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Study of Wear of Rotavtor Bldes Treated With Surface Hardening Processes

Engineering

KEYWORDS :

Syed Irshad Ali — Research scholar, Faculty of Engineering , Pacific Academy of Higher Education and Research University, Udaipur-313 001 (Rajasthan), India.

Prashant Sharma — Pacific Academy of Higher Education and Research University, Udaipur-313 001 (Rajasthan), India.

S.N.A.Jaaffrey — Pacific Academy of Higher Education and Research University, Udaipur-313 001 (Rajasthan), India.

ABSTRACT

We present an analytical study of experimental data collected during the experimentation of hardened Rotavator blades with abrasive medium specifically a field soil used for different kinds of crops. The techniques of surface hardening like flame shot peening, metal coating and process parameters tested on Rotavator blade for wear loss while using in the field, are implemented in this piece of research. Under recent refined model, the work coefficient and the mean life of rotavator blades on continuous use in the experiments are estimated to be 852.83 m3 Rc and 100.4 Hours or 8.36 days respectively. The high temperature of the flame hardens the blade which is found be 45.3 RC (i.e. about 11.5 % more than untreated virgin blade), hardness produced by the shot peend blade is measured to be 49.2 RC (which turned out 21.2 % harder than virgin blade). Above all, Metal coated blades show hardness quit large and is observed to be 60.4 RC , which turns out to be 40.6 % harder than virgin blade.

Introduction:

In the field of agriculture, most of the recent research works confine their focus on the improvement of the ingenious tools used by the farmer for working efficiency. The tools like **Rotavator blades** have been very useful in the field's preparation for optimal yield output [1, 2, and 3]. The multifold growth of agricultural mechanization has been quite impressive during the last few years. Recently we have witnessed useful electronic gadgets coupled with computers and software to monitor the mechanization associated with cultivation. According to Salokhe, V.M. [4], wear is main cause of huge losses in tools. Variety of abrasive wear processes lead to material specialization with the aim of assurance for the working resistance on wear in specific conditions [5, 6, 7, 8, and 9]. On the basis of the present state of the theoretical knowledge as reported by Alkimove, et al. [10], the analytic value of abrasive wear in different tribologic systems is not possible because of the fact that processes which occur are very complicated to differentiate according to Khruschov, M.M [11]. In one of the study, Ballard, W.E [12] investigated that wear resulted due to hardness of the materials, sharp edge of particles which often happened to be the percussive effects. Steel is material of rotavator which has wide chemical composition in whole range of Alumina ceramics as described by Foley, A.G et al. [13], and it is known as white cast iron. Besides Alumina ceramics it includes other alloy in additions among which the most important are: 3% Mo and 5%. Ni (d-elements). Taking into account of different chemical compositions, Zheng, G., and Ota, Y. [14] revealed that its initial microstructure was made up of compact lattice matrix. In practice, criteria of materials selection is a function of many parameters, among them are: static and dynamic load, workability, weld ability, cost of production etc [15]. The most profitable solution of this problem seems under the use of materials of high hardness, high plasticity and heterogeneous in structures. It is noticed that hardness of hard phase should be higher than abrasion medium. Interatomic forces in the chemical bonds and the composition strength between structural components reciprocally at the borders of grains play a decisive role [16]. However in order to address the question like, how to decrease abrasive wear (abrasive-percussive) rate of Rotavator blades of iron in non-typical systems or what type of effective coating elements (mineral?), we conducted this present analytical study to focus on treatments of flame, shot peening and thin layer coating of d-orbital elements alloy model for Rotavator blade.

Instrumental: Rotavator

Although large sets of tools are used in seed bed preparation but typically one using them are the rotavators those do simultaneous ploughing and harrowing before and after rains. Rotavators are employed to remove sugarcanes stubbles or incorporate every kind of crop residue in to soil mainly to improve soil organic health [17, 18, 19 and 20]. These features are attributed to the growing popularity of rotavators amongst Indian formers. Always rotavators consist of steel frame, a rotary shaft on which L-type blades are mounted and coupled with powered gear box. Such design (see figure-1) makes rotavator strong to work out ploughing & harrowing in land

Figure -1: Rotavator blades with different treatments after 100 hours of working. T_1, T_2, T_3, and T_4 represent virgin (untreated), heat, shot peend, metal coating treated samples of blades respectively.

under all conditions of either dry or wet. In principle the PTO of tractor drives the rotavator on seed bed achieving pulverization of the soil by its single pass. However soil with abrasiveness due to quartz, stone and silica components [21, 22, 23, and 24] is hard and produces scratches on rotavator blade through friction among the surfaces which is interatomic interaction.

Observations:

The experiments were conducted to assess the wear loss under different treatments to the rotavator blades for the measurements of several parameters relevant to physical properties like effect of surface hardening treatment and effect of working period [25]. Initially Rockwell hardness of untreated virgin blade was found to be 40.6 R_C in the experiment but after the surface hardening treatments on the Rotavator blades, hardness of blades were increased. The high temperature of the flame hardens the blade which was found 45.3 R_C and that was measured to be 11.5 % more than virgin blade [26]. Most of the time, Hardness of the shot peend blade was found 49.2 R_C which was 21.2 % harder than virgin blade. On the other hand, Metal coated blades showed hardness quit large and was observed to be 60.4 R_C, but that was 40.6 % more harder than virgin blade [27]. The hardness of different treated blades under various conditions T_1, T_2, T_3, T_4 are depicted below systematically in figure- 2.

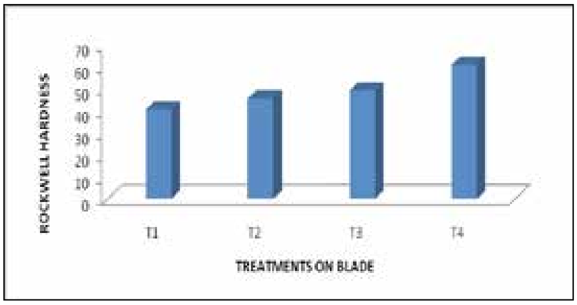

Figure-2: Hardness of rotavator blades

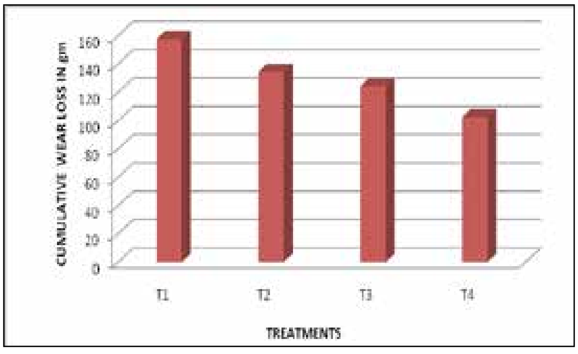

Figure-3: Wear loss in different rotavator blades.

Table -1: Wear loss and Wear rate rotavator blades after 100 Hours.

S. No	Treatments	Wear loss after 100 h, gm	Wear rate, mg/min
1	Virgin blade- T_1	157.6 ± 12.5	26.26 ± 2.5
2	Flame hardening- T_2	134.4 ± 11.5	22.4 ± 2.1
3	Shot peening- T_3	124.2 ± 11.1	20.7 ± 1.9
4	Metal coating - T_4	102.3 ± 10.2	17.05 ± 1.8

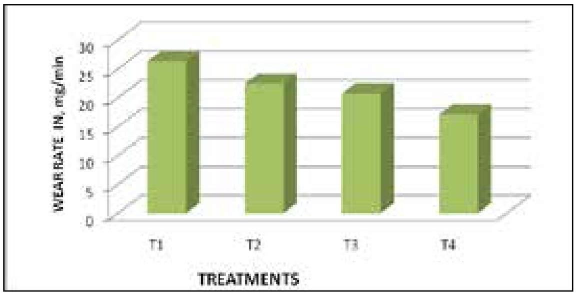

Figure -4: Wear rate of different treated blades.

The cumulative wear loss in blade with treatments T_2, T_3, and T_4 after 100 hours of operation, were 134.4, 124.2, and 102.3 gms respectively. The wear in virgin blade was observed 157.6 gms [28]. The minimum wear loss was observed in blade with metal coating which can be seen in figure -3.

The overall wear loss and rate for above three surface hardening treatments after 100 working hour is given in table -1. The variation in wear rate of blades with different surface hardening treatments is depicted in figure- 4. The wear rate of blade with metal coating, shot peening and flame hardening treatment were found to be 52.85%, 30.96%, and 20.34% less than that of untreated virgin blade. The drastic reduction in wear of metal coated blade was due to the nickel chromium powder having boron and silica particles which have excellent resistance to abrasion and 50% molybdenum present in coating powder have good weld ability and excellent cutting edge retention [29]. In shot peend blade, reduction in wear was due to the surface hardened by cold working of shot blast and induced compressive stresses on the surface of the blade [30]. In flame hardened blade, the micro structure of surface particles changes locally and surface becomes harder so wear resistance improves.

Hypothesis of abrasive wear:

In order to infer the results quantitatively we tried to analyze the data using refined recent model. The foremost used mathematical formula which helps in proving the proposed mechanisms of interaction with grain material and rotavator blade involved for the abrasive wear at atomic level is discussed [31]. It is commonly known as Archard's equation for adhesive wear loss but has proven very useful in understanding the phenomenon involved at atomic level for the abrasive wear loss as well [32]. The Archerd's equation, with little modifications may be tested as a starting point and wear loss mass in gm may be expressed as

$$M = \varrho\,(k_1\, L\, k_2\, d_1) / H = \varrho\, C / H \quad - (1)$$

Where $C = k_1\, L\, k_2\, d_1$ is called **"work coefficient"** of rotavator blades because it is proportional to product of force (load) L and displacement d_1 [33]. k_1 is the constant and depends on the shape of blades [34], k_2 is the other constant and many factors affect k_2 such as, the possibility of plough rather than cutting [35]. H represents the hardness of the blades. Also wear loss rate may be written as

$$dM / dt = \varrho\,(k_1\, L\, k_2\, (dd_1 / dt) / H \quad - (2)$$

Where dd_1/dt is velocity of rotavator blade. Now taking ratio of both equations (2) and (1) ,we get

$$dM / dt = M\,[(dd_1 / dt) / d_1] = M / \tau \quad - (3)$$

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Where $T = [(dd_1/dt) / d_1]^{-1}$ is called "**mean life**" of rotavator blade [36].

Data Analysis:
The data analysis was computed using software "origin". The recent working theoretical model obtained under the assumption of atomic interactions between two surfaces of Rotavator and soil in contact. In model, equation (1) justifies the relation between M (wear loss in gm) and H (Hardness, R_c) and the plot further reconciles it. The data used in graph are tabulated in table -2 with observed statistical errors in measurements during conducting the experiment in the field using differently treated Rotavator blades [37]. The M is obtained after 100 hours use of the Rotavator blades in the designed device filled with the interacting material brought from the fields and H, hardness (in R_c) enhanced for Rotavator blades after various treatments, whereas rate of wear is measured in terms of milligram per minutes in the experiments [38]. Table-3 represents data of H^{-1} with M.

Table- 2: Measured data of M (Wear loss in gm), H (hardness) and Wear Rate

S. No	Treatments	M (Wear loss) after 100 h, gm	H (Hardness, R_c)	Wear rate mg/min
1	Virgin blade- T_1	157.6 ± 12.5	40.6 ± 2.2	26.26 ± 2.5
2	Flame hardening- T_2	134.4 ± 11.5	46.3 ± 2.3	22.4 ± 2.1
3	Shot peening- T_3	124.2 ± 11.1	49.2 ± 2.9	20.7 ± 1.9
4	Metal coating - T_4	102.3 ± 10.2	60.4 ± 3.8	17.05 ± 1.8

M (wear loss in gm)	157.6 ± 12.5	134.4 ± 11.5	124.2 ± 11.1	102.3 ± 10.2
H^{-1}	0.0246	0.0223	0.0203	0.0165

Table- 3: Data for M (wear loss in gm) and inverse of hardness H^{-1}.

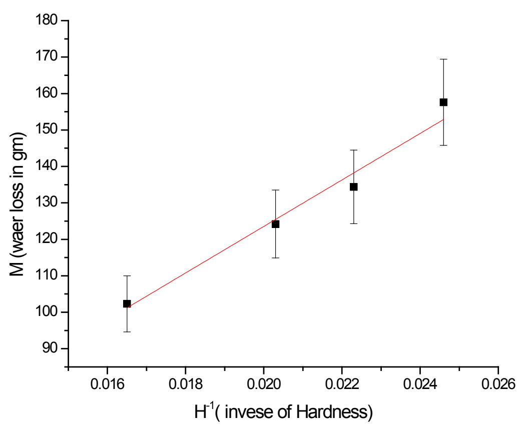

Figure- 5: represents the graph between M (wear loss) and inverse of Hardness.

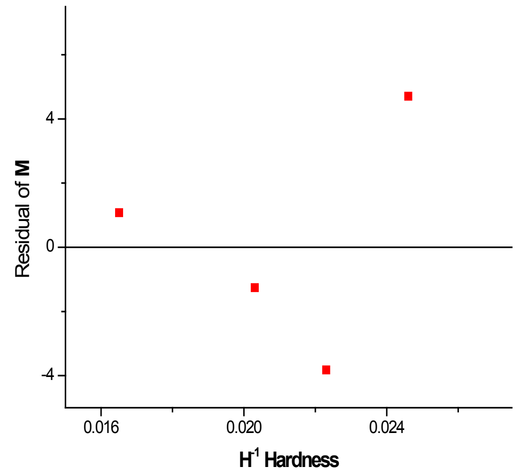

Figure- 6: represents graph between Residual of M and inverse of hardness.

Figures -5 and 6 depict the plots justifying the data taken during the experiment done in the laboratory and the fields for the M wear loss and H^{-1} (inverse of hardness) of the Rotavator material which interacts with the grains of soil [39].

Discussion and conclusions:
Under refined hypothesis at atomic level of abrasive wear of rotavator blade we derived results after attempting analysis of data for further understanding through estimation of the following parameters with essential rectifications.

Determination of Work Coefficient C:
From figures -5 and 6, the fitted parameters obtained in the analysis of the data in the equation

$$M = a + b^* H^{-1} \qquad - (4)$$

with Adj. R-Square to be 0.9702 ,are intercept (**a**) of the plot to be -4.03 ±1.29 and Slope of the fitted line (**b***) to be 6379.19 ± 64.22. Now from equation -1, the slope can be equal to

$$b^* = \varrho C \qquad - (5)$$

$$6379.19 = 7.48 C$$

$$C = 852.83 m^3 R_c$$

Where ϱ =7.48 gm per cc be the density of the Rotavator material, therefore C = 852.83 $m^3 R_c$ is **"work coefficient"** of Rotavator blades. The estimated value of C is quite large because it is product of hardness and volume of the blade [40]. Thus **"work coefficient"** of Rotavator blades is more if more is the hardness and more is the volume of the blades. On the other hand **"work coefficient"** of Rotavator blade is also dependent of the load (L) exerted on the blade to penetrate in to soil at d_1 (distance) deep. When both load and distance are more in experiment then obviously **"work coefficient"** of Rotavator blades is more [41].

Estimation of Mean Life of Rotavator blade:
In order to estimate the mean life of Rotavator blade we attempted to analyze the data of the Wear rate (dM/dt) and Wear loss (M) of different blades after different treatments. A graph is plotted as given below.

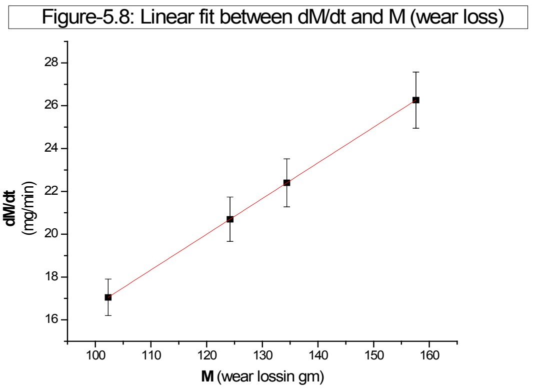

Figure -7 : Linear fit between dM / dt and M (wear loss)

The equation -3, dM / dt = M [(dd$_{1/}$ dt) / d$_1$] = M / Ʈ is tried to fit in data of dM/dt and M in the form of equation y = a + b*x. The fitted parameters like Adj. R-Square is equal to 1 with intercept of 0.0107± 0.0033 and slope to be 0.1665 ± 0.026. The corresponding residual of Wear rate is also obtained and it is shown in figure- 8.

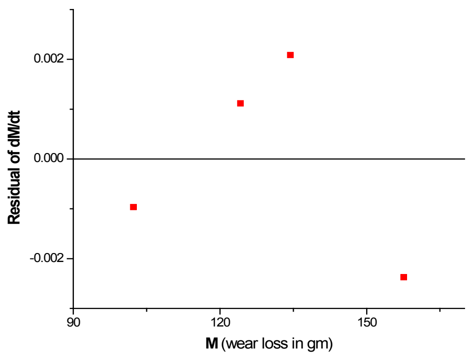

Figure-8 : represents the plot between the residual of dM/dt and wear loss M.

From slope 0.1665 ± 0.026 the analysis provides the Mean Life of the Rotavator blade to be 100.4 Hours or 8.36 days on continuous use in the experiments. The physical meaning of Mean Life Ʈ may be understood in terms of the speed (dd$_1$/dt) in experiment for the Rotavator blade as

Ʈ α (dd$_1$/dt)$^{-1}$ -(6)

More is the speed (dd$_1$/dt) of the Rotavator then more is the d$_1$ (distance covered by Rotavator blade) in short time interval giving extremely large friction between blade material and grains of soil of the field in the experiment [42]. This would remove the more mass of the blade and enhance the wear loss so as would be the small Mean Life of the Rotavator blades. Its inverse is also true i.e. small is the speed (dd$_1$/dt) more would be the Ʈ [43]. This can also be understood on the basis of strength of atomic bonding between the atoms of the coating matter and the Rotavator material. The chosen coating atoms specifically belong to d- elements group and outer most d-orbital electrons for valence which have energy levels below the other higher S and P- orbits set up strong and inner bonds among atoms residing within the thin layers of coatings. It results into the compactness of the coating layers with increase in the density of the coated layer which happens to be hardly few atomic layers in the thickness. This all conclusively amounts to the enhancement in the hardness of the rotavator blades provided coated with the order of nanometers thickness, indeed work coefficient and mean life of blades become larger than the other treated blades with the processes of flame and shot peening.

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