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Studies the Effect of Iron Based Hardfacing Electrodes on Stainless Steel Properties Using Shielded Metal Arc Welding Process

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Abstract: Hardfacing, also known as "Hardsurfacing", is the application of build-up of deposits of specialized alloys by means of welding process to resist abrasion, corrosion, high temperature, or impact. Hardfacing is one of the most useful and economic way to improve the properties and then performance of a component that depends upon the selected alloys for filler and welding process. Shielded metal arc welding (SMAW) is most commonly used process for hardfacing due to its easy availability and versatility. In the present work, a detailed study was done to study the effect of different compositions of iron based harfacing electrodes on stainless steel, deposited by SMAW process. Three different iron based viz Hard Alloy 400, Hardloy III , Hardloy V electrodes were chosen for hardfacing. A single and double layer was applied by each electrode. The investigation was done on the samples prepared by these electrodes. Micro-hardness test, wear test, and microstructure investigations were carried out for analysis. It was found that the hardness values can be enhanced by approximately 1.7 times using Hard Alloy 400 hardfacing electrode, 2 times by using Hardloy III hardfacing electrode and 2.4 times by using Hardloy V hardfacing electrode and Wear resistance can be increased up to 29% using Hard Alloy 400 hardfacing electrode, 60% using Hardloy III hardfacing electrode and 66% using Hardloy V hardfacing electrode. .In the microstructure the grains are very fine and distributed uniformly in $(E3)^2$ samples.

***Keywords**: Hardfacing; Wear; Electrode; SMAW.*

1. INTRODUCTION

In 1922 researchers introduced the concept of "resurfacing worn out parts, instead of replacing them" with wear resistant high Chromium Manganese alloys. Hardfacing is a commonly employed method to improve surface properties of agricultural tools, components for mining operation, soil preparation equipments and others. An alloy is homogeneously deposited onto the surface of a soft material (usually low or medium carbon steels) by welding, with the purpose of increasing hardness and wear resistance without significant loss in ductility and toughness of the substrate [8]. This process is called hardfacing because the deposited surfaces are harder than the base metal usually [13].The hardfacing layers are highly resistant to spalling due to strong metallurgical bond with the substrate material and a wide range of alloys can be applied in order to achieve the best performance in a wear environment[9]. Welding processes are used to apply hardfacing materials ranging from traditional (oxyacetylene torch) to new and sophisticated (plasma transferred arc and laser) methods [12]. The hardfacing technique has in the mean time, grown into a well-accepted industrial technology. Due to a continuous rise in the cost of materials as well as increased material requirements, the hardfacing has been into prominence in the last few decades. Developments in hardfacing techniques as well as advances in hardfacing electrode have given rise to surface coatings with excellent wear resistant properties under severe service conditions, thus enlarging the field of its application [2].

Wear of machinery parts is one of the most common problems faced in industry. Wear is the predominant factor that controls the life of any machine part. Metal parts often fail their intended use not because they fracture, but because they wear, which causes them to lose dimension and functionality. Research is going on over years to reduce the wear either in the form of using a new wear resistant material or by improving the wear resistance of the existing material by addition of any wear resistant alloying element etc. As the wear is a surface phenomenon and occurs mostly at outer mating surfaces, therefore it is more appropriate and economical to use the latter method of making surface modification than using the former one which will not only involve very high cost of the operation but also involve longer time as compared to the second technique.

In this presented paper, the Shielded Metal Arc Welding method for surface modification to improve the wear properties of stainless steel materials has been used. The stainless steel is hardfaced with three different types of iron based electrodes (Hard Alloy 400, Hardloy III and Hardloy V) and were investigated with regard to their wear, microhardness, and microstructure analysis.

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2. EXPERIMENTAL DETAILS

2.1 *Selection of base metal*

Stainless steel was selected as base material for hardfacing purpose, as we know that it is mainly used in wide application in the fabrication industry.

Fig. 1. Stainless Steel (base metal)

The general composition of stainless steel is given below:

Table 1. Chemical composition of base metal

C	Cr	S	P	Si	Mn	Ni
0.053	18.060	0.005	0.033	0.290	1.170	8.080

2.2 *Selection of electrodes*

Three different type of iron based hardfacing electrodes were selected which are commercially available in the market. The electrode names and composition is given below:

Table 2. Chemical composition of electrodes

Electrode Name	C	Mn	Si	Cr
Hard Alloy 400 (E1)	0.2-0.4	0.4-0.8	0.2-0.6	2.5-3.0
Hardloy III (E2)	0.60	0.35	0.40	6.50
Hardloy V (E3)	2.50	1.20	0.35	3.50

2.2.1 *Hard Alloy 400 (low carbon content) electrode*

A rutile type electrode developed for hardsurfacing of steels subjected to wear due to abrasion and impact. Very stable arc and smooth transfer of alloying elements to weld deposit ensures completely crack free weld metal. The weld metal is air hardening type and gives 350-450 BHN hardness.

Fig. 2. Hard Alloy 400

2.2.2 *Hardaloy III (medium carbon content) electrode*

A medium heavy coated rutile type air hardening electrode for hard surfacing applications on mild steel, carbon steel and low alloy steel where 550 Brinell hardness is required. The welds are non-machinable and can only be ground. Slag is easily detachable.

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Fig. 3. Hardaloy III

2.2.3 *Hardaloy V (high carbon content) electrode*

A medium heavy coated basic type graphitic electrode for hardfacing and build up of worn out machine parts and components. Weld beads are flat and smooth. Slag is easily detachable. The weld metal is alloyed cast iron which is hard and extremely resistant to abrasion and metal to metal wear.

Fig. 4. Hardaloy V

2.3 *Deposition of layers on plate*

Two Layers were deposited from every single electrode. One was single layer and other was double layer. Double layer was deposited by taking 50% overlap of single layer. Samples were cut from work piece for further analysis. Parameters used for welding process are given as Table 3.

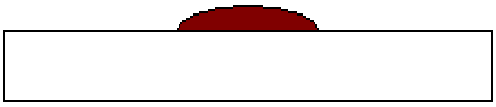

Fig. 5. Sample with single layer deposition

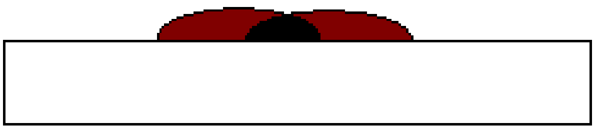

Fig. 6. Sample with double layer deposition

Table 3. Experimental conditions used for welding process

Category of samples	Electrode	Current(A)	Voltage(V)	Type of layer
E_1	E_1	100	22	Single Layer
$(E_1)^2$	E_1	100	22	Double Layer
E_2	E_2	80	25	Single Layer
$(E_2)^2$	E_2	80	25	Double Layer
E_3	E_3	90	23	Single Layer
$(E_3)^2$	E_3	90	23	Double Layer

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The various work samples are shown in Fig. 7, Fig. 8 and Fig.9

Fig. 7. Sample E1 & (E1)²

Fig. 8. Sample E2 & (E2)²

Fig. 9. Sample E3 & (E3)²

2.4 *Testing of samples*

Three tests conducted after the hardfacing are given below:-

1. Microhardness test on micro hardness tester machine.
2. Wear test on Pin-on-Disc machine.
3. Microstructure test on metallurgical micro scope machine.

2.4.1 *Microhardness test on microhardness tester machine*

A sample size 25×25 mm square is cut from the hardfaced stainless steel pieces with the help of surface grinding machine. All the four lateral faces of the samples are made parallel and then ground to right angles. Then the surface is prepared for microhardness testing on Microhardness Tester.

Fig. 10. Microhardness testing machine

Fig. 11. Samples for Microhardness Testing

2.4.2 *Wear Tested by Pin on disc Machine*

Wear test was carried out on a pin on disc wear testing machine. The speed of rotating wheel is 475 rpm and applied constant load of 3 kg. Then the pin type sample is holding on the pin on disc wear testing machine, the weld beed tip was placed against the rotating wheel. The pin type sample size was 12mm diameter & 30mm of the length of the pin sample.

Fig. 12. Pin type samples for wear testing

For every wear test, a new rotating wheel was used to ensure identical initial wear conditions. Each sample was initially weighted before the test and final weighted after the test (15 minutes) is taken and then we calculated the average wear rate in grams per hour. The following figure shows the wear test configuration:

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Fig. 13. Pin on disc Wear test Apparatus

Fig. 14. Electronic weighting machine

2.4.3 *Microstructure test on Metallurgical micro machine*

A sample size 25×25 mm square is cut from the hardfaced stainless steel pieces with the help of surface grinding machine. Then microstructures of samples were carried out at 100* magnifications to analysis types of grain formed so that we can understand the reason of higher microhardness and wear resistance achieved.

Fig. 15. Metallurgical Microscope Machine

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3. RESULTS AND DISCUSSION

3.1 *Microhardness*

The microhardness was checked on top, middle and heat affected zone position. At every place three readings were taken. Average of three readings as shown in Table 4, Table 5 and Table 6. Average microhardness of base metal is 254 HV.

Table 4. Microhardness result using E1 hardfacing electrode

Type of Layer	Microhardness (HV) At Top Position	Microhardness (HV) At Middle Position	Microhardness (HV) At Bottom Position
Single Layer	375	278	251
Double Layer	440	399	263

Table 5. Microhardness result using E2 hardfacing electrode

Type of Layer	Microhardness (HV) At Top Position	Microhardness (HV) At Middle Position	Microhardness (HV) At Bottom Position
Single Layer	415	261	246
Double Layer	520	453	254

Table 6. Microhardness result using E3 hardfacing electrode

Type of Layer	Microhardness (HV) At Top Position	Microhardness (HV) At Middle Position	Microhardness (HV) At Bottom Position
Single Layer	534	269	244
Double Layer	610	464	256

Comparison of microhardness of single layer and double layer using three electrodes as shown in Fig. 16, Fig. 17, Fig 18 and Fig. 19.

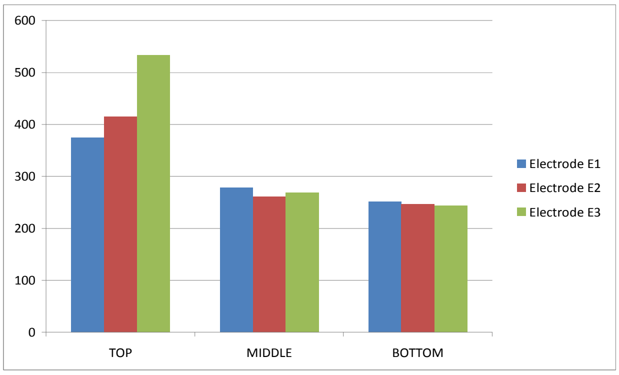

Fig. 16. Comparison of microhardness of single layer using three electrodes

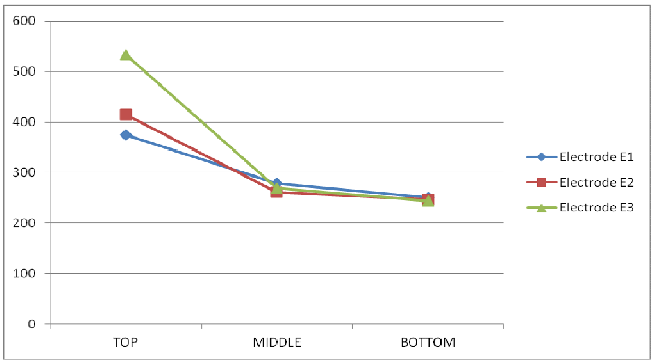

Fig. 17. Line graph comparison of microhardness of single layer using three electrodes

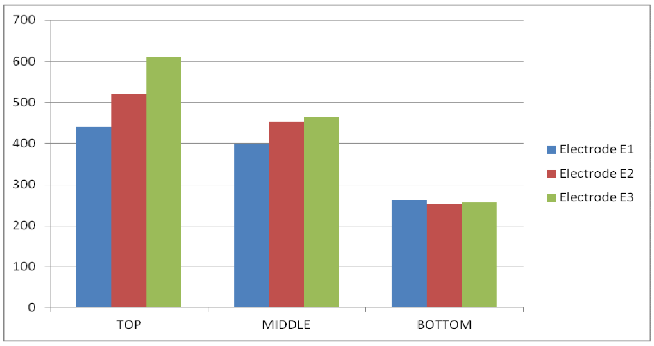

Fig. 18. Comparison of microhardness of double layer using three electrodes

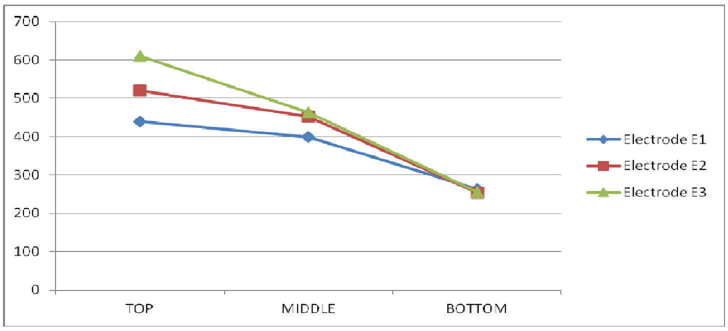

Fig. 19. Line graph comparison of microhardness of double layer using three electrodes

3.2 *Wear Test*

Wear rate was calculated by measuring initial and final weight of sample. Loss in weight shows wear rate as shown in Table 7. Comparison of wear rate of different work samples as shown in Fig. 20.

Table 7. Weight losses of samples due to wear

Samples	Type of Layer	Average Initial weight in grams	Average Final Weight in grams	Average Net Wear in grams	Average Wear Rate in gm/hr
Sample 1 (E1)	Single	27.8836	27.8707	0.0129	0.0516
Sample 2 (E2)	Single	28.5976	28.5871	0.0105	0.0420
Sample 3 (E3)	Single	28.9680	28.9587	0.0093	0.0372
Sample 4 $(E1)^2$	Double	29.2720	29.2609	0.0111	0.0444
Sample 5 $(E2)^2$	Double	28.7806	28.7743	0.0063	0.0252
Sample 6 $(E3)^2$	Double	29.5269	29.5215	0.0054	0.0216
Sample 7	Without hardfacing	26.7360	26.7204	.0156	0.0624

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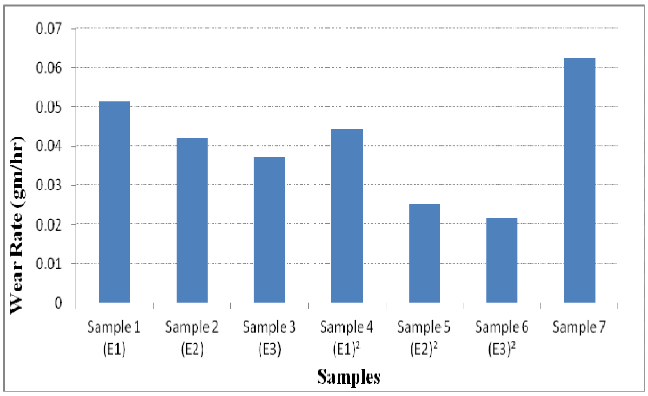

Fig. 20. Comparison of wear rate of base metal and hardfaced samples

3.3 *Microstructure*

Microstructure for the work samples having sufficient wear resistance was done. It is clear from the readings that the $(E1)^2$, $(E2)^2$ and $(E3)^2$ have the maximum wear resistance. So microstructure of all these samples was taken. Fig 21, Fig 22 and Fig. 23 shows the microstructure of $(E1)^2$, $(E2)^2$ and $(E3)^2$ respectively. It is clear from the figures that the grains are very fine and distributed uniformly in $(E3)^2$ samples which are responsible for highest microhardness value and lowest wear rate value as compared to other samples.

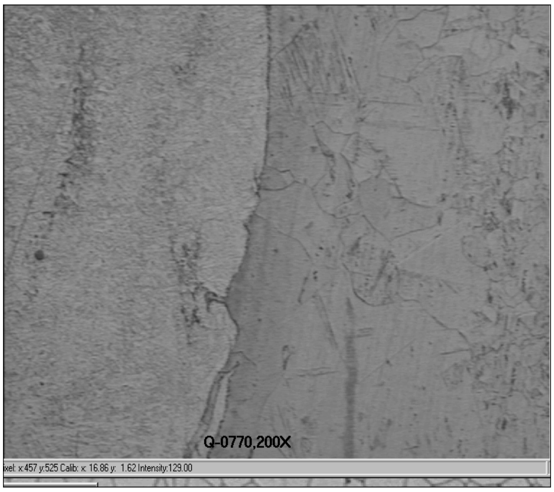

Fig.21. Microstructure of sample $(E1)^2$

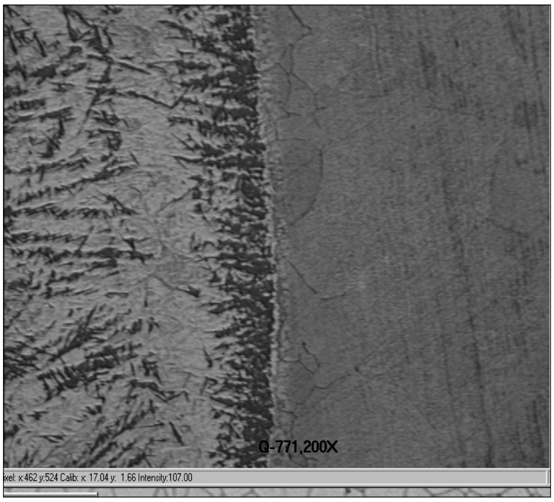

Fig.22. Microstructure of sample $(E2)^2$

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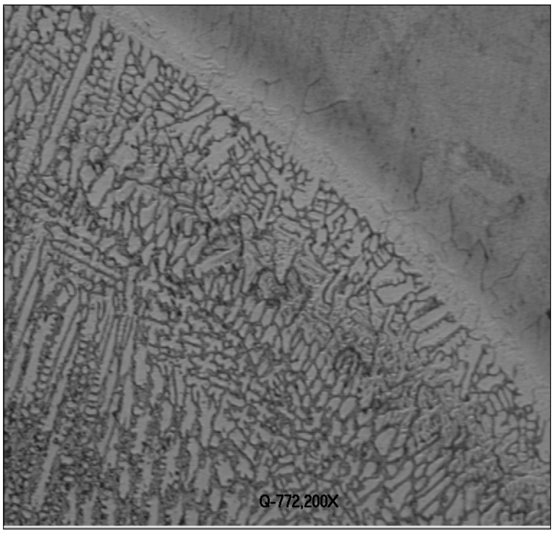

Fig. 23. Microstructure of sample (E3)²

4. CONCLUSIONS

Following conclusions have been made from the work:

- The hardness values can be enhanced by approximately 1.7 times using Hard Alloy 400 hardfacing electrode, 2 times by using Hardloy III hardfacing electrode and 2.4 times by using Hardloy V hardfacing electrode.
- Wear resistance can be increased up to 29% using Hard Alloy 400 hardfacing electrode, 60% using Hardloy III hardfacing electrode and 66% using Hardloy V hardfacing electrode approximately.
- In the microstructure the grains are very fine and distributed uniformly in (E3)² samples which are responsible for highest microhardness value and lowest wear rate value as compared to other samples.
- Considering all the aspects it may be concluded that Hardaloy V electrode gives better wear properties and microhardness within the specified domain as compared to its counterparts for the applications in scrapers, buckets and bucket teeth, conveyer, cutting tools, crusher cones etc, followed by Hard Alloy 400 and Hardaloy III, within work domain of present study.
- Hardaloy V can be recommended for general hardfacing. As it has been observed that the wear rate of E3 electrode with double layer deposited has highest wear resistance and micro hardness which may be attributed to the fact that it has higher Carbon content than all.
- The microstructure, hardness and wear resistance of hardfacing layer were affected obviously by amount of (C–Si–Mn–Cr-Ni) component. The hardness and wear resistance of hardfacing layer increases with increasing of carbon and chromium contents.

5. SCOPES FOR FUTURE WORK

- The toughness properties can also be tested from different point of view depending upon the service condition of hardfaced component.
- Corrosion testing may be incorporated along with wear testing depending upon the specific service condition of hardfaced component.
- In future bending testing also may be incorporated with hardness and wear testing.
- Other hardfacing processes may also be investigated on similar aspects.

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