Materials and Design 32 (2011) 2851–2857

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Finite element analysis of the effect of welding heat input and layer number on residual stress in repair welds for a stainless steel clad plate

W.C. Jiang [a,*], B.Y. Wang [a], J.M. Gong [b], S.T. Tu [c]

[a] College of Mechanical and Electronic Engineering, China University of Petroleum, Dongying 257061, PR China
[b] School of Mechanical and Power Engineering, Nanjing University of Technology, Nanjing 210009, PR China
[c] Key Laboratory of Pressure System and Safety (MOE), School of Mechanical and Power Engineering, East China University of Science and Technology, Shanghai 200237, PR China

ARTICLE INFO

Article history:
Received 17 May 2010
Accepted 16 December 2010
Available online 21 December 2010

Keywords:
A. Ferrous metals and alloys
D. Welding
E. Mechanical

ABSTRACT

Stainless steel clad plate is widely used in petroleum, chemical and medicine industries due to its good corrosion resistance and high strength. But cracks are often formed in clad layer during the manufacture or service, which are often repaired by repair welding. In order to ensure the structure integrity, the effects of residual stress need to be considered. The objective of this paper is to estimate the residual stress and deformation in the repair weld of a stainless steel clad plate by finite element method. The effects of heat input and welding layer number on residual stresses and deformation have been studied. The results show that large residual stresses have been generated in the repair weld. The heat input and layer number have great effects on residual stress distribution. With the heat input and welding layer number increasing, the residual stresses are decreased. Using multiple-layer welding and higher heat input can be useful to decrease the residual stress, which provides a reference for optimizing the repair welding technology of this stainless steel clad plate.

1. Introduction

Clad plate consisting of a thin layer of reactive metal bonded onto a lower cost, thicker base metal, has been widely used in construction of corrosion resistant equipment. Explosion bonding, roll bonding and weld overlay are the primary technologies to manufacture the clad plates. But during the manufacture or service life, defects are often formed in the clad layer and penetrate into the base metal [1]. The best method to repair the cracked region is removing and refilling that part by repair weld. The repair welding of clad plate belongs to dissimilar steel welding, which causes great difficulties in quality control [2,3]. For repairing clad plates, it is vital to decrease the welding residual stresses, because the tensile residual stress has an adverse effect on fracture [4], fatigue [5,6] and corrosion [7,8]. The stainless steel clad plate often serves at hydrogen contained environment, and the absorption of hydrogen in metals is a serious problem for clad plate. Our work [9] and other research [10] found that the occurrence of residual stresses can promote the hydrogen diffusion, which can lead to the interface de-bond [11], hydrogen embrittlement [12], hydrogen induced cracking (HIC) [13] and stress corrosion cracking (SCC) [14]. Therefore, it is very import to predict the residual stress distribution accurately for structural integrity assessments [15,16].

Finite element method (FEM) has been widely used to predict the residual stress in the repair welding [17–21]. Welding related parameters [22–24] and geometric conditions [25,26] have great effect on residual stress. Lee and Chang [27] discussed the effect of pipe diameter on residual stress in circumferential welding of a pipe component. Bouchard et al. [28] discussed the repair length on residual stress in a stainless steel pipe girth weld, and found that the residual stresses at mid-length of the heat affected zone of the short repair were found to be higher than in the long repair. During the recent years, we researched the brazing residual stress in stainless steel plate–fin structure [29], and the effects of geometric conditions including brazing gap, plate thickness, fin thickness, fin pitch, fin height and fin layers on residual stress have been investigated [25]. In addition, the material mismatching between filler metal and base metal on residual stress has also been studied [30]. Meanwhile we also used experimental tests to study the effects of brazing temperature [31], holding time [32], filler metal thickness [33] and cooling rate [34] on tensile strength and microstructure for stainless steel plate–fin structure, through which the brazing technology is optimized to provide a reference for design and manufacture of plate–fin structure. In recent we [35] paid attention to the residual stresses in the repair weld of a stainless steel clad plate, and found that the residual stresses are decreased with an increase of repair width. In this paper, the effects of welding heat input and layer number on residual stress are studied, aiming to provide a

* Corresponding author. Tel.: +86 546 8391776; fax: +86 546 8393620.
E-mail address: jiangwenchun@upc.edu.cn (W.C. Jiang).

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doi:10.1016/j.matdes.2010.12.037