Asian Review of Mechanical Engineering
ISSN: 2249-6289 (P) Vol.1 No.2, 2012, pp.51-54

DOI: https://doi.org/10.51983/arme-2012.1.2.2295

Enhancing Wear Resistance of Low Alloy Steel Applicable on Excavator Bucket Teeth Via Hardfacing

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Abstract - **New developments in the field of continuously operating earth moving equipment demand a new way of improving wear resistances of these equipment parts which directly involved with different types of sand and rocks during their operation in harsh field environment. Wear caused by the impact and abrasion action of hard particles is a major problem in the area of earth moving machinery. The objective of this study was to enhance the useful life of the excavator bucket teeth in order to decrease the idle time required to reinstate the teeth periodically during working. The objective was carried out by means of hardfacings, where the effect of the hardfacings on the extent of wear and the wear characteristics of the excavator bucket teeth were examined. Four types of iron-based hardfacing electrodes with a wide range of C (0.75-5% by weight) and Cr (2-33% by weight) were selected to deposit by manual metal arc welding process on the low alloy steel. It was observed that the wear rates of the hardfaced low alloy steel were significantly lower than those of the un-hardfaced steel, indicating a great improvement in the wear protection provided by hardfacings.**

Keywords : **Excavator bucket teeth, Wear, Hardfacing, Pin-on-disk**

I. Introduction

Wear is a surface phenomenon and occurs mostly at outer surfaces. Every part that is moving in service will be subject to wear at the contact point with other parts. The consequence of this wear is that the parts need to be replaced, which costs more and causes downtime on the equipment. The surface characteristics of engineering materials have a significant effect on the serviceability and life of a component thus cannot be neglected in design. Abrasive wear produces the premature failure of many components of the extraction machinery with considerable economic costs [1-3]. The ongoing challenge of engineers in these fields is to find or design materials that are the most wear resistant, in order to extend the life of the parts and reduce the frequency of part replacement. Surface engineering is an economic method for the production of materials, tools and machine parts with required surface properties, such as wear resistance [4-5]. Wear related failure of machinery components counts as one of the major reasons for inefficient working of machines in a variety of engineering applications. Many such applications involve handling of abrasive materials or contact with the material in service. Abrasion is one of the important and commonly observed wear modes in these cases.

Wear resistance of materials can be improved through bulk treatment and surface modification. While bulk treatment has been practiced for a long time, surface treatment is fairly recent and gaining importance. Because wear is a surface phenomenon, it is possible to use a relatively inferior bulk material for a specific (wear related) application by modifying the surface characteristics of the material economically. A variety of techniques/materials exist for modifying the surface properties of substrates. However, their success depends on an appropriate selection of the techniques/materials depending on the application of the modified components. This emphasizes the need to characterize the modified surfaces accordingly [6-7]. Among many proven techniques of surface modification, hardfacing has been especially effective in cases not requiring close dimensional tolerances. Any equipment needs to be maintained properly to work effectively so that it is to regularly inspect for signs of wear, corrosion, fatigue and cracks. The equipment is subjected to various types of wear especially the abrasion wear. The wear causes hundreds of tons of material to be lost and productivity that can never be recovered. This represents significant expenses to companies in the recovery or replacement of these wear prone elements. Surfacing is a process of depositing a material layer over substrate either to improve surface characteristics like corrosion resistance, wear resistance, and hardness, etc. or to get the required size or dimension [8-10]. A variety of bulk materials (ferrous and non-ferrous metals and alloys) can be modified by alloying, mixing, compositing, and coating to achieve adequate resistance to wear corrosion and friction. Hardfacing technique is discussed in the current research. In order to properly understand the hardfacing technique it is necessary to understand the wear that has occurred and its causes.

The purpose of this research was to study the wear characteristics and wear resistance of low alloy steel that were processed with four different commercial hardfacing alloys by shielded metal arc welding (SMAW) and comparing these with the un-hardfaced low alloy steel under laboratory conditions. The wear rates obtained from laboratory can then be used to predict service lives of the excavator teeth.

II. Experimental Procedure

A. Materials and Weld Metal Overlays

Excavator teeth used in the experiment were made from low alloy steel with a composition given in Table I. It can be hardened and tempered to offers good combination of ductility and hardness combined with excellent resistance to shock. The substrate material is the material from which the excavator bucket teeth are made up of. Spectroscopy is done to determine the actual composition of the original bucket teeth. Spectroscopy was done at National Institute of Secondary Steel Technology (NISST), Mandigobindgarh, Punjab (INDIA). From Spectroscopy analysis it was found that the excavator bucket teeth are made up of low alloy steel - 27Mn2 (EN14B).

Table I Chemical Composition (WT %) Of Low Alloy Steel

ELEMENTS	Wt % of ELEMENTS
C	0.24
Mn	1.29
Si	0.27
S	0.024
P	0.032
Al	0.03
Cu	0.14
Cr	0.34
Mo	0.01
Ni	0.04
Pb	0.01
V	0.01
W	0.02

Selection of the hardfacing electrodes was done on the basis of the chemical composition of the excavator teeth. The actual chemical composition of the bucket teeth had been determined with the help of Optical Emission Spectrometer. The result obtained from the spectroscopic analysis of original bucket teeth helped in the selection of various hardfacing electrodes. Also, from the literature survey it was found that number of alloying elements like Cr and C etc. can be added into the substrate in the form of weld consumables to improve wear resistance. The percentage composition of the four different hardfacing electrodes used in the current research work is as given in Table II.

Table II Chemical Composition (WT%) Of Hardfacing Alloys Used In Present Research Work

Hardfacing Alloy	Chemical Composition (wt%)
H 1	C – 4.5, Si – 0.8, Mn – 1.6, Cr – 33
H 2	C – 5, Si – 2, Cr – 23, Mn – 0.7
H 3	C – 3, Si – 0.6, Mn – 1.0, Cr – 6.25, Mo – 1.3, Nb – 0.6
H 4	C – 0.75, Si – 0.4, Mn – 0.6, Cr – 2, P – 0.03, S – 0.03

For laboratory tests, samples were prepared in the form of cylindrical pins having final diameter of 8 mm and length of 30 mm with the help of lathe machine, surface and cylindrical grinding machines.

B. Deposition of Hardfacing Layers

Shielded metal arc welding (SMAW) technique was used to deposit the hardfaced layers. Constant current type power source was used, the reason being that with this type of characteristics, the welding current remains constant, irrespective of small variation in arc length and consequent slight change in arc voltage, which are unavoidable even in the case of a skilled worker.

Table III Welding Parameters For Each Hardfacing Electrode

Type of Electrode	Diameter of electrode (mm)	Current (amps)	Voltage (volts)	Preheat for 1 hour (degree C)
H 1	3.2	125	24	180°C
H 2	3.2	120	22	180°C
H 3	3.2	120	17	180°C
H 4	3.2	125	23	180°C

As the welding current was fairly steady, the weld quality is consistent. The various welding parameters are given in Table III. DC was used for welding because DC has the advantage of two polarities, which means that the electrode can be made negative or positive. Straight polarity (i.e. electrode negative) can be used for SMAW of all steel, but not for most non-ferrous metals. With straight polarity, more of the arc heat is concentrated on the electrode and consequently melting and a deposition rate higher, welding is more rapid and the distortion of work piece is less. On completion of the weld deposits, each test piece was cooled down in air.

III. Laboratory Test

The specimens were then subjected to wear tests on a pin-on-disc test apparatus, which is shown schematically in Fig 1.

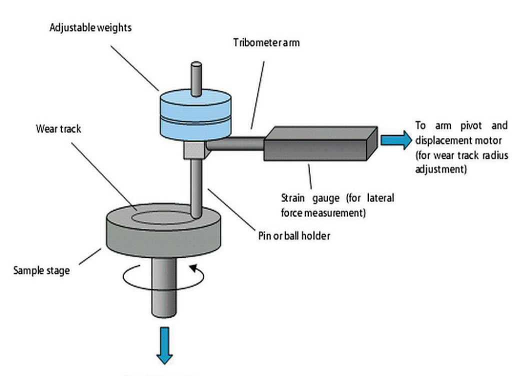

Fig. 1 Schematic illustration of the pin-on-disc wear test

The pin-on-disk test is generally used as a comparative test in which controlled wear is performed on the samples to study. The mass lost allows calculating the wear rate of the material. Since the action performed on all samples is identical, the wear rate can be used as a quantitative comparative value for wear resistance. The device used was "Wear and Friction Monitor Tester TR-201 of Make-M/S Ducom Instruments Pvt. Ltd., Bangalore-INDIA, conforming to ASTM G99 standard as shown in Fig 2. This testing apparatus is designed to study the wear and friction characteristics in sliding contacts. It is also used for evaluating the rate of wear and ranking of materials. It is fully guarded for operator safety. It is operated with a pin perpendicular to the flat circular disc. The sliding path is a circle on the disc surface.

Fig. 2 Wear Testing Apparatus as per ASTM G99 standards

Three samples of each hardfacing i.e. H 1, H 2, H 3 and H 4 on EN-14B were subjected to wear on Pin-On-Disc wear test rig at normal loads of 30N, 40N and 50N respectively. Three samples of EN-14B substrate were also subjected to wear on Pin-On-Disc wear test rig at the same loads. The comparisons of wear with respect to sliding distance at different values of load acting have been made by plotting the graphs of different hardfaced and unhardfaced samples.

The Fig 3 shows the comparison of weight loss between hardfaced and un-hardfaced samples at load of 30N.

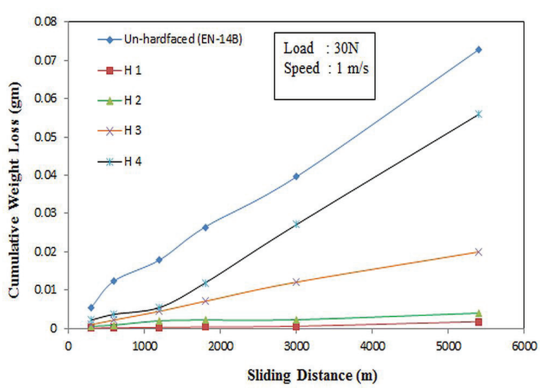

Fig. 3 Variation of cumulative weight loss with the sliding distance at 30 N subjected to dry sliding wear

It shows that H 1 hardfacing alloy is at the lowest position on the graph and un-hardfaced sample at the top most position on graph and it can be seen that the wear w.r.t. sliding distance lowest slope for H 1 alloy. The wear goes on increasing w.r.t. sliding distance for all the samples. The curves of H 2 and H 3 are approximately overlapping each other. Similarly the comparison for wear between hardfaced and un-hardfaced samples has also been made from the graph of wear with respect to sliding distance at 40 N and 50 N load acting (Fig 4 & Fig 5).

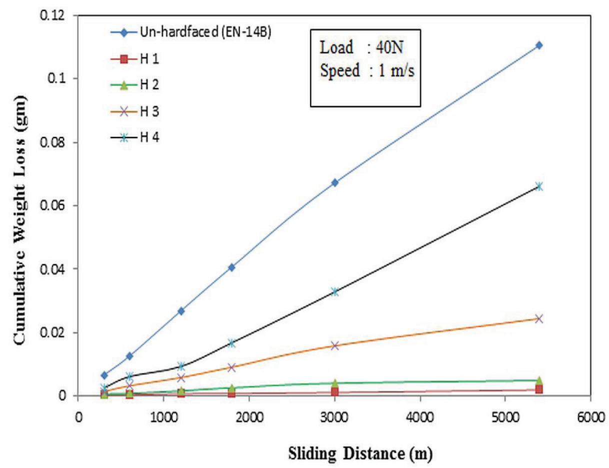

Fig. 4 Variation of cumulative weight loss with the sliding distance at 40 N subject to dry sliding wear

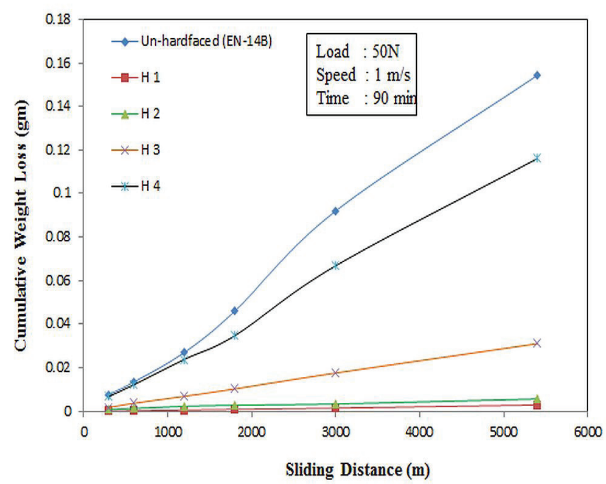

Fig. 5 Variation of cumulative weight loss with the sliding distance at 50 N subject to dry sliding wear

IV. Conclusions

Based upon experimental results obtained in the present work, the following conclusions have been drawn:

- H 1, H 2, H 3 and H 4 hardfacing alloys have successfully been deposited on EN-14B substarte using SMAW process.
- The specimen's hardfaced with H 1, H 2, H 3 and H 4 alloy on low alloy steel showed significantly lower

cumulative weight loss as compared to uncoated EN-14B substrate.

- Cumulative weight loss for hardfaced and un-hardfaced (EN-14B) specimens increases with increase in load.
- The cumulative weight loss for H 1 hardfacing alloy was observed to be minimum in the present study.
- The wear resistances for EN-14B, hardfaced with H 1, H 2, H 3 and H 4 alloys followed a general trend as given below:

H 1 > H 2 > H 3 > H 4 > Low alloy steel.

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