Influence of laser welding heat input on HAZ cracking in newly developed Haynes 282 superalloy

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A study of the cause of heat affected zone (HAZ) cracking and its dependence on heat input during laser beam welding of a newly developed γ' precipitation strengthened nickel based superalloy Haynes 282 was performed. Careful microstructural study coupled with Gleeble thermomechanical simulation showed that HAZ cracking in the alloy is attributable to the degradation of hot ductility of the alloy due to subsolidus grain boundary liquation. A decrease in the magnitude of heat input during laser beam welding resulted in increased HAZ cracking. The cracking variation with heat input is discussed in relation to the time that the subsolidus HAZ region spent at peak temperatures and thermally generated stress during welding.

Keywords: Joining, Welding, Nickel based superalloy, Heat Affected Zone Cracking

Introduction

The increasing overall efficiency of aero and land based gas turbines by increasing the service temperature has necessitated the design and development of higher performance nickel based superalloys that are used for producing turbine hot section components. Haynes 282 (HY 282) is a new γ' precipitation strengthened nickel based superalloy with improved elevated temperature properties over some of the commonly used nickel based superalloys like Inconel 718, Waspaloy and Haynes 263.[1] Joining is an essential process in assembling simple to complex shaped turbine parts during fabrication. In addition, hot section turbine components are often subjected to complex combination of severe thermal and mechanical stresses for extended time periods, which normally causes cracking and/or wear. Owing to the high cost of part replacement, it is increasingly becoming economically desirable to repair and rejuvenate service damaged components. In general, fabrication of new component and repair of service damaged nickel based superalloy components are performed using conventional fusion welding process such as gas tungsten arc welding. However, the high heat input associated with these processes often results in large heat affected zone (HAZ) size and undesirable distortion of welded parts. A recent trend in the aerospace, automotive and power generation industries is the drive to utilise high power beam density sources to rapidly produce deep, narrow and low heat input welds during component fabrication and repairs. Laser beam welding is an attractive and promising welding technique for achieving these goals with high reliability and productivity necessary for industrial manufacturing system.[2]

A preliminary laser beam welding of HY 282 showed that the alloy is susceptible to cracking in the HAZ during welding. There is, however, limited reported weldability data, and no discussion on the cause of HAZ cracking in the literature. Understanding the cause of cracking and how it is influenced by welding parameters is vital to develop optimum welding procedure for preventing or minimising the cracking problem and facilitate the application of laser beam for joining the newly developed alloy. Therefore, the primary objective of the present research was to carefully study the fundamental cause of HAZ cracking, and its dependence on heat input, during laser beam welding of the new superalloy HY 282. The results are presented and discussed in the present communication.

Experimental

Wrought HY 282 superalloy with a nominal chemical composition of Ni–1·5Al–2·1Ti–10Co–20Cr–8·5Mo–1·5Fe–0·3Mn–0·15Si–0·06C–0·005B (wt-%) was used in the present study. The alloy was received in the form of mill bright annealed plates. Welding test coupons of dimension $65\times15\times5$ mm were machined by a numerically controlled wire electrodischarge machine and subjected to preweld solution heat treatment (SHT) at 1050°C for 2 h followed by water quench. The preweld heat treated specimens were surface ground, properly cleaned to remove surface oxides and then autogenously welded by a single pass CO_2 laser beam using two heat input values, as presented in Table 1: a high heat input corresponding to 120 J mm^{-1} and a low heat input of 60 J mm^{-1}. In order to carefully study the non-equilibrium microstructural changes and hot ductility in the HAZ during welding, physical simulation was

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