STUDY ON WEAR BEHAVIOUR OF Fe-Cr-C HARDFACING DEPOSITS

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Wear is a major problem leading to the replacement of components and assemblies in engineering industries. For many years welding technology has supplied an effective means of protecting the surface of engineering components which would otherwise be scrapped. To protect parts against mineral wear, chromium-containing Fe-C surfacing alloys are in use for deposit welding. Besides the chemical composition, the properties of such coating alloys are influenced mainly by specific welding parameters. The welding conditions, in particular the cooling rate of the deposited material, have important influence on the microstructure of the coating, and therefore on the hardness and wear resistance.

Numerous empirical correlations between abrasive wear of carbon steels and both hardness and carbon content have been established (1-3). Khruschov (1) proposed a linear relationship of wear resistance and hardness, which was later confirmed (2-3). For tempered structures, Larsen-Badse and Mathew (3) and Larsen-Badse (4) suggested that wear resistance should be a linear function of the logarithm of the absolute tempering temperature above 250°C and the square root of distance between carbides. The volume fraction of pearlite is evidently important in controlling the wear of annealed carbon steels, and it has been agreed (5) that wear resistance is, in fact, proportional to this volume fraction in hypoeutectoid steels. Furthermore, the original orientation of the colony and the mean interlamellar spacing have effects on wear resistance (6). Wear of hypereutectoid steels is controversial (3) since the effect of networks of cementite is not clear. On the other hand, it has been argued (5-7) that the relationship between wear resistance and hardness is affected by microstructure. For example, wear resistance increased in the structural sequence from spheroidite to pearlite and from tempered martensite to bainite (3,8). For tempered martensite, however, Mutton and Watson (7) concluded that the relationship between wear resistance and hardness was non-linear.

Against this background, the present work was carried out to study the influence of mechanical variables such as sliding velocity & load and metallurgical variables such as deposit chemistry & heat input on microstructural variation, and subsequently on the abrasive behaviour of Fe-Cr-C hardfacing deposits in a statistically designed experiment.

EXPERIMENTAL PROCEDURE

Experimental Design Layout

In order to vary the machanical and metallurgical parameters simultaneously during experimentation, a statistical design of experiment was selected. The experimental design layout is given in **Table 1**.

Materials and Welding procedure

Two types of covered electrodes e.g. Type - 1 and Type - 2 were used for hardfacing deposits. The deposits were made by manual metal - arc welding process at two different heat inputs e.g. 9.36 KJ/cm and 12.24 KJ/cm on a mild steel plate to build up a thickness of 50 mm.

Table - 1
Experimental design layout

SAMPLE NO.	COMPOSITION	HEAT INPUT	TIME	VELOCITY	PRESSURE
1	-1	-1	-1	-1	1
12	1	-1	-1	-1	-1
8	-1	1	-1	-1	-1
16	1	1	-1	-1	1
2	-1	-1	1	-1	-1
13	1	-1	1	-1	1
9	-1	1	1	-1	1
17	1	1	1	-1	-1
3	-1	-1	-1	1	-1
14	1	-1	-1	1	1
10	-1	1	-1	1	1
8	1	1	-1	1	-1
4	-1	-1	1	1	1
15	1	-1	1	1	-1
11	-1	1	1	1	-1
19	1	1	1	1	1

COMPOSITION -1 low alloy deposition (Type I)
1 high alloy deposition (Type II)

HEAT INPUT -1 low heat input of welding
1 high heat input of welding

TIME -1 low duration (2 hours)
1 high duration (4 hours)

VELOCITY -1 low velocity (3.6 x 10^{-4} m/sec.)
1 high velosity (5 x 10^{-4} m/sec.)

PRESSURE -1 low load (30 Kg)
1 high load (40 Kg)

Table - 2
Composition of Weld deposits

ELEMENTS	C	Mn	Si	Cr	Mo	V	S	P	Fe
TYPE I	0.24	0.6	0.5	1.5	0.7	-	0.03	0.03	rest
TYPE II	0.35	0.5	0.5	5.5	0.8	0.4	0.03	0.03	rest

Table - 3
Hardness test of the different weld deposits

SAMPLE NO.	DESCRIPTION OF THE SAMPLES	AVERAGE HARDNESS
1 – 4	Low alloy high heat input	229
8 – 11	Low alloy Low heat input	386
12 – 15	High alloy low heat input	676
16 – 19	High alloy high heat input	608

These test pads were fabricated to make wear samples of size 17 mm x 17 mm x 25 mm. The nominal composition of the two types of weld deposits are presented in **Table 2**.

Hardness Test

Hardness testing of different weld deposits was carried out in a Vicker's hardness testing machine using 30 Kg load and 136° diamond pyramid indentor. Three hardness values were taken for each sample and the average hardness values are given in **Table 3**.

Wear Test

Initial weight of each sample was taken before wear testing in a single pan electronic balance. The samples were then fixed in a holder which was connected to a bar; one end of the bar was fixed and the other end was loaded. Thus the specimen holder was acting as a fulcrum in a lever system. **Fig. 1** shows the abrasion wear test unit. The specimen was made in contact with a base made of white cast iron which was rotating by a motor at 17 r.p.m. The wear testing experiment was performed as per the design-layout. After the test the specimens were taken out carefully and then weighed in a single pan electronic balance. The difference between the initial and final weight of the samples was considered as the amount of wear.

Optical and Scanning Electron Microscopy (SEM) studies

Different hardfacing deposited samples were first polished in the usual manner for optical microscopy and then etched with 2% nital. Photomicrographs of the samples were taken at different magnifications.

A few wear tested samples were observed under SEM to characterise the surface morphology and to establish possible mechanisms for material removal.

RESULTS AND DISCUSSION

Microstructure Study

Typical microstructures of weld deposits made with different electrodes and heat inputs are shown in **Fig. 2 to Fig. 5**. Microstructures show pearlite with subsequent formation of interdendritic carbides. However, the carbide content in the weld deposit made with Type II electrode is higher (**Fig. 4**) than that in weld deposit made with Type I electrode (**Fig. 2**). The relative high amount of carbide in weld deposit, made with Type II electrode, is not unexpected considering that greater amounts of carbon, chromium and vanadium were present in the weld deposit (**Table 2**). Furthermore, coarser microstructures are observed in weld deposits made with higher heat input for a given electrode keeping more or less similar micro structural constituents. These microstructural charateristics are also reflected in the hardness values (**Table 3**). Higher amount of carbide and finer structure, in general, resulted in higher hardness, whereas lower hardness values were recorded in weld deposits with less amount of carbide and coarser structure.

Wear Test

Wear testing data under various combinations of the parameters are presented in **Table 4.** Qualitatively it can be stated that weld deposits made with Type II electrode are more wear resistant than the weld deposits made with Type I electrode. The higher wear resistance values recorded for the weld deposit made with Type II electrode could be correlated to the higher hardness values. Several authors (9,10) have suggested that abrasive wear resistance increases in direct relationship with the volume of the hard constituent. Therefore, it is thought very much likely that the relationship between wear resistance and hardness could exist for weld deposits having similar microstructural characteristics.

The statistical analysis of the experimental wear data is shown in **Table 5**. It is evident from Table 5 that three parameters e.g. time of sliding, heat input and composition are significant among the five different parameters chosen for the present study.

When two surfaces slide together, most of the work done against the friction is turned into

Fig. 1 : Abrasion Wear Test Unit

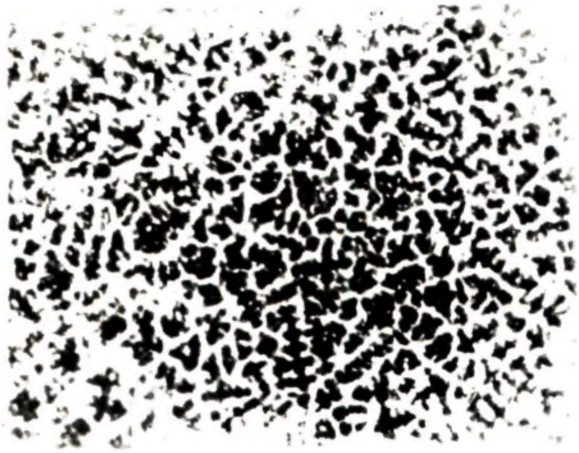

Fig. 2 : Microstructure of weld deposit made with Type I electrode at Low Heat Input, X 225

Fig. 3 : Microstructure of weld deposit made with Type I electrode at High Heat Input, X 225

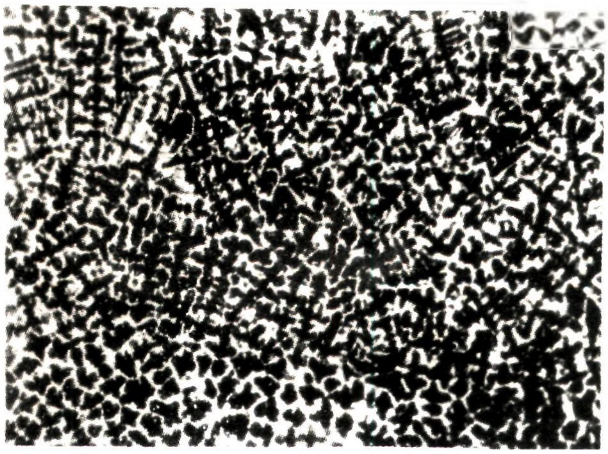

Fig. 4 : Microstructure of weld deposit made with Type II electrode at Low Heat Input, X 225

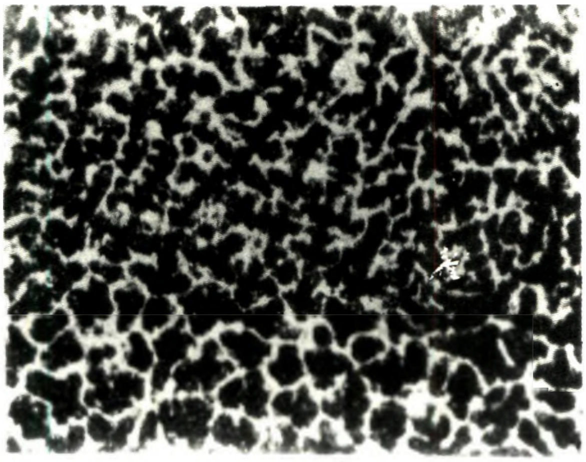

Fig. 5 : Microstructure of weld deposit made with Type II electrode at High Heat Input, X 225

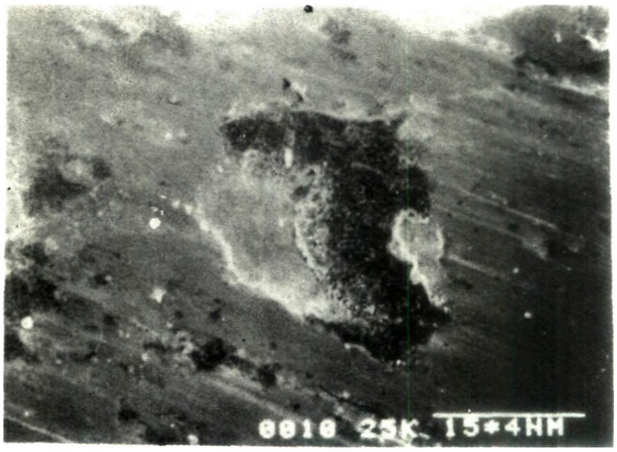

Fig. 6 : Scanning Electron Micrograph of wear surface of weld deposit showing large abrasion groover

Fig. 7 : Scanning Electron Micrograph of wear surface of weld deposit

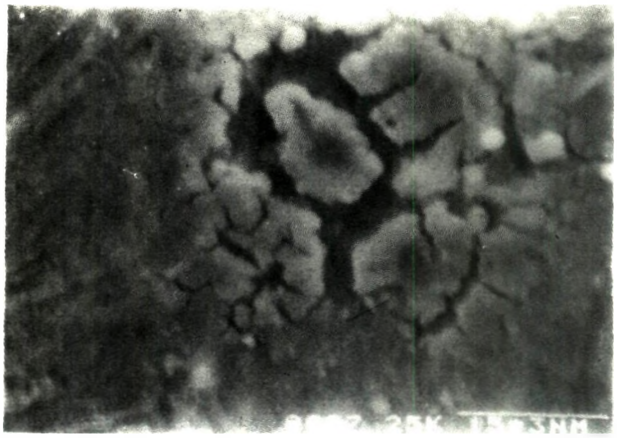

Fig. 8 : Scanning Electron Micrograph of wear surface of weld deposit

heat. In addition, when two surfaces touch, the localised pressure on the asperity contacts causes plastic flow. The local hardness depends not only on temperature but on strain rate too. As the sliding velocity increases, the bulk temperature increases, causing the hardness to drop. At the same time, due to high strain rate, the hardness rises. It is probable that the two effects roughly cancel each other and hence no significant effect of these two parameters e.g. sliding velocity and pressure, on the wear resistance is observed in the present experimental condition. It is interesting to note that weld deposits made with high heat input for the same alloy system possess high wear resistance. Apparently one would expect lower wear resistance in the weld deposit made with high heat input, due to lower hardness value. However, the wear phenomenon can be explained by micro mechanism of metal removal. It is probable that the precipitated carbides could not sustain plastic deformation during abrasion, resulting in ftracture along the grain (dendrite) boundaries. Such fracture contributed significantly to metal removal (11). The higher wear resistance of high heat input weld deposit could be attributed to higher fracture resistance due to less available grain boundary area.

SEM Observation

Figures 6 to 8 show typical wear surface morphologies. It is evident that the main wear mechanism is microcracking and microploughing which is involved in producing the large abrasion grooves (**Fig. 6**) For microploughing, the substantial mechanism of metal removal is fracture resulting from plastic flow (Fig. 7&8). Wear surface topography suggests that microploughing is the predominant mechanism for metal removal.

CONCLUSIONS

The following conclusions may be drawn from the present study :

i. Among the different param-

Table - 4

Wear testing data for different samples

SAMPLE NO.	INITIAL WEIGHT (gm)	FINAL WEIGHT (gm)	WEIGHT LOSS (gm)
1	55.92540	55.90190	23.5
12	71.75000	71.73927	10.73
8	55.21750	55.20138	16.12
16	71.81100	71.79401	16.99
2	56.15080	56.12080	30.00
13	69.13800	69.11935	18.65
9	56.65880	56.6367	22.1
17	72.00320	71.98384	19.36
3	56.22500	56.20350	21.5
14	71.83000	71.81722	12.78
10	58.74580	58.72740	18.4
18	70.70200	70.68910	12.90
4	56.15830	56.1273	31.7
15	72.00040	71.98507	15.33
11	59.54550	59.52480	20.7
19	69.31200	69.28919	22.81

Table - 5
Anova table for the data of table 1

Source of Variation	Degree of freedom	Sum of square	Mean square	Computed "f"
Composition	1	831.60	831.60	63.0*
Heat Input	1	1028.40	1028.40	77.9*
Time	1	1070.52	1070.52	81.1*
Velocity	1	283.80	283.80	21.5
Pressure	1	308.88	308.88	23.4
Erra	10	132.16	13.216	
Total	15	3655.36		

* Significant

eters studied, weld metal chemistry, welding heat input and test duration have significant influence on wear property.

ii. Hardness can be used as a predictor of wear resistance only for weld deposits having similar microstructural characteristics.

iii. Wear resistance property increases with increase in chromium and carbon content of weld deposit as well as with increase in heat input.

iv. Microstructure plays an important role in the abrasive wear of the weld deposits. Though a linear relationship between wear resistance and hardness has been observed for similar microstructural characteristics, microstructure having coarser carbide and less grain boundary area, in general, possesses better wear resistance properties than microstructure containing fine carbide and fine grain size.

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