Effects of Alloy Composition on Microstructure and Mechanical Properties of Iron Hardfacing Layers Developed by Submerged Arc Welding

Ashutosh Sakwar[1] AshishYadav[2] Rajkumar Pankaj[3]
[1]M.Tech Student [2]Assistant Professor [3]Assistant Professor
[1,2,3]Department of Mechanical Engineering
[1,2,3]Maharana Pratap College of Technology Gwalior, Madhya Pradesh India

ABSTRACT

A high carbon Fe-Cr-C alloy is applied over low carbon steel to make it more resistant to wear. In the industry, welding is commonly used to apply these hard layers. Among all welding methods, submerged arc welding (SAW) is the most popular because it provides a higher deposition rate than other methods. In this study, three hardfacing layers with different carbon levels were made using SAW. The final layers were tested to understand their properties. The first test checked the chemical composition and showed that the hardfacing layers had a high amount of alloying elements. Microstructural analysis revealed that as the carbon content increased, more carbide formed, and the structure included hard carbides in an austenite matrix. Hardness testing showed that as carbon levels went up, so did the hardness, indicating better mechanical and wear-resistant properties in the layers.

1. INTRODUCTION

Continuous deterioration of material takes place due to Various factors can impact the lifespan of a component or part. These factors include causes of corrosion, abrasive wear, erosive wear, and other changes in the mechanical or chemical properties of materials [1]. The wear rate of a part can be affected by too much loading, excessive movement, wrong temperature, or poor lubrication. There are many ways to deal with wear, but the easiest way to prevent it is to put a coating on the surface that is getting damaged [2]. Protective coatings can be applied to these materials using different methods like cladding, buttering, spraying, or hardfacing. These methods are used for different purposes, but hardfacing is the most commonly used surfacing method [3]. Hardfacing is generally the process of putting a hard material on a softer base material [4–5]. This method is widely used because it is easy to apply, reduces wear, and is cost-effective. These days, hardfacing is commonly used in industries like mining and coal to reduce downtime caused by wear [6–7]. Hardfacing can be done in different ways, but welding is a simple, common, and affordable option for applying the coating. The most popular welding process is arc welding, which is used to build up an alloy on a base material [8–10].

Shielded metal arc welding (SMAW) is the most commonly used welding method and many industries rely on it [11].

There are other welding methods used 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 needed to create a composite or alloy without melting the hard parts [12–13]. When a high deposition rate is needed, submerged arc welding is the best choice [14]. Fe-Cr-C alloys are commonly used in various conditions to prevent wear. These hard alloys are often preferred due to their low cost and good resistance to wear. These Fe-Cr-C hardfacing alloys work well in harsh environments and provide good wear resistance [15]. These Fe-Cr-C hardfacing alloys form primary carbides and eutectic carbides of the M7C3 matrix. These hard alloys have a high hardness value (1600HV) after forming carbides with the base metal [16].

The purpose of this study is to examine how adding graphite affects the microstructure and mechanical properties of Fe-Cr-C alloys by looking at their hardness.

The submerged arc welding process is used to achieve high deposition rates and to discuss the wear resistance properties based on the test results.

2. EXPERIMENTATION

Mild steel was chosen as the base metal for the final experiment because it is commonly used in the industry. The welding workpiece, which was a plate, had dimensions of 280x50x12 mm. Before starting the experiment, the plates were cleaned with acetone to remove any oil or grease. The chemical composition of the base material is shown in 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 chosen to create the hard-faced layer because it is inexpensive and works well with other materials at the metal level. The metal powder was applied as a paste onto the base material. A submerged arc welding method was used to heat and attach the metal powder to the surface. The welding settings stayed the same for all the welding steps and are listed in table 2. Three final hard-faced layers, as shown in figure 1, were made with different amounts of graphite, as listed in 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 made and then tested in different ways. The first test was to check the chemical makeup of the layer. It's important to know how much of each element is present because these elements can cause problems by forming carbides in the hardfaced layer. To test the chemical composition, Optical Emission Spectroscopy (OES) was used on a specimen that was 10x15mm in size.

Next, a hardness test was done.
A Rockwell hardness tester was used because it measures the overall hardness, which is important for hardfacing layers. A major load of 150 kilograms was applied and then released after 10 seconds onto a specimen that was 10x15x12mm in size. Three tests were conducted at three different points on the welding bead.

For the microstructure observation, a specimen of size 10x10mm was used.

The specimen was first polished with 220-grade emery paper, and then sequentially with emery papers of grades 320, 400, 600, 800, 1000, and 1200 to achieve a smooth surface. An alumina paste was used to give the sample a mirror-like finish. The final step was etching with a chemical agent to reveal the microstructure under an 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

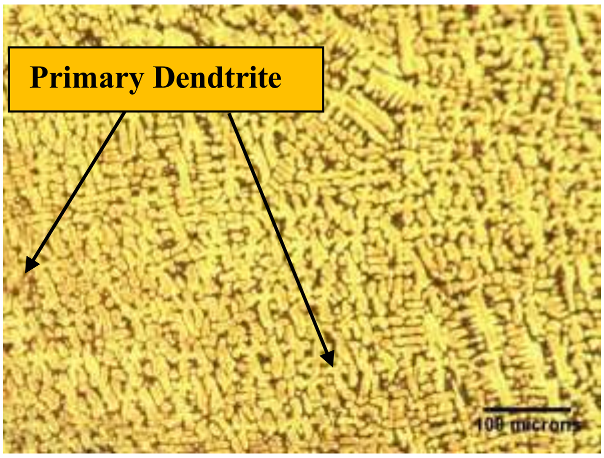
Table 4 shows as the graphite content in the paste is increasing, the amount of carbon is increasing but when we are using more than 10 % graphite there is very less amount of increase in carbon content. Since the thermal conductivity of graphite is very high so after a certain percentage it takes more 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

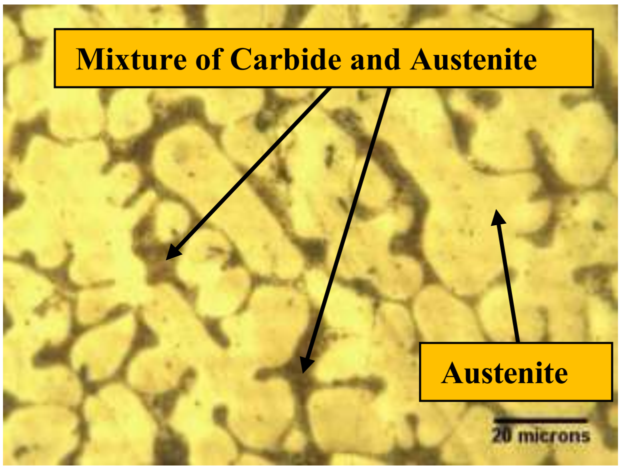
The microstructure of all samples was examined at various magnifications to understand how the hardfaced layer behaves from a metallurgical point of view. Figure 2 shows the microstructure of all samples at different magnifications.

Looking at the optical microstructure, metal carbides were found in the areas between the dendritic structures in the eutectic mix.
A layered pattern of dark and light areas was seen in these spaces. The dark areas represent metal carbides, while the dendritic areas are made up of the austenite phase in the hardfacing alloy.

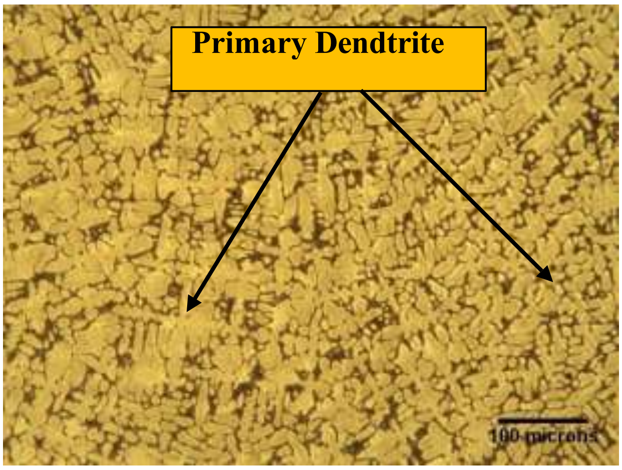
When comparing the microstructures of all the samples, it is clear that as the amount of carbon and chromium increases, so does the amount of carbides.
This suggests that the hardfaced layer has better mechanical and metallurgical properties when there is more carbon and chromium.



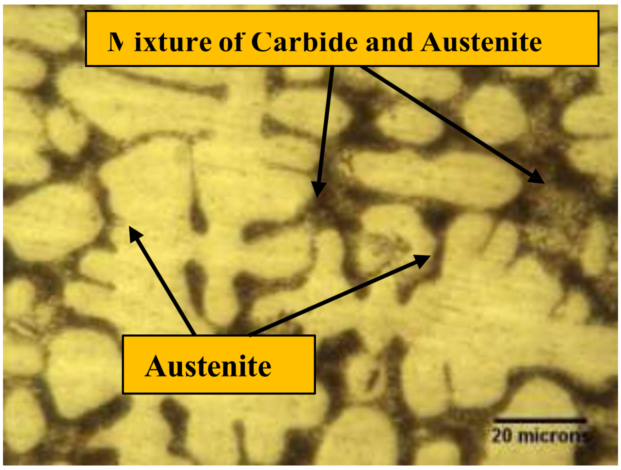
Sample-1 at 100X



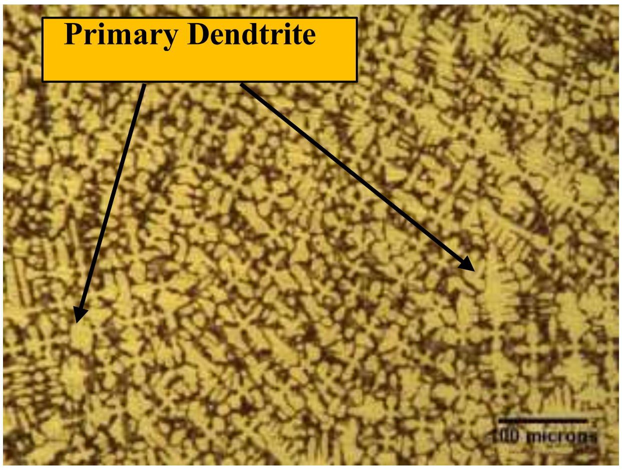
Sample-1 at 500X



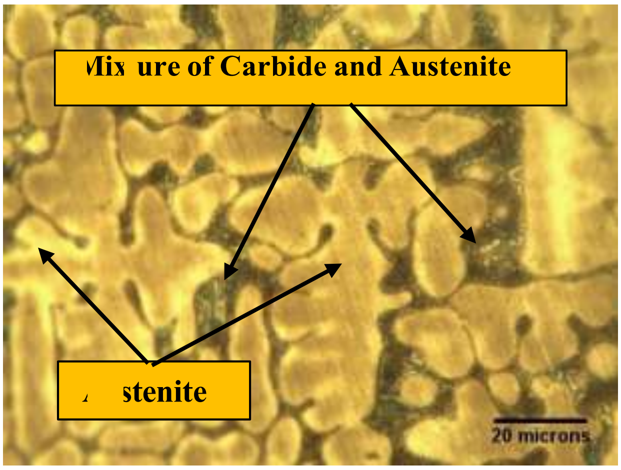
Sample-2 at 100x



Sample-2 at 500X



Sample-3 at 100X



Sample-3 at 500X

Figure 2 Microstructures of hardfacing surface

3.3 Hardness Analysis

A hardness test was done on each sample to measure the hardness value. Table 5 shows the hardness values for the developed hardfaced layer and the base metal. The hardness of the base material was measured using the HRB scale, while the hardness of the other samples was measured using the 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

The table shows that as the alloying percentage increases, the hardness of the hardface layer also increases. A small increase in carbon percentage leads to a significant change in the hardness value, which shows that carbon is the key element among all the alloying elements for increasing hardness. When the amounts of carbon and chromium increase, they form different carbides, and harder carbides are produced when there is a higher amount of carbon and chromium content.

4 CONCLUION-

1. The desired chemical makeup of the hardfacing layer was achieved using the paste method in this process.

2. The hardfaced layer has much better mechanical and metallurgical properties than the original base material.

3. The final alloy's structure is a mix of metal carbides and austenite. As the carbon content increases, more metal carbides are formed and spread throughout the softer austenite matrix.

4. The overall hardness of the final alloys is much higher than the base material, and as the amount of carbides increases, so does the hardness.

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