

PERFORMANCE EVALUATION OF C-CR- FE HARDFACING DEPOSITS PRODUCED USING SHIELDED METAL ARC WELDING (SMAW)

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Abstract: This study explores the microstructure and abrasive wear behavior of chromium-based hardfacing alloys deposited using Shielded Metal Arc Welding (SMAW). Hardfacing materials made of chromium carbide are frequently used to enhance the wear resistance of industrial parts that are subjected to extreme abrasive conditions. Since, there is not much research work being done on how welding procedures affect these alloys' microstructure and tribological performance. Hardfacing layers were deposited in this study utilizing both SMAW techniques with single bead weld and double bead welds. Phase composition, carbide distribution, and the impact of welding conditions on the coatings' structural properties were all investigated by microstructural investigation utilizing optical microscopy, scanning electron microscopy (SEM), and energy dispersive X- ray spectroscopy (EDS). Standardized dry sliding wear tests were carried out to assess abrasive wear resistance, and surface profilometry and SEM measurements of the worn surfaces under controlled conditions to determine each sample's hardness. The findings showed that double bead welding techniques showed superior improvement in terms of microstructure and wear performance. In comparison to single bead welding by SMAW, Double bead welding created a finer dispersion of carbides and increased hardness, which led to superior wear resistance. These results obtained will give adequate advice for choosing appropriate welding techniques to enhance the functionality of hardfacing of materials based on chromium in abrasive conditions.

Keywords: SMAW, Hardfacing, SEM, EDS, wear, microstructure.

I. INTRODUCTION

Hardfacing is a popular surface engineering approach which is used to extend the life of parts that are subjected to extreme abrasion, impact loading, and wear. Because of their exceptional wear resistance, chromium-based hardfacing alloys enhanced with elements like silicon and manganese are especially prized among different alloy systems. The development of hard chromium carbide phases, which greatly increase surface hardness and durability under demanding operating circumstances, is the main cause of this improved

performance. As a result, these hardfacing coatings are widely used in sectors including heavy machinery, mining, and agriculture where component deterioration can result in frequent failures and higher maintenance expenses.

The welding method used has a considerable impact on the performance of hardfaced layers. Shielded Metal Arc Welding (SMAW) has been one among the most widely accepted methods because of its affordability, ease of use, and suitability for a variety of industrial settings. Because SMAW, or stick welding, is portable and simple to operate, it is especially popular for field applications. The hardness, microstructure, and general performance of the deposited layer may be negatively impacted by its comparatively long arc duration, which could lead to increased heat input and slower cooling rates.

The main intension of this study is to examine how important welding process parameters affect the microstructure and hardness of chromium-rich hardfacing weldments made using single and double bead welding utilizing shielded metal arc welding (SMAW) techniques. By controlling crucial parameters, particularly welding current and voltage, through controlled adjustments over certain time intervals, the main goal is to improve the mechanical performance and microstructural integrity of the welded joints. Both single- bead and double-bead arrangements are adopted to weld specimens. In view of determining the best circumstances for creating high-quality hardfaced layers, a comparison study of SMAW processes is conducted to determine the benefits and drawbacks of each. Microstructural analysis and hardness testing are prioritized in order to investigate the relationships between welding parameters and material properties.

II. MATERIALS AND METHODS

AISI 1020 mild steel plates with specific dimensions of 100 mm × 25 mm × 12 mm were selected as the substrate material for the hardfacing process. Prior to welding, the substrate surfaces were cleaned using a wire brush followed by acetone treatment to eliminate surface contaminants such as oil, grease, rust, and scale. Surface preparations are very much essential to ensure optimal adhesion between the hardfacing layer and the base metal. A commercially available chromium- based alloy electrode was employed as the hardfacing material. Table 1 shows the elemental composition of base metal AISI 1020 which is a low carbon steel.

TABLE 1 Chemical Composition of base metal AISI 1020 Low Carbon Steel (wt. %)

Element	C	Mn	P	S	Si	Fe
Content	0.20	0.50	0.04	0.05	0.280	Bal



Fig. 1 Hardfacing samples by SMAW welding

Shielded Metal Arc Welding (SMAW) is the welding technique used in this study for hardfacing applications. For both single and double bead processes, the welding current was adjusted at predetermined intervals to achieve hardfacing at M/s Deccan Hydraulics Pvt. Ltd., Kolar Gold Fields (KGF), Karnataka. After hardfacing welding, the specimens were cut to dimensions of 76 mm × 25 mm × 10 mm using a water jet cutting machine to allow for wear testing using the Dry Sand Rubber Wheel test method as per ASTM G65 specifications. In order to conduct the microstructural examination, specimens from the remaining portion of the welded specimens were also cut to dimensions of 10 mm × 10 mm × 10 mm. Table 2 gives the nominal chemical composition of the chromium- based hardfacing electrode .

TABLE 2 : Chemical Composition of the Hardfacing Electrode (wt.%)

Element	C	Mn	P	S	Si	Fe
Content	0.20	0.50	0.04	0.05	0.280	Bal

Hardfacing Technique

Hardfacing which is a surface engineering method is the one used to improve the hardness, wear resistance, and satisfactory service life of parts that are exposed to impact, erosive, or abrasive environments. Welding-based techniques are the most popular hardfacing technology because they create strong metallurgical bonds between the overlay material and the substrate. This method uses SMAW or any other appropriate welding process to deposit a layer of wear- resistant alloy, such as boron, molybdenum, or chromium, to the surface of base metal. By carefully adjusting important process variables like welding current, voltage, and traveling speed, hardfacing layers can be applied. This changes the heat input, which affects the final microstructure.

Shielded Metal Arc Welding

SMAW is a frequently used technology because of its ease of use, low equipment cost, and adaptability in a range of working situations, in hardfacing applications. During welding, flux is injected to the electrode, acting as a source of shielding gas and a filler. While the flux breaks down to create a gaseous barrier that functions as a layer of slag to shelter the molten pool from oxidation and contamination, the electrode is deposited as a layer of weld metal onto the substrate. Hardfacing coatings are typically applied to steel components using SMAW. In harsh operating conditions, rich alloy coatings like chromium and molybdenum can improve surface hardness and wear resistance. When heated, the flux in the electrode breaks down, producing a layer of slag and a protective gas that shields the molten weld pool. This works especially effectively for overlays composed of materials that can withstand wear, including hardfacing alloys rich in chromium. Furthermore, the performance and quality of hardfaced layers are significantly appraised by the process conditions.

The samples of specimens made using SMAW welding with periodic variations in the welding current are displayed in the figure. Welding current, arc voltage, and travel speed all have a definite impact on the heat input and bead geometry, which in turn affects the microstructure and hardness of the deposited material. Table 4 presents the welding parameters employed in this study.



Fig 1: Hardfacing samples by SMAW welding

Single Bead welding

Element	C	Mn	P	S	Si	Fe
Content	0.20	0.50	0.04	0.05	0.280	Bal

Microstructural Characterization

Scanning electron microscopy (SEM) was utilized to conduct a thorough microstructural analysis in order to analyze the impact of welding parameters and conditions on the microstructure and characteristics of chromium-based hardfacing layers. First, an optical microscope was used to examine cross-sections of the appropriately etched and polished weldments in order to evaluate the overall properties of the microstructure. Grain form, phase distribution, and the integrity of the metallurgical contact between the deposited layer and the mild steel substrate beneath the hardfacing layer 130A were assessed. The primary objectives of measurements were to identify variations in grain size, the appearance of distinct phases such as chromium-rich carbides and molybdenum-based compounds, and the presence of structural defects such as porosity, microcracks, or segregated areas.

These initial optical analyses were significant in revealing the effectiveness of the heat input and cooling rates along with different welding settings on the solidification dynamics and resulting microstructural patterns. For a more in-depth analysis and higher-resolution pictures, SEM was used. This facilitated the identification of fine-scale features like the shape, distribution, and interconnectivity of hard phases, particularly chromium carbides, which are known to have a significant impact on wear resistance. Localized elemental analysis was performed using Energy Dispersive X-ray Spectroscopy (EDS) in combination with SEM to determine the chemical composition of individual phases and the spatial distribution of alloying elements.

The integration of data from optical microscopy, SEM imaging, and EDS analysis revealed a substantial correlation between mechanical parameters, particularly hardness, and microstructural features such as carbide shape and grain refinement [12]. This multimodal approach improved comprehension of the microstructural evolution in response to altering welding parameters and provided valuable insights into how to optimize processing conditions for better performance of chromium-based hardfacing systems.

Hardness Testing

The prepared specimens were subjected to Vickers hardness testing to evaluate the mechanical properties of the chromium-based hardfacing layers. The Vickers hardness test is a popular method for measuring microhardness that applies a precise load to the specimen surface using a diamond-shaped indenter with a square base. The hardness value is determined by measuring, under a microscope, the size of the indentation left on the polished surface. Because it enables localized assessment across several microstructural regions, such as the substrate, heat-affected zone, and hardfaced zone, it is appropriate for evaluating the hardness of heterogeneous materials like weldments and hardfacing layers. In order to examine hardness distribution and correlate these results with microstructural differences seen through metallographic investigation, hardness profiles were created in this work

III. RESULTS AND DISCUSSIONS

Assessment of Material Microstructure

Shielded metal arc welding (SMAW) was employed to deposit a chromium-rich hardfacing alloy onto mild steel substrates, with welding current varied in stages. A total of eight specimens were created, four of which had a single bead deposition and four of which had a double bead arrangement. The influence of current level and bead configuration on microstructural evolution was investigated in detail. The comparatively mild heat input at lower welding currents hastened solidification and created a refined microstructure with smaller chromium-rich carbides and borides dispersed throughout the matrix. This microstructural refinement is associated with increased hardness because carbide coarsening has a finite lifetime. Higher residual tensions and a greater propensity for brittleness are likewise produced in the single bead cases, where localized cycles of heating and cooling predominate. As currents increased, a consistent increase in heat input was observed.

Overall, the results demonstrate that the microstructural characteristics of chromium-based hardfacing are significantly influenced by welding current and bead design. While lower currents polish the microstructure and promote hardness, higher currents and several passes increase metallurgical cohesion and toughness at the expense of hardness. This highlights the need for ideal current and deposition methods that are appropriate for the desired balance between wear resistance and structural integrity in hardfacing applications.

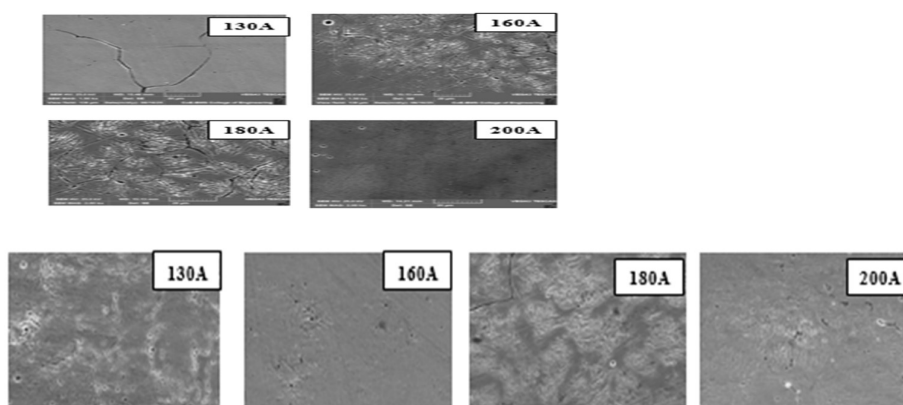


Fig 2: SEM images of double bead welding varying current at different intervals (B1 – B4)

V. CONCLUSIONS

This study reveals a clear correlation between welding parameters—particularly current levels and bead configurations—and the resulting hardness of chromium-based hardfacing layers. The Vickers Hardness data shows that adding a double bead configuration consistently improves surface hardness. These points to enhanced heat input control and microstructural refinement. Balanced properties are attained at moderate current levels, which are similar to the outcomes seen in double bead applications, where improved fusing and finer grain structures result in higher bonding and hardness. Conversely, the single bead state, which has a lower hardness, is associated with a lower current. This is most likely due to poor bonding and limited penetration. Higher current levels suggest deeper penetration, while dilution and coarser particle production negatively impact hardness. It appears that finding a balance between penetration depth, dilution, and temperature input is necessary to achieve the best welding results in hardfacing applications. Similar to welding at moderate current, double bead designs in SMAW offer improved mechanical performance and microstructural control. These findings highlight how crucial it is to properly select the equipment and welding technique in order to tailor surface properties for wear-resistant applications. According to microstructural study, this welding technique promoted the development of carbide phases rich in chromium, which enhanced wear resistance and surface hardness. Because of the reheating effect, which improved grain refinement in the heat-affected zone, double bead designs showed finer microstructures and more uniform carbide dispersion.

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