JOINING OF MILD STEEL TO AUSTENITIC STAINLESS STEEL BY MANUAL METAL ARC WELDING

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ABSTRACT

This paper investigates the weldability of a dissimilar joint between the SS41 mild steel and the 304 austenitic stainless steel using manual metal arc. Sheets of 3 mm thickness of the two different steels have been welded using three different electrodes: E308L, E430 and E6013. Tensile tests performed on specimens taken transverse to the welds showed that specimens welded using either E308L or E430 electrode fail in tension outside the weld metal eventually at the mild steel base metal. The joint welded by E430 electrode showed greater ductility than that of E308L electrode. On the other hand, the specimens welded using E6013 electrode failed inside the weld metal at a stress that is fairly lower than the strength of mild steel. The properties of the different zones of the joints have been studied using microhardness testing as well as microscopic observations. The structure of the weld interfaces at the two base metals has been also investigated and the results have been reported.

NTRODUCTION

Engineering and economic specifications frequently equire components to be constructed from more than one naterial. Table (1) shows some applications where lissimilar metal joints are used

Today there is a large number of joining techniques vailable for joining dissimilar metals. These include elding adhesive bonding and mechanical fastening. Velding has the advantage of having much wider range f applications than other joining processes. Moreover the elded joint is more rigid and provides the most truly ontinuous structure. There are however many difficulties at arise in welding two dissimilar metals. The most nportant of these is the possibility of interactions oducing either brittle or low melting point eutectics at e weld interfaces [1]. The difference in heating capacity e to different thermal properties and the difference in formability at the welding temperature are also serious tors that affect the properties and the service life of the lded joints (2-5). Several premature failures have been curred in joints at a service time well below the design time (2-4, 6-8).

Another problem is the choice of suitable filler material ectrode) that has to work well with both of the two se metals (9). The objective of the present study is to investigate the weldability of a dissimilar joint between the SS41 mild steel and the 304 austenitic stainless steel using manual metal arc. Different welding electrodes are used on the basis of composition of base metals and strength of welded joint required.

EXPERIMENTAL PROCEDURE

Materials and Welding Consumables

The dissimilar base metals used in the present investigation are the SS41 mild steel in the hot rolled condition and the 304 austenitic stainless steel in the cold rolled condition. Both of them were received in the form of sheets of 3 mm thickness with the following chemical composition, table (2).

Three types of electrodes have been used. E6013 mild steel, E308L austenitic steel, and E430 ferritic stainless steel. The first electrode type is conventionally used to weld mild steel, the second type is often used to weld similar joints of 304 austenitic stainless steels whereas the third type is used often to weld similar joints of ferritic or artensitic stainless steels. E430 electrode is used in the present investigation for its high strength.

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Table 1. Some applications of dissimilar metal joints

Field (industry)	Example (component)
boilers	boiler tubing, hot steam piping
steam generator	steam generator circuits
reactors	Seal discs in heavy water reactor
electric parts	connection of different wires
transmission pieces	clutches, brakes, couplings
refrigeration industry	sealed tubular joints

Table 2. Chemical composition of base materials.

Element	5541 mild steel	304 austenitic steel
C	0.14	0.04
Si	0.06	0.49
Mn	0.70	0.83
P	0.018	0.026
S	0.014	0.09
Ni	---	9.15
Cr	---	18.13

Welding and testing of welded joints

The manual metal arc process has been used to weld the two dissimilar steel sheets prepared with square edges using 2.5 mm dia. electrodes. The welding current has been changed in the range 70-130 amp.

Tensile test specimens taken transverse to the weld line have been tested in tension until failure. Using inscribed marks on the gage length of the specimens, the local elongation of the different zones of the welded joints has been determined. Brinell hardness measurements at equal spans transverse to the weld line have been performed. Microhardness measurements at intervals of 500 µm using a load of 50 g have also been carried out across the weld joint.

Transverse sections of the welded joints have been prepared metallographically and etched for microstructure observations. The microstructure at the different zones transverse to the welds has been investigated using both the optical and the scanning electron microscopy.

RESULTS AND DISCUSSION

Using both visual and ultrasonic inspection it has been found that the welded joint performed using E308L electrode is free from detectable surface and subsurface defects. The joint made using E430 electrode suffered face weld cracking whereas the joint welded by E6013 electrode contained porosity.

The stress-strain curves for specimens of the dissimilar joints made using different electrodes are shown in Figure (1).

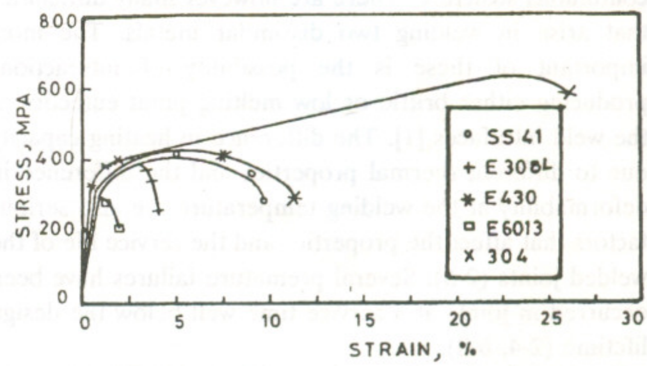


Figure 1. Stress strain curves for specimens taken transverse to the weld line.

It shows also the same curves for the two base metals for comparison. The specimens of the weld of E6013 electrode failed at a fairly low stress compared to the fracture strength of the two base metals. The fracture occurred eventually inside the weld metal. Both specimens of the welds of E308L electrode and E430 electrode failed at nearly the same strength which is equivalent to the fracture strength of mild steel. Indeed, the failure of both of these specimens occurred outside the weld metal and eventually at the mild steel base metal.

The specimens welded using E430 electrode experienced greater total elongation than those of E308L electrode. The local elongation in tension of the different zones of the welded joint has been determined and plotted in figure (2). It shows that the joint made using E430 electrode experiences high local elongation at the weld and at the heat affected zone of mild steel. This local elongation is at least three times greater than the local elongation of other sections of the joint. Conversely the specimen of the weld of E308L electrode showed a nearly uniform local elongation at the different zones as shown in Figure (2).

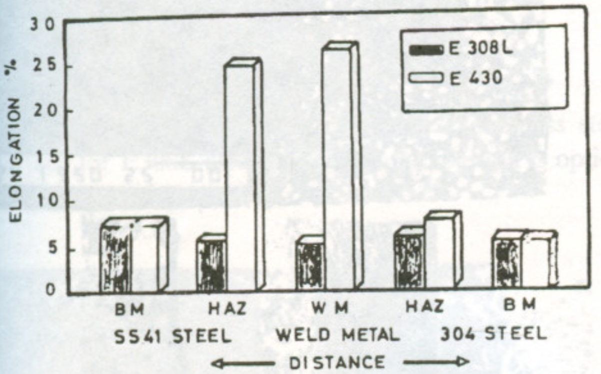


Figure 2. Local elongation of different zones of tensile specimen taken transverse to the weld.

The hardness distribution along line perpendicular to the weld is shown in figure (3). For the three different electrodes, it is shown that near the weld centre the hardness is maximum and is not highly sensitive to the electrode type. Around the weld interfaces the joint of E308L electrode showed higher hardness than the joints of the other electrodes specially at the interface weld-stainless steel base metal. This can be attributed to the negligible dilution effect as the composition of E308L electrode is close to the composition of stainless steel base metal. The joint of E6013 electrode showed the lowest hardness profile at the stainless steel interface. This local softening is expected to be a result of migration of carbon at weld interface to the stainless steel base metal. It is worth mentioning that similar results have been reported [6] on other welds of other dissimilar metals.

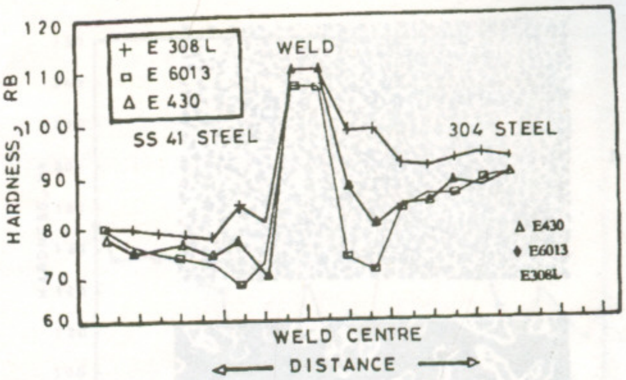


Figure 3. Hardness distribution alonge a line perpendicular to the weld for differnt electrodes.

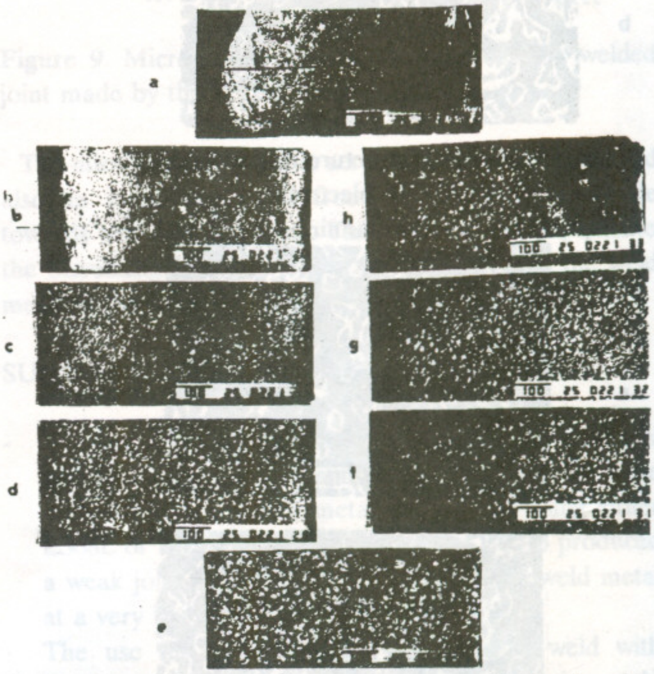


Figure 4. a- Scanning electron macrograph showing the weld metal- b to h- scanning electron micrographs showing the structure at the differnt zones transverse to the weld line:

The structure of the different zones of a joint made using E308L electrode is shown in Figure (4). The line b-h on the macrograph is a line transverse to the weld starting from weld-stainless base interface at b to weld-mild steel interface at h. The scanning electron micrographs from b to h represent the microstructure of the weld at the points indicated on the macrograph at the centre of figure (4). All the micrographs show a structure consisting of α particles of equiaxed dendritic shape dispersed in a matrix of γ austenite as shown in figure (5).

a

b

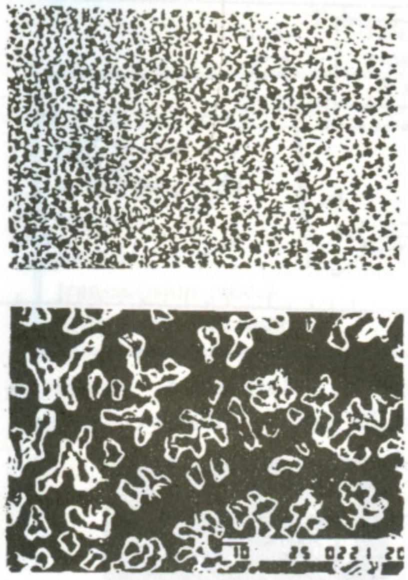


Figure 5. Microstructurcture of the weld metal made by E308L electrode.
a- optical b- scanning

a

b

c

Figure 6. Micrographs of the weld microstructure at different locations a- at mild steel base b- at weld centre c- at stainless steel base.

Figure (6) shows that the volume fraction of γ phase decreases as we move towards mild steel base metal. It shows also that the α particles are coarser at the centre of the weld and decrease in size as we move towards the weld interfaces.

The microstructure of the interface of the weld, made by E308L electrode is shown in Figure (7.a). Both the optical and the scanning electron micrographs show a clearly distinct dilution zone at the weld interface with mild steel. This zone (which appear as a white band of 100 μm wide, on the optical micrograph and dark on the scanning micrograph) corresponds to a carbon depleted zone resulting from carbon migration from mild steel melt to the weld metal.

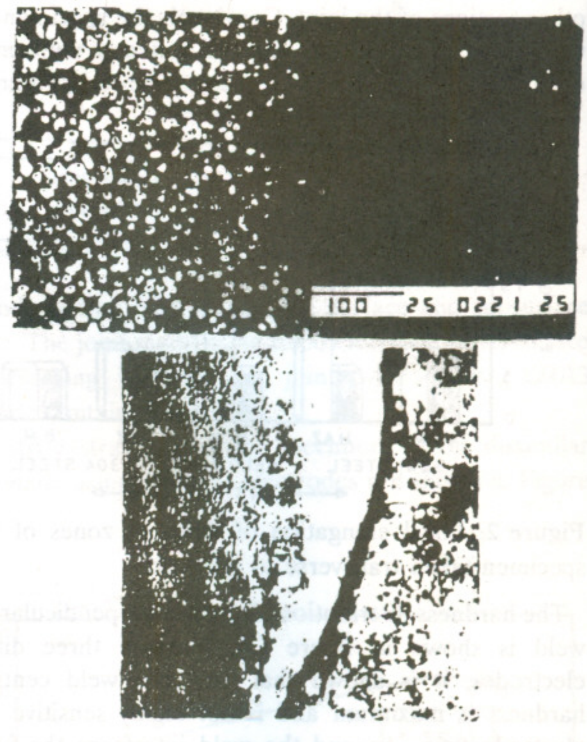


Figure 7-a. Microstructure at weld mild steel interface for E308L electrode, lower micrograph is optical and upper one is scanning.

The microstructure of the other interface (stainless steel interface) is shown in figure (7.b). It shows a narrow transition zone (50 μm wide) containing solidification microstructure in the 304 stainless steel. Similar results have been previously reported by different authors [10,11].

The microstructure of the interfaces of the weld made by E430 electrode is shown in Figure (8). It shows a sharp weld interface at mild steel without any evidence of dilution. The interface with stainless steel base metal is again characterized by a transition zone similar to that observed in the case of E308L electrode.

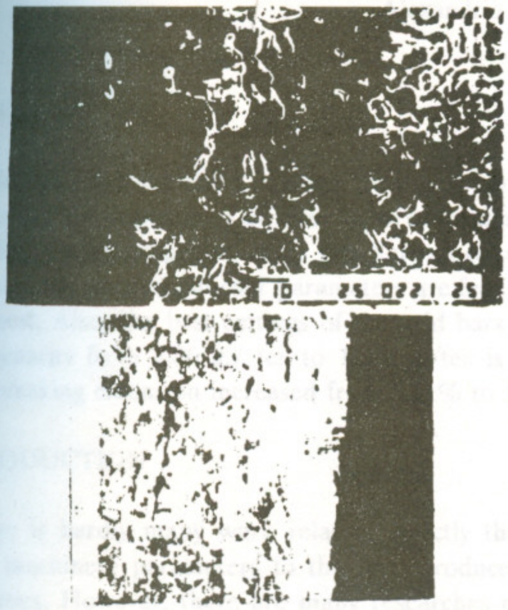
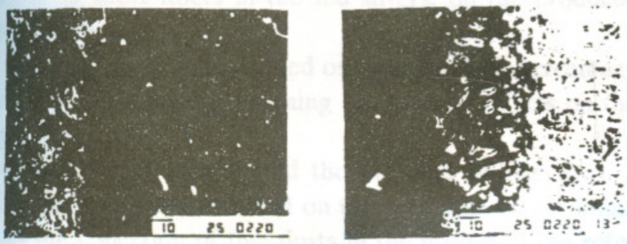


Figure 7-b. Microstructure at weld metal-stainless steel interface for E308L electrode lower micrograph is optical and upper one is scanning.



a b

Figure 8. Scanning electron micrographs for the structure at the interfaces of the weld madde by E430 electrode a- mild steel interface b- stainless steel interface.

Figure (9) shows the microhardness distribution across the weld of E308L electrode. There is a considerable decrease in the microhardness near the stainless steel interface. At the mild steel side, there is a first drop in hardness profile corresponding to the carbon depleted zone discussed above; then the profile has a steep rise at the mild steel heat affected zone possibly due to quench hardening effect.

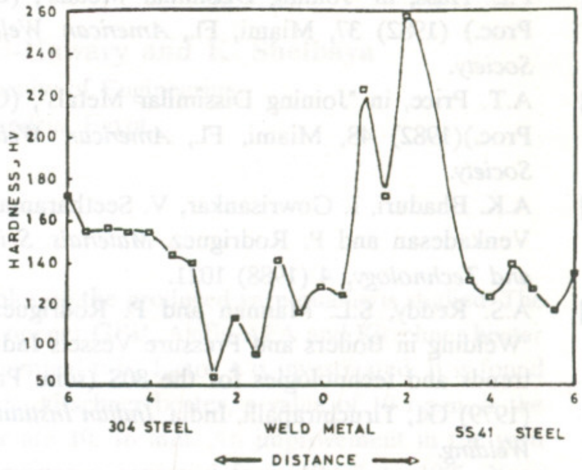


Figure 9. Microhardness distribution across the welded joint made by the E308L electrode.

The microhardness profile across the weld metal showed also an increasing trend from the stainless steel side towards the mild steel one. This increase corresponds to the increasing volume content of α particles in the weld metal in the same direction.

SUMMARY AND CONCLUSION

- Welding a dissimilar joint between the SS41 mild steel and the 304 austenitic stainless steel could be made successfully by manual metal arc process using either E308L or E430 electrodes. The use of E6013 produced a weak joint that fail in tension inside the weld metal at a very low stress.
- The use of E430 electrode produced a weld with higher ductility, same hardness but inferior weld soundness as compound to the weld of E308L electrode.
- The microstructure of the weld interfaces could be revealed. The E308L weld metal produced an interface with mild steel which is characterized by a carbon depleted dilution band of 100 μm width. The interfaces with stainless steel are characterized by a transition zone of γ austenite of 50 μm width.

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