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Review Article

STUDIES ON WEAR CHARACTERISTICS AND SURFACE MODIFICATION TECHNIQUES OF ROTAVATOR BLADES

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Abstract: In agriculture, tillage is one of the most important filed operation. The land is usually ploughed by using plough and cultivators. But these cannot serve the purpose as they invert only the upper layer of soil, without proper mixing. Hence, to have a good soil tilth, additional field operations using rotavator, harrow *etc.* are highly essential. Compared to cultivator, a tractor mounted rotavator saves 30-35% of time and reduces 20-25% in the cost of operation. But there is a limitation that the rotavator blades might be subjected to wear and fatigue under dynamic loading. Abrasive wear has been emerged as a serious problem in rotavator blades. It increases the down time and maintenance cost. Wear of rotavator blades occurs because the material used are softer than the natural abrasives in the soil. The rotavator blades available in the market are not properly heat treated so the wear rate is considerably more as compare to the heat-treated blades. So, there is a need to study wear characteristics of rotavator blades.

Keywords: *Wear, Rotavator blade, Surface hardening*
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Introduction

India has a geographical area of around 328.7 million hectares, out of which 141.4 million hectares of land is found to be net sown area. The gross cropped area is 200.9 million hectares, with a cropping intensity of 142%. The net sown area works out to be 43 percent of the total geographical area. The net irrigated area is 68.2 million hectares. Agriculture plays a vital role in India's economy. 54.6 percent of the population is engaged in agriculture and allied activities and it contributes 17 percent to the country's Gross Value Added [1]. The scenario of agricultural mechanization has been increasing during last four decades. The application of machinery in Indian agriculture has assumed importance for increasing agricultural production, productivity and profitability by timely farm operations, labour saving, as well as maximizing input efficiency by effective and proper utilization. The newly developed appropriate technology of farm mechanization with improvement in existing design, newer material and production techniques will cater the needs of farms [2].

The growth in large scale adoption of agricultural machinery in the country has been possible due to efforts not only by organized sectors but also by village craftsmen and small-scale industries. Different components in agricultural machineries are mostly subjected to dynamic loads, abrasive wear and chemical action of the external environment during their operation. Wear as the common people understand is the deterioration due to continuous use. Fundamentally, it is an acceptable phenomenon but the scientists and engineers are more concerned with very case of wear and the search for remedial measures to increase the durability of equipment's, hand tools and machines used for various farm operations in daily life. Machine breakdown hampers farm operations to a great extent if failure occurs at a crucial time. Hence, increasing the service life of machines has become one of the important necessities of newly developing technology. The study of increasing durability is clearly linked with a study of wear pattern of machine components when in operation. It helps in developing the quality material of machine parts to increase their working life.

In recent years rotavator is becoming popular among the farmers for land preparation where two or more crops taken in a year. Result shows that rotavator saved 30-35 percent of time and 20-25 percent in the cost of operation as compared to tillage by cultivator [3]. It gives higher quality of work (25-30 percent) than as cultivator. Rotavator produces a perfect seedbed in fewer passes. It is well known that one operation of rotavator equal to one MB plough and 2 harrow operations.

The primary cause that limits the persistence of rotavator is wear of blade. The wear of agricultural soil cutting tools have their own characteristics, which are different from other types, since they interact with soils of various textures, moistures and other unpredictable conditions in the field. Among the soil-cutting agricultural tools currently used, the rotavator is one of the most proficient equipment, saving operating time and human effort. The rotavator is energy and time efficient pieces of equipment, under dynamic loading, rotavator blades are subjected to fatigue and abrasive wear. Wear of tillage equipment is caused by natural abrasion which is mainly different forms of silica. The consequences of wear are serious in terms of both replacement cost (parts, labor, downtime) and its effect on timeliness of field operations. Therefore, materials used in tillage equipment's require strength and toughness to resist distortion and impact. To overcome the wear problems of tillage equipment, surface modifications has emerged as an important process that improves the surface properties like hardness and wear resistance. Abrasive wear means removal or displacement of materials from solid metallic surface due to pressure exerted by continuous sliding of hard soil particles. It is classified as gouging, high stress, grinding or low stress scratching abrasion.

One of the serious problems in the field of engineering is the wear of metallic surfaces of the working components in a machine. The life of machine is reduced due to the wear of surfaces. Hence, scientists are making efforts to reduce the abrasive wear rate of machines by changing the microstructure, chemical composition and mechanical properties.

Studies on wear of rotavator blades

A study was conducted to know the wear performance of different materials of rotary blades. For this study, T1 (Low carbon steel), T2 (Low alloy steel), T3 (High carbon spring steel) and T4 (Low carbon steel) was selected. The blade was operated for 150 h duration. The performances of blades were noted on the basis of weight losses and width losses in percentage. This study shows that in loamy soil, the T2 blade having 0.280 percent carbon content has maximum average weight loss *i.e.* 6.76 percent, whereas the T3 blade having carbon content of 0.64% has minimum average weight loss *i.e.* 0.86%. In sandy loam soil, the T4 blade having carbon content of 0.250% has maximum average weight loss of 10.02%, whereas the T3 blade has minimum average weight loss of 4.09%. The width of worn out blades decreased with operational hours. In loam soil maximum average loss in width was 13.20% in blade type T2 and minimum average width loss was 3.18% in blade. In sandy loam soil maximum average width loss was 14.68% in blade type T4 and minimum average width loss was 8.27% in blade type T3 [4].

Chouhan and Saxena [5] were examined that the shot peening technique to resist wear of critical components of agricultural machinery. They were observed that in-depth about shot peening techniques to resist abrasive wear of these components. It was observed that wear intensity of soil engaging parts of agricultural machine depends upon the soil physio-mechanical properties of the environment such as compaction, adhesion, coefficient of friction, resistance to shear, intensity of load, contact pressure, construction and heat treatment of the material of soil engaging parts of agriculture machine. So, to enhance the wear resistance of these critical components, surface treatments and use of appropriate material is usually suggested.

By using the Pin-on-Disc technique under sliding conditions, wear behavior of al-sic coatings on steel substrate has been tested. Usually by incorporation of Sic reinforcement, the wear resistance of the aluminium coatings enhances. As the load increases, it was found that the wear rate of coating increases. Also, with increase in SiC particle, the coefficient of coating was found to be decreased. But when examined by using SEM (scanning Electron Microscope), it was finalized that the main reason for wearing was due to adhesion, deformation and abrasion [6]. Later another study was conducted to observe the effect of hard facings on the wear characteristics of tiller blades. In this study the influence of Cr on tiller blades made of high tensile steel was examined by using four different electrodes. The field test results showed that the average wear rate of the un-hard-faced blade was found as 7.08 g/acre. Similarly for other blades of 5HCr, 7.5 HCr, 12 HCr and 8 HCr, the average wear rate was 5.02, 4.3, 2.84 and 4.22 g/acre respectively.A significant improvement was observed in the wear protection provided by hard facings over the un-hard faced blade [6-7].

Wear of tillage tools of different materials

Agricultural machinery and tools must endure stressful condition of continuous wear and tear, with fieldwork exposing equipment to severe abrasion. The modern agricultural machine manufacturers need hard, tough but flexible steels that prolong the life span of implements while reducing the frequency and cost of replacement of worn parts. Several studies showed that the variation of friction and wear rate depends on interfacial conditions such as normal load, geometry, relative surface motion, sliding speed, surface roughness of the rubbing surfaces and type of material. Owsiak[8] conducted laboratory studies on steel samples and field trials on ridger shares. Wear was measured by the change in length, thickness and weight of share. Relative resistance against abrasive wear was determined for four grades of steel in different types and conditions of the soil. The effect of steel hardness and microstructure on wear was analyzed. It was found that the abrasive wear resistance of steel increased with a decrease in carbide size and with an increase volume fraction of carbide in the metal microstructure. Also, it was observed that the loss of share thickness due to wear and the distance travelled were linearly proportional to each other. Similarly, the wear of cutting edges was dependent on the distance travelled and the distance of the measurement point from the share point. A mathematical model of wear of a symmetrical wedge-shaped tillage tool was also determined. Influence of surface hardening processes on wear characteristics of soil working tools was conducted. Results show that the wear resistance of agriculture implements can be increased by process of heat treatments of substrate material and by the surface modification of the implements. Heat treatment techniques used by various researchers are annealing, tempering, water quenching, oil quenching, case hardening, precipitation hardening, etc. Many researchers have also recommended surface modification techniques like hard facing, electro deposition, shot peening, diffusion coating, vapor deposition and Thermal spraying for wear resistance. Material hardness, moisture content, abrasive particle size, length of abrasive path, speed and normal load play significant role on abrasive wear of soil working elements. Wear rates in common sweep shares for the seeding and cultivation of cereal crops in Australia reduced the efficiency of farmers costing millions of dollars annually. In sandy clay-loam soils, as the soil water content decreases, the wear rate was found to increase. The damage to the tools and the mechanisms of wear were also done by metallographic analysis [9-10].

Owsiak[11] reported that correct evaluation and forecasting of durability of soil cutting parts are the decisive factors for proper operation of agricultural machinery. It was observed that there is a two-fold difference in wear of cultivator points during its operation, which makes it extremely difficult to establish the exchange periods. Some research conducted with an aimed to determine the relationship between arrangement of the points in individual cultivator rows and their wear. The results indicated the need of field experiments to compare wear of spring tine points made of different materials or of different designs to take into account differences in wear due to positioning of the points on cultivator frames. A study was conducted on various types of steel such as leaf spring steel (En 47), medium carbon steel (EN 8), medium carbon low alloy steel (EN 19), medium carbon low alloy steel (EN 24) and mild steel (EN 3) for duck foot sweep application. The study revealed that the weight loss was minimal (18 g) in heat-treated EN 19 in comparison to all other grades of steel. It was observed maximum weight was 29 g in the case of carburized mild steel (EN 3), whereas the weight loss was 72 g in the control sweep made of mild steel (EN 3) and 61 g in used EN 47 made from 'as-received' automobile leaf steel. They concluded that the surface modification is simple, flexible and cost-effective technique by which the desired mechanical properties such as hardness, strength, ductility and wear resistant can be achieved [12].

Wide range of materials of plough share with varying carbon content and other alloying materials under laboratory as well as field condition using rotating wheel type wear testing machine. Although, wear found to decrease with increase in hardness of the material but no definite correlation was observed. Shovels used in cultivators are largely manufactured by the small scale industries. But due to improper material and surface hardening treatments, the quality of shovels does not conform to the Bureau of Indian Standards (BIS) resulting in high wear rates and reduced life. Thus, the study conducted to find out the wear characteristics of shovel with best surface hardening treatment at different soil and operational parameters. It was concluded that the overall performance of surface hardened shovel was superior to other shovels [13-14].

A study was conducted on wear characteristics of rotavator blades for power tillers. He found that spring steel with 0.6 percent carbon content, quenched and tempered at 400°C for 30 minutes may provide most suitable combination of carbon content and hardness level (Rc55) to obtain good resistance for wear and impact for rotavator tynes. The specific wear loss of tynes material decreased with increased in carbon content from 0.41 percent to 0.6 percent and hardness level from Rc 40.6 to 60.8 when tested under bonded abrasive as well as in different types of soil [15-24].

Chahar *et al*.[16] studied wear of four shovels with different carbon content of 0.41, 0.50, 0.59 and 0.65 percent. Abrasive sand at 10-15 percent moisture content was used for the wear studies. It was found that minimum wore out observed in the shovel having maximum carbon content. Cumulative wear loss in shovel decreased by 37.44 percent with increase in carbon content from 0.41 to 0.65 percent. The shovels with same relative hardness, but having high carbon content, were more resistant to abrasive wear. The maximum wear occurred at the tip of the shovels. Dimensional wear was measured with respect to width and thickness of shovel. Test shovels wore out along the thickness. Change in length and width of shovels were negligible as compared to their thickness.

The shovel with 0.65 percent carbon gave the best results. In order to resist the abrasive wear four grades of spring steels (two Boron based and two Boron-free) was selected. The wear analysis of six treatments was carried out in three stages. Firstly, in laboratory scale by using DUCOM make dry sand abrasion test Rig (ASTNG 65). Secondly in specially designed rotary soil bin and finally in the field trial. The study revealed an identical wear ranking order of treatments in all three stages. Due to the higher cost of boron steels in Indian market are suggested to put on second place and SAE–6150 observed to be the best suitable steel. Similarly, A study on influence of material condition on the dry sliding wear behavior of spring steels (EN-47 / SUP 10) was conducted. The result indicated that the material condition had significant influence on the performance of the spring steel. Tribological properties of Austempered Ductile iron grade 4 materials, a new material widely used in North America and Europe for wear resistance application in critical parts of agricultural machines. They used five different material named medium carbon spring steel (EN 45) containing 0.48-0.51 percent carbon steel. It was observed that the Austempered Ductile iron grade 4 exhibited significantly low wear rate, lower abrasion coefficient and 20-50 percent higher benefit cost ratio compared to commercially available brand sweep material [17-19].

Abrasive wear behavior and characteristics

Moore and McLees [20]conducted a study on wear tests on bonded commercial flint abrasives in the laboratory and in sandy clay loam soils in the field at speed between 0.25 and 7.0 m/s. The laboratory result showed about 90 percent increase in the wear rate for steel with increase in speed from 0.25 to 5 m/s, but no increase was observed for copper. The result showed that for different soil types and materials, maximum increase of wear rate of about 180 percent was found in the speed range of 0.25 to 7 m/s.A study to examine the influence of operational parameters and soil type on the abrasive wear of cultivator shovel. Soils like pure sand, loamy sand, sandy loam, sandy clay loam, clay loam and light clay were included in the study. It was noted that the intensity of wear (mg/km) was more in soils having higher percentage of sand. The intensity of wear was observed more in soils like pure sand, loamy sand and sandy loam soil [21]. For determining wear characteristics of agricultural tool materials in sand and soil centrifugal accelerated wear testing apparatus was developed. Tests were carried out using centrifugal wear tester by employing seven different tool metals. There is a wide range of variation in wearing characteristics of tool materials in sand as well as soil. The rate of wear was higher in sand than that obtained in soil [22]. Nathan and Jones [23] Conducted abrasive wear tests to study the variation of volume of wear of metals like aluminium, brass, bronze, copper, iron and steel. It was concluded that the volume of abrasive wear increased linearly up to 70 mm and the gradient continuously decreased between 70 mm to 150 mm.

Muammer and Tufan [25] studied the wearing behavior of coated layers on plough shares used in soil tillage. Plough shares produced from DIN EN 10 083 (30 MnB5) steel, widely used in ploughs, were coated with 20 µm hard chromium by electrolysis method, 20 µm electro-less nickel by chemical treatments, and 4 µm titanium nitride (TiN) by physical vapor deposition to increase wear resistance. The coated and uncoated plough share specimens were mounted on the test equipment and proceeded for analysis of wearing characteristics in a sandy clay loam soil at a speed of 5.8 km/h. The thickness of the coating and the mass loss of the plough share were measured each 1.18 km up to 10.8 km for all the coated layers. Before and after tillage, the specimens were analyzed metallographic ally using a scanning electron microscope (SEM) and energy dispersive spectroscopy (EDS). Abrasive wear occurred on all the plough share. They resulted that the wear values for the uncoated and coated plough were in a close range for the tillage length of 10 km in the soil bin. Over that distance, all coated layers showed wear together with the basic material of the plough share body. Overall, the wear length of the electro less nickel coated specimen was found to be higher but the TiN coated material appeared to have a higher wearing resistance.

A study was conducted by Singh *et al*. [26] shows that reducing the low stress abrasive wear of materials has emerged as a major challenge for researches in the field of engineering and efforts were made for development of prediction model for abrasive wear rate of medium carbon steel like SAE 6150. For precise prediction of wear rate, SAE 6150 steel was tested using dry sand abrasion test rig after heat treatment and shot peening (ranging 0.17-0.47 A at an interval of 0.1 ALMEN 'A'). The hardness and abrasive wear resistance of as-received and annealed steel were significantly lower in irrespective of peening intensity. The peening intensity reduces the wear rate, if limited to a critical value of 0.17 ALMEN 'A'. The functional relationship between the factors influencing abrasive wear and wear rate was found to be significant and this can be used for prediction of abrasive wear at a given level of factors.

Effect of surface hardening techniques

Umit [27] studied that abrasive wear behaviour of untreated and heat treated AISI (SAE) 15B35H and 15B41H boron steel specimens in the laboratory conditions. He observed that the abrasive wear resistance of boron steel specimens increased with increase in hardness values of the test material. Also, various tests were performed to study the effect of shot peening on the surface integrity and the tribological behaviour of tool steels.

Surface modification characterized by randomly overlapping craters with dimensions increasing with the increase of shot size and pressure was identified in all cases, a thin work-hardened zone was developed on all treatments; the extent of this zone and the position of peak micro-harness value depends upon the peening parameters and it was observed that shot peening exerts a beneficial effect on tribological behaviour reducing wear and friction coefficient Vaxevanidis *et al*. [28].

A comparison study was made between the mouldboard shares made of different materials like steel EN 10027 (HF-1) and EN 50Mn7 (HF-2), by adopting welding methods like shielded metal arc welding (SMAW) and high-frequency induction welding (HFIW). Wear was determined by measurements of the changes of dimensions and weight during ploughing in sandy clay soil. It was stated that when compared with regular shares, the hard faced plough shares have lower weight losses and lower fuel consumption. Also, a high rate of work was achieved with hard faced plough shares. Hard faced plough shares also offer lower production costs in comparison to regular plough shares [29].

Rautaray and Sharma [30] carried out investigation on shot peening to reduce wear of soil engaging components of tillage machinery. They described the effect of shot peening on wear characteristics of blade specimens. A blade of low carbon steel (0.19 percent C) with UTS 632.3 MPa and hardness of HRC 33.1 was taken for surface treatments. Comparison was made of the in two methods of surface treatments: carburizing – hardening – tempering and carburizing - hardening – tempering and shot peening. The specimen being shot peened after carburizing hardening and tempering had shown improved wear performance as compared to other treatments tested in the study. Blades of carbon steel AISI 1536 through the microalloying addition of boron was developed. The primary function of boron additions to heat treatable steels was to increase their hardness. The results showed that the addition of boron up to 0.0023 percent can improve the steel properties at the lowest temperature and tempered time [31].

Belete *et al*. [32] investigated the mechanical and wear characteristics of steel samples for better performance of farm implements. It was observed that the mechanical properties of steel samples strongly influenced by the process of carburization. Sample carburized at 950 0C soaked for 1 hrs 30 min followed by water quenching gave best result than the other samples. They recommended carburizing, for hardening of farm implement. Sapkale [33] studied the effect carbonitriding, hardfacing and shot peening for reversible cultivator shovels of medium carbon steel, medium carbon low alloy steel, spring steel, boron alloy steel and mild steel. He tested for wear against abrasive sand for 100 h without any hardening maintaining soil conditions as per BIS standards. Results revealed that shovel of 30MnB5 boron alloy steel having carbonitriding can be recommended best among all the shovels tested.

Effect of time, depth, rotor speed and speed of operation on wear

Wear caused by hard soil particles is abrasive in nature and may have a damaging effect on the cutting edge of the tillage tool. Abrasive wear is the most common degradation process in machines and components used in agricultural industries, Allen and Ball [34].

Koszeghy [35] studied the wear ability of rotary cultivators fitted with right-angle blades to bury green manure and in general its effect on soil mixing. Theoretically, the path described by the blade for different forward speeds to peripheral speed of the blade and the relationship between the relevant parameters were studied. The importance of operating the cultivator at the optimum speed was stressed. Blade wear greatly increased as a result of variations in speed. During ploughing of sandy soil with a moisture content of 2.8-4 percent, plough shares mainly worn out along the width and with a moisture content of 9.4-12 percent its wore out along the thickness specifically at the top portion. Moisture had a significant influence on the state of soil particles as well as on the surface layers of the metal. The experimental data showed that in clayey soils, wear rate decreased as the moisture increased while there was an increase in the intensity of wear in sandy and sandy loam soils for moisture content of 10-12 percent. Study on the effect of soil moisture and operating speed on intensity of wear. Maximum cumulative wear of 16.5 gram was found below 5 percent moisture content in silt clay loam abrasive medium under laboratory condition. Maximum wear in sand was found 67.3 percent more than that in silt clay loam soil. Magnitude of wearing capability of this soil with respect to sand was found to 1.00, 0.45 and 0.33 in the moisture range of 0-5, 5.10-10 and 10.1-15 percent respectively under laboratory conditions. He also reported that wear rate of shovels increased with the increase in operating speed. There was an increase of 41.7 percent in wear rate when the speed was increased from 0.7 to 1.4 m/s[36 -37].

Fouda and Tarhuny[38] studied the wearing behavior of plough shares at different soil moisture content and working time in sandy loam soil. Results reveals that increasing working time from 10 to 60 hours for the front share at soil moisture content of 8 percent increased share mass losses from 1.40 to 16.47, from 2.66 to 21.63 and from 3.79 to 25.66 percent for the three used shares A, B and C respectively. Also at soil moisture content of 11 percent under the similar conditions results showed that increasing working time from 10 to 60 hours, share mass losses increased from 1.70 to 21.70, from 2.80 to 23.67 and from 3.70 to 26.40 percent for shares A, B and C respectively.

Ahmad [39] tested sweep in a well-planned split-plot factorial design in the field at the depth 25 to 170 mm and for 10 h. The results indicated that the test pieces wore by 11.27, 14.48 and 16.51 grams for 5, 10 and 15 minutes respectively. The wear loss was found to increase with increase in depth. Studies on wear characteristics of commercially available tractor drawn cultivator sweeps with different hardness (S1 - 295, S2 - 254 andS3 – 360 HB) in abrasive sand. The experiments were conducted in rotary soil bin. Sweeps of three different makes were tested at speed 1 m/s and depth 100 mm respectively. After 20 operating hour of sweeps in the soil bin, gravimetric wear and dimensional wear was measured. Similar procedure was followed for 100 h time intervals. They observed that linear relationship exists between operating time and gravimetric and dimensional wear. Moreover, maximum wear was observed in S2 sweep followed by S1 and S3 sweeps when operated for 100 h. Wear rate was more during initial hours of working up to 40 h and it reduced when further operated for 60 h for all the sweeps in abrasive sand. Gravimetric wear increased linearly with increase in operational time, depth and speed of operation in soil. However, depth of operation resulted in more wear as compared to speed of operation [40].

Methods to reduce wear

There are different methods are available for reducing wear by modifying surface of wear bodies. Out of which important and effective methods those have been studied, are detailed below:

Quenching and heat treatment

Abbas and Alwan[41] were analyzed the effect of quenching media on the mechanical properties and abrasive wear resistance of steel blade (34cr4) with the soil texture was used as like as agricultural lands. It was observed that the wear resistance increases with increase in hardness. Hardness of blade was increased with varying quenching media as follows; 38HRC, 56.6 HRC, 58.3 HRC and 60.6 HRC for as–received sample, caustic Soda(10%),engine oil and flaxseed oil respectively. It was also observed that the wear resistance increases with decreasing toughness to values 48.3J, 45J, 40.2J and 27J respectively. From this study, it was found that wear resistance depends upon the hardness, toughness and mechanical properties such as microstructure which consists of martens tic structure and some amount of carbide particles.

Singh *et al*. [42] studied the work effect of heat treatment under changeable applied load on wear response of agricultural grade medium carbon steel. The treatments were SAE-6150 steels has undergone different heat treatment processes like Control 86% pearlite and remaining ferrite annealed 80 % pearlite and remaining ferrite Inter-critical annealing 85% tempered marten site and remaining ferrite quenching & tempering. After study it was observed that under low load (75N) condition, both the inter-critically annealed and quenched and tempered SAE-6150 medium carbon steels gave identical wear resistance. Although, inter–critically annealed material under medium load (200N) condition and quenched and tempered material under high load (375N) condition exhibited more in terms of abrasive wear resistance.

Shot peening

Sharma and Modi [43] conducted a study on effect of shot peening and metal-spraying on abrasive wear of carbon steel. The treatments used in this study were virgin sample (SAE-1022), virgin and shot peened, virgin and coated with material-1 (*i.e*. self fluxing alloy of Ni-Cr-Fe-3-6), virgin and coated with material II (*i.e*. ceramic material which is a combination of Al2O3 - Ti02), virgin and coated with material III (*i.e*. super performance stainless steel), virgin, coated with material I and again shot peened, and actual blade material sample (En42).

The results shows that the mass wear of the virgin blade (SAE-1022) was the maximum of 6.25 percent followed by virgin - shot peened (5.84 percent), virgin - coated with stainless steel (0.9802 percent), virgin coated with ceramic material (0.07127 percent), virgin-coated with self fluxing alloy (0.06728 percent) and virgin-coated with self fluxing alloy and again shot peened (0.03217 percent).

The use of ceramic materials (alloy of Al2O3 - Ti02) for coating in this study has also improved surface hardness and reduced wear considerably. Similarly, the use of stainless-steel coating has also increased the surface hardness, improved wear resistance but it was not as harder as the other coating material so its wear is pronounced than other coating materials. Effect of shot peening on low stress abrasive wear behaviour of SAE-6150 steel at various intensities varying from 0.17A to 0.47A was studied by Singh *et al*. [44]. It was concluded that abrasive wear test on un-peened and peened specimens by dry sand abrasion tester revealed that shot peening reduced abrasive wear considerably, when it was restricted up to 0.17A, but over peening led to higher abrasive wear rate. In critical period, the peened and un-peened samples exhibited comparable wear rate. This phenomenon indicates that peening was required on regular interval to maximize wear resistance. It was also observed that the wear rate decreased with sliding distance irrespective of peening intensities and applied loads. It increases monotonically with increase in applied load, irrespective of peening intensity. Study suggested that this technology would be useful for manufacturer of agricultural implements in India, due to its simplicity and cost effectiveness.

Thermal spray coating

Effect of enamel coating on the performance of a tractor drawn rotavator was examined by Salokhe*et al*. [45]. In this study the power requirement and quality of work of uncoated and enamel-coated tines was compared under similar working conditions.

The effect of enamel coating on the power requirement; maximum saving in power of 22 percent was obtained at 1.5 km/h speed during the first pass of enamel-coated tines compared to that of uncoated tines.

It was also observed that the power requirement of the enamel-coated tines was higher than the uncoated tines in the second pass, but it gave better soil inversion, the quality of work in terms of bulk density, cone index and mean weight diameter of soil mass were almost the same for both tines and soil inversion by enamel coated tines was higher than the uncoated tines by 30 and 50% during the second and third pass, respectively. This study was concluded that rate of wear of enamel coated tines was found to be less than that of the uncoated tines.

Murthy and Venkataraman [46] worked on abrasive wear behavior of WC–Co Cr and Cr3C2 20(Ni Cr) deposited by HVOF and detonation spray processes.

Abrasive wear tests were conducted using a three-body solid particle rubber wheel test rig using silica grits as the abrasive medium. The results indicate that DS coating performs somewhat better than the HVOF coating possibly due to the higher residual compressive stresses induced by the DS coating and WC-based coating has higher wear resistance in comparison to Cr3C2-based coating. Also, the thermally sprayed carbide-based coatings have excellent wear resistance with respect to the hard chrome coatings.

Mruthunjaya and Parashivamurthy [47] conducted microstructural study and tribological behavior of Wc-co coatings on stainless steel produced by HVOF spray technique. WC-Co coating was developed on the stainless steel AISI 304 by HVOF spray technique. It was observed that tungsten carbide (WC) coatings exhibit high wear resistance at low and high temperatures and WC - Cobalt coatings has demonstrated anti-resistive and wear characteristics better than those of conventional materials. The study concluded that service life of the WC-Co coatings depended on varying compositions of tungsten and cobalt. The grain size of WC varied in three ranges of 10-40µm, 15-63µm and 45-90µm. WC coatings exhibit increased in hardness and resistance to wear. It was also concluded wear rate of tungsten carbide of sample C mesh size (45 to 90 µm) is less compare to two remaining samples by considering different loads.

Electro spark coating

Johnson and Sheldon [48] conducted study on advances in the electro spark deposition coating process. It was stated that The ESD process is a pulsed arc micro -welding process that can apply metallurgically bonded coatings with such a low heat input that the bulk substrate material remains at or near ambient temperatures. It eliminates thermal distortions or changes in metallurgical structure of the substrate. When properly applied, the ESD coatings can provide exceptional wear and damage resistance to materials that otherwise would be subject to galling or excessive wear or friction. The process may also be used to modify surface compositions of materials for a variety of other applications. Electro-spark coating with special materials was introduced by Verbitchi*et al*. [49]. It was examined that the electro-spark coating is a deposition process, with consumable electrodes used were made of stainless steel, nickel, other metals, sintered tungsten carbide, metal-ceramics or ceramics. The results of this study showed that the thickness of the coating is 0.01…0.5 mm, there is no distortion of the base metal and the operator has full control on the process, the deposition rate depends on the power of the device (0.160-1.6 kVA).Krzysztof *et al*. [50] conducted study on Microstructure of electro-spark coatings for sliding friction pairs. The objective of this study was to investigate the microstructure of coatings made from bearing alloys on the bronze substrate. It was stated that this process is used for slide bearing bushings to improve break-in parameters.

Conclusion

Wear resistance of rotavator bladecan be increased by heat treatment of substrate material and by the surface modification techniques.

Material hardness, abrasive particle size, moisture content, length of abrasive path, speed and normal load play significant role on abrasive wear of soil working elements.

Application of review: Several researches have also suggested surface modification techniques like electro deposition, shot peening, vapour deposition, diffusion coating, hard facing and thermal spraying for wear resistance.

Research Category: Farm Machinery & Power Engineering

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