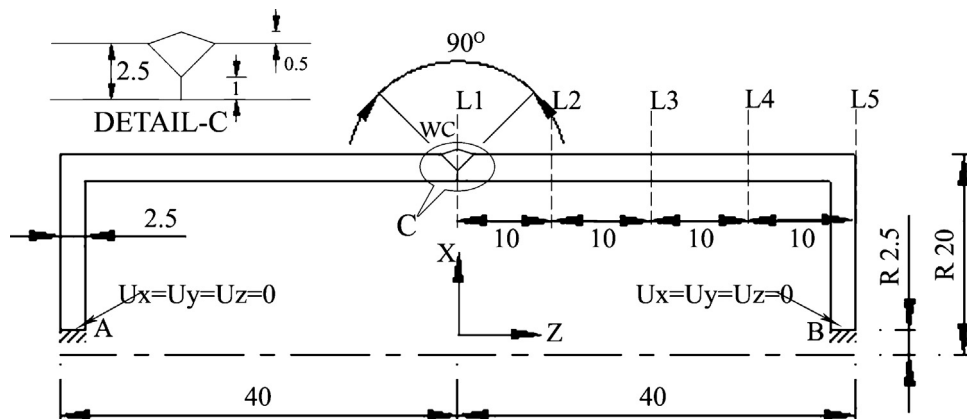


Fig. 1. Schematic 2-D line diagram of cylindrical work piece with boundary condition.

Download English Version:

<https://daneshyari.com/en/article/1697123>

Download Persian Version:

<https://daneshyari.com/article/1697123>

[Daneshyari.com](https://daneshyari.com)