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# Effect of Intermetallic Compound Deposits on Wear Resistance and Microhardness on AISI 1020 Steel Substrate Using GTAW Process

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**Abstract.** Enhancing the oxidation resistance along with sufficiently improved mechanical properties of low carbon steel has always been a challenging task for surfacing industry. Modern automobile industry is looking for joining the dissimilar ferrous and non-ferrous metals to reduce the weight of the overall structure and not compromising the strength of the fabrications. This paper deals with the deposition of iron-aluminium intermetallic over a low carbon substrate using gas tungsten arc welding (GTAW) process. Oxidation resistance of the iron and aluminium metal powders deposits in varying ratios and few mechanical and metallurgical properties such as microhardness, microstructure and wear resistance were investigated and are reported in the present paper.

## 1. Introduction

Surface of a given material can be improved by depositing the filler metal of the desirable properties. During hardfacing process surface is made relevantly harder than the substrate material for surface improvement. This may lead to extra expenditure on the production costs of components, but it leads to an improved surface both in terms of strength achieved and improved life of the components. It may be applied to a new part during production to increase material's surface properties as well as it may be used to restore a worn-down surface [1]. Surfacing is one of the most useful and economical way to improve the surface properties and wear behaviour of a component [2]. Surface properties and quality achieved of the surfaced component depends upon the selected surfacing alloys and the welding process used for the surfacing. In the present work low carbon steels were subjected to hardfacing by depositing a layer of iron-aluminium (Fe-Al) intermetallic using GTAW process in autogenous mode. Fe-Al intermetallic compounds are regarded as promising materials for industrial applications because of their low cost, low density (5.56 g/cm$^3$), high specific strength, high temperature strength, lighter weight than steels as well as excellent oxidation and corrosion resistance [2-4].

## 2. Experimentation

Fine Iron (300 mesh size) and Aluminium powders (120 mesh size) in the varying ratios such as 2:3, 1:1, and 3:2 were thoroughly mixed. Paraffin wax 3% and acetone to adequate quantity were added in the mixture to form a paste applied to the grooved specimens of AISI 1020 low carbon steel which was selected as the substrate material. The base metal composition is shown in Table 1 given below:

After removing rust, oxide film and other impurities the specimens of 150 × 35 × 25 were machined a groove or a slot of 3 mm deep and 10 mm wide on the shaper machine as shown in the Figure 1 given below:

**Table 1.** Base Metal Composition

| | | | | |
|---|---|---|---|---|
| C (%) | Mn (%) | Cr (%) | Mo (%) | Ni (%) |
| 0.114 | 0.6 | 0.034 | 0.013 | 0.018 |
| Si (%) | S (%) | Al (%) | Cu (%) | Fe (%) |
| 0.043 | 0.015 | 0.019 | 0.042 | Balance |

The slots were fabricated to guide the application of pastes. Pastes of the iron and aluminium metal powders mixed in the required ratios as mentioned above were categorized as C1, C2 and C3whereas letter C designate about the composition of the filler material. The specimens were heated to 50°C in muffle furnace [6] and held for one hour after the application of paste and hence dried. Figure 1 given below shows the actual photograph of the specimen before welding.

**Figure 1** Actual Photograph of The Specimen before Welding

Some trials were conducted to conduct the feasibility studies of the hardfacing deposits by varying different welding conditions. The welding parameters for the experimentation were selected on the basis of results obtained from these trial experiments. GTAW process was used to Industrially pure argon gas was used for experimentation with gas flow rate of 10 litres/min, average arc travel speed was maintained around 3 mm/s. Thoriated tungsten non consumable electrode with diameter of 2.4 mm was used in GTAW process in autogenous mode Electrode polarity used was selected to be DCEN (Direct Current Electrode Negative) the arc voltage used during welding was 16 V whereas the welding current was around 120 A. The following tests were performed to investigate the wear behaviour of the weld deposits.

### 2.1 Oxidation test

Oxidation test was performed to check the resistance of surfaced material against oxidation at high temperature by heating the specimens to the sufficient temperature and holding them for sufficiently long-time intervals.

### 2.2 Micro-hardness test

Micro-hardness measurements were carried out on VHN (Vickers Hardness Number) Scale. Micro-hardness readings along x-axis and y-axis were taken from surfaced area of all specimens. Specimens of the different compositions for micro-hardness test were prepared by polishing them with emery papers of grade 100 to grade 1500, and with alumina paste on velvet cloth on disc polishing machine. The average values of micro-hardness have been reported in this paper.

### 2.3 Pin on disc wear test

Wear test was carried out on pin-on-disc wear testing machine as per ASTM G99 standards. Cylindrical pins of 8 mm diameter with spherical tip of radius 4mm and length of 35 mm was selected.

### 2.4 Micro-Structural analysis

Micro-structral changes have been studied to know the morphology of structural growth with addition of variable composition of intermetallic compound [4].

## 3. Results and discussions

The oxidation resistance of the surfaced area was evaluated by heating the specimens for 800˚C and holding for 4 and 8 hours in furnace and then cooled in air for 12 hours. All the samples were thoroughly washed with acetone before and after performing the experiment and then weighed. Oxidation resistance has been correlated to the weight loss [5,6 & 7].

The results after conducting the test has been collected and presented in the Table 2 and graphically presented in Figure 2 given below. It was found that the effect of higher temperature as well as longer exposure time at that temperature has significant effect on the weight loss and thus oxidation resistance of the surface. It is also worth reporting that the composition C1 found to be most resistant to oxidation as compared to the other two compositions.

**Table 2** Weight Loss of Specimens after Oxidation Test

| Specimen designation (according to composition) | Weight loss (mg) for (800°C/4 hours) | Weight loss (mg) for (800°C/8 hours) |
|---|---|---|
| C1 | 9.32 | 9.98 |
| C2 | 11.14 | 14.81 |
| C3 | 19.21 | 22.37 |

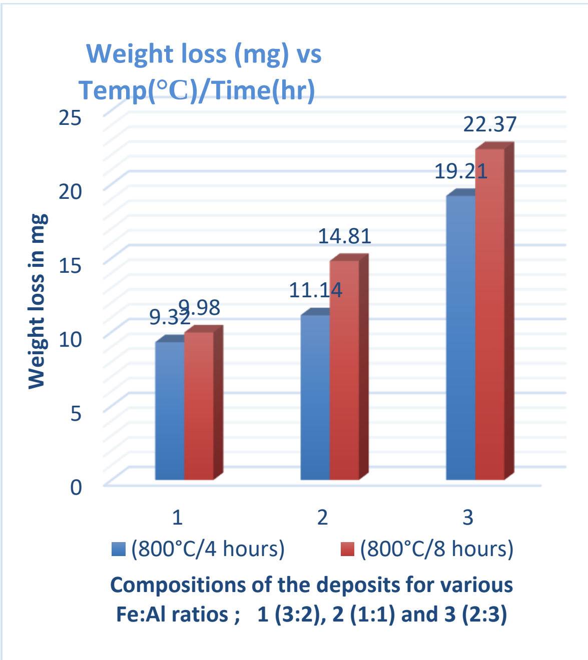
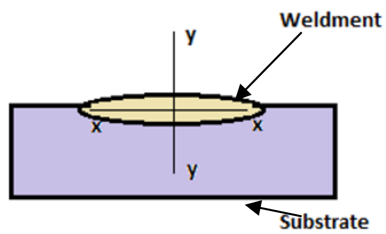



**Figure 2** Graphical Representation of Weight Loss after Oxidation

Microhardness testing was conducted on the specimens on Vickers hardness tester under the constant load of 500 gm. The hardness values have been taken along the x-x axis with difference of 1 mm distance and y-y axis with difference of 0.5 mm distance. Then, average value of each composition has been calculated. The results are shown in Table 3 and the graphical representation is shown in Figure 3. Wear test was also done to access the resistance offered by surface rubbing against some hard metal due to which pin on disc tests wear tests were conducted. Wear tests were performed under normal atmospheric conditions. All the specimens prior and after the test were cleaned with acetone and weighed with digital electronic balance having accuracy of ±0.001 g. Difference between initial weight and final weight gave the total weight loss after sliding wear test. Wear rate is considered by total weight loss during experiment. Table 4 shows the results performed in sets

wear rate (mg/hr) = $\frac{(\textbf{Final wt.} - \textbf{Initial wt.})}{\textbf{Time (minute)}} \times \mathbf{60} \times \mathbf{1000}$

**Table 3** Microhardness Results of The Specimens

| Composition | Weld bead profile for Micro hardness | Micro hardness values (VHN) | | Micro hardness avg. value (VHN) |
|---|---|---|---|---|
| C1 |   (a) | y-y axis | x-x axis | 422 |
| | | 424.1 | 418.7 | |
| | | 426.2 | 421.5 | |
| | | 415.7 | 425.8 | |
| C2 | | y-y axis | x-x axis | 385 |
| | | 382.5 | 390.4 | |
| | | 392.4 | 383.2 | |
| | | 378.6 | 387.3 | |
| C3 | | y-y axis | x-x axis | 396 |
| | | 405.3 | 392.2 | |
| | | 394.1 | 402 | |
| | | 387.4 | 398.6 | |
| Base metal | | | | 242 |

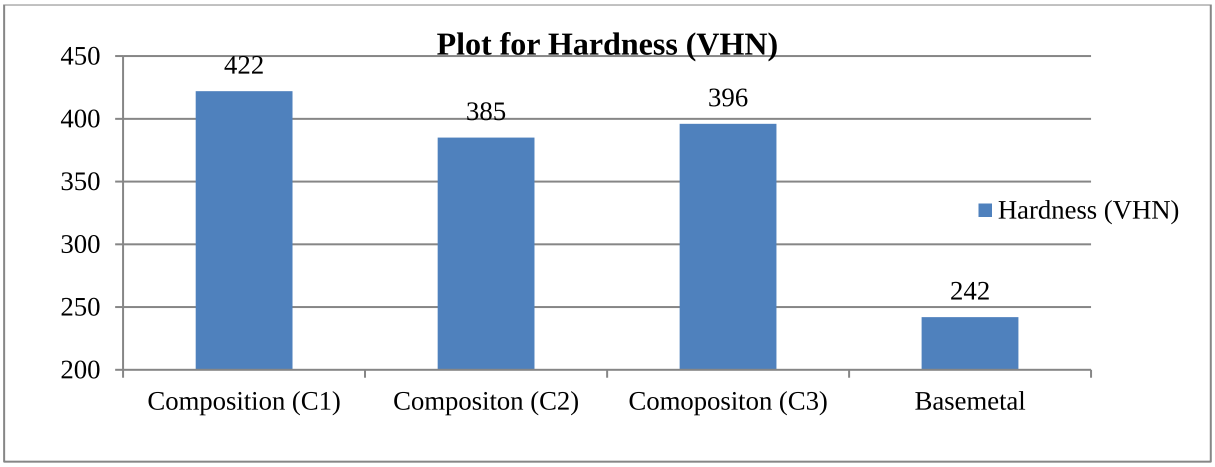



**Figure 3** Graphical Representations of Microhardness Results

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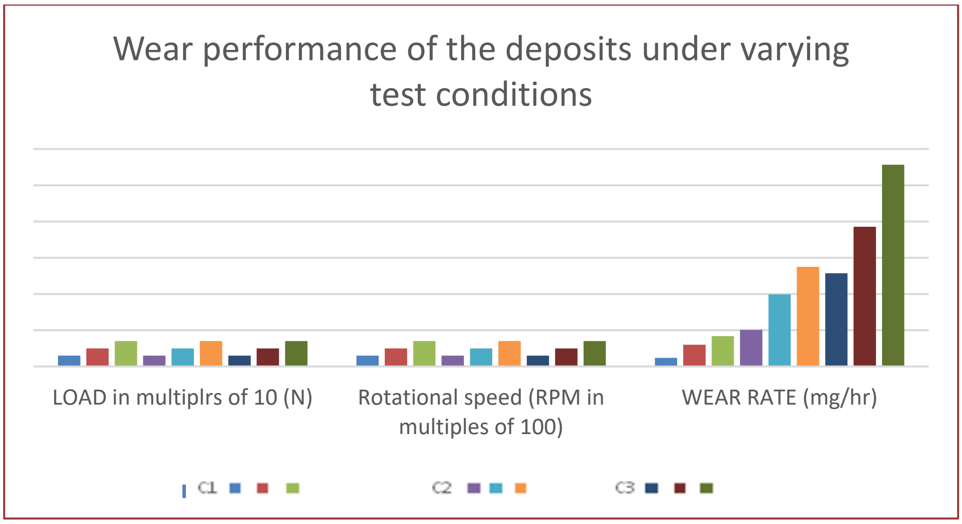


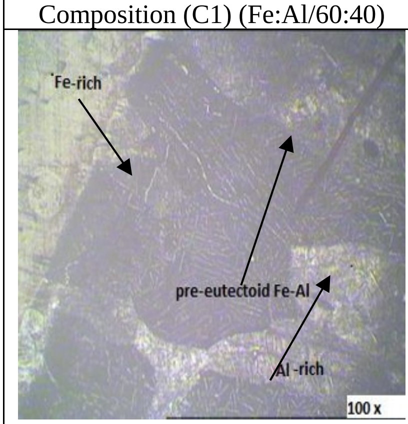

**Figure 4** Wear Resistance of the Fe-Al Intermetallic Deposits

**Table 4** Wear Rate Results at Different Loads and Rotational Speeds

| Specimens | LOAD (N) | Rotational speed (RPM) | WEAR RATE (mg/hr) |
|---|---|---|---|
| C1 | 30 | 300 | 2.4 |
| | 50 | 500 | 6.0 |
| | 70 | 700 | 8.4 |
| C2 | 30 | 300 | 10.1 |
| | 50 | 500 | 19.9 |
| | 70 | 700 | 27.5 |
| C3 | 30 | 300 | 25.71 |
| | 50 | 500 | 38.56 |
| | 70 | 700 | 55.67 |

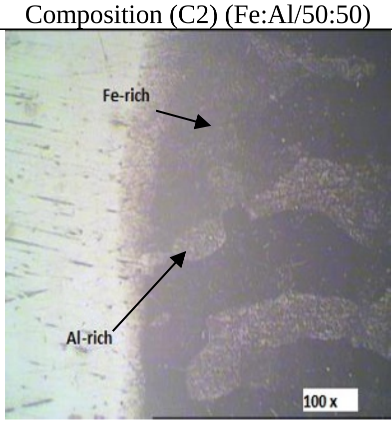
The samples were polished as per the ASTM standards for further metallurgical investigations. Few of the optical micrographs are presented below in Figure 5.

Composition (C1) (Fe:Al/60:40)



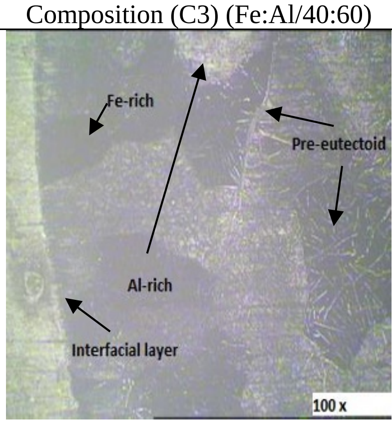

(a) Microstructure of weldment of composition (C1)

Composition (C2) (Fe:Al/50:50)




(b) Microstructure of weldment of composition (C2)

Composition (C3) (Fe:Al/40:60)




(c) Microstructure of weldment of composition (C3)

**Figure 5** Optical Micrographs of Fe-Al Intermetallic Deposits of Varying Compositions

## 4. Conclusions

From above mentioned results and discussions it can be concluded that surfacing by GTA welding process shows 100% feasibility of filler material used for experimentation and few important conclusions can be made:

Weight loss of the specimens due to oxidation results show that both the temperature and the time duration of exposure play significant role by affecting the oxidation resistance.

Further it is found that composition C1 in which Fe was mixed in excess as compared to C2 and C3 showed remarkable results in wear resistance and microhardness,

Composition C2 in which iron and aluminium metal powders {Fe:Al= (1:1)} mixed in equal ratio showed reasonable microhardness, and reasonably high wear resistance and can be recommended for industrial use. The ease of the deposition and the surface texture obtained by this composition mixture was found to be best amongst all other composition mixtures used in the present study.

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