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Microstructure and Mechanical Characterization of Iron Based Hardfacing Developed by Submerged Arc Welding

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Abtract

A high carbon Fe-Cr-C alloy is used to deposit over a low carbon steel to improve its wear resistance. Welding processes are generally used in the industry for depositing these hard layers. Among all welding processes, submerged arc welding (SAW) process is most widely used as it gives high deposition rate as compared to the other welding process. In this study three hardfacing layers with different carbon percentage were developed with the help of SAW. Final developed layers were subjected for different tests for its characterization. First test was performed for chemical composition analysis and results shows high amount of alloying elements in the hardfacing layers. Microstructural analysis was also done which shows more amount of carbide volume precipitation with increase of carbon percentage and it shows mixture of hard carbide in a matrix of austenite. Hardness test was also performed and result shows as the amount of carbon is increasing in the hardfacing layer, hardness value is also increasing which shows a better mechanical and tribological property of the layers.

1. INTRODUCTION

Continuous deterioration of material takes place due to various reasons which effects the service life of the component or a part. Those can be the reasons which cause corrosion, abrasive wear, erosive wear and effect other mechanical or chemical properties of any material [1]. The wear rate of any component may affected due to excessive loading, over motion, improper temperature and lubrication. There are so many ways but the simplest way to avoid wear rate is to apply coating over the substrate which is getting deform [2]. Protective coating can be applied over these material to increase its service life by different methods like cladding, buttering, spraying, hardfacing. These different methods were used to fulfill different purposes. But most widely used surfacing method is hardfacing [3]. Hardfacing can be generally defined as deposition of any hard material over any soft base material [4-5]. This method is widely used due to its ease of applying, can decrease wear rate and also economic. Now a day’s hardfacing is widely used in mineral and mining industries and coal companies to decrease downtime which cause due to wear [6-7]. Hardfacing can be done by different methods but welding is an easy, commercial and economical choice to deposit the required material as coating. The most widely used process is Arc welding process for developing any alloy over any substrate [8-10].

Shielded metal arc welding (SMAW) is most commonly used method and many of industries are habitual to use this process of welding [11]. There are another different method uses for different purposes such as Gas Tungsten Arc Welding (GTAW), Gas Metal Arc Welding (GMAW), Submerged Arc Welding (SAW) or Flux Cored Arc Welding (FCAW). Plasma arc welding or laser beam welding is used when a fine powder is used to prepare any composite or alloy to avoid melting of hard phase material [12-13]. When high deposition rate is needed submerged arc welding is a right choice [14]. Fe-Cr-C alloys are widely used in several conditions for prevention from wear. These kind of hard alloys are generally preferred due to its low cost and good performance against wear resistance. These Fe-Cr-C hardfacing alloys works in aggressive environment condition and gives good wear resisting property [15]. These Fe-Cr-C hardfacing alloy makes primary carbide and eutectic carbides of M_7C_3 matrix. These hard alloys represent high hardness value (1600HV) after making carbide with the base metal [16].

The purpose of this study is to investigate the effect of graphite addition on microstructure and mechanical characterization by observing hardness property in Fe-Cr-C alloy. The submerged arc welding process is used for getting high deposition and wear resisting properties are discussed from the observation of testing.

2. EXPERIMENTATION

Mild steel was selected as a Base metal for the final experiment as it is widely used in the industry. Welding work piece (Plate) for experiment was taken of size 280x50x12 mm. Plates were pre cleaned with the acetone to remove any oil or grease. The chemical composition of base material was given in the table 1:

Table 1: Chemical composition of base material

Element	C	Si	Mn	Cr	S
Weight Percentage (%)	0.178	0.162	0.49	0.081	0.038

Ferro-chrome metal powder was selected for development of hard-faced layer due to its low cost and better metallurgical compatibility with other materials. Metal powder was sprayed over the base material in the form of paste. Submerged arc welding procedure was used to melt and fix this metal powder over the substrate. Welding parameter are constant for all welding procedure and shown in table 2. Final three hard faced layer (Figure: 1) was developed with different graphite percentage as per the table 3. Graphite percentage was varied intentionally for producing three hardface layer with different carbon percentage.

Table: 2 Final welding parameters

Current (Amp)	300-500
Voltage (V)	42
Speed (mm/s)	4
Nozzle to Plate Distance (mm)	15
Wire feed (mm/s)	12

Table 3: Final metal powder composition

Sample	Fe-Cr (wt%)	Fe-Mn (wt%)	Fe-Si (wt%)	Graphite (wt%)
Sample-1	90	2.5	2.5	5
Sample-2	85	2.5	2.5	10
Sample-3	80	2.5	2.5	15

Figure 1(a): Hardfaced layer- Sample-1

Figure 1(b): Hardfaced layer- Sample-2

Figure 1(c): Hardfaced layer- Sample-3

After welding, hardfaced layers were prepared for different testing processes. The layer was first tested for chemical composition. It is very necessary to know the amount of different element available in the hard-faced layers, because these elements are responsible for the problem enhancement as it forms carbides in the hard-faced layers. For testing of chemical composition OES (Optical Emission Spectroscopy) was used on the specimen of dimension 10x15mm. The next test was done is hardness test. The hardness of the specimen was tested by an Apparatus called Rockwell hardness tester because it gives bulk hardness which is always required for hardfacing layer. Major load of 150 Kg was applied and released after 10 second from a specimen dimension of 10x15x12 mm. Three test runs were applied at different three points of welding Bead.

The microstructure was observed of the specimen of size 10x10mm. the specimen was first polished over 220 grade of emery paper and sequentially emery paper of grade 320, 400, 600, 800, 1000, 1200 were used to get fine polished specimen. Alumina paste was used to get mirror finished surface of sample. Etching by chemical agent was the last step for taking microstructure of sample by optical microscope.

3. RESULTS

The results and analysis of developed hardfacing alloy is explained as follows-

2.1 Chemical Composition Analysis

Chemical composition analysis was done to determine the chemical composition of the developed hardfaced layer. The specific focus of this study was on the transfer behavior of Chromium, Carbon and other metals. Table 4 shows the chemical composition in developed hard faced layer.

Table 4 shows that there is significant increase in the carbon, chromium, manganese and silicon content in the hardfacing layer as compared to the base metal.

Table 4: Chemical composition of hardfaced layer

Element	Base Metal	Alloy 1	Alloy 2	Alloy 3
Carbon	0.178	1.18	1.31	1.38
Chromium	0.081	14.2	13.25	14.92
Manganese	0.49	1.19	1.08	1.12
Silicon	0.162	1.19	1.16	1.1

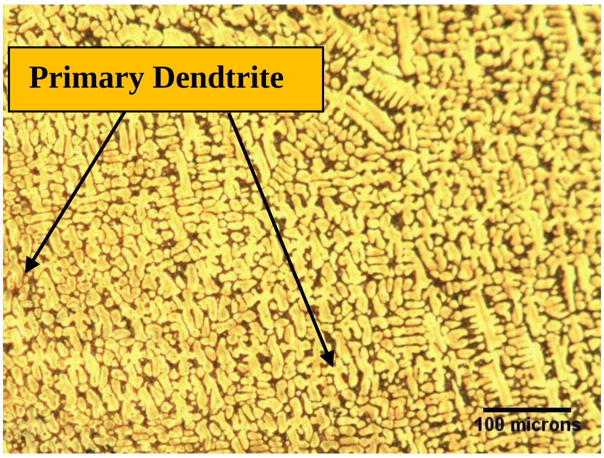
Table 4 shows as the graphite content in the paste is increasing, the amount of carbon is increasing but when we are using more than 10 % graphite there is very less amount of increase in carbon content. Since the thermal conductivity of graphite is very high so after a certain percentage it takes more heat and it doesn't allow heat flow towards the base metal so less amount of alloying elements transferred in the developed hardface layer.

3.2 Microstructure Analysis

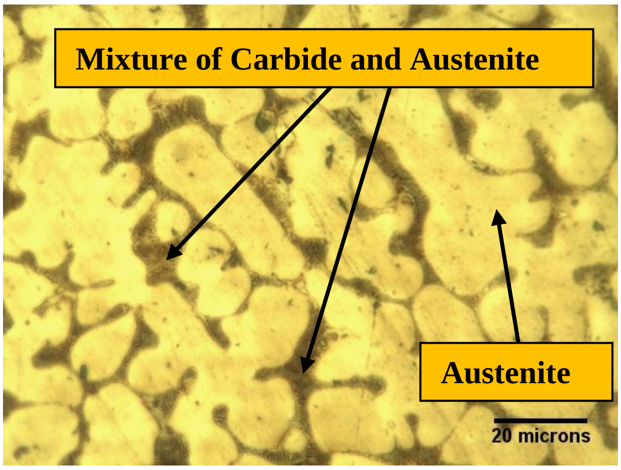
Microstructure of all samples were taken at different magnification to understand the metallurgical behavior of developed hardfaced layer. Figure 2 shows the microstructure of all sample taken at different magnification.

Optical microstructure study reveals that the metal carbide was found in the inter-dendritic region of the eutectic mix. Lamellar structure of dark and bright layers was observed in the inter-dendritic region. Dark region corresponds to metal carbide. The dendritic region corresponds to austenite phase of the hardfacing alloy.

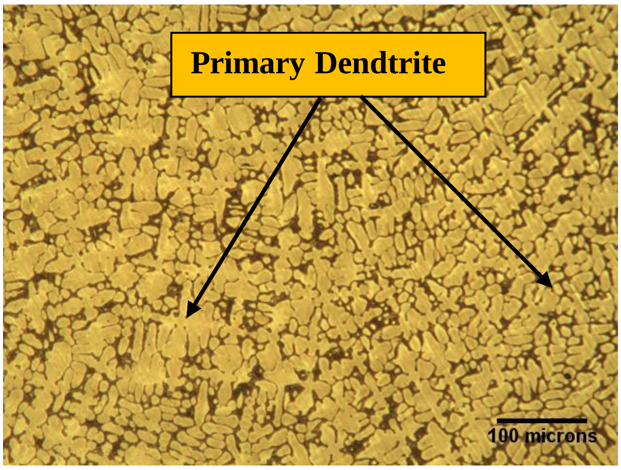
On comparison of microstructure of all samples it is evident that as the percentage of carbon and chromium is increasing, amount of carbides are also increasing which shows better mechanical and metallurgical properties in the hardface layer.



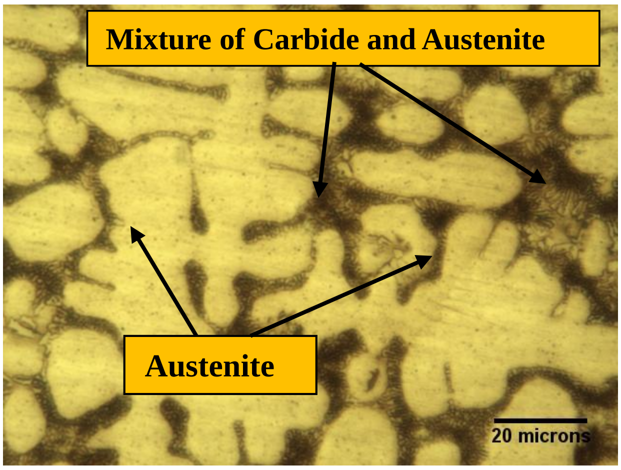
Sample-1 at 100X



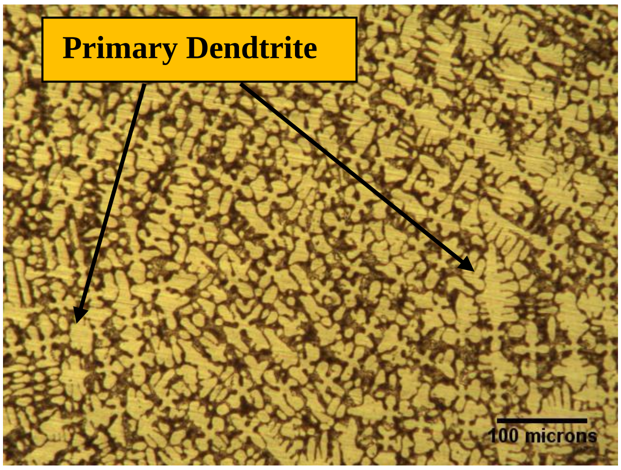
Sample-1 at 500X



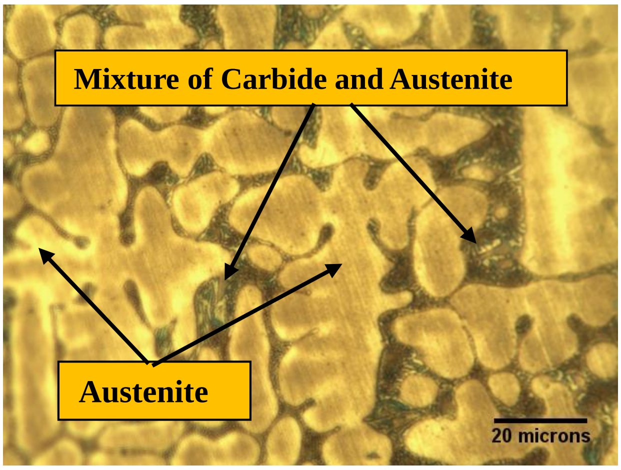
Sample-2 at 100x



Sample-2 at 500X



Sample-3 at 100X



Sample-3 at 500X

Figure 2 Microstructures of hardfacing surface

3.3 Hardness Analysis

Hardness test was performed on each sample to check the hardness value. Table 5 shows the hardness value of developed hardfaced layer and the base metal. Hardness of base material was taken in HRB scale while hardness of other samples were taken in HRC scale.

Table 5: Hardness value of developed hardfaced layer

Sample	Base Metal	Alloy 1	Alloy 2	Alloy 3
Hardness	82 HRB	41HRC	43HRC	44HRC

Table shows with increase in alloying percentage hardness value of hardface layer is increasing. Small amount of increase in carbon percentage, significant hardness value is changing it shows that among all the other alloying element carbon is playing key element for increase in hardness value. When the amount of carbon and chromium is increasing it forms different carbides and harder carbides are produced with high amount of carbon and chromium content

3. CONCLUION-

1. Desired chemical composition in the hardfacing layer has been produced with the paste technique used in this process.
2. Hardfaced layer has significant improvement in mechanical and metallurgical properties as compared to base material.
3. Microstructure of final alloy shows mixture of metallic carbides and Austenite. In this structure hard carbides are embedded in matrix of relatively soft austenite as the carbon content is increasing in the alloy amount of metallic carbides are also increasing in the matrix.
4. Bulk hardness of final alloys shows significant improvement in hardness value as compared to base material and also it shows as carbide content is increasing hardness value is also increasing.

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