EFFECT OF POST WELD HEAT TREATMENTON MICROHARDNESS OF TAILOR TIG WELDED BLANKS

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Abstract : The present study reports on the effect of post-weld heat treatment (PWHT) on microhardness of Tailor TIG welded joint between low carbon steel of draw quality and austenitic stainless steel 304 grade of both 1.2mm thickness at 650°C and 1050°C. 304L filler rod is used for joining process. Detailed characterization across the welded joint was conducted using optical microscope and micro hardness test. Results showed that PWHT had significant effect on the microhardness of both the weld metal and heat affected zone (HAZ), the hardness in the fusion zone reduced to 16% in 650°C sample and further to 32% in 1050°C sample and a slight deviation of hardness reported in HAZ of low carbon steel side while it had little influence on the ASS side. By using proper PWHT, the hardness gradient attenuated across the dissimilar welded joint. The correlation among various heat treatment, microstructure evolution and microhardness were analyzed in detail.

Keywords: PWHT, TIG, Microstructure, Microhardness, Characterization

I. INTRODUCTION

Tailor Welded Blanks are made of different materials with same or varying thickness, coated or uncoated etc., that are welded together prior to forming. In the automotive industry, tailored blanks are used only at areas where a higher strength or stiffness is necessary [1]. Apart from automobile industry joining of structural components using dissimilar materials are extensively used in aerospace, chemical, petrochemical, nuclear, power generation and other industries. Tailor-welded blanks give the product designer the opportunity to eliminate reinforcements while improving structural and dimensional characteristics. Although tailor-welded-blank (TWB) technology with Aluminium alloys is an area of development but the main application is with steel were automotive components such as body side frames, door inner panels, motor compartment rails, center pillar inner panels, and wheelhouse/shock tower panels are made from steel[2]. The main benefit of using TWBs is to reduce overall mass of the vehicle, crash worthiness and to improve fuel efficiency[3]. In addition, the TWB process allows for part integration, eliminating the need for reinforcements and stiffeners (e.g., in situations when weight is reduced by using lighter-gage high-strength steel in place of heavier gage steels, leading to reduced structural stiffness)[1]. Stainless steels show very good combinations of strength and ductility which is of special interest in automotive applications. The use of this materials presuppose the safe and correct use in all stages automotive development and production[4]. In general Laser welding is the process used for joining the tailored blanks, but little is the work done on using TIG welding process, so in this work we have employed TIG welding process to join tailored blanks[5].

During heat treatment processes the phenomena that occur always involve atomic diffusion and to relieve the internal stresses which developed during the fabrication and mechanical working of metal, annealing is done and it being a type of heat treatment which is a micro structural modification process that impact on both the hardness and strength of weld region[6].

II. EXPERIMENTAL PROCEDURE:

Dissimilar materials such as AISI 304 SS and Low Carbon Steel of deep drawn quality of dimension 350 x 110 x 1.2 mm were used as base metals and AISI 304L filler wire is used for fabrication in this work. The chemical composition of the base metals and filler wire is presented in Table I.

CONSTITUENT (WT%)	C	MN	SI	P	S	CR	NI	N	FE
SS 304	0.078	1.75	0.7	0.04	0.03	17.2	7.42	0.065	Balnce
SS 304L	0.034	1.7	0.65	0.04	0.25	17.5	7.6	0.06	Balance
LOW CARBON STEEL	0.075	0.5	-	0.038	0.035	-	-	-	Balance

Dissimilar butt weld joints were fabricated by using AC DC Pulse Tig Welding Machine 400iPA. Before welding the edges were thoroughly cleaned with acetone to remove impurities. 304L filler wire is used for welding and welding parameters selected are Argon at a rate of 8 liters/min is used as shielding gas. After welding, heat treatment of the welded samples was carried out in which one sample at a temperature of 650°C and holding time of 60 minutes followed by air cooling and for another sample solution annealing process is adopted, it is heated at a temperature of 1050°C and holding time of 30 minutes followed by water quench.

Metallographic samples were wet grounded on progressive finer grit sizes of silicon carbide impregnated emery paper using water as lubricant. The grounded samples were then polished mechanically using a polishing cloth. Micro structural features in the as-received, and the as-welded heat-treated samples was mounted by standard procedure and observed using optical microscopy across the cross section of the weld. Due to the nature of the dissimilar metal joint, the samples were etched using Nital solution (2% HNO_3 acid and 98% alcohol for the low carbon steel side, and HNO_3 acid (3ml), HCL acid (9ml), acetic acid (2ml) and glycerin (1ml) for the stainless-steel side). The specimen then immersed in the solution for 40-45 seconds, washed in running water followed by rinsing with alcohol and finally dried before viewing under the optical microscope. The hardness was measured across the weld at a load of 500g for a dwell time of 10s through the heat affected zone and into the base metal.

III. RESULTS AND DISCUSSIONS:

Microstructure and Microhardness of as welded Tailored Blanks in the Figure 1 presents a macroscopic view of a cross-section of the obtained dissimilar welded joint. There were no welding imperfections in the specimen, i.e., no cracks visible. Figure 2b shows the microstructure of the as-received stainless-steel alloy before welding which is essentially an austenitic matrix, and the microstructure of the low carbon steel alloy figure 2a comprises of grains of ferrite and pearlite in form of bands. Perfect weld is obtained as examined through Macro structure study of the dissimilar welded material from the stainless steel side to the low carbon steel side.

The variations in the microstructure across the as-welded samples (figure a-e) from the base alloy of the stainless steel to the HAZ of the stainless steel to the fusion zone and the HAZ of the low carbon steel to the base metal of the low carbon steel may be attributed to the difference in the materials solvus temperature and the two base alloys experiences peak temperature at the joint during the welding process. In general during fusion welding processes the fusion zone experiences peak temperature that is well above the liquidus temperature of the materials been joined, hence complete melting and solidification is expected to takes place in the fusion zone (figure 2e). However, there is a limitation in complete mixing to produce a homogeneous liquid within the fusion zone[7] . The observed microstructure in the fusion zone of the dissimilar welded sample is completely different from that in the base-alloys. Presence of δ-ferrite is evident in the fusion zone and consists of both alloys that had melted and subsequently solidified with features of ferritic-austenitic solidification mode. Micro segregation across the dendritic structure because of solute redistribution during solidification is possible which in turn results of fluctuations in grain growth rate. The microstructure of the base-alloys i.e., stainless steel side and low carbon steel side is unaffected by the welding process, but in the heat affected zone of the stainless-steel side there is significant increase in size of the grains. Whereas in the low carbon steel microstructure of the heat affected zone appears to indicate solid state transformation without significant difference in the ferritic and pearlitic structure distribution and morphology.

Figure 1. Macrograph of as welded sample

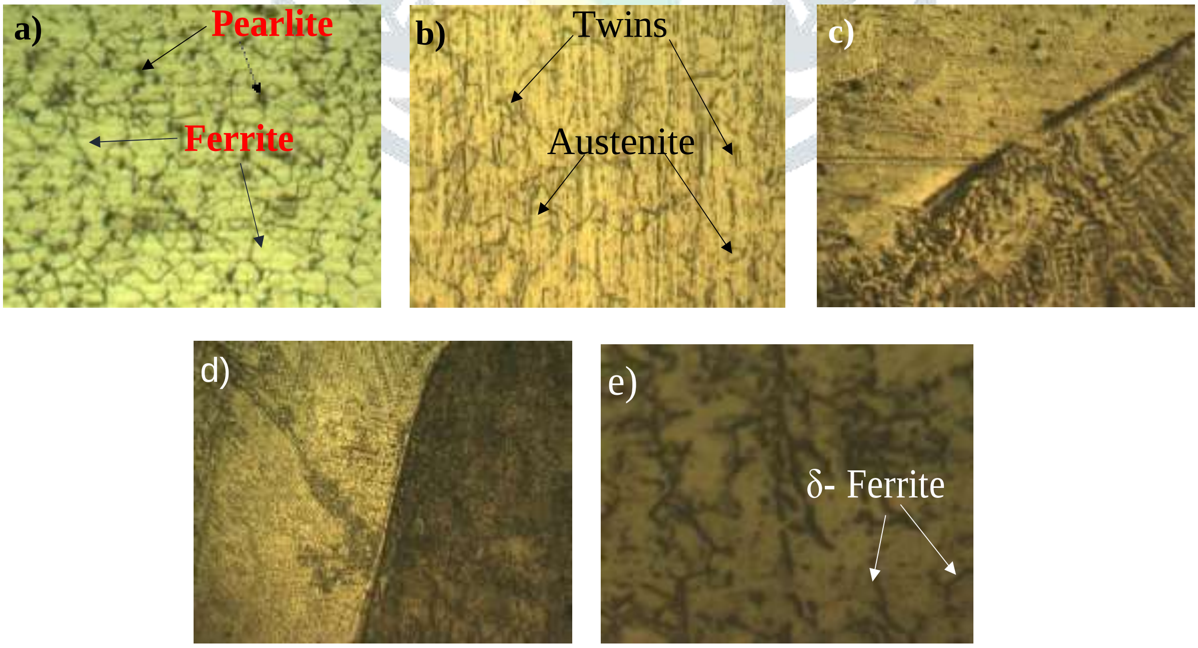

Figure 2: Optical Micrographs of as- welded sample a) Base metal of Low carbon steel b) Base metal of SS304 c) HAZ of LCS side d) HAZ of SS304 Side e) Fusion Zone

Effect of post welding annealing heat treatment on the microstructure and microhardness are shown in figure 3 & 4 respectively. The purpose of doing post weld heat treatment is to minimize the induced internal stresses during welding and reducing the microstructural inhomogeneity. In this study the as-welded samples were heated at 6500C soaked for 60 minutes and solution annealed at 10500C soaked for 30 minutes. Figure 4 shows the comparison of microhardness with and without heat treatment. It is evident that sample with solution annealed reduced the hardness gradient across the dissimilar welded joint when comparing with other two. In the fusion zone micro segregation can be reduced significantly by solid-state diffusion during and after solidification[8] and when the observations made in this is evident in the post-weld heat treated materials. Figures 3 (a-e) shows the microstructure of the post weld annealed heat-treated sample at 10500C, and a holding time for 30 minutes. Figure 3e shows the post weld fusion zone indicating dendritic solidification with apparent thick and longer dendritic arm when compared to as welded fusion zone as we can observe improved homogeneity of the previously unhomogenized fusion zone microstructure. The microstructure of the heat affected zone close to the low carbon steel (draw quality) side in figure 3c and the Austenitic stainless-steel side in figure 3d after post-weld annealing heat treatment both indicate a coarse microstructure relative to the as received microstructure. The base alloy microstructure of both materials after welding and post-weld annealing treatment (figure 3a and 3b) however remain same the as-received microstructure.

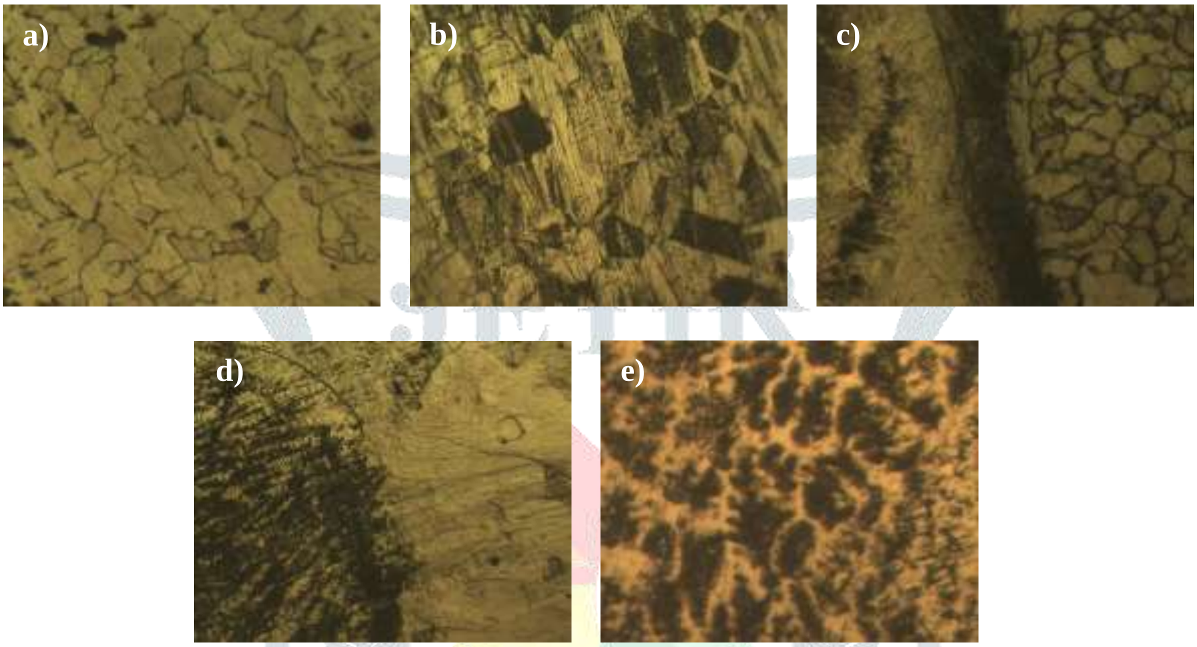

Figure 3: Optical Micrographs of Solution Annealed at 10500C Heat Treatment sample a) Base metal of Low carbon steel b) Base metal of SS304 c) HAZ of LCS side d) HAZ of SS304 Side e) Fusion Zone

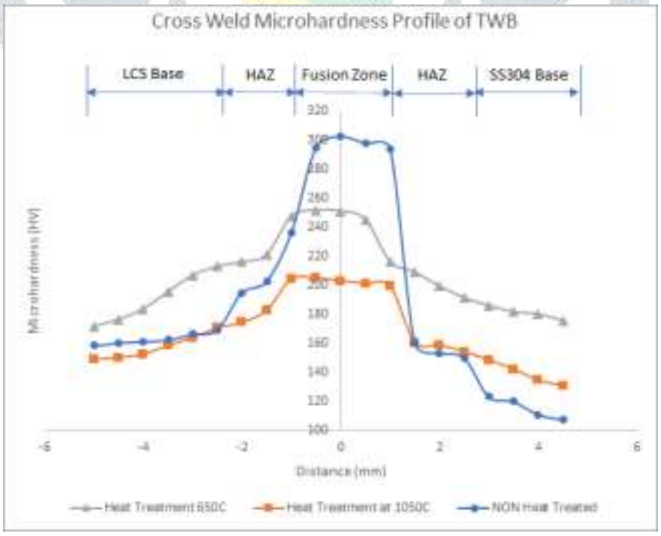

Figure 4: Comparison of Microhardness profile across the weld

IV. CONCLUSION:

The tailor welded dissimilar joint of austenitic stainless steel of 304 grade to low carbon steel of draw quality was determined with a view to homogenize the as-welded fusion zone hardness, which could eliminate or reduce the potential detrimental effects of inhomogeneous fusion zone on mechanical properties.

The following conclusion points are being derived as:

- Sound/good welds without any defects were obtained between 304 grade austenitic stainless steel and low carbon ferritic steel of draw quality using AISI 304L electrodes.
- There is a steep variation in the micro hardness profile in the as-welded fusion zone from the low carbon steel region to the austenitic stainless-steel region.
- Post weld annealing heat treatment of dissimilar metal weld of austenitic stainless steel and low carbon steel were carried out at temperatures of 6500C, 10500C held for 60 and 30 minutes each. The best homogenization of the fusion zone was found to occur at solution annealing temperature of 10500C soaked for 30 minutes, where the deviation of micro hardness in the fusion zone reduced to 16% in 650°C sample and further to 32% in 1050°C sample and a slight deviation of hardness reported in HAZ of low carbon steel side while it had little influence on the ASS side.

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