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Review on Effect of Repetitive Rework on Dissimilar Austenistic Stainless Steel Pipes by using GMAW Orbital Welding

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Abstract. Dissimilar metal welding is widely applied to meet the rquirement of transition in mechanical properties and/or difference in working conditions. For instance, even though AISI 304 and AISI 316L are both belong to austenitic stainless steels, but they are applied in different working environment. AISI 304 is used at high temperature applications, whereas AISI 316L is used at low temperature. Repair welding is able to return a part back to its normal service life if weld failure happened due to service deterioration or defects during fabrication stage. However, repetitive heat input due to repair welding will cause changes in welded structure and properties. In this article, the effect of repetitive repair welding of dissimilar austenitic stainless steel pipes to the microhardness, tensile strength, microstructure and quality of the weldment has been reviewed.

Introduction

Orbital welding is defined based on the circular movement of welding tool or welding torch around the workpiece to be welded. Orbital welding always has priority for joining tubes or pipes over the other types of joining methods. This is because it not only provides sophisticated weld quality; meanwhile, it can also perform easily and smoothly in the congested working environment [1]. Dissimilar metal welding has gained its popularity and well established in joining stainless steel to other materials. This method is commonly employed in order to cater the requirement of transition in mechanical properties and/or variation of service environments [2]. Repair welding is often carried out in steel-made structural components. The primary purpose of repair welding is to prolong the service lives or performance of the components by providing remedy for presence of welding defects during initial stages or weld deterioration during their service [3]. However, the older machinery used in industry, construction site or agricultural sector, they are frequently break down and wear out. It is relatively impossible to get back a part that is identical to the one that is broken down or wore out. The practicable solution for this problem is repair welding. It is comparatively economical than make replacement of the part. This is because delay time during waiting the replaced part might cause an irreparable lost to a company [4].

In addition, occurrence of weld failures is inevitable in the fossil and nuclear power plants as the metal components are always operated under extremely high temperature and pressure. Besides that, susceptibility of welded metals to cracks, corrosion, ruptures and pitting will also initiate the weld to fail. Therefore, Electric Power Research Institute (EPRI) realized the importance of welding repair, especially in saving the cost, minimizing break down time and extending the service life [5]. In this article, the effect of repetitive repair welding of dissimilar austenitic stainless steel pipes to the microhardness, tensile strength, microstructure and quality of the weldment has been reviewed.

Microstructure Evolution

According to AghaAli et al. [6], the main constituents for AISI 316L were ferrite precipitate and black carbide particles embedded in austenitic matrix. However, it was found that the morphology of δ-ferrite in the base metal had undergone changes with the number of welding. The original lathy morphology of δ-ferrite was first became less lathy and then slowly turned into vermicular morphology. When number of weld repair increased, ferrite precipitate was also gradually getting finer and shorter together with some carbide precipitation as shown in Fig. 1.

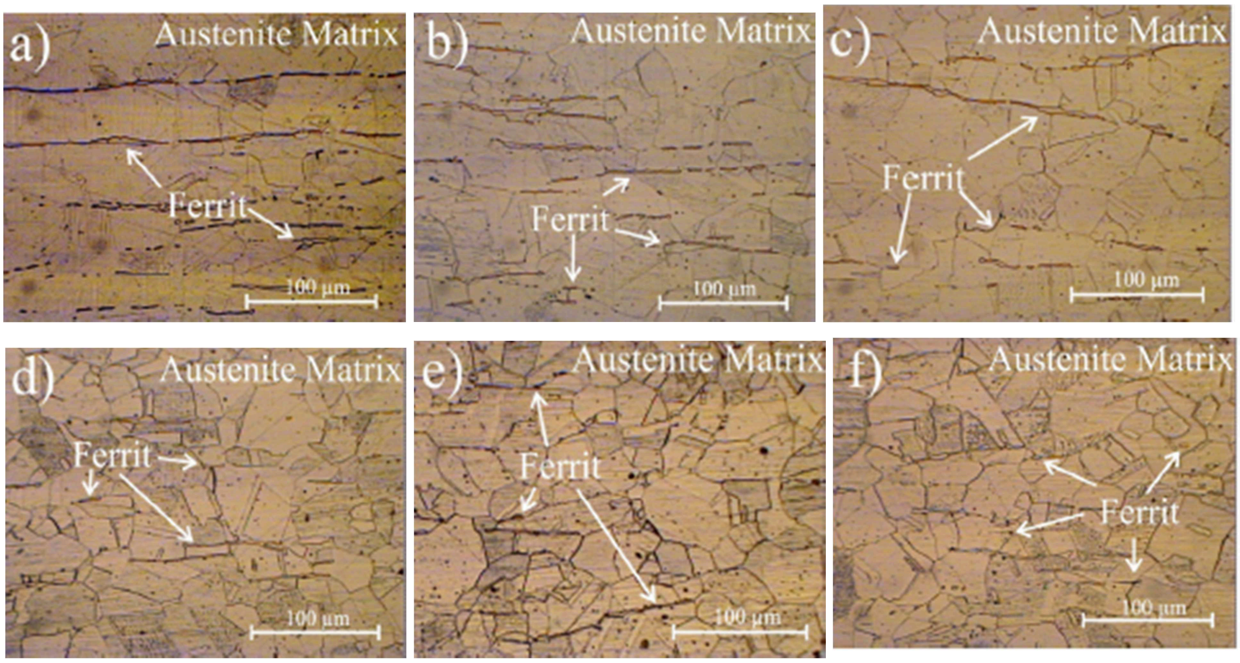

Fig. 1 Microstructure of AISI 316L Stainless Steel. (a) base metal (b) 0 repair HAZ (c) 1 repair HAZ (d) 2 repairs HAZ (e) 3 repairs HAZ (f) 4 repairs HAZ [6].

Lin et al. [7] stated the primary phases of AISI 304L also comprised of austenite matrix and lathy ferrite precipitates. Similar to AISI 316L, the lathy ferrite was also become shorter and thinner in accordance to increasing of weld repair. For every repair welding, the material is subjected to additional heat input and the heat input is accumulated in the weldment.

On the other hand, Kumar and Shahi [8] clearly stated heat input is a function for both dendrite size and interdendritic spacing. Slower cooling rate due to high heat input facilitates formation of coarser dendrites and they are separated in wider distance compared to low heat input. Besides that, numerical data as illustrated in Table 1 was also provided by them in order to support their findings.

Table 1 Microstructural details of weld joints [8]

Heat Input	Microstructural Details	
	Dendrite size (µm)	Interdendritic spacing (µm)
Low	111.10	10.29
Medium	151.75	15.42
High	201.14	22.87

Grain Size. AghaAli et al. [6] mentioned that grain size number in HAZ is increased corresponded to the number of weld repair that had done on the same location as shown in Fig. 2. This phenomenon can be explained by formation of new grains that induced by the heat input and thus numerous grain size is produced. Yet, subsequent heat input due to repeated weld repair will facilitate grain growth and therefore grain size number is decreased. On the other hand, Vega et al. [9] stated that grain growth is observable in coarse grain HAZ corresponding to the number of repair welding. However, they reported that there are no much changes found in the HAZ microstructure constituents as compared to the as-welded condition.

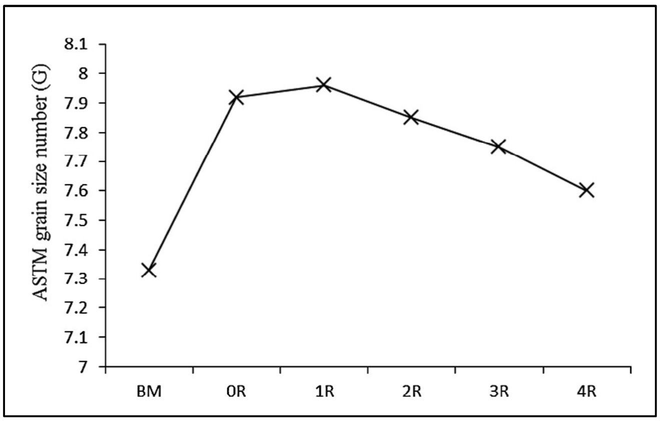

Fig. 2 Interrelation between ASTM grain size number in HAZ and number of weld repair [6].

Volume Fraction of δ-ferrite. As reported by AghaAli et al. [6], quantity of δ-ferritehas shown a decreasing trend when number of weld repair increased as shown in Fig. 3. This is because higher welding heat input contributed to lower cooling rate, therefore the quantity of δ-ferriteis greatly reduced. Slower cooling rate indicates the heat input to the weld zone takes longer time to dissipate, so that it gave sufficient time for transformation of δ-ferrite into austenite, γ. Consequently, more δ-ferrite will be transformed into γ by increasing the number of weld repair as the material is introduced to higher heat input.

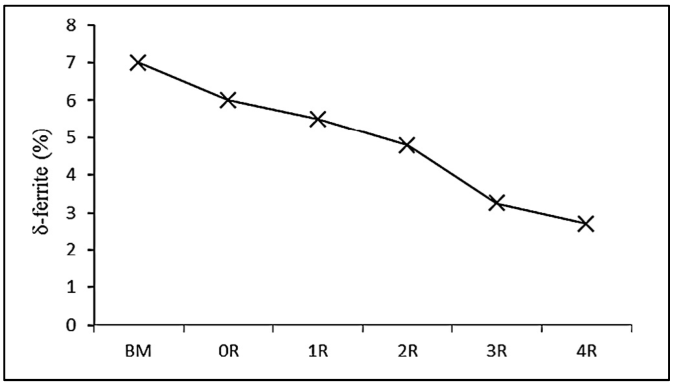

Fig. 3 Volume Fraction of δ-ferrite corresponded to number of weld repair [6].

Mechanical Properties

Microhardness. Brinell hardness test was carried out by AghaAli et al. [6] for stainless steel 316L and the result of testing showed that hardness value of HAZ is affected by number of weld repair. Brinell hardness of HAZ increases in first repair but decreased with increase in number of weld repair. This is because in the first repair new grain is generated and grain refinement is observed, but those grains are started to growth in the following weld repair. The grain growth occurred especially in the HAZ region because it experienced slower cooling rate [10].

In addition, reduction of δ-ferrite composition and changes in lathy morphology of δ-ferrite are another factor that caused decrease in hardness value [11]. Nevertheless, HAZ always has lower hardness in comparison to base metal and Kianersi et al. [10] also agreed with it. Yet, hardness value of weld metal remains unchanged due to application of same filler metal. Similar result is also obtained by Vega et al. [9] for the repetitive welding of seamless API X-52 microalloyed steel pipe.

On the other hand, multipass GTAW on AISI 304L also showing the same trend in which the microhardness value is increasing in the order of weld metal, HAZ and base metal. This is mainly due to the cooling rate that took place in each zone, where it is highest for base metal, moderate for HAZ and lowest for weld metal. Therefore, hardness of HAZ adjacent to fusion zone is certainly lower due to apparent grain growth, whereas hardness of HAZ adjacent to base metal is higher due to fine grain structure [12]. The same result is also evidenced by Kumar and Shahi [8] for GTAW welded AISI 304 and Monika and Chennaiah [13] for GMAW welded dissimilar joints.

Tensile Properties. Tensile strength of AISI 316L exhibited the same behavior as the Brinell hardness in the study of AghaAli et al. [6], where the yield strength (YS) and ultimate tensile strength (UTS) tend to increase only up the first repair and YS and UTS begin to decrease after that. This is shown in Fig. 4. Elongation of specimen is associated to its tensile properties, since it is a measure of changes in the specimen length to original length under tensile test. Therefore, it is observed that as-welded AISI 316L experienced lower elongation than base metal, but after first repair the elongation is increased and gradually decreased started from second repair.

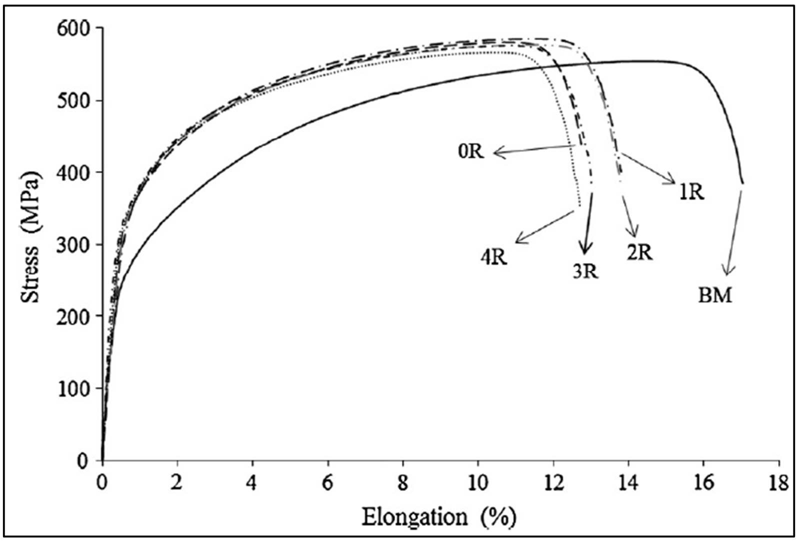

Fig. 4 Stress versus elongation profile [6].

On the contrary, Vega et al. [9] reported that the tensile strength of API X-52 microalloyed steel pipe can be increased up to second weld repair, where a maximum value is reached. However, both researchers are concluded that changes of tensile strength are due to reason of grain refinement occurred in the materials.

Conclusion

Orbital GMAW can be applied for welding stainless steel made tubular products, such as pipes. It provides higher productivity due to its welding mechanism in nature as the wire electrode is fed automatically to the weld zone. Besides that, dissimilar metal welding such as joining of AISI 304 and AISI 316L allows transition in service conditions, for example from high temperature to low temperature. Currently, repair welding has been widely practiced in industry because it is more beneficial compared to make a purchase or do replacement. Yet, repair welding can lead to changes in mechanical properties of welded structure. From previous researches, it stated that microhardness, ultimate tensile strength and yield strength only increased up to first repair welding, it is then showed decreasing trends. All of these changes are attributed to microstructural evolution due to repetitive heat input applied by repair welding. For future work, the effect repetitive rework on dissimilar stainless steels pipes will be studied experimentally on the microstructural formation, microhardness variations, tensile properties and non-destructive testing for internal defects.

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