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ON THE VARIATION OF HARDNESS OF DUPLEX STAINLESS STEEL CLAD LAYER DEPOSITED BY FLUX-CORED ARC WELDING

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Abstract: By cladding, one refers deposition of a relatively thick metal layer onto a cheap grade base material to protect it against severe abrasive / erosive /corrosive working condition. Enhancing hardness of a surface through cladding is given the name hardfacing. In this investigation, FCAW (Flux-Cored Arc Welding) cladding is performed using fluxed-core duplex stainless steel electrode onto low alloy steel substrate using 100% CO_2 as the shielding gas. Different values of welding current and welding voltage were selected for the experiment in such a way that 3 sets of constant heat input were maintained. Welding torch travel speed was kept constant throughout the experiment. Hardness test results revealed much improved hardness of the clad part compared to that of the base material. Only slight change in hardness can be noticed under varying weld current when heat input remains the same.

Keywords: Cladding; hardfacing; FCAW; heat input; process parameters; hardness.

1. INTRODUCTION

Cladding is a popular method that makes deposition of thick layer of a material on a low grade low alloy steel substrate [1, 2] to improve erosion/corrosion resistance properties. Cladding by GMAW/FCAW process is one of the well-accepted methods. Among different cladding materials, duplex stainless steel is becoming a better option as it overcomes different drawbacks arising in case of other popular filler materials used for cladding [3-7]. Cladding improves resistance to corrosion and erosion, and also enhances mechanical properties like hardness, notch toughness, etc. [8, 9]. Weld cladding technique is widely used in various types of industries such as chemical, naval, mining, agriculture, power generation, etc. either for the purpose of maintenance, or manufacturing new components.

Hardfacing is commonly employed in industries in which the components are subject to abrasive wearing. It commonly increases the wear resistance properties and thus enhancing service life of components [10-12]. Slurry pump is one such common component where successful implementation of hardfacing is done by GMAW cladding. Cladding technique could be used to reduce wearing of cast iron mill rollers in the sugarcane industry. In one observation, metal cored tubular electrode (AISI H13 martensitic tool steel) was used to create multilayer GMAW cladding on low alloy steel using weaving technique. The shielding gas used was the combination of argon and CO_2. Results depicted maximum wear resistance generated at a lower heat input [13].

In some recent works, components which undergo severe compressive stress as well as impact load are subjected to erosion. The loss of weight may cause design failure after a short period. Cladding is one solution imparting hard bearing surface, and thus, improving life of components. Continuous casting roll, press tools, gears, etc. are some examples, where this method can be applicable.

In the present work, hardness of the E2209-01 duplex stainless steel clad layer on low alloy steel by FCAW technique using 100% CO_2 as shielding gas was investigated. Process parameters like welding current and welding voltage were altered in 3 levels keeping arc travel speed constant in such a way that heat input was varied at 3 levels. The aim of this work is to establish good bulk dependent property, like hardness of the particular duplex stainless steel so that it can be used in cases like screw conveyer and roller drum used in paper and pulp industries, chemical tanker, bridges in aggressive atmosphere, repair of transmission devices beneath seawater, etc. where already different duplex stainless steel are being used [14].

2. EXPERIMENTAL PROCEDURE

In this experiment work, E250 low alloy steel base plate of 70mm x 60mm x 25mm size is taken. 1.2 mm diameter Flux cored wire electrode made of duplex stainless steel (E2209 T0-1) and manufactured by ESAB, Sweden, is used as clad material. FCAW cladding is performed using ESAB India Ltd. made Auto K400 Gas Metal Arc Welding machine (Fig. 1), having 60% duty cycle. The welding gun is mounted on a motor driven vehicle (Fig. 2).It has a provision of speed variation. In association to guide the vehicle moves along a guided straight line path is made. Shielding gas used is 100% CO_2 with a constant gas flow rate of 16litre/min. Composition of base metal and clad material evaluated are shown in Table 1 and Table 2 respectively. Cladding is done by a single layer deposition with 50% overlap as shown in Fig 3.

Heat input determines degree of melting and cooling rate, and thus, influences bead geometry, hardness and microstructure. In this work, three different heat inputs were chosen to test for variation of hardness of clad/ hardfaced layer. At one heat input, current and voltage were varied maintaining constant torch travel speed. This was done to explain presence of any effect of voltage and current on hardness at a single heat input. Heat input during welding is calculated using the given formula,

$$H = \eta \frac{60VI}{1000S}$$

Where, H= Heat input *(kJ/mm);*

V= Voltage (V); I= Current (A);

S= Welding speed (mm/min) and η= Efficiency of the welding process, which is taken 0.8.

Table 1: Composition of E250 Grade low alloy Steel base metal

%C	%Si	%Mn	%P	%S	%Mo	%Ni	%V
0.1985	0.1402	0.4976	0.0609	0.0308	0.0378	0.0253	0.0024
%Pb	%Sn	%As	%Fe				
0.0104	0.0137	0.0662	<98.8810				

Table 2: Composition of Duplex Stainless Steel (E2209 T0-1) wire electrode

%C	%Si	%Mn	%P	%S	%Cr	%Mo	%Ni	%N
0.020	0.76	1.01	0.018	0.0087	22.52	2.91	9.09	0.125

Fig. 1 Gas metal arc welding machine

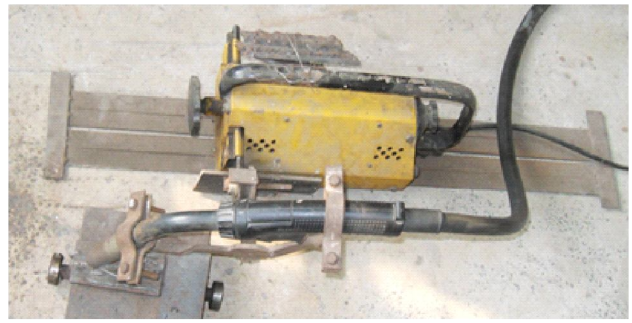

Fig. 2 Welding gun mounted on a guide

Fig. 3 Schematic diagram of 50% overlap

Table 3: Heat input and other process parameters used in weld cladding experiment

Sl. No.	Voltage (V)	Current (A)	Heat input (kJ/mm)
1	24	160	0.492
2	26	150	0.492
3	28	140	0.492
4	26	180	0.567
5	28	170	0.567
6	30	160	0.567
7	28	200	0.660
8	26	215	0.660
9	30	190	0.660

Design matrix of process parameters chosen is shown in Table 3. Two replicated experiments were carried out in this investigation.

3. RESULTS AND DISCUSSION

Hardness is measured on a Rockwell Hardness Testing Machine. Average hardness of the base plate is measured to be 87 HRB. The hardness obtained after cladding are given in Table 4. Hardness observed varied between 35 HRC and 38 HRC.

Results of hardness test for replication 1 and 2 experiments indicate substantial increase in hardness after hardfacing. Hardness does not differ considerably with heat input of 0.492kJ/mm, 0.567kJ/mm and 0.660kJ/mm. Fig. 4 shows 3-D plot of variation of hardness varying with reference to weld current and voltage.

There exists similarity in hardness data obtained among the two replicated experiments. The effects of heat input (0.492 kJ/mm, 0.567 kJ/mm and 0.660 kJ/mm) on hardness of 1st and 2nd replication of cladding test are shown in Fig. 5.The plot shows that hardness of 1st and 2^{nd} replications of cladding experiments not varying appreciably at a given heat input.

Therefore, at every combination of process parameters within the domain of the present experimental investigation, hardfacing can be done effectively.

Microstructure of the clad part shows that austenitic phase (darker) surrounded by lighter ferrite phase. The sharp leaf like austenitic structure indicates greater hardness whereas blunt leaf like austenitic structure indicates lower hardness. Figure 6 and figure 7 show the microstructure of Sample RSC2 and RSC 9 having highest and lowest hardness values.

Table 4: Hardness values measured after cladding of 1st and 2nd replications at a constant travel speed of 7.5 mm/s

Serial No.	Heat Input (κJ/mm)	Current (I)	Voltage (V)	1^{st} Replication		2^{nd} Replication	
				Sample No.	Hardness Value(HRC)	Sample No.	Hardness Value(HRC)
1	0.492	160	27	CS3	36	RCS3	36
2	0.492	170	24	CS1	35	RCS1	36
3	0.492	190	29	CS2	36	RCS2	38
4	0.567	180	27	CS6	35	RCS6	36
5	0.567	200	25	CS4	37	RCS4	36
6	0.567	210	30	CS5	36	RCS5	37
7	0.660	200	28	CS9	35	RCS9	37
8	0.660	210	29	CS8	36	RCS8	35
9	0.660	220	31	CS7	36	RCS7	36

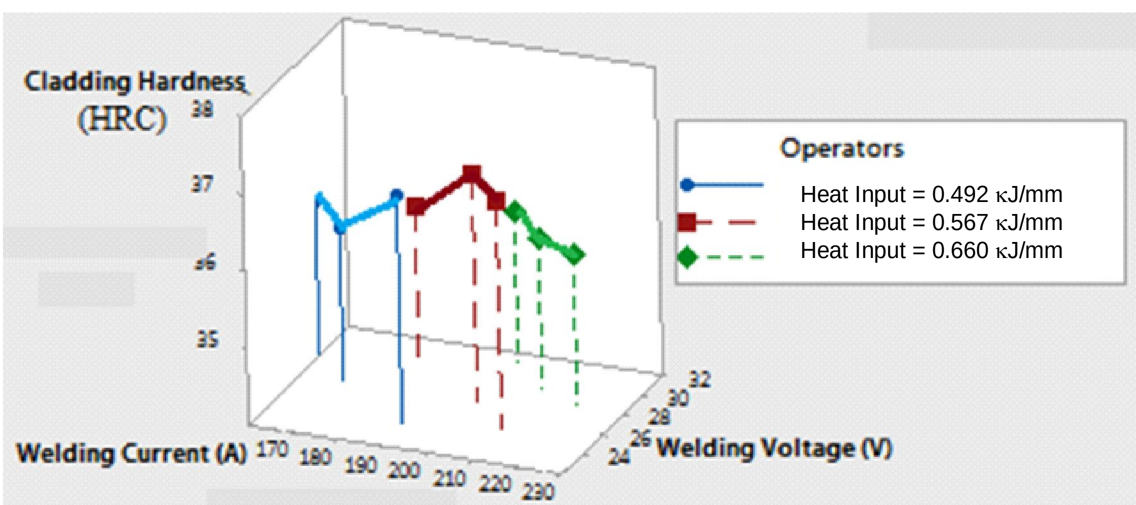

Fig. 4 3-D plot of hardness of reference to welding current and welding voltage

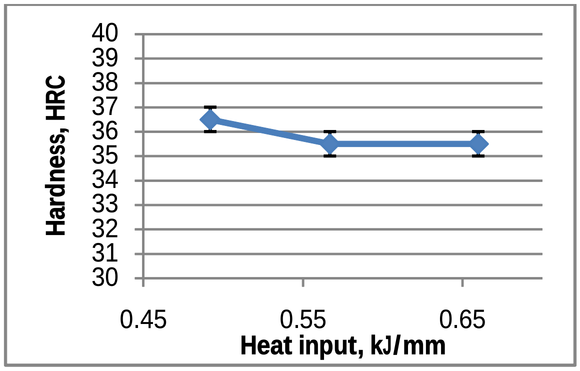

Fig. 5: Plot of variation of hardness with heat input as obtained from 1st and 2nd replications of cladding experiments

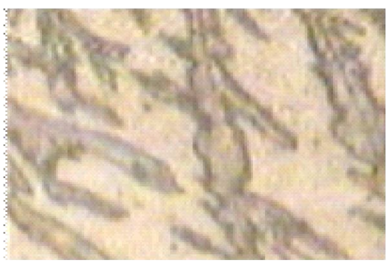

Fig. 6: Microstructure of Sample No. RCS2 (X500)

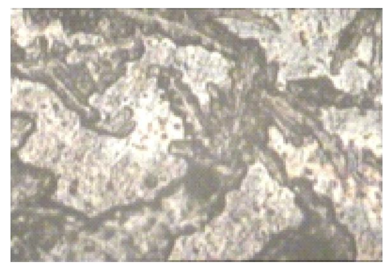

Fig. 7: Microstructure of Sample No. RCS9 (X500)

4. CONCLUSIONS

After cladding (hardfacing) experiments, hardness of duplex stainless steel clad portion is found to be quite high compared to that of low alloy steel base plate. Cladding hardness does not show remarkable difference with varying heat input. Therefore, any set of process parameters within the domain of experiments taken up in this work may be recommended to undertake hardfacing work.

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