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# The Influence Of Welding Processes On The Microstructure And Mechanical Properties Of Hardfacing

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## Abstract

This investigation delves into the efficacy of three distinct welding methodologies, specifically Gas Tungsten Arc Welding (GTAW), Shielded Metal Arc Welding (SMAW), and Flux Cored Arc Welding (FCAW), within the framework of hardfacing applications. The primary objective of the study is to assess their influence on the mechanical properties and microstructure of the resultant welded materials.

Empirical analyses were undertaken to appraise the hardness and wear rate ensuing from each welding process. The results unveiled the superior efficacy of the GTAW welding process, manifesting in the attainment of the highest levels of hardness and wear resistance. Subsequent microstructural examinations elucidated the pivotal role of carbide formation, with a particular emphasis on the amalgamation of molybdenum and tungsten, contributing to heightened hardness in scenarios characterized by substantial welding volume.

This research not only furnishes valuable insights into the relative efficacy of welding hardfacing methodologies but also underscores the significance of microstructural considerations in attaining optimal mechanical properties. The ramifications of this study contribute to the progression of welding technology, furnishing guidance for the judicious selection of processes contingent upon the desired material attributes in hardfacing applications.

**Keywords**: Microstructure, Mechanical properties, Welding hardfacing

## I. INTRODUCTION

Hardfacing is a technique used to improve the surface properties of metal components such as those found in agricultural machinery sugarcane milling equipment and mining soil preparation equipment. It involves depositing a layer of hard metal on a softer base metal typically a low-carbon steel. This is commonly done using welding processes. Hardfacing increases the hardness and wear resistance of the surface layer without sacrificing its ductility or tensile strength. This is achieved by developing a martensitic microstructure within the austenitic parent material, which is a common approach to improving wear resistance. The hardness of the weld bead depends on a number of factors, including the geometry and distribution of hard phases, as well as the density, size of particles, and strain hardening behavior. Weld bead properties are also influenced by the welding process.

The general process commonly used for solid-state welding includes various Oxyacetylene gas welding (OAW), gas metal arc welding (GMAW), and shielded metal arc welding (SMAW) are all different techniques used in welding. and flux-cored arc welding (FCAW). These different welding processes impact the efficiency of welding, weld penetration, mechanical properties, chemical properties, and the cost of solid-state welding [6-11,12]. John J. Coronado et al. [13] studied the influence of the welding process on the durability of solid-state welds and compared flux-cored arc welding with shielded metal arc welding. using chromium-molybdenum filler wire.

They found that the crack susceptibility of welds made using flux-cored arc welding was lower than that of shielded metal arc welding. G.R.C. PRADEEP et al. [14] compared gas welding to gas metal arc welding and its influence on the workpiece's toughness using a nickel-based filler wire. They found that the gas welding process resulted in lower crack susceptibility compared to gas metal arc welding.

As previously mentioned, high-quality welding wires are predominantly used in the connection process. Therefore, as an alternative for application and cost reduction in the maintenance of worn components, this research study has examined the comparative welding processes using carbon steel wire on medium carbon steel. This serves as an option for decision-making for industry groups and individuals interested in exploring. This experiment utilized the gas tungsten arc welding process, electric arc welding, and flux-cored arc welding processes, which affected the hardness value, welding penetration rate, chemical composition of the weld, and the microstructure of the welded joint.

## II. Methodology

The research process involves comparing The extent to which metal hardness as a result of welding, weld penetration rate, chemical composition of the weld, and the microstructure of the welded joint surface. The research method is as follows:

### 2.1 Materials and Processes.

In the experimental process of welding hard surfaces, GTAW and FCAW processes are employed. The welding is performed on medium carbon steel composite material, as indicated in Table 1. The welding for this experiment is conducted in a single-pass manner, as shown in Figure 1. For the experiment, three types of carbon steel group welding wires are used, and the ingredients of the welding wires are listed in Table 2. This experiment utilizes a heat input of 2.08 Joules per millimeter square.

### 2.2 Microstructure

The changes in the microstructure of solidified surface-welded joints, as shown in Figure 1, were examined in accordance with ASTM E470 [15] standards. The microstructure of the joint area was studied to compare the microstructures and chemical compositions of the welds. The examination of the specimens in the weld area was Carried out with the use of a scanning electron microscope (SEM). to observe the different effects of welding processes. The mechanical properties, including hardness and toughness, were tested in the welds. The hardness of the welds was determined following the ASTM E384 [16] standard, using the Rockwell Test (HRC) testing machine, and the obtained values were then averaged. As for the toughness testing of the welds in a notched square-shaped specimen with dimensions of 76x25 millimeters, the test specimens were prepared as shown in Figure 1 and polished with abrasive paper. The testing duration was 5 minutes with a load of 50 newtons. The characteristics of the toughness testing are depicted in Figure 2

## III. RESULT

### 3.1 Hardness and Wear of Weld

This research project involves a comparison of the weld processes, Compare electric arc welding, tungsten inert gas welding, and flux cored arc welding on medium carbon steel in detail. The study investigates the heat input of 2.08 joules per square millimeter. Subsequently, the

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workpieces are examined for mechanical properties. The experiments revealed that the welding process impacts the workpiece's strength and ductility.

**Table. 1** chemical properties of Material (Wt%)

| C | Si | S | P | Cr | Mn | Fe |
|---|---|---|---|---|---|---|
| 0.48 | 0.23 | 0.009 | 0.007 | 0.32 | 0.64 | Balance |

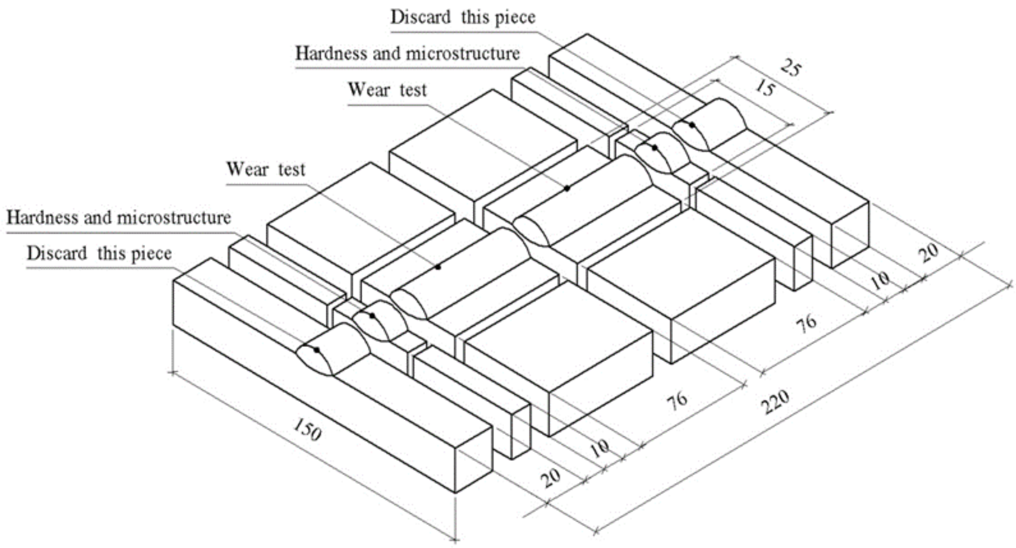


**Fig.1** Dimensions and Cutting Specimen

**Table. 1** chemical properties of Wire (Wt%)

| Welding Process | Chemical composition | | | | | | |
|---|---|---|---|---|---|---|---|
| | C | Si | Cr | Mn | Mo | W | Fe |
| FCAW | 2.00 | 1.00 | 5.00 | 8.00 | - | - | Bl. |
| GTAW | 5.00 | 1.50 | 6.40 | 3.00 | 0.94 | 0.98 | Bl. |
| SMAW | 4.00 | 1.50 | 8.50 | 2.00 | - | - | Bl. |

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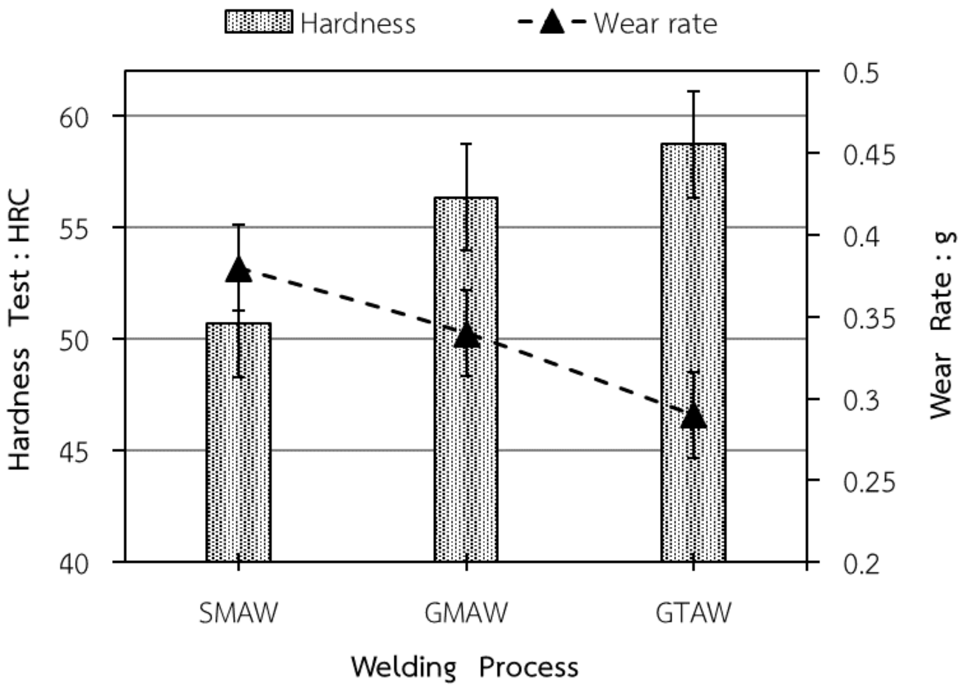
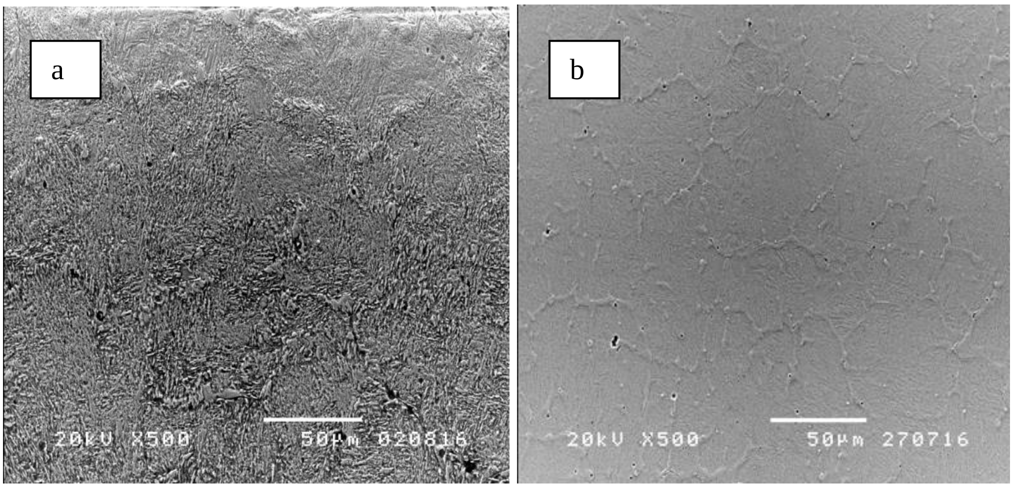



**Fig.2** The relationship between hardness and the strength of welds on a solid surface.

The welding procedure qualification, the maximum hardness value for GTAW welding is 58.72 HRC with a dilution rate of 0.29 grams. As for FCAW welding, the average hardness value of the weld joint is 56.35 HRC, and the dilution rate is 0.34 grams. Lastly, for SMAW welding, the minimum hardness value of the weld joint is 50.68 HRC, and the dilution rate is 0.38 grams, as shown in Figure 2.



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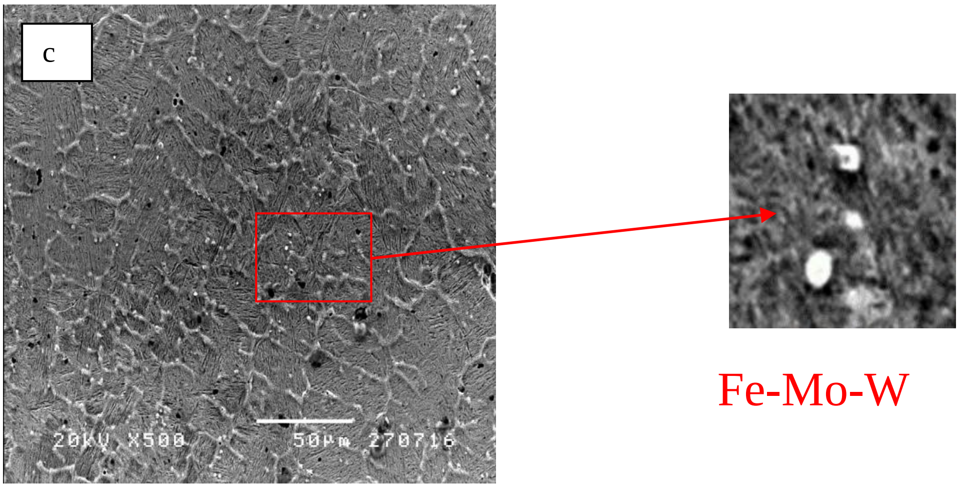


**Fig.3** Microstructure of Weld (a) SMAW, (b) FCAW, (c) GTAW.

### 3.2 Microstructure of Weld

The microstructure of welds in various welding processes. It was found that the microstructure of the weld joint produced by The SMAW process bears resemblance to the ferrite-pearlite structure. As shown in Figure 3 (a), this resulted in the lowest hardness value and the highest toughness rate. However, when the welding process was changed to Flux-Cored Arc Welding (FCAW) with the same heat, The microstructure of the weld will also change. It has a structure similar to martensite at the weld seam. As a result, the maximum value increases. The hardness values are shown in Fig. 3 (b). On the other hand, The GTAW process offers the lowest strength to hardness ratio. from inspection It was found that carbides occur in high volume fractions within the weld zone. The carbides are Fe-Mo-W, resulting in the highest hardness values compared to other welding processes. As shown in Figure 3(c), and the hardness test results as shown in Figure 2.

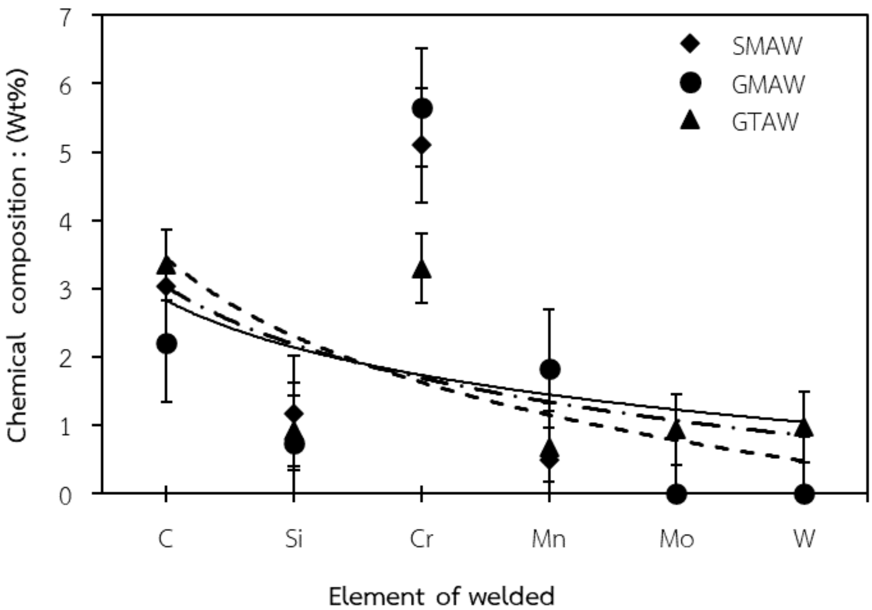


**Fig.4** Chemical of Weld (a) SMAW,(b) FCAW, (c) GTAW.

### 3.3 Chemical Properties of Weld

chemical composition of the weld joint in different welding processes, as shown in Figure 4, reveals that the GTAW welding process consists of C-Si-Mn-Mo-W, which has a higher composition compared to other welding processes, as indicated in Table 2. The maximum hardness value is greatly influenced by the chemical composition of the weld. Research has shown that the presence of Mo and W in the metal affects an increase in hardness and promotes the formation of intermetallic compounds in the metal's hardening mechanism, as shown in Figure 3 (c). High levels of carbides in the weld joint result in lower weld dilution rates. On the other hand, in other welding processes, the presence of elements such as C-Si-Mn-Cr has no effect on carbide formation but aids in phase transformation in the metal, resulting in a relatively lower hardness of the weld joint.

## VI. DISCUSSION AND CONCLUSION

experimental results comparing the joining processes of metallic properties, microstructure, and chemical composition can be summarized as follows:

4.1 Comparative analysis of the weld joint hardness and toughness reveals that the GTAW welding process provides the highest hardness and the lowest toughness when compared to the FCAW and SMAW welding processes for this experiment.

4.2 The microstructure of the weld joint indicates that welds produced using the GTAW process exhibit carbide precipitation in the high weld zone, resulting in the highest hardness and lowest toughness.

4.3 The chemical composition of the GTAW welding process includes alloying elements that promote carbide formation, leading to increased weld hardness.

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