GLOBAL JOURNAL OF ENGINEERING, DESIGN & TECHNOLOGY
(Published By: Global Institute for Research & Education)
www.gifre.org

The Effects of Welding Parameters on Abrasive Wear Resistance for Hardfacing Alloys

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Abstract

In this research work, three welding parameters were used, applied through one welding process: that is shielded metal arc welding (SMAW). The three welding variables of the tests are used to deposit hardfacing layer on mild steel specimens. The hardfacing deposits were evaluated using the dry sand-rubber wheel machine according to procedure A of the ASTM G65 standard. Optical and scanning electron microscopy was used for the characterization of the microstructure and worn surface of deposits. The hardfacing deposit formed by uniformly distributed carbides rich in chromium and carbon presented the highest abrasive wear resistance.Hardfacing-1 (electrode-I) having more abrasive wear resistance than hardfacing-2 (electrode-II). The investigation reveals that a clear relation between hardness and the abrasive wear resistance of the deposits has been observed. The results showed that the most important variable to improve abrasion resistance is the microstructure of hardfacing deposits, where the carbides act as barriers to abrasive particle cutting or ploughing into the surface layer during the wear process, thereby noticeably lowering the wear loss.

Keywords: Abrasion resistance, Hardfacing alloys, Microstructure, SMAW, Wear mechanisms.

1. Introduction

The weld deposition of hardfacing alloys is employed in earth moving equipments, agriculture tools, mining, sugar industry and others to increase hardness and abrasive wear resistance of the mechanical components. Abrasion wear occurs in contact situations between two surfaces when one is considerably harder than the other [1]. Two abrasive wear mechanisms are observed using a scanning electron microscopy (SEM): microcutting and microploughing formation [2, 3]. The abrasion resistance of materials depends very much on the particles size [4-6]. Thus, its selection is particularly important in the evaluation of abrasive properties. A strong diminution of the abrasive wear rate happens when the hardness of the material exceeds the hardness of the abrasive [7].

Several studies on the evaluation of abrasive wear resistance have found that using hard deposits in welding processes is a good alternative to recover parts under abrasive wear, as in the case of the mining industry [7, 8]. In other studies, which have used hard coverings deposited on mild steel, have shown that abrasion resistance is mainly due to the variation in chemical composition and microstructure of the deposits, where the chromium and carbon content is a determining factor in the carbide formation and the matrix of the deposits [9]. According to Zum Gahr [10] abrasive wear resistance can be substantially improved by second phases embedded in a hard or soft matrix. The present investigation aims to study two hardfacing electrodes applied in the welding process utilizing three welding variables such as current, arc travel speed and arc voltage (used typically in the sugar cane industry for recovery of worn elements in terms of their microstructure, hardness and abrasive wear resistance) [12-14].

2. Experimental Details

2.1. Base metal

The selection of base metal is very essential in deciding what alloy to use for hardfacing deposit. Since welding procedure differs according to the base metal. The base metal selected for this study is mild steel which composes the main elements of carbon, silicon, manganese, sulphur, and phosphorous. The chemical composition is given in table1.

Table 1. Chemical composition of base metal (in weight percentage)

C	*Si*	*Mn*	*S*	*p*	*Fe*
0.18	*0.32*	*1.47*	*0.013*	*0.029*	*Bal*

2.2. Hardfacing alloys

Two different commercial hardfacing alloys were used for overlaying. These are basically iron – based alloys having varying amount of chromium, carbon, silicon and other alloying elements as they are more suitable for shielded metal arc welding process. The chemical composition of hardfacing alloy 1 and 2 is given in table 2.

Table 2: Chemical composition of hardfacing alloy (In weight percentages)

Electrode	C	Si	Mn	S	P	Cr	Mo	Ni	V	Fe
Hardfacing 1	0.33	0.28	1.15	0.014	0.025	2.22	-	-	-	Bal
Hardfacing 2	0.1	0.38	1.51	0.024	0.03	2.15	0.745	1.09	0.103	Bal

2.3. Welding conditions

The standard size test specimens of 16 nos. with the dimensions of 250×100×12 mm were selected for the experiment. The following precautions are taken before hardfacing.

- The electrodes are perfectly dried in the furnace and baked at 250^{o} C one hour before the use
- Area of the weld is properly cleaned
- Preheated the hardfacing area to a minimum of 200^{o} C

2.4. Methodology

The experiment was carried out in three stages to investigate the effect of current, travel speed and voltage on hardfacing electrodes, and the corresponding hardness was determined.

(i) In first stage, voltage (V) and travel speed (S) were kept constant and current (A) was increased.

(ii) In second stage, voltage (V) and current (A) were kept constant and travel speed (S) was increased.

(iii) In third stage, current (A) and travel speed (S) were kept constant and voltage (V) was increased

3. Microstructure Analysis

Optical microscope (OM) was used to analyze the microstructure of the specimens. Different types of carbides present in the microstructures were first identified on the basis of their morphologies and confirmed by micro-hardness measurements.

3.1. Microstructures of different hardfacing deposits

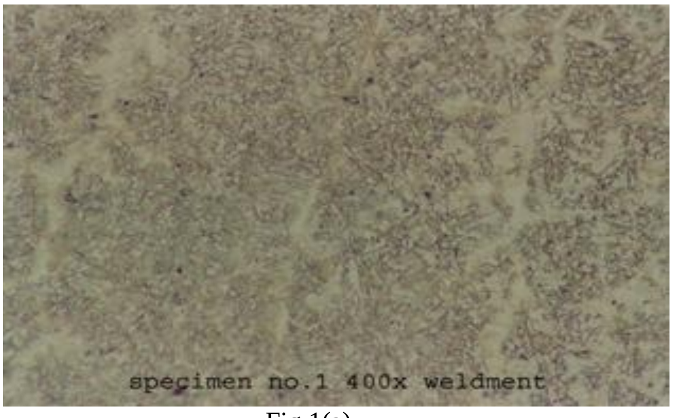

Fig 1(a)

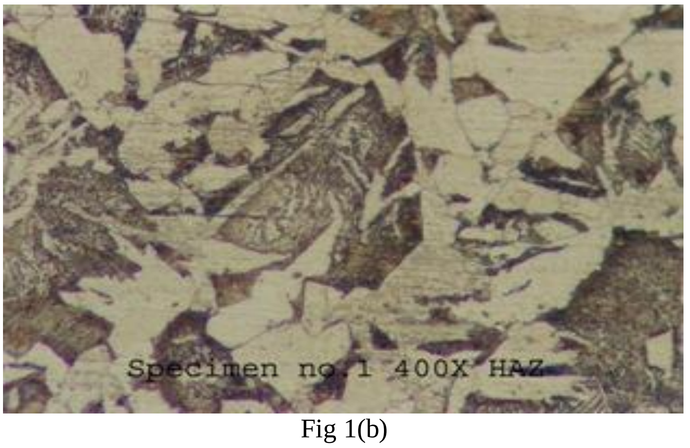

Fig 1(b)

Fig 2(a)

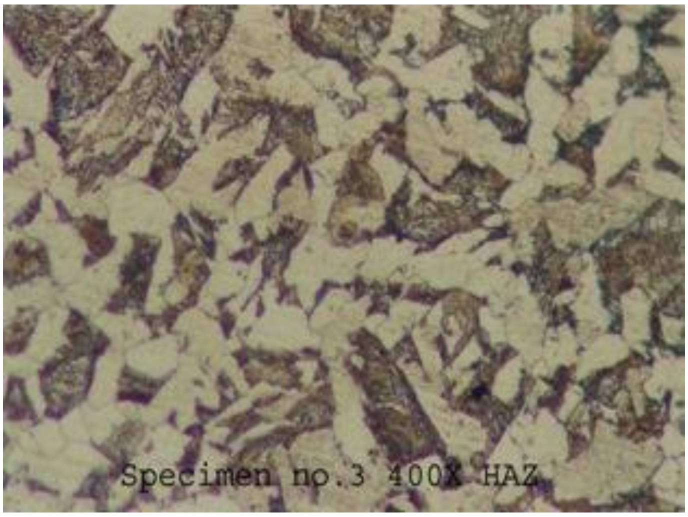

Fig 2(b)

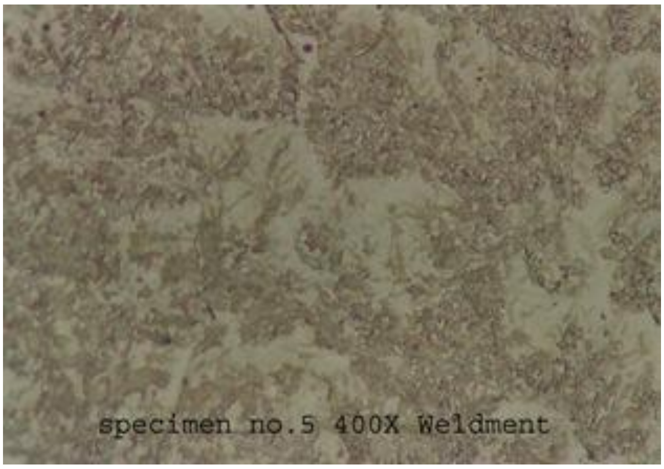

Fig 3(a)

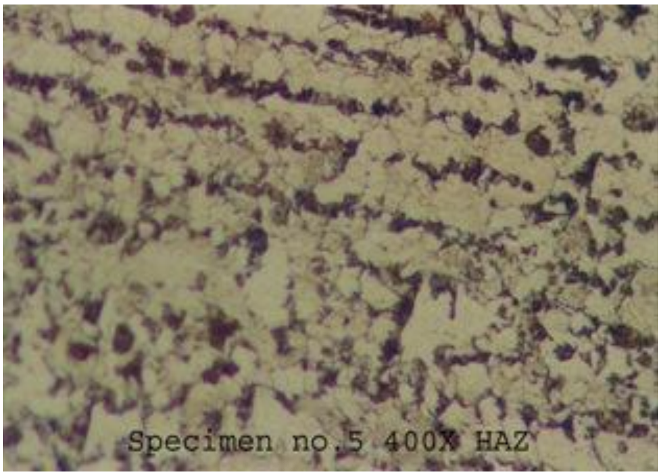

Fig 3(b)

In fig 1(a) & (b), the amount of ferrite and Pearlite is more hence resulting in lower hardness and wear resistance. In fig 2(a) & 2(b) the amount of ferrite and pearlite is medium hence moderate hardness and wear resistance. In fig 3(a) & (b), the structure consists martensite with retained austenite and patches of pearlite distributed uniformly.

3.2. Scanning electron micrographs

The photographs for the specimens 1, 3and 5 after dry sand abrasion test through SEM are shown in figures 4, 5 and 6. The worn out specimens consists of low, medium and high abrasion resistance at the entry and exit. Examination of the wear scars indicate that morphologies for all the samples were similar consisting of three zones, a short entrance and exit area and the main wear zone in middle. At the entrance and exit zones where the pressure applied to the abrasive is lowest the damage morphologies were consistent with particle rolling. In the centre of wear scar, parallel grooves were formed, typical of particle sliding, a result of the higher pressures forcing abrasives in to rubber wheel. The worn surfaces are characterized by shallow continuous grooves and micro cuttings in sample in fig 6 (a) & (b) indicating that material removal is associated primarily with ploughing mechanism. The fine grained silica sand corresponds to low wear level where as the high energy level of coarse corundum particles is resulting in a severe wear region abrasion test were carried out on a dry sand rubber wheel with three body abrasion condition under low stress according to ASTM G65 procedure A. rotational speed, normal load work kept constant at 200 rpm and 130.5 N respectively, characterization of microstructure has been done with optical microscopy and scanning electron microscopy quantitative analysis of the microstructure was carried out by the use of intronic image C software. Hardness measurements were carried out with a standard Vickers hardness technique HV0.5 for microscopic hardness. Quantitative wear characterization has been done by gravimetric mass loss of the testing specimen during wear testing. Qualitative characterization of worn surfaces and worn edges has been carried out by evaluating of macroscopic and cross section images and by SEM investigations. The sample numbers & its relation between hardness and abrasion resistance is shown in table 3 and 4.

4. Results And Discussion

The typical microstructure of the studied hardfacing alloys are shown in figures 4, 5 and 6. The worn surfaces were observed under SEM and secondary electrons were used to analyze these surfaces, to establish the possible mechanisms of material removal. In Figure 4, the surface wear is presented for all the three hardfacing alloys. Figure 4 shows, wear loss increases with the abrading distance and demonstrate that sample 1 wear loss is higher than that of sample 5, suggesting that carbides indeed have a reinforcing effect.

Figures 4 (a) & (b) shows the worn surface features of sample 1, where micro-ploughing and micro-cutting are the main abrasive wear mechanisms. Figure 5 (a) & (b) indicate the surface of sample 3, where micro-cutting and wedge formation were the main abrasive mechanisms. The worn surface of samples 1 and 3 clearly shows obvious evidence of cutting and ploughing (Fig. 4 and 5). However, no obvious plastic deformation can be found on the worn surface of sample 5 (Fig. 6) although there are some slight traces of ploughing to be seen on the matrix area, these cease when elements such as carbides are encountered, indicating that the silica and chromium elements effectively stop the abrasive form cutting or ploughing into the surface layer during the wear process, thereby noticeably lowering the wear loss. However, the grooves were not deeper than samples 1 and 3; this hardfacing deposit presented higher abrasion resistance, because the large quantity of carbides rich in titanium, uniformly distributed in the matrix, blocked the abrasive particles. Further, the resistance of silica, manganese and chromium elements to the abrasive could be attributed to its higher hardness. Further observations of figure 6 also provide evidence of cutting and cracking of the carbides. It is reasonable to believe that the wear resistance of the materials will increase if the hardness of the hardfacing alloy is improved.

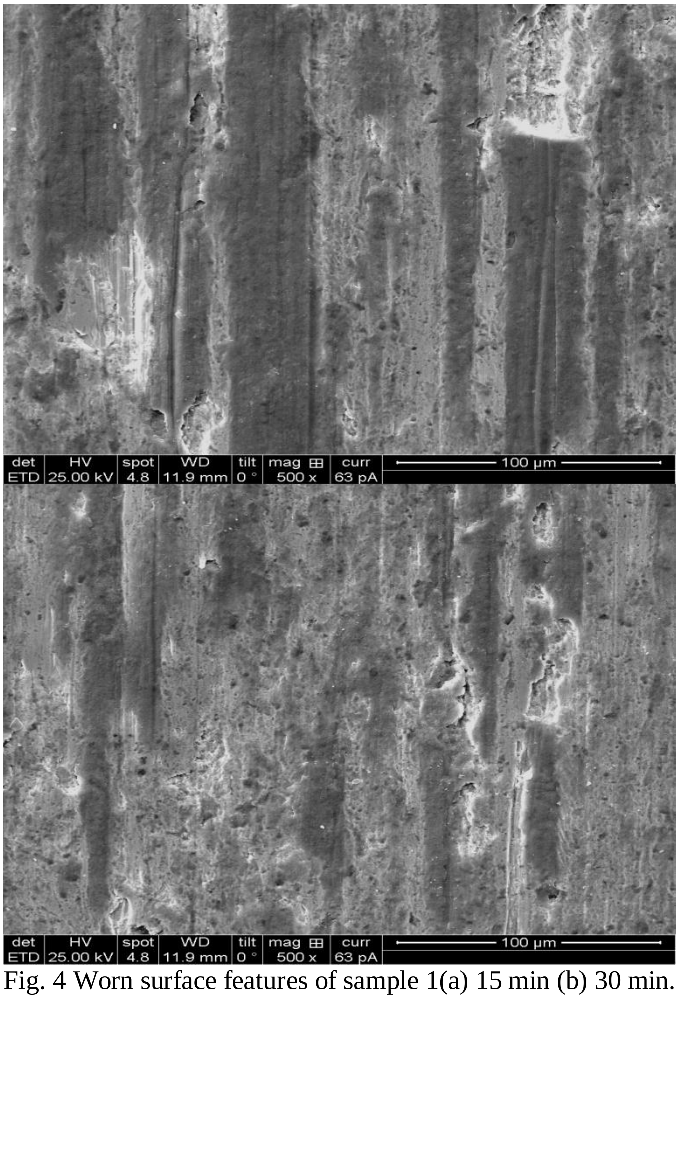

Fig. 4 Worn surface features of sample 1(a) 15 min (b) 30 min.

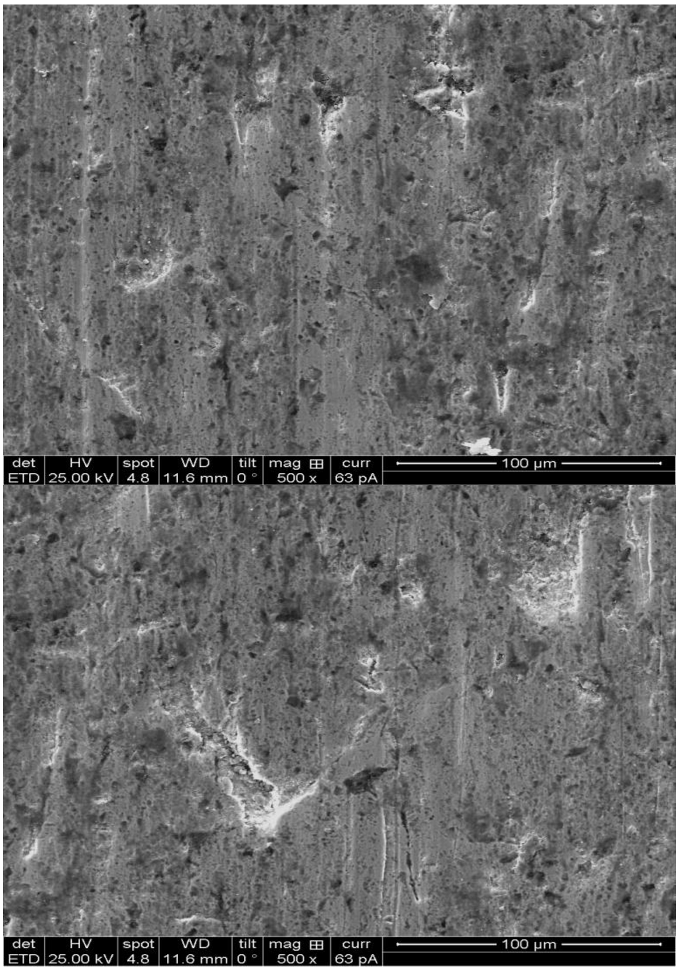

Fig. 5 Worn surface features of sample 3(a) 15 min (b) 30 min.

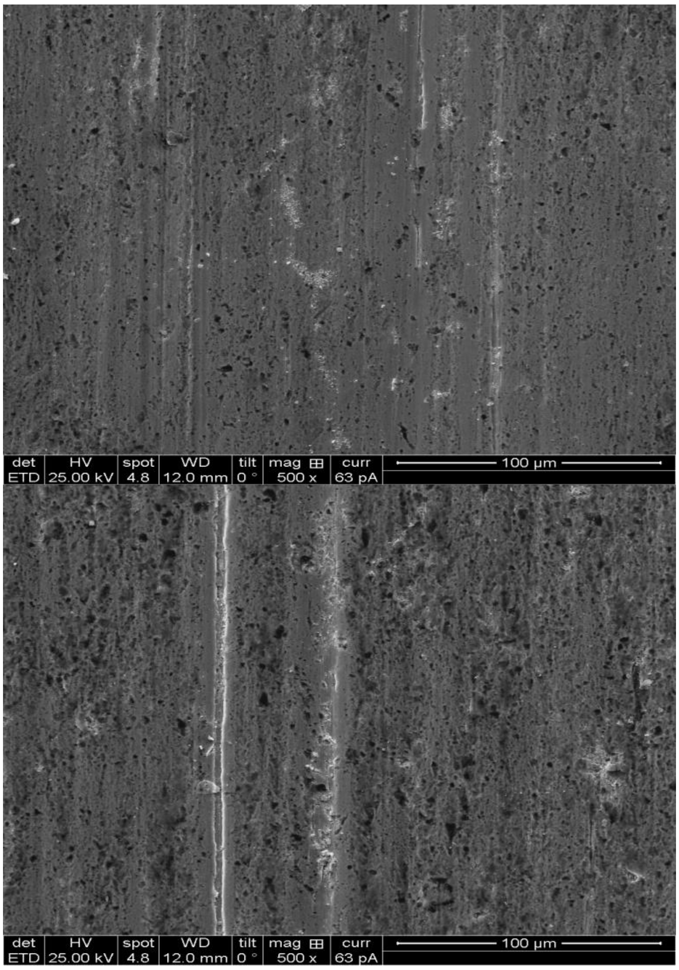

Fig. 6 Worn surface features of sample 5(a) 15 min (b) 30 min.

Table 3: The Relation between Hardness and Abrasion Resistance for Hardfacing 1(Electrode 1)

Sample number	Load (N)	Weight loss (g)	Hardness (HV 0.5)
1	130.5	1.6075	377
2	130.5	1.3345	318
3	130.5	0.9861	380
4	130.5	0.638	417
5	130.5	0.6007	418
6	130.5	0.8454	356
7	130.5	1.0923	537
8	130.5	0.5934	390

Table 4: The Relation between Hardness and Abrasion Resistance for Hardfacing 2(Electrode 2)

Sample number	Load (N)	Weight loss (g)	Hardness (HV 0.5)
9	130.5	0.9051	330
10	130.5	0.9698	416
11	130.5	0.9746	370
12	130.5	0.9205	406
13	130.5	1.1571	388
14	130.5	1.0576	377
15	130.5	0.9852	357
16	130.5	0.9506	401

5. Conclusions

Two-body abrasive wear tests were conducted to investigate the effect of abrading distance, composition and welding parameters of hardfacing alloys. A wealth of information was obtained based on experiments. The results can be summarized as follows:

- Abrading distance exerted the greatest effect on the abrasive wear followed by hardfacing carbides. The load applied has a much lower effect.
- In addition, hardfacing elements such as chromium, carbon, silicon, manganese, sulphur, and phosphorous improved the wear resistance of the hardfacing alloy. Wear loss increased with load applied.
- The principle of wear mechanism was micro-cutting and micro-ploughing in hardfacing alloys, except the fracturing accompanied by elements such as chromium, carbon, silicon, manganese, sulphur, and phosphorous increasing the hardness of hardfacing alloy could improve wear resistance.
- In general terms, the relation was found between hardness and the abrasive wear resistance. This due to the fact that the carbides and matrix microstructure was more important than the hardness in the abrasion wear resistance of the deposits.

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