A STUDY ON THE WELDABILITY OF CAST NITROGENATED STAINLESS STEELS

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INTRODUCTION

The beneficial effects of nitrogen addition to wrought stainless steel have been known for some time [1]. Cast grades of nitrogenated stainless steels are comparatively of more recent origin (2). In India, partial substitution of nickel by manganese in cast stainless steels has become an attractive proposition for reasons of economy. In view of the known beneficial effect of nitrogen on weldability of conventional stainless steels (3,5), it would be of interest to assess the benefit of nitrogen addition to such Fe-Cr-Ni-Mn type stainless steels as well. The present study, which is a part of a broad program, was therefore undertaken to compare the weldability of a nitrogenated CF8 grade steel with that of stainless steels alloyed with manganese. Weldability has been assessed in terms of the microstructural characteristics and corrosion susceptibility of the weldments.

Experimental Procedure

The specimens which were used for the investigation were melted in an induction frunace and then chillcast in the form of 40 mm dia rods. The alloy compositions are given in Table 1. In alloy 1 to 3, nitrogen was added as nitrided manganese (5-6%N) @ 4 wt.% of the melt at 0,28 Kg/cm^2 (4 psi) pressure. The circular specimens were cut into two equal halves and a V-notch was made on each half (figure 1).The V-notch was welded with semibasic flux coated stainless steel electrodes of approximately 316 L grade in two passes at 28 volts and 110 amps alternating current. The composi-

Table 1 : Chemical Analysis

Chemical analtsis	**Alloys**				**Welding Electrode**
%	**1**	**2**	**3**	**4**	
C	0.05	0.03	0.03	0.06	0.03
Mn	3.5	3.5	4.6	1.2	5.3
Cr	19.8	20.4	21.7	20.1	19.8
Ni	3.16	14.8	6.0	8.4	15.5
Mo	-	2.1	0.76	0.04	2.7
SI	0.32	0.72	1.0	1.15	0.48
YI	0.1	0.026	0.007	0.0087	-
Cu	0.3	0.07	0.03	0.028	
S	Maximum 0.02 for all the cases				
P	Maxumim 0.05 for all cases				
N	Not analysed				

Table 2 : Microhardness (VPN)

Alloy No.	**Parent metal**	**Interface**	**Weld deposite**
1	222	265	245
	225	270	240
	231	254	232
2	244	269	238
	234	262	230
	253	257	228
3	221	212	201
	237	217	215
	226	220	201
4	207	221	209
	209	221	212
	212	214	210

tion of the electrode is given in Table 1. The microhardness (VPN) of the weld Zone., HAZ and parent metal of each welded specimen was measured after metallographic polishing and etching. Representative photomicrographs of the weldments were also taken. The welded speciments were cut into two equal pieces through the middle of the welded zone. Each welded sample was then subjected to corrosion test in 65% boilling nitric acid and the weight loss was determined after every ten minutes on an electronic balance. The parent metal was then cut off from the weldment leaving a wide margin to avoid the heat affected zone. After grinding and polishing, the section from the base alloy was again subjected to corrosion test in 65% boiling nitric acid. Weight loss was recorded at ten minutes interval as before. On conclusion of the corrosion test, the samples were further examined under SEM. Thin foils prepared from a few samples were also examined in TEM.

Results

The results of the present investigation reveal some interesting features. Microstructures of the welded speciments are presented in Figure 2 (a-d) to highlight the effect of composition on the HAZ width. The darkened layer at the weld-deposit parent metal interface marks the heat affected zone. The HAZ was fairly wide in alloy two three, but it was quite narrow in alloy 4. The microhardness data given in Table 2 suggest hardening of the HAZ relative to that of the martix in alloys 1,2 and 3. The reaults of the corrosion test are reported in the form of mass loss (gm/mm^2) versus time plots in Figures 3 and 4. The weldment of alloy 1 was conspicuously lower than that of the weldment (figure 4). The SEM photographs in Figures 5 and 6 compare the corrosion pattern in the heat affected zones in alloys 1 and 2 respectively. The corrosion in alloy 3 was identical to that in alloy 2. Alloy 4 suffered very little corrosion damage (Figure 7). The weld deposit on alloy 1 suffered extensive interdendritic corrosion (Figure 8), while the deposits on the other alloys suffered much less corrosion (Figure 9). The weld deposit in alloy 1 had also suffered hot cracking (Figure 10).

Discussion

A limited comparison of the weldability of the nitrogenated CF8 grade steel (alloy 4) with that of the nitrogenated Fe-Cr-Ni-Mn type stainless steels may be made from the results of this investigation. The corrosion susceptibility of the weldment was highest in case of alloy 1, which had the lowest Ni content. It was nearly equal for the other three alloys. The corrosion resistance of sensitised AISI 200 series stainless steels (manganese bearing) was previously reported to be higher than that of the 300-series steels in boiling 65% HNO_3 or boiling (H_2SO_4 + $CuSo_4$) solution (4). But the data in Figure 4 suggest that the large increase in the corrosion damage in alloy 1 occured only after welding. Therefore a combined scrutiny of the weight loss data and the SEM photographs is necessary to identify the reasons for corrosion, Figure 8 indicates that the interdendritic regions in the weld deposit in alloy 1 was preferentially corroded in 65% boiling nitric acid. On the other hand, the stepped structure in Figure 5 is an evidence that the HAZ in alloy 1 had suffered general corrosion only. HAZ in alloy 2 and 3 had suffered intergranular corosion (Figure 6), but the weld deposits were corroded to a much lesser extent (Figure9). The weld deposit in alloy 4 had practically resisted corrosion (Figure 7). The heat affected zone in this alloy was very narrow (Figure 2d) and did not suffer either intergranular corrosion or general corrosion to any appreciable extent. These resilts may be interpreted to suggest that the weldability of alloy 4 was among all the experimental alloys. Although the general corrosion resistance of alloy 1 was reasonably good, susceptibility of its weldment to corrosion was higher that that of other alloys. But alloying with nitrogen had prevented intergranular corrosion in this alloy, nitrogen increases solubility of carbon in austenite. Therefore intergranular precipitation of Cr_{23} C_6 carbide is prevented. Alloying with nitrogen thus prevented sensitisation in this alloy [6]. It is however not clear why sensitisation could not be prevented in alloys two and three. It could not be prevented in alloys two and three. It could be due to a variation in heat input during manual metal arc welding.

Rise in hardness in stainless steel weldments was not observed in any of the previous experiments of the present authors (7). Filler rods of exactly identifical composition were used in those experiments, the rise in HAZ hardness in alloys 1,2 and 3 therefore apprears to be a consequence of the substitution of nickel by manganese. Bavadekar [8] had observed considerable diffusion of manganese from the base metal to the parent metal/weld deposit interface when a Manganese rich stainless steel was welded with a similar filler metal. Such build up of manganese may lead to some degree of workhardening of the manganese rich austenite in alloys 1,2 and 3 under welding thermal stress. Manganese rich austenite is known to be prone to work hardening [1]. TEM photography (Figure 11) of the HAZ in alloy 2 also suggests a high dislocation density in the region. The rise in HAZ hardness may be a consequence of such work hardening. It is further likely that the extensive interdendritic corrosion and hot cracking of the weld deposit in alloy 1 also occured due to segregation of manganese. The mechanisms involved may however be conclusively established only through extensive TEM and EPMA studies.

CONCLUSION

Weldability of a nitrogenated CF8 grade stainless steel is superior to that of the grades in which manganese and nitrogen are added.

Nitrogen addition to a lean nickel Fe-Cr-Mn-stainless steel prevents intergranular corrosion in the HAZ of its weldment in 65% boiling HNO_3, but does not retard its general corrosion.

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