EXPERIMENTAL INVESTIGATION INLIFE ENHANCEMENT OF ROTAVATOR BLADE AGAINST ABRASIVE WEAR BY HARD FACING

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Abstract— Rotavator blades are subjected to extreme abrasive wear when it cuts, pulverizes mixes and level the soil in single pass, which severely affects its working life. The objective of this study was to enhance the life of the rotavator blade made of EN-42J spring steel by means of hard facings. Four types of iron-based hard facing electrodes with range of Chromium (3.1 - 29% by weight) were used to deposit on the rotavator blade. Four different hard facings namely H-1, H-2, H-3, and H-4 were deposited by manual metal arc welding (MMAW) on rotavator blade. Pin-On-Disc (ASTM G99) test was done for the hard faced and un-hard faced samples of rotavator blades. Hard facings were examined by XRD analysis. The results showed that the hard faced EN-42J has shown comparatively high wear protection as compared to un-hard faced EN-42J. The wear rate was minimum in case of H-1 hard facing. The H-1–EN-42J hard facing-substrate combination showed maximum wear protection. The test result showed that the wear rate of the un-hard faced blade was 1.679 gm/hr, while those of the H-1, H-2, H-3, and H-4 hard facing alloys were 0.112, 0.239, 0.924 and 1.421 gm/hr respectively. The wear rates of H-2, H-3 and H-4 hard faced blades were also improved as compared to the un-hard faced blade. Examination showed that the life of rotavator blade improves approximately by 14.99 times as compared to un-hard faced blade.

Keywords— Rotavator, Hardfacing, MMAW, Pin-on-Disc, Wear

INTRODUCTION

Degradation of materials by wear results in very high losses in industries such as automobiles, agricultural, constructional, metal working etc. Industry tends to focus on the wearing surface that has the greatest impact on their economic situation. Wear is a surface phenomenon and occurs mostly at outer surfaces. Every part that is moving in service will be subjected to wear at the contact point between two parts. The consequence result of this wear is that the parts need to be replaced, which increase cost and downtime on the equipment. The surface characteristics of engineering materials have a significant effect on the serviceability and life of a component which cannot be neglected in design. The current challenge of engineers in these fields is to modify or design materials that are the most wear resistant, in order to enhance the life of the parts and to reduce the need of part replacement.

The rotavators do simultaneous ploughing and harrowing before and after rains. It can remove sugarcane stubbles or incorporate every kind of crop residue into soil mainly to improve soil organic health. It retains soil moisture, increases the soil porosity and aeration - a condition for enhanced germination and crop growth. It can be used for dry land and wetland cultivation. These features are attributed to the growing popularity of rotavators amongst Indian farmers. Critical components of agricultural machinery like rotavator blades are exposed to abrasive wear, the removal of material from solid metallic surface due to pressure exerted by continuous sliding of hard soil particles. The critical components are to be hardened against wear. This is achieved through the process of surface hardening.

Hardfacing is a low cost method of depositing wear resistant surfaces on metal components to extend service life. Among the surface modification techniques used in engineering applications, hardfacing probably is the most common one to improve the wear resistance of the components. It primarily involves deposition of a hard, wear-resistant material to the specific areas of the surface of the components by any of the techniques such as welding, thermal spraying, plasma spraying, etc. A number of hardfacing materials are available and the proper choice has to be made depending on the alloy chemistry, area of application and the cost factor.

The study of the surface characteristics of engineering materials is important because this affects on the serviceability and life of a component. The study of the published literature shows that there is still lack of understanding about the hardfacing techniques on rotavator, welding process used for hardfacing and alloys

Kocher et al. [1] made an effort to increase wear resistance properties of material while using in industry and agricultural work by the mean of hardfacing. A hard electrode was used for hardfacing by manual metal arc welding on material which had low hardness comparison to hard electrode. EN31 was material of tiller blade. A weld coating was applied on the surface of EN31 with the use of MR 3LH electrode in order to increase wear properties. The result was made on the basis on wear test by Pin on disc machine and SEM analysis. It was found that with the help of hardfacing the wear resistance property of EN-31 were increased. **Shibe et al. [2]** made an attempt to discuss the various types of wear, surface protection by hardfacing techniques, Manual Metal Arc Welding (MMAW) process and applications of hardfacing.It was concluded that the economic success of the hardfacing process depends onselective application of hardfacing material and its chemical composition for a particular application. It revealed that carbon and chromium are the major elements whichare used in hardfacing alloys. It was found that the by varying the percentage of carbon andchromium corrosion and wear resistance can be enhanced. **Arora et al. [3]** deposited a hard and wear resistant layer on metal components to reclaim or extend the service life of machine parts used for various applications in industries. The prime requirement of a metal is to have good resistance to wear, corrosion and high temperature. The study primarily focuses on the impact of Composition (in terms of C, Si, Cr and Mn), load applied and the time for which the tool is used on the weight loss of the tool and thereby analyzes the wear of the material. The results were optimized in an experimental study while using Design of Experiment, based on which it was concluded that the H-1 type hard-faced alloy provides us with least weight loss and thus least wear.

The aim of this paper is to increase the wear resistance of rotavator blade by selection of appropriate hard facing method and material.

EXPERIMENTATIONS

The scheme of experimentations have been setup to perform the experimental studies on the the wear resistance of rotavator blade by selection of appropriate hard facing method and material

The substrate material is the material from which the rotavator blades are made up of. Spectroscopy is done to determine the actual composition of the original blades. Spectroscopy was done at Munjal Castings, Ludhiana, Punjab (INDIA). From Spectroscopy analysis it was found that therotavator blades are made up ofhigh tensile steel EN-42J. The test pins are prepared of length 60mm and diameter 14mm originally and the final length of length 30mm and diameter 8mm is attained by the turning and grinding operations. These operations are performed after the hardfacing upon the one end of the pins. The other end of the pins does not hardfaced for the checking of un- hardfaced properties.

Selection of the hardfacing electrodes was done on the basis of the chemical composition of the rotavator blades. The actual chemical composition of the blades had been determined with the help of Optical Emission Spectrometer in the laboratory at Munjal Castings, Ludhiana. The result obtained from the spectroscopic analysis of original blades helped in the selection of various hardfacing electrodes like chromium rich, carbon rich electrodes etc. is shown in table-1

Table 1: Chemical composition (wt %) of Hardfacing Alloys

Hardfacing Alloy	Chemical Composition (wt %)	Welding Technique used
H-1	C – 4.5, Si – 0.8, Mn – 1.6, Cr – 29	MMAW
H-2	C – 4.8, Si – 2, Cr – 23, Mn – 0.7	MMAW
H-3	C – 3, Si – 0.6, Mn – 1.0, Cr – 6.25, Mo – 1.3, Nb – 0.6	MMAW
H-4	C – 0.69, Si – 0.4, Mn – 0.6, Cr – 3.1, P – 0.03, S – 0.03	MMAW

For laboratory tests, figure-1 shows the samples which 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 on the surface and cylindrical grinding machines.

Figure 1: Samples for Pin on disc test

Manual metal arc welding 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. As the welding current was fairly steady, the weld quality is consistent. The table-2 shows the welding parameters which are maintained while the welding operation. This is very important to achieve the proper hardness upon the base material. The parameters like the current, voltage or preheat conditions, are different for each electrode which are taken from the manufacturing companies of these electrodes.

Table 2: Welding parameters for each welding electrode

Type of Electrode	Size = diameter x length of electrode (mm)	Current (amps)	Voltage (volts)	Preheat for 1 hour (°C)
H-1	3.2 ×350	125	24	180°C
H-2	3.2 ×350	120	22	180°C
H-3	3.2 ×350	120	17	180°C
H-4	3.2 ×450	125	23	180°C

The specimens were then subjected to wear tests on a pin-on-disc test apparatus, which is shown in Figure-2(a).

Figure 2(a): Wear Testing Apparatus

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 Figure-2(b).

Figure 2(b) Wear and Friction Monitor Tester TR-201

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.

RESULTS AND DISCUSSIONS

The tables are formed for weight loss of material and graphs are made for the comparison of effect of different hard facing electrodes. Results of Laboratory tests have been reported and the following results are obtained after experimentation:

1. Visual Examination: The samples subjected under abrasive wear are visually examined during study. During lab tests of hardfaced samples on Pin on Disk wear testing machine, it has been found that the pins of samples having hardfaced deposits at their edges have got wearing as the time period of abrasive action increases and there is no other change in the pins were noticed. Similarly the un-hardfaced pins have got wearing more rapidly under abrasion as the time period of abrasive action goes on increasing.

2. Weight Loss Determination: The weight loss of all samples are calculated by subtracting the final weight of sample after abrasive wear from initial weight of samples before abrasive wear and on the basis of same, the rates of wear of samples per unit time have been determined both for hardfaced as well as un-hardfaced samples and comparison made among the different types of samples. The weight loss is measured three times in every cycle of 10-20-40 minutes for the proper determination of the readings. This makes the complete cycle of 60 minutes as discussed above. Same precision is followed for the each weight loss reading to measure. The following table shows the weight loss of hardfaced and un- hardfaced material which are tested upon the pin on disk machine in laboratory.

Table 3.1: Wear Loss of Hardfacing Electrode H-1

Hardfacing Type	**Load (N)**	**Time (min)**	**Initial wt. (gms)**	**Final wt. (gms)**	**Cumm. Wt. Loss (gms)**
H-1	30	10	3.8124	3.8120	.0004
		20	3.8120	3.8112	.0008
		40	3.8112	3.8096	.0016
	40	10	5.1049	5.1042	.0007
		20	5.1042	5.1031	.0011
		40	5.1031	5.1012	.0019
	50	10	4.3436	4.3429	.0007
		20	4.3429	4.3419	.0010
		40	4.3419	4.3397	.0022

Table 3.2: Wear Loss of Hardfacing Electrode H-2

Hardfacing Type	**Load (N)**	**Time (min)**	**Initial wt. (gms)**	**Final wt. (gms)**	**Cumm. Wt. Loss (gms)**
H-2	30	10	14.3404	14.3402	0.0021
		20	14.3402	14.3400	0.0023
		40	14.3400	14.3383	0.0040
	40	10	15.3560	15.3557	0.0027
		20	15.3557	15.3543	0.0041
		40	15.3543	15.3534	0.0050
	50	10	13.3356	13.3351	0.0027

		20	13.3351	13.3345	0.0033
		40	13.3345	13.3322	0.0056

Table 3.4: Wear Loss of Hardfacing Electrode H-4

Hard facing Type	**Load (N)**	**Time (min)**	**Initial wt. (gms)**	**Final wt. (gms)**	**Cumm. Wt. Loss (gms)**
H-4	30	10	13.8123	13.8120	0.0003
		20	13.8120	13.8119	0.0006
		40	13.8119	13.8107	0.0018
	40	10	15.4746	15.4682	0.0119
		20	15.4682	15.4530	0.0271
		40	15.4530	15.4242	0.0559
	50	10	13.6618	13.6432	0.0578
		20	13.6432	13.6112	0.0892
		40	13.6112	13.4553	0.1559

Table 3.5: Wear Loss of Un- Hard Faces Base Material EN-42J

Hard facing Type	**Load (N)**	**Time (min)**	**Initial wt. (gms)**	**Final wt. (gms)**	**Cumm. Wt. Loss (gms**
High Tensile Steel EN42J	30	10	11.8563	11.8477	0.0265
		20	11.8477	11.8346	0.0396
		40	11.8346	11.8014	0.0728
	40	10	10.9796	10.9657	0.0408
		20	10.9657	10.9393	0.0672
		40	10.9393	10.8942	0.1106
	50	10	11.1636	11.1446	0.0460
		20	11.1446	11.0986	0.0920

		40	11.0986	10.9533	0.1453

From the tables, it is shown that the wear of samples of hardfacing alloy is very low as compared to others. The sample of H-4 hardfacing are also undergone the greater weight loss as compared to the other hardfaced sample and it has shown the wear approximately similar to the un-hardfaced sample as the un-hardfaced sample has been subjected to greater wear as compared to hardfaced ones. At maximum load of wear test, it has been found that the weight losses of H-2 and H-3 hardfacing samples are approximately same.

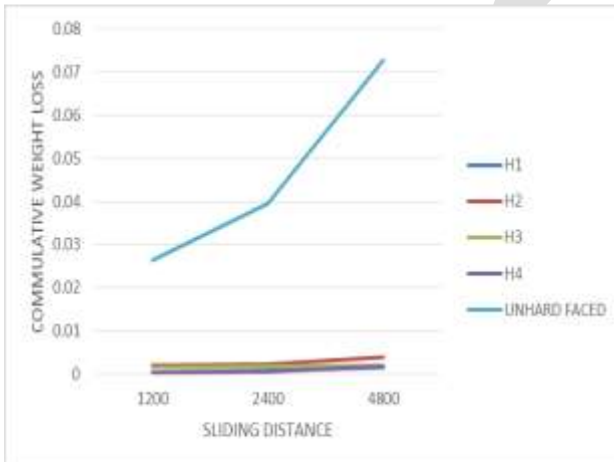

Figure 3.1: Cumulative weight loss at 30N

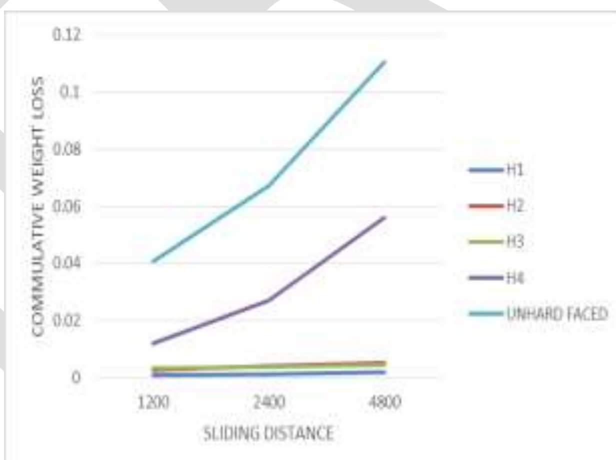

Figure 3.2: Cumulative weight loss at 40N

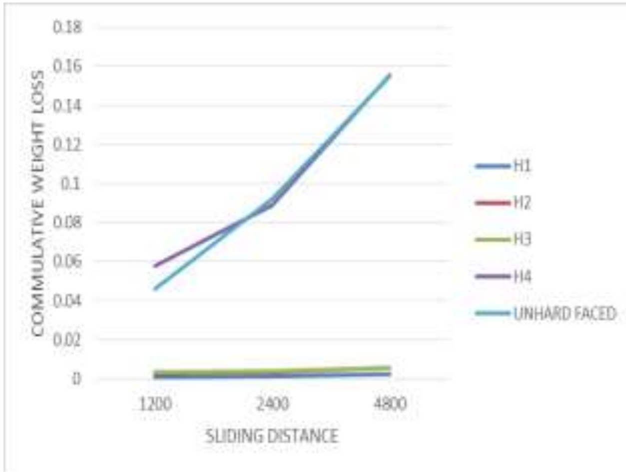

Figure 3.3: Cumulative weight loss at 50N

The following figures show the comparison between the hardfaced and un- hardfaced material in the graphical representation at 30N, 40N and 50N load. The graphs are plotted between cumulative weight loss and the sliding distance on the disk i.e. 1m/s. the vertical line shows the cumulative weight loss and horizontal line shows the sliding distance. All the hardfaced and un-hardfaced graphs plotted collectively at different loads for comparison**.**

As shown from the graphs, all the hardfaced as well as un-hardfaced samples have undergone increasing wear w.r.t. increase the load acting. The variation in the weigh losses with respect to increase in load has been plotted for the comparison of wear rate among the hardfaced as well as un-hardfaced samples. The overall order of increasing wear rates of hardfacing alloys deposited on EN-42J are given as below: H-1 < H-2 < H-3 < H-4 < Un-hardfaced.

The results shows that the H-4 hardfacing alloy cannot provide additional wear resistance for the blade due to the low fracture strength of hardfacing, causing continuous wear of the hardfacing on the leading edge. It shows only 1.31 times superiority over the un-hardfaced teeth as tabulated in Table 5.6. The H-3 hardfacing alloy shows only marginal increase in wear resistance. It exhibits 2.04 times superior wear resistance than the un-hardfaced blade. The H-1 and H-2 hardfacing alloy, on the other hand, exhibits superior wear resistances, at approximately 15.85 and 7.69 times better performance respectively than the un-hardfaced blade. For the H-1, the wear did not reach the blade metal, and the result shows a very small wear.

CONCLUSION

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

1) H-1, H-2, H-3 and H-4 hardfacing alloys have successfully been deposited on EN-42Jsubstrate using MMAW process.
2) The specimen's hardfaced with H-1, H-2, H-3 and H-4 alloy on steelEN-42J showed significantly lower cumulative weight loss as compared to uncoated EN-42J substrate.
3) Cumulative weight loss for hardfaced and un-hardfaced (EN-42J) specimens increases with increase in load.
4) The cumulative weight loss for H-1 hardfacing alloy was observed to be minimum.
5) The wear resistances for EN-42J, 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>EN-42J
6) The H-1 hardfacing alloy and substrate combination has shown minimum cumulative weight loss among all the four combinations. The wear resistance for hardfacing-substrate combinations in their decreasing order (at 30N, 40N & 50N) is H-1–EN-42J>H-2-EN-42J>H-3-EN-42J>H-4-EN-42J
7) It is observed that the life of teeth hardfaced with H1alloy is enhanced approximately by 15 times as compared to un-hardfaced teeth.

FUTURE WORK

1. Some other surfacing technique may also be evaluated to enhance the service life of the rotavator blades.
2. The effect of other alloying elements on microstructure and wear properties of hardfacing alloys for specific application may be studied.
3. Life of rotavator blades can be enhanced by optimizing the chromium and carbon percentage in the hardfacing alloy.
4. Some other hardfacing alloys with different compositions should be formulated and evaluated for wear behavior

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