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Effect of Fe–Cr Hardfacing on Hardness and Microstructure of Carbon Steel Using the SMAW Process

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***Abstract*— *Wear is one of the primary causes of failure in machine components operating under high friction and loading conditions. One effective method to improve wear resistance is the hardfacing process using iron–chromium (Fe–Cr) alloys, which are well known for their ability to form hard phases on the material surface. This study aims to analyze the effect of welding current variations on hardness values and microstructural characteristics of medium carbon steel S45C coated with Fe–Cr HV-600 hardfacing using the Shielded Metal Arc Welding (SMAW) method. The welding current variations applied in this research were 100 A, 150 A, and 200 A. Hardness testing was conducted using a portable NOVOTEST T-UD3 device with the Ultrasonic Contact Impedance (UCI) method, producing Vickers-equivalent hardness values. Additionally, microstructural observations were performed to identify morphological changes resulting from differences in heat input during the welding process. The results indicate that welding current variation significantly affects the hardness improvement of the hardfacing layer. The highest hardness value was obtained at 150 A, indicating the formation of a more homogeneous microstructure with a uniform distribution of hard phases. Excessively low current resulted in suboptimal alloy melting, whereas excessively high current increased heat input, slowed the cooling rate, and potentially promoted grain growth.*

***Keywords*— *Hardfacing, Fe–Cr, SMAW, Welding Current, Hardness, Microstructure, S45C..*

I. INTRODUCTION

Wear in machine components is a critical issue that can reduce performance and shorten service life. Hardfacing is widely used to enhance wear resistance by depositing an alloy layer with superior mechanical properties compared to the base material [1].

Fe–Cr HV-600 hardfacing electrodes are designed to produce high hardness layers and excellent wear resistance through the formation of martensite and chromium carbides during cooling. This microstructure directly contributes to improved hardness and makes the electrode suitable for repairing components subjected to abrasive wear[2].

S45C carbon steel is classified as medium carbon steel with approximately 0.45% carbon content. It is commonly used for machine components due to its balance of strength, toughness, and hardenability. Its initial microstructure typically consists of ferrite and pearlite but may transform into martensite in the heat-affected zone during welding[3].

Therefore, this study analyzes the effect of welding current variation on hardness and microstructure after applying Fe–Cr HV-600 hardfacing using the SMAW process[4].

II. RESEARCH METHOD

This research employed a laboratory experimental approach to analyze the effect of Fe–Cr HV-600 hardfacing on the hardness and microstructure of S45C carbon steel using the SMAW process[5]. The experiment was conducted under controlled conditions with welding current as the primary variable while other parameters were kept constant.

The independent variable was the welding current set at 100 A, 150 A, and 200 A. The dependent variables included surface hardness and microstructural characteristics in the Weld Metal (WM), Heat Affected Zone (HAZ), and Base Metal (BM)[6].

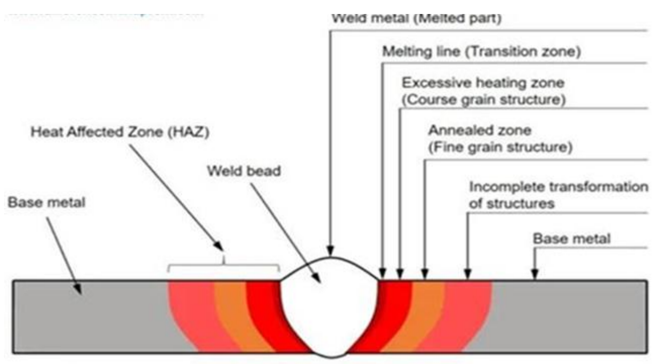

Fig. 1. Welding zones consisting of Weld Metal (WM), Heat Affected Zone (HAZ), and Base Metal (BM).

The materials used were medium carbon steel S45C as the base metal and Fe–Cr HV-600 electrodes as filler metal. Hardness testing was performed using the Vickers/UCI method, while microstructural observations were conducted using an optical microscope after metallographic preparation[7].

The research stages consisted of specimen preparation, preheating, hardfacing deposition, natural cooling, specimen preparation, hardness testing, microstructure observation, and data analysis to ensure the relationship between welding parameters and resulting material properties[8][9][10].

Hardfacing deposition was carried out using the SMAW process

After welding, the specimens were allowed to cool naturally at room temperature.

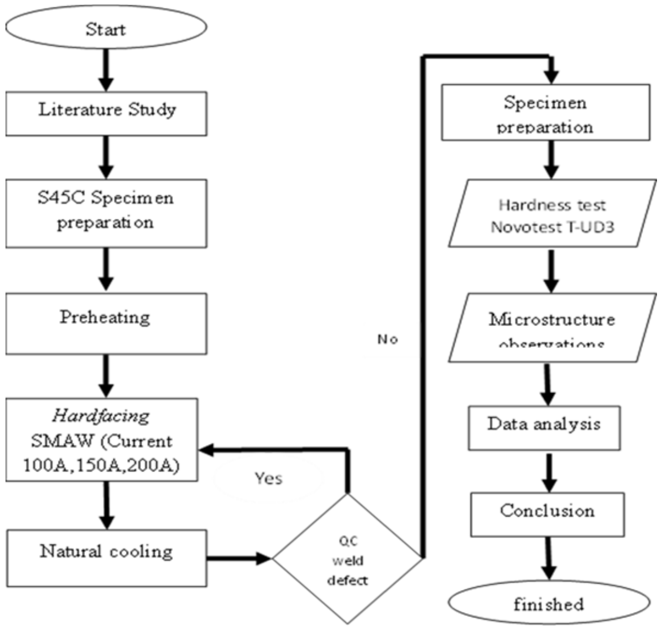

Fig. 2. Research flowchart of the experimental procedure.


Fig. 3. Hardfacing Process using the SMAW


Fig. 4. Specimen after Fe–Cr HV-600 hardfacing deposition.

III. Results and Discussion

Initial hardness testing showed that untreated S45C steel had an average hardness of approximately 264 HV, which served as a baseline for evaluating the improvement after hardfacing.

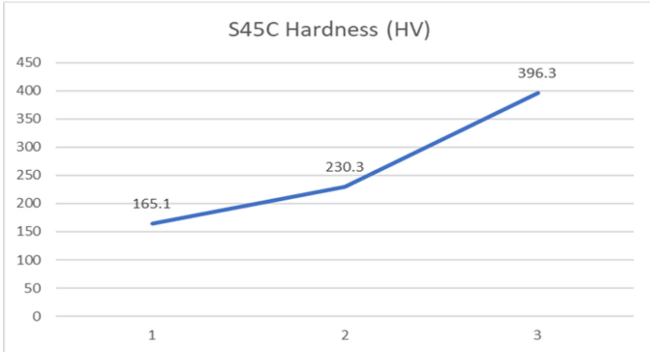

Fig. 5. Intial hardness of untreated S45C steel

At 100 A, the Weld Metal exhibited the highest hardness values ranging from 417.9 to 801.9 HV, followed by the Heat Affected Zone (340.8–546.2 HV) and Base Metal (284.3–413.6 HV). This increase confirms the effectiveness of the Fe–Cr HV-600 hardfacing process in enhancing surface properties.

Increasing the current to 150 A produced the highest hardness with a more stable distribution, indicating optimal heat input that promoted the formation of hard microstructures. However, further increasing the current to 200 A led to a reduction in hardness due to slower cooling rates and possible grain growth.

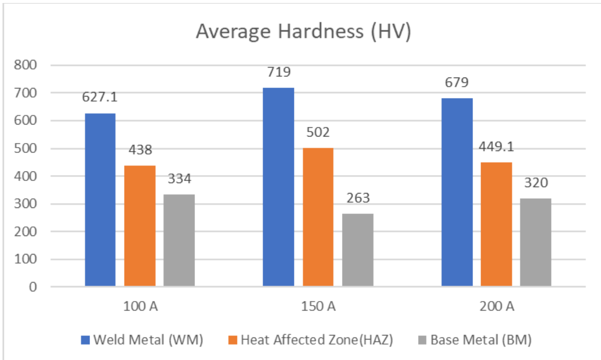

Fig. 6. Average hardness distribution at different welding currents.

Microstructural observations revealed that the 100 A current produced relatively fine morphologies due to rapid cooling.

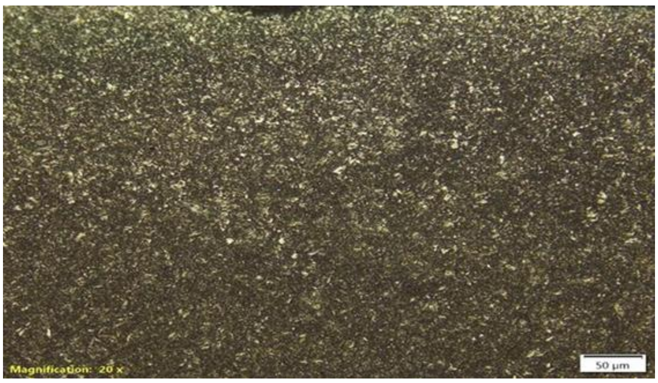

Fig. 7. Microstructure of Fe–Cr HV-600 hardfacing at 100 A.

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The 150 A variation showed a more homogeneous structure with evenly distributed hard phases,

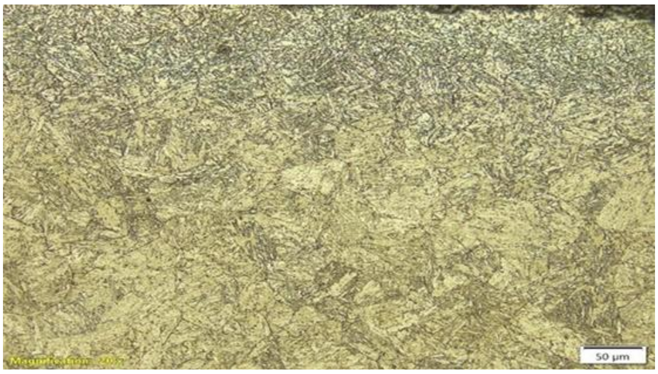

Fig. 8. Microstructure at 150 A showing a homogeneous structure.

while the 200 A current resulted in a coarser morphology caused by higher thermal cycles.

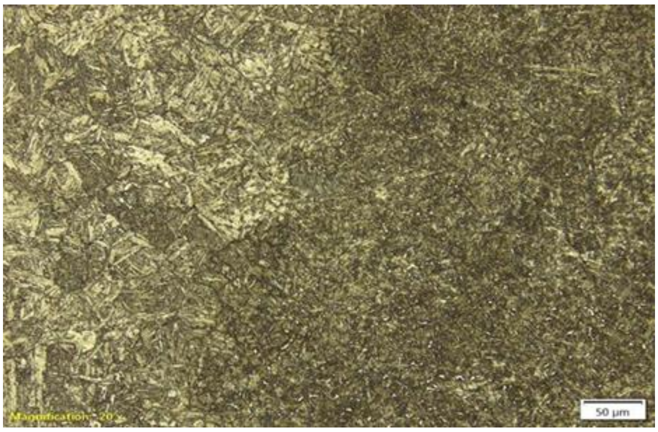

Fig. 9. Microstructure at 200 A indicating grain coarsening.

The relationship between microstructure and hardness demonstrates that the formation of hard phases such as martensite and chromium carbides directly enhances the mechanical properties of the surface layer.

IV. Conclusion

Welding current variation has a significant influence on the hardness improvement of Fe–Cr HV-600 hardfacing applied to S45C carbon steel. The 150 A current was identified as the optimal parameter because it produced a more homogeneous microstructure and uniform distribution of hard phases.

The application of Fe–Cr HV-600 hardfacing has proven effective in improving surface hardness and shows strong potential for extending the service life of machine components operating under high friction and loading conditions. Selecting appropriate welding parameters is essential for achieving optimal coating performance.

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