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# "AN INVESTIGATION ON HARDNESS OF CHROMIUM AND MANGANESE BASED HARDFACINGS FOR HEAVY EARTH MOVING EQUIPMENT"

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## ABSTRACT

***Surfacing is a process which is used for deposition of a layer over a base material to improve the surface quality of the base material. Hardfacing is surfacing technique in which hard layer is deposited over soft material to improve the wear resistance. There are so many techniques used in the industry to deposit these hard layers. Welding is also used in the industry to produce these harfacing layer as it has so many advantages including high deposition rate, low dilution and high productivity. In this project iron based hardfacing has been successfully developed with the help of submerged arc welding. Since iron based alloy associates with low cost and better metallurgical property it has chosen for final experiment in this study. Three hardfacing layer with different carbon content has been successfully developed without any defect. Mechanical and metallurgical characterization of developed hardfacing alloy has been studied and it shows significant improvement in the property as compared to the base material. Microstructures of deposited layer show mixture of hard carbides and austenite in which carbides are embedded in the matrix of soft austenite. Microstructure also shows increment of carbide volume fraction as the amount of alloying element is increasing. Hardness of hardfacing layer has been also improved as compared to the base material and it is also increasing with increment of carbon and chromium percentage.***

***Keyword**:* Iron based hardfacing, Submerged arc welding, Fe-Cr-C, Hardness.

## I. INTRODUCTION

Tribology is the science and engineering of interacting surfaces in relative motion, including the study of friction, lubrication, and wear. Understanding tribological principles is essential for minimizing wear in machine elements and improving their performance and longevity.

Depositing another layer of material over a base metal or substrate to improve its surface quality is known a surfacing. In other word, For improving the wear resisting properties like resistance to abrasion, corrosion, friction of any metal i.e. base metal, an or multi- layer of another metal or alloy is depositing over it. This process is known as Surfacing.

Initially surfacing was developed for the needs of oil-well drilling industry but now it is widely used on all types of equipment, implements, and containers to enhance their lives against wear and chemical action. It extends the service life of the product and saves expensive material.

It can maintain certain dimension, lower production and parts costs.

When any metal or alloy is deposited over another metal i.e. base metal to improve it hardness and also protect the base metal from different wear (abrasion, impact, erosion, galling, and cavitations) is known as hardfacing. Majorly hardfacing makes a metal to be abrasion resistant. Approx. three layer of any alloy needed to be deposit in hardfacing. In this process one should avoid excessive penetration so that excessive dilution may not take place which reduces the effectiveness.

The process of surfacing will extend the service life of the product. To get good service life and saves expensive materials, lot of engineering products are surfaced regularly. Surfacing is much applicable for the manufacturing of new parts and reclamation of worn components.

## II. LITERATURE REVIEW

**Liu et al. (2021)** Superior hardfacing materials, such as Ni-WC blends, are commonly applied to rock-engaging regions of oil & gas drill bits and other downhole tools to provide sufficient wear protection. In this work, it was found that drill bits were subjected to severe high-stress abrasive wear while rubbing against rock formations. The wear behavior of drill bits could be appropriately evaluated by the wear test in accordance with ASTM standard B611 rather than ASTM standard G65. This work also found that the toughness of tungsten carbides was a predominant factor determining high-stress abrasion resistance of Ni-WC hardfacing. Any choices from various types, sizes, and shapes of tungsten carbides would contribute to the improvements of wear resistance as long as this choice delivered better toughness, such as cemented tungsten carbide and spherical tungsten carbide. Large particle size was also beneficial for reinforcing wear resistance, but played a secondary role as compared to carbide toughness. Therefore, large-sized cemented tungsten carbide pellets provided the best high-stress abrasion resistance for drill bits, with large-sized spherical tungsten carbide being a close second. In addition, the comprehensive hardness of Ni-WC composite could be well represented using a linearly additive approach. The calculated hardness established a strong positive correlation with the wear behavior of Ni-WC hardfacing.

**Buntoeng Srikarun (2020)** Coal crusher is an important piece of equipment in the production of coal, but its abrasive wear remains a troublesome problem. A worn coal crusher damaged by abrasive wear is usually repaired by hardfacing weld deposit to prolong its lifespan. Currently, submerged arc welding with added metal powder is gaining interest as a hardfacing process. This study aimed to find alternative materials for hardfacing a coal crusher by submerged arc welding, possibly with powder added into the weld pool. Five samples were welded with a single hardfacing layer. Metal powders were added to some samples. The macroscopic structure and dilution of the deposited layer were examined using a stereo camera, across the cases. The chemical composition of the weld metal was investigated using an optical emission spectrometer. The worn surface layers, as well as the metallurgical structure of the hardfaced surfaces, were characterized optical microscopy, scanning electron microscopy, and energy dispersive X-ray diffraction. Mechanical properties were assessed from micro hardness testing and abrasive wear testing. The results showed a variety of chemical compositions in the hard faced deposit, depending on the type of wire used, the dilution of the weld metal, and the type of metal powder added. There are advantages and disadvantages to welding dilution of hard faced metal, and the degree of dilution depends on the type of wire and added powder used. Carbon, chromium, manganese and nickel contents in the dilution layer and in the added powder with the welded metal lead to structures that are mixtures of martensite and austenite, and this combination greatly improves hardness and wear resistance. The addition of ferro-carbon-chromium produced intergranular carbides, which were a major cause of decreasing wear resistance of the martensite structure. The worn surfaces of hardfacing layer showed micro cutting, micro ploughing, and micro fracture.

**M. Nagentrau (2019)** Tungsten carbide (WC) hardfacing coating technique is widely used to improve the performance of carbon steel blade exposed to acidic and abrasive conditions during production. This paper deals with the influence of welding parameters on the microstructure and carbide distribution of WC. WC hardfacing was deposited onto carbon steel by shielded metal arc welding (SMAW). Welding parameters such as welding current, number of weld layers, electrode drying and base material preheat were the focus of this work. Coating hardness, microstructure and elemental composition were analysed in detail. The effects of the welding parameters on WC hardfacing coating microstructure and hardness value were characterized by scanning electron microscope (SEM) and micro-Vickers hardness tester respectively. The larger carbide growth in overall coating region is mainly dictated by high current (200 A), increased number of weld layers (3 layers) and presence of base material preheat due to sufficient heat energy initiating carbide growth. The investigation also revealed that high current affected the growth of smaller carbide particles in matrix region significantly. Meanwhile, number of weld layers and base material preheat influences were seen during hardfacing with lower welding current. The absence of electrode drying led to uniform smaller carbide distribution in matrix region. It was found that increased number of large carbides and uniformly distributed smaller carbides in WC hardfacing deposit increased the hardness value of the coating.

## III. METHODOLOGY

### 3.1. Selection of base metal

Mild steel was selected as a Base metal for the final experiment as it is widely used in the industry for machine and structural application. These plates were cut in 280x50x12 mm size by power hacksaw, plates were pre cleaned with the acetone to remove any oil or grease before the welding. The chemical composition of base material is given in the Table 1.

**Table: 1 Chemical composition of base material**

| Element | C | Si | Mn | Cr | S |
|---|---|---|---|---|---|
| Weight Percentage (%) | 0.176 | 0.16 | 0.52 | 0.08 | 0.039 |

### 3.2. Powder selection for hard facing

Ferro-chrome metal powder was selected for development of hard-faced layer over the base material. The reason behind selection of Fe-Cr powder is its low cost and better metallurgical compatibility with other materials. Metal powder was sprayed over the base material in the form of paste; paste was made up of pre- defined amount of powder mixture with silicate binder. Coated Plates were left for 24 hours to dry and baked in oven at 200$^{o}$C so that no moisture remains. Submerged arc welding procedure was used to melt and fix this metal powder over the substrate. Baked plates were kept over the table of welding machine. DC electrode positive was used during the welding. An arc was formed over the paste to melt the metal powder. After solidification the slag was removed and a hardfacing layer was formed over the surface. The weld bead was cleaned with chipping hammer and later with acetone for further processes. As trial runs was started, too many defects were observed initially because the suitable welding parameters and proper material composition was not known.

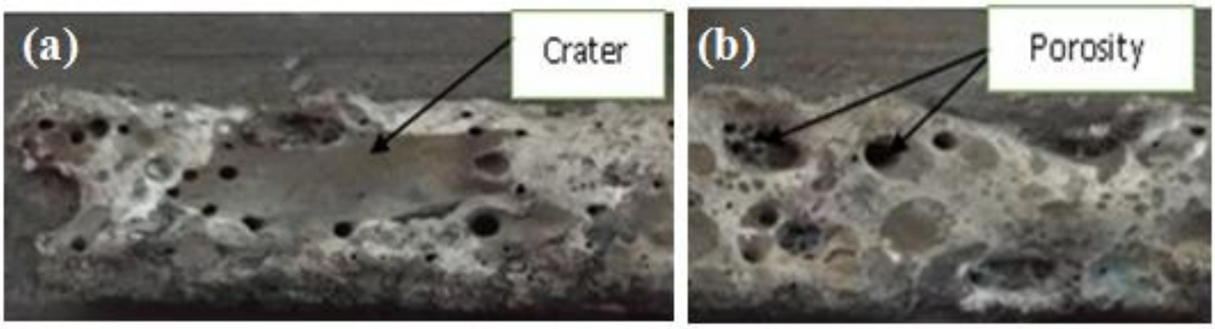

Figure 1 Defect-1

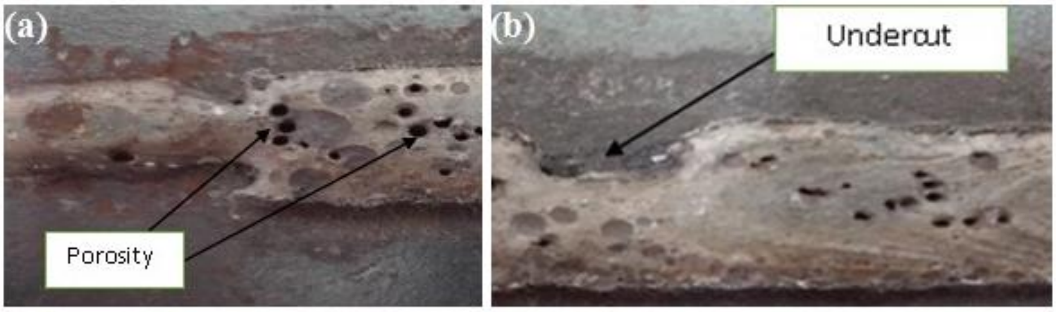

Figure 2 Defect-2

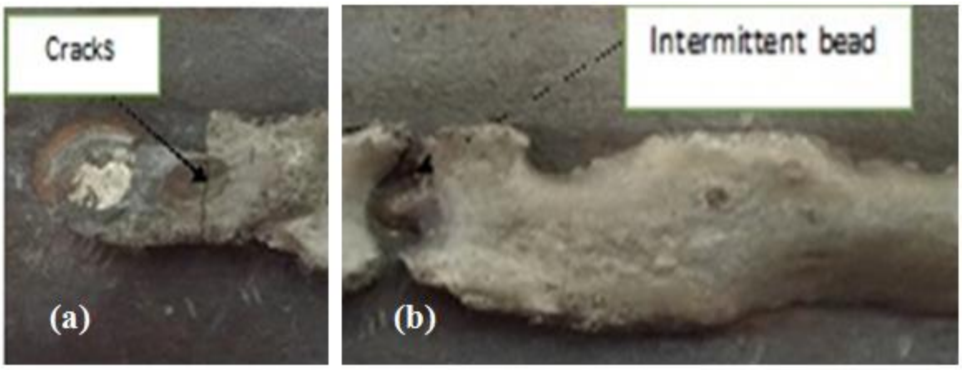

Figure 3 Defect-3

| Table: 2 Final welding parameters | |
|---|---|
| Voltage (V) | 40 |
| Current (Amp) | 390 |
| Speed (mm/s) | 6 |
| Nozzle to Plate Distance (mm) | 16 |
| 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** | 85 | 2.5 | 2.5 | 10 |
| **Sample-2** | 80 | 2.5 | 2.5 | 15 |
| **Sample-3** | 75 | 2.5 | 2.5 | 20 |

After finalizing welding parameters & metal powder composition final three hard faced layer 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. These experiments were planned to study the effect of carbon percentage in the developed hardfaced layer. Figure 4 (a, b and c) shows the three different hardface layer with different carbon percentage.

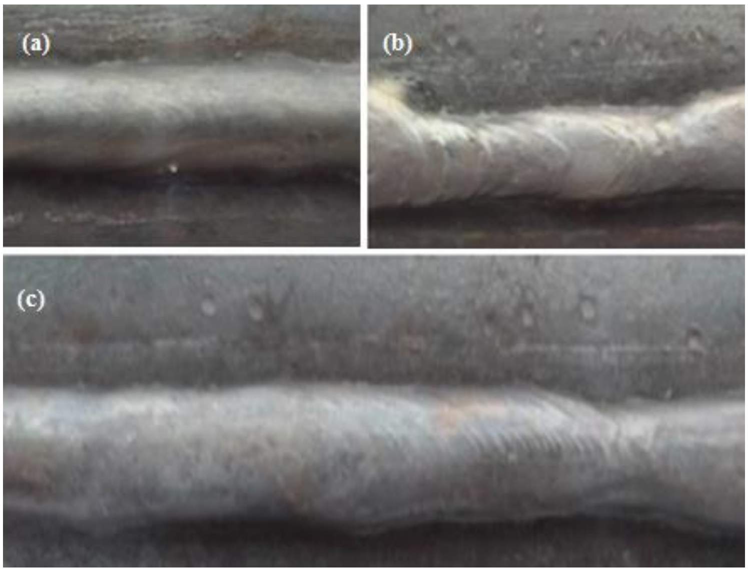

Figure 4 Hardfaced layer (a) Sample-1 (b) Sample-2 (c) Sample-3

### 3.2. Hardness Test

The hardness of the specimen was tested by Brinell hardness tester because it gives bulk hardness which is always required for hardfacing layer. Specimen was placed on a steel anvil and the Minor load is applied. The dial is adjusted to zero and major load of 150 Kg was released for 10 second, which intended the surface of a specimen. Three test runs were applied at different three points of welding Bead.

## IV. RESULTS & DISCUSSION

### 4.1. 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 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 | Sample 1 | Sample 2 | Sample 3 |
|---|---|---|---|---|
| **Carbon** | 0.178 | 1.18 | 1.31 | 1.38 |
| **Chromium** | 0.081 | 1.42 | 1.32 | 1.49 |
| **Manganese** | 0.49 | 1.19 | 1.08 | 1.12 |
| **Silicon** | 0.162 | 1.19 | 1.16 | 1.1 |

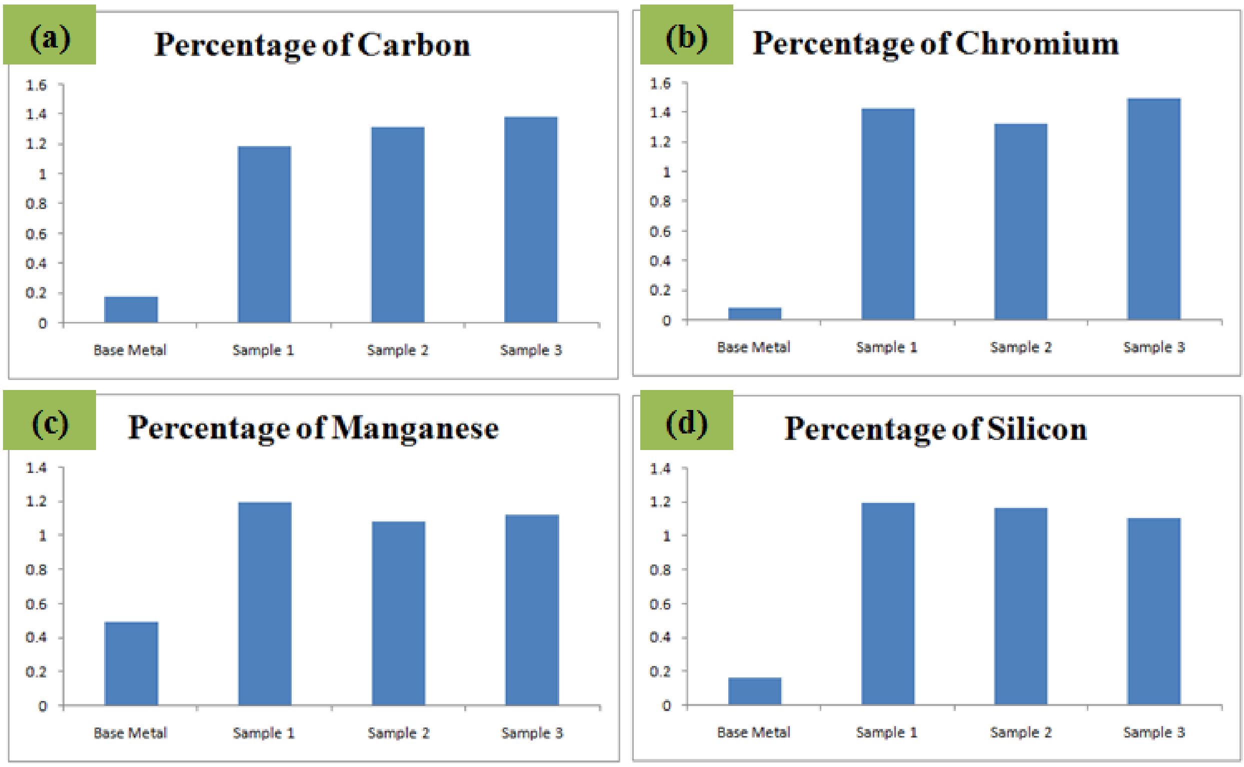

Figure 5 Distribution of element in chemical composition

### 4.2. 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.

**Table: 5 Hardness value of developed hardfaced layer**

| Sample | Base Metal | Sample 1 | Sample 2 | Sample 3 |
|---|---|---|---|---|
| **Hardness** | 89 HRB | 116 HRB | 122 HRB | 132 HRB |

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. Microstructures of hardfacing layer also shows carbide presence and the amount of these carbides are more when hardfacing alloys has the high amount of alloying element.

## V. CONCLUSION REMARK

Following the completion of the final set of experiments and comprehensive mechanical testing, the following conclusions have been drawn:

- A successful development of an iron-based hardfacing layer has been achieved through the submerged arc welding process. Visual inspection of the final alloy reveals a defect-free hardfacing layer.
- The desired chemical composition within the hardfacing layer has been effectively achieved using the paste

technique employed in this process.

- The hardfaced layer exhibits significant enhancements in mechanical properties in comparison to the base material.
- The microstructure of the final alloy exhibits a combination of metallic carbides and austenite. Within this structure, hard carbides are embedded in a matrix of relatively soft austenite, and as the carbon content within the alloy increases, the quantity of metallic carbides within the matrix also increases.
- Bulk hardness measurements of the final alloys reveal a substantial improvement in hardness values when contrasted with the base material. Furthermore, it is observed that as the carbide content increases, the hardness value also experiences an increment.

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