Research on the Welding Process of High Nitrogen Steels with Mid-thickness by MIG Welding

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Abstract. The process parameters were optimized by bead weld in high nitrogen austenitic stainless steel with 12mm thickness. High nitrogen austenitic stainless steel plates with 20mm and 40mm thickness were welded with the optimum process parameters. The mechanical properties of weld joints were inspected. The experimental results indicate that the best process parameters of bead weld are that welding current is 260 A, welding speed is 600 $mm.min^{-1}$, the flow rate of gas is 20 $L.min^{-1}$, and torch height is 15 mm, the angle of welding torch is 6 degree. The internal qualities of weld bead were beyond the grade Ⅱ and heat-affected zone were small. The mechanical properties of welded joints were excellent. For instance, the tensile strength can achieved move 80% than that of the base metal and the impact absorbing energies also approach 50% than that of the substrate metal. The optimum process parameters can effectively solve the problem of welding process of high nitrogen steels with mid-thickness by MIG welding.

Introduction

High nitrogen austenitic stainless steels obtain the austenite by replacing the bulk of nickel in the traditional stainless steels with nitrogen elements. Low production costs, excellent corrosion resistance and high strength-toughness can be achieved by nitrogen alloying [1]-[6].

High nitrogen austenitic stainless steel is a developing new engineering material [7]. Its application depends not only on the excellent comprehensive properties but the welding characteristics [8][9]. In the some fields of particular application, tandem MIG welding is a widely used and high-efficiency bonding technology. Therefore, the research on tandem MIG welding process of high nitrogen austenitic stainless steels for the application and research has a very important significance. High nitrogen austenitic stainless steel with 12mm thickness was tested by bead welding, and the welding parameters of bead welding were optimized. High nitrogen austenitic stainless steel plates with 20mm and 40mm thickness were welded with the optimum process parameters. The internal qualities, mechanical properties and micro-hardness of weld joints were tested.

Experimental Materials and Procedure

High nitrogen austenitic stainless steel (HNS) was used in the experiment and its chemical compositions (mass fraction in percent) as showed in Tab.1. Welding wire ER309L with the diameter of 1.2mm was used to bead welding. The shielding gas consisted of 5% N_2 and 95% Ar. The flow rate of gas is 20$L.min^{-1}$. The microstructure of the HNS is austenite with a small quantity of δ-ferrite.

TAB.1. Chemical compositions of the HNS

Elements	C	Cr	Mn	Si	N	Ni	Fe
Mass %	0.11	21.4	14.94	0.32	0.64	1.8	Balance

A Robot and the tandem MIG welding machine were used in the bead welding experiment for 12mm-thickness HNS. The middle of the HNS weld was cut by water cutting jet. The internal cracks and penetration were observed and measured by etching the weld junction with $FeCl_3$

hydrochloric acid solution. And then the results of weld quality were recorded in detail.

Besides, high nitrogen austenitic stainless steel plates with 20mm and 40mm thickness were welded with the optimum process parameters. The butt weld groove of the samples was double-V, and the angle was 60 degree, and the width of gap was 2mm. There were four-pass weld in the sample of 20mm-thickness HNS and seven in 40mm thickness for needing more enough filler metal. An X-ray detection machine XXQ 1650 was used to check the internal quality of weld for non-destructive testing after tandem MIG welding. The standard samples of tensile and impact were prepared by water cutting jet.

The micro-structure of the heat-affected zone was observed by the optical and scanning electron microscopy, and the mechanical properties and micro-hardness of weld joints were tested.

Results and Discussions

Experiment of Bead Welding

In the welding process of HNS, the stable welding arc, small welding spatter, excellent external appearance and non-gas cavity in surface. Figure 1 shows the cross sectional morphology of bead welding. There is no obvious welding crack and the weld fusion zones are all V-shaped.

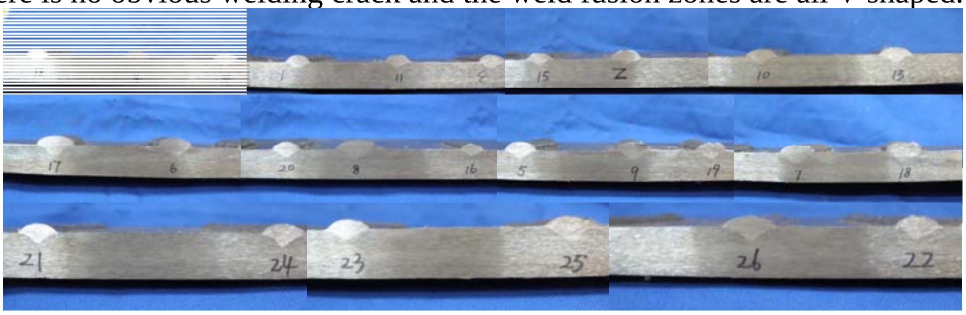
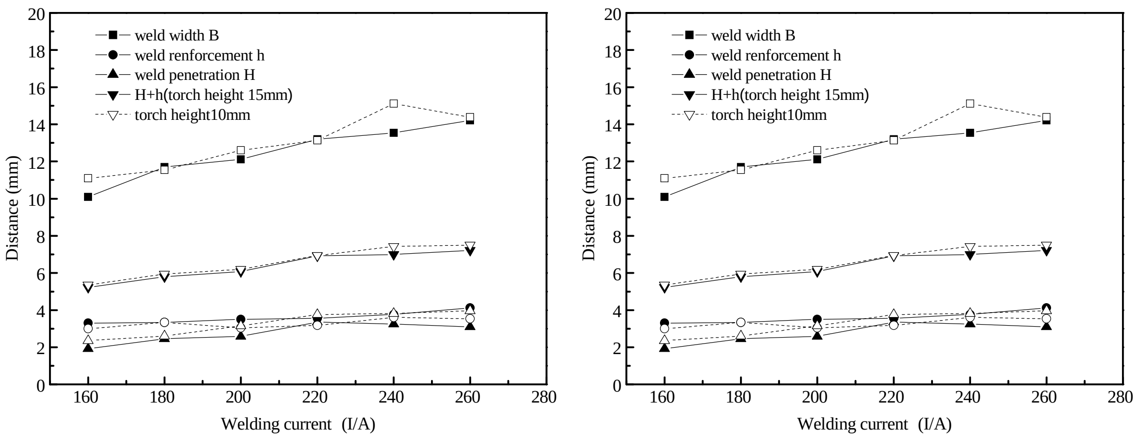


Fig.1. Cross sectional morphology of bead welding

The weld width, weld reinforcement and weld penetration were measured in order to further explore the effects on different welding process of weld quality. The results were shown in figure 2. From Fig.2a and Fig.2c, it can be observed that the weld width B, weld reinforcement h and weld penetration H have no change with the different torch height and the flow rate of gas. The torch height and the flow rate of gas have no effect on the weld quality. Therefore, the flow rate of gas is 20L.min^{-1} and torch height is 15mm can be set as the best welding process of bead welding for reducing the waste of shielding gas and torch head burned.



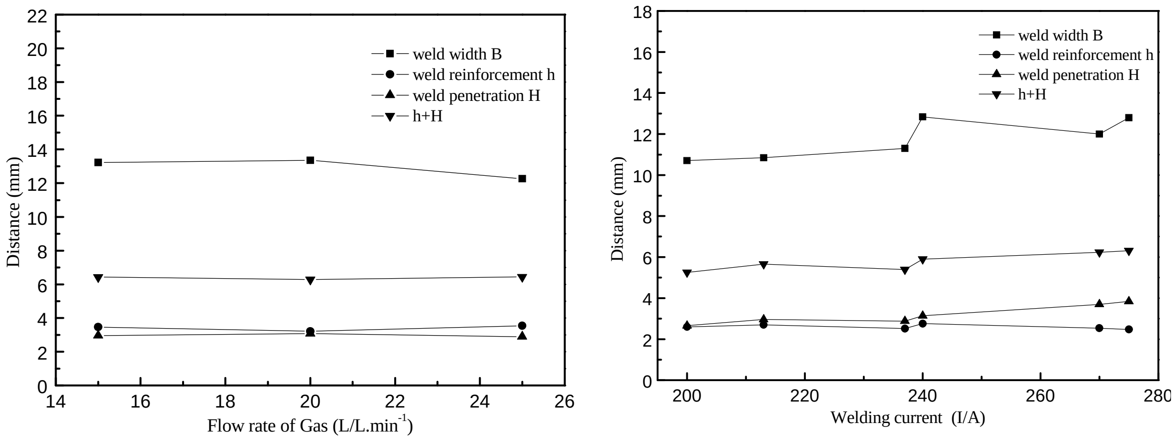


Fig.2. Effect on weld quality of bead welding with different welding process: (a) Welding current and torch height, (b) Welding speed, (c) Flow rate of gas, (d) Welding current

From Fig.2a and Fig.2d it can be observed that the more welding current is, the more weld width B, weld reinforcement h and weld penetration H are. The amplifies becomes little when the welding current is 240A or even more. Simultaneously, from Fig.2a and Fig.2d, it can be observed that the values of weld width B, weld reinforcement h and weld penetration H were inversely proportional to the corresponding welding speed. Hence, the decrease becomes slow when the welding speed is 600mm.min^{-1} or even more. So the welding current 240A and welding speed 600mm.min^{-1} can be set as the best welding process of bead welding.

Experiment of Butt Joint

Internal quality of weld

Figure 3 shows the results of internal quality of weld of HNS with 20mm and 40mm thickness by nondestructive testing. The 6 linear pores existed in the side of arc striking, as shown in Fig. 3. The reason that causes the pores is that hydrogen elements which melted into superheat weld pool or adhered in the oxide film formed the bubbles in cooling process. These hydrogen elements originated in the decomposition of water molecules stay in surface of weldments, combined water or protective gas in high temperature. The internal quality of weld is grade-Ⅱ. From Fig.3b, it can be observed that the internal quality of weld of HNS with 40mm thickness is grade-Ⅰ with no defects. It indicates that the welded joints had excellent internal quality by tandem MIG welding with the best process parameters of bead weld.

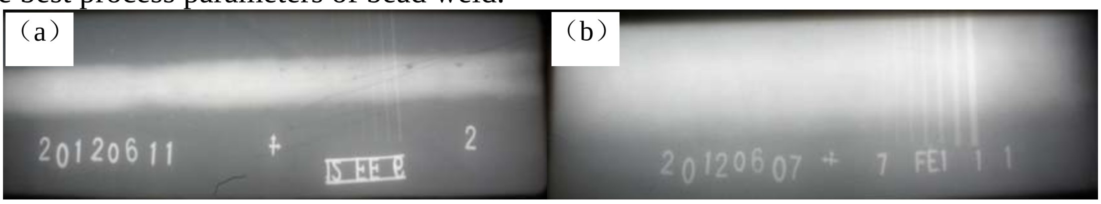


Fig.3. Weld internal quality of 20mm and 40mm thickness plates: (a) 20mm, (b)40mm.

Heat-affected zone

The micro-hardness of HNS with two kinds of thickness in the selected location is shown in Fig. 4. From the trend line of the micro-hardness distribution law, it can be observed that the width of the heat-affected zone is about 1-2mm. It indicates that the width of the heat-affected zone is small by tandem MIG welding with the best process parameters of bead weld.

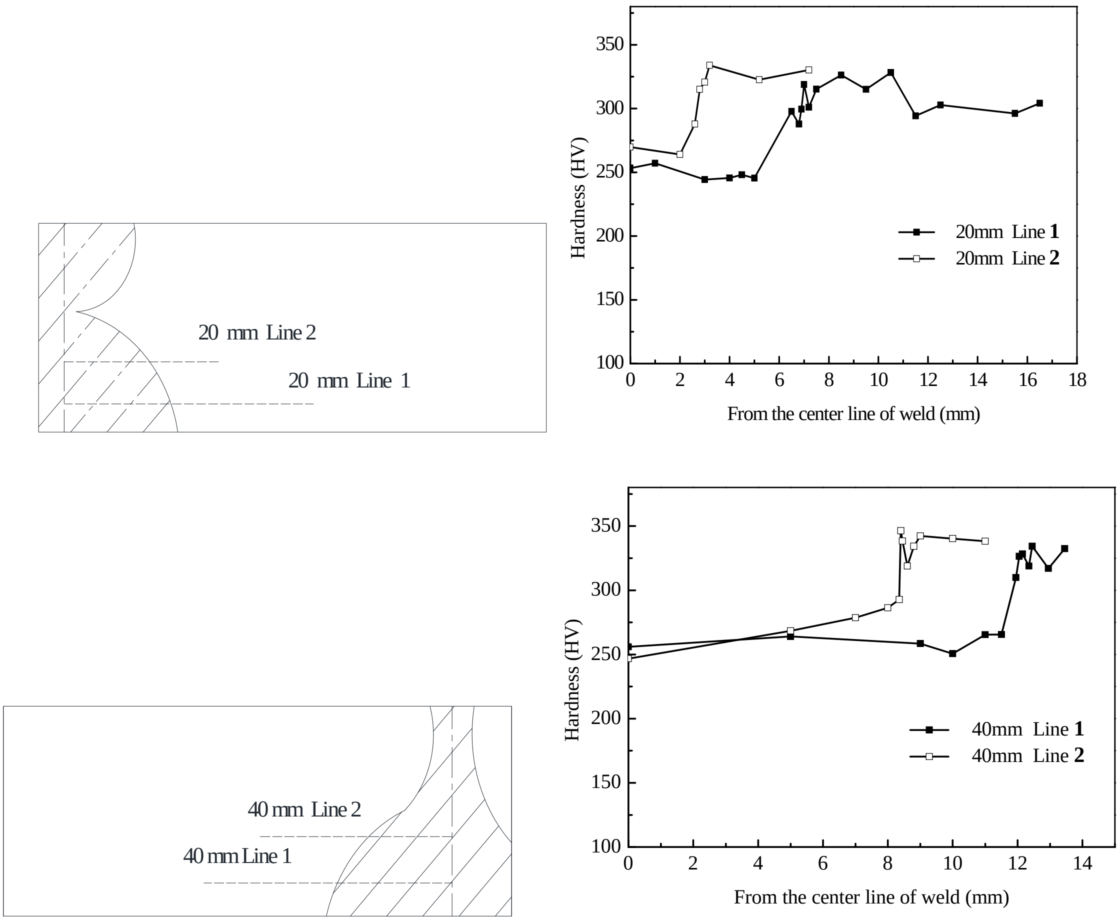


Fig.4. Micro-hardness distribution law of 20mm and 40mmthickness HNS: (a) 20mm, (b) 40mm.

Mechanical properties

The specimens of tension test fractured in the location of weld entirely. The data of tensile test with preferable consistency can be used as tensile samples of analysis mechanical properties. The non-proportional extension strength (Rp0.2) and ultimate tensile strength (Rm) of 20mm thickness HNS, respectively were 720 Mpa and 844 Mpa. The tensile strength can be achieved move 80% than that of the base metal and the elongation is 12.8%. And for HNS with the 40mm thickness, the strength is decreased significantly than that of HNS with 20mm thickness. But the ultimate tensile strength (Rm) also can reach more 80% than that of the base metal and the elongation is 18%. The impact absorbing energy of HNS with 20mm and 40mm thickness were 158J and 130J, and respectively were 58% and 48% of the substrate metal. The toughness of welded joints is excellent.

Conclusion

The internal qualities of weld, mechanical properties and micro-hardness of weld joints for tandem MIG welding conditions were investigated. The following conclusions can be obtained.

(1) The experimental results indicate that the best process parameters of bead weld that welding current is 260A, welding speed is 600mm.min^{-1}, the flow rate of gas is 20L.min^{-1}, and torch height is 15mm, the angle of welding torch is 6 degree.

(2) The internal qualities of weld both over in grade Ⅱ and weld heat-affected zone were small.

(3) The mechanical prosperities of welded joints were excellent. For instance, the tensile strength can be achieved move than 80% of the base metal and the impact absorbing energy also approach 50% than that of base metal.

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