Advantages of Shot Peening on Abrasive Wear Resistance of Agricultural Grade Steel

Dushyant Singh[1] (LM- 10222), D.P. Mondal[2], V.K. Sethi[3] and A.C. Saxena[4] (LM- 10284)

ABSTRACT

During field operations, agricultural implements are subjected to fatigue and abrasive wear, as a result these implements (components of implements) required frequent replacement, which add to implement running cost as well as down time. Various surface modification techniques have been used to overcome the wear situation of agricultural implements. Of this, shot peening operation is carried out being a very fast and cheap surface treatment technique. Agricultural grade steel (medium carbon) was taken for assessing the wear response in dry sand and field. Surface modification was done using shot peening operation at various peening intensities varying from 0.17A to 0.47A at an interval of 0.1A. The study revealed that the wear resistance improved considerably at mild peening (0.17 A), but further increase in peening intensity led to formation of cracks at surface and sub-surface level that decreased the wear resistance. The study further suggests that the soil working components should be re-shot peened after a certain sliding distance (1.7 km) at 200 N load for better abrasive wear response.

Keywords: *Agricultural implements, Abrasive wear, Steel, Field operations, Bulk and Surface Treatments*

INTRODUCTION

Most of the agricultural implements are used in soil for various unit operations and during the operation, these are subjected to fatigue and abrasive wear, as a result these implements (components of implements) required frequent replacement which add to implement running cost as well as down-time. Wear (loss of material from a surface by means of some mechanical action) is a quite common phenomenon in components of agricultural implements that is responsible for more energy consumption and lowering overall performance and efficiency. The improvement in wear resistance of components of the agricultural implements using various techniques is necessary to increase their service life as long-lasting agricultural implements can provide many advantages to the farmers like greater productivity, seeding in optimum conditions, uniform ploughing, less fuel consumption etc. Because it has been reported that wear reduces the efficiency of farmers and costing huge loss of money (Ferguson, et al, 1998).

Various surface modification techniques have been used to overcome the wear situation of agricultural implements. Enamel coatings are also used in agricultural implements for reducing draught force, avoiding soil sticking and improving scouring and minimizing wear (Salokhe and Gee–Clough 1988; Salokhe et al 1991). Of this, shot peening imparts a small indentation or dimple to the surface due to bombardment with small spherical particles called shots. Over lapped dimples develop a more or less even layer of material experience with residual compressive stresses (Anonymous, 2005) because of the cold working induced on the surface (Fouvry, et al 2006). This technique is being used in automobile industries to increase their fatigue strength vis – a-vis performance including weight saving (LidaKisuke 1996 and Kumar, 2001).

In India, majority of manufacturers of critical

[1, 2, 4] Central Institute of Agricultural Engineering, Bhopal – 462 038, [3]Director, UIT, Rajeev Gandhi Proudyogiki Vishwavidyalaya, Bhopal

components of agricultural implements are using used leaf springs to make these components as this is generally made of medium carbon low alloy steels and available at very cheaper rate. Singh and Saxena (2008) reported that medium carbon steels were being used by 55% manufacturers followed by high carbon steel (27%), mild steel (12%) and high carbon tool steel (6%) for making fast wearing components of agricultural implements. Although medium carbon steels could attain very good combination of mechanical and tribological properties but these steels are used without treatment or improper treatments, which leads to more wear. Rautaray and Sharma (1996) reported that the surface properties of 0.18% carbon steel being shot peened after carburizing, hardening and tempering has been found to be comparable to that of bulk material properties of 0.78% carbon steel, giving better cost effectiveness. Rautaray (1997) also found that the fatigue and wear life of shot peened specimens (rotavator blade) exhibited much longer than the unpeened specimens. Saxena and Sharma (2001) reported that the wear resistance (thresher pegs) to relative cost ratio was 1.77 in bulk harden shot peened compare to bulk harden low carbon steel.

Keeping the advantage of shot peening operation to improve surface properties of medium carbon steel, a study was conducted in laboratory on medium carbon (SAE 6150) steel used in making components of agricultural implements.

MATERIAL AND METHODS

The investigated steel (SAE-6150) contains 0.52 wt.% C, 0.22 wt.% Si, 0.70 wt.% Mn. The chemical analysis of the steel was carried out using SPARK MET. The microstructure of the specimens was examined in a Scanning Electron Microscope (SEM). After polishing the specimen, hardness was measured in a Vickers Hardness Tester using a load of 30 kg. Further, polished specimens were shot peened using shot of 0.6 mm dia (Mec Shot, Jodhpur make machine) at varying peening intensities (0.17A, 0.27A, 0.37A and 0.47A). 'ALMEN A' strips were used to calibrate the peening intensity under selected test parameters. The principal of shot peening operation is depicted in Fig. 1. DUCOM, Bangalore, India, make rubber wheel dry sand abrasion test rig was used for measuring low stress abrasion wear at 200 N load as per ASTM G-65. The specimen surface was cleaned with acetone prior to and after each test interval. The wheel was rotated at a fixed speed of 1.86 m/s and moved up to a distance of 2.592 km. During tests, wear rate of the specimen was measured at a regular interval of 144 m of sliding distance. The wear rate was calculated from the weight loss measurement. The data obtained in laboratory were compared with the data obtained in field for operation of duck foot sweep made of similar steel to get the benefit of this operation (shot peening).

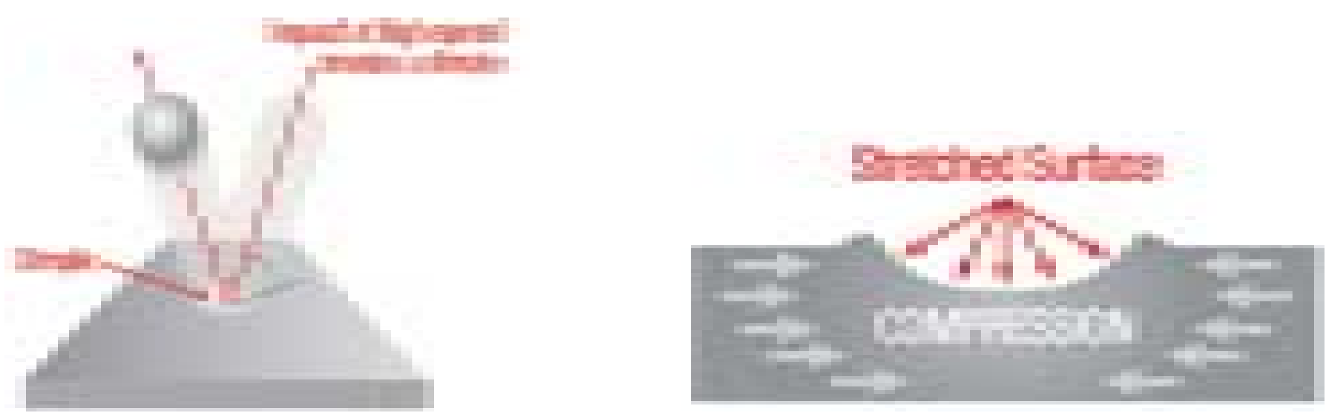

Fig. 1. Principal of Shot peening operation.

RESULT AND DISCUSSION

The micro-structure of steel was found combination of ferrito-pearlitic structures, i.e, 85%pearlitic colonies with 15% ferrite net work. The normal impact of the shots over the specimen surface formed the dents and refined the micro-structure. The leaps formed due to extrusion of materials between the dents (shots in action). In addition, due to continuous impact of shots over the specimens, some of the previous dents/leaps suffered from impact and thus hapes of the dents/leaps are distorted.

Reduction in contact area during wear due to formation of leaves around the dents, improvement in surface hardness and development of residual compressive stresses at the surface are the factors led to improvement in wear resistance. But as the peening intensity increased the material at surface and sub surface level got brittle, a large number of micro dents and cracks formed on the surface. Due to formation of cracks less energy is needed for removal of material during abrasion test, this led to reduction in wear resistance at higher peening intensities and some times wear resistance of peened specimen may be less than that of un-peened material.

All above mentioned properties (work-hardening, micro-structural refinement and the expected residual stress) may lead to increase in the surface or subsurface hardness. The maximum hardness of the specimen improved about 80% (from 150 to 270 Hv i.e. 190, 215, 240 and 270Hv respectively when peened at 0.17A, 0.27A, 0.37A and 0.47A respectively) due to shot peening operation, but it is only up to a certain depth i.e. 400 µm in this study.

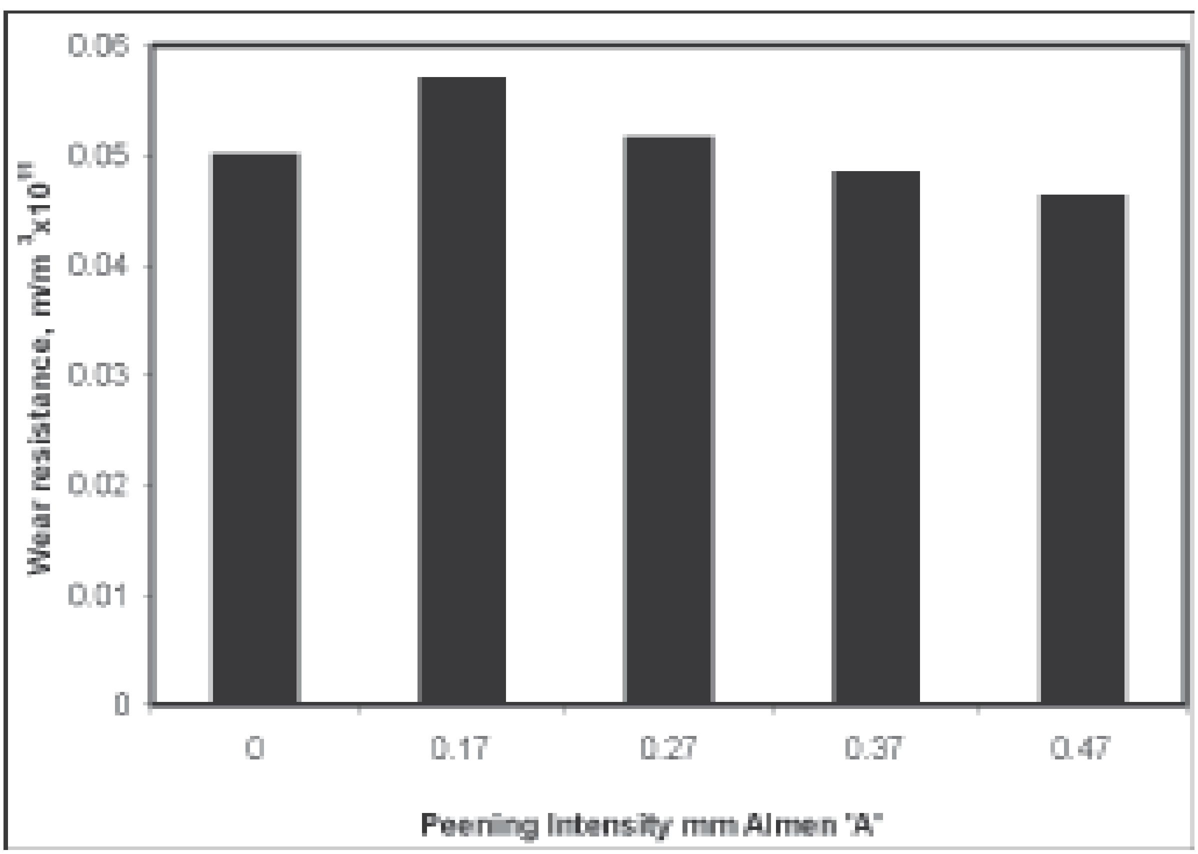

Fig. 2. Variation of wear resistance with peening intensity.

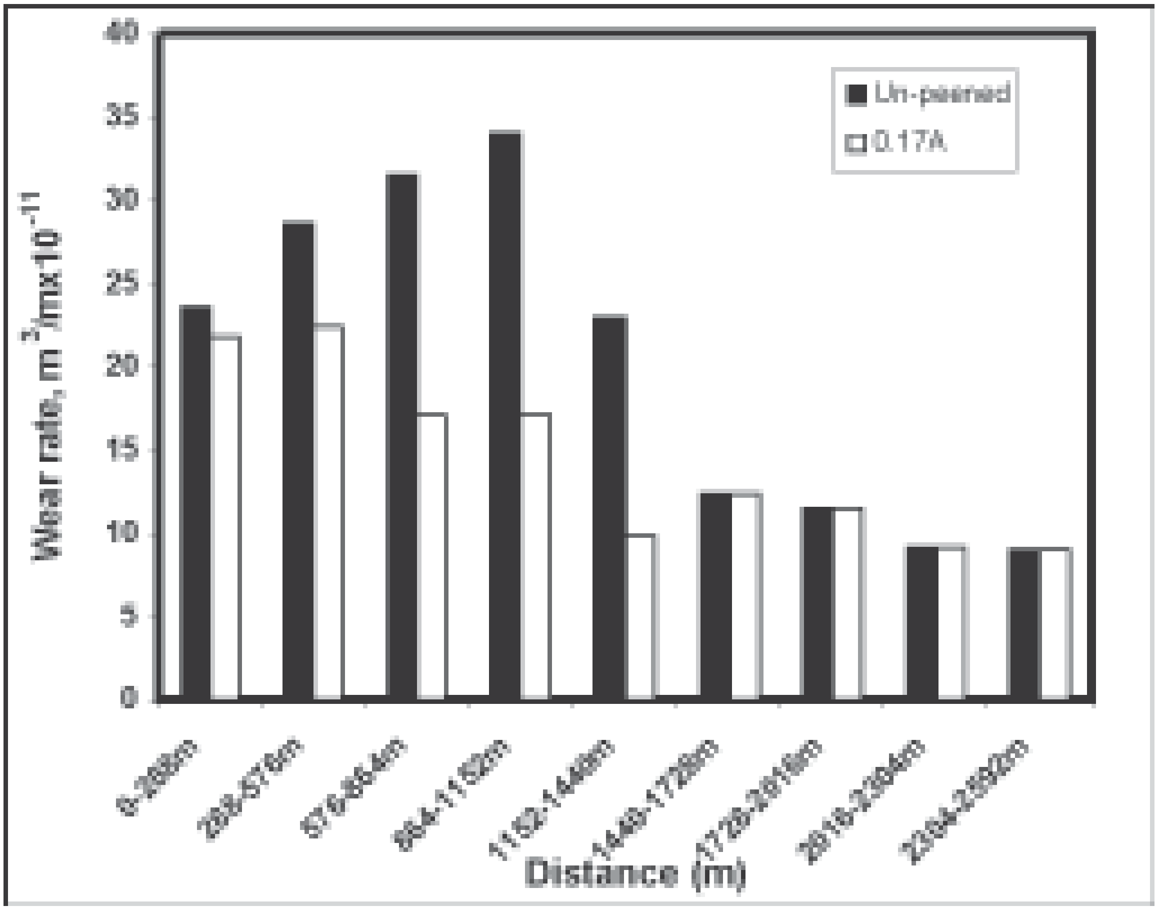

Fig. 3. Effect of sliding distance intervals on wear rate.

Effect of Peening Intensity and Sliding Distance on Abrasive Wear Resistance

The effect of shot peening on abrasive wear resistance is shown as bar chart in Fig. 2. It is revealed from this figure that the wear resistance of the up-peened steel is around $0.05 x 10^{11}$ m/m^3. This could be improved to $0.0575 x 10^{11}$ m/m^3 due to peening to the extent of 0.17A. The data signified around 15% wear resistance due to shot peening. It is also clear from the figure that further increment in peening intensity led to continuous decrease in abrasive wear resistance. At 0.27 A peening intensity, the wear resistance is marginally higher than that of un-peened specimen. As the peening intensity further increased to 0.37A and 0.47A, the trend of wear resistance was towards decreasing. This is in agreement of the work done in China (Yan, Fang, Sun and Xu 2007).

For better understanding of the wear response of shot peened steel, the wear rate at each interval for the investigated samples was compared (Fig. 3). The Fig. 3 shows the wear rate of unpeened and peened samples (at 0.17 A) at different intervals. It was noted from this figure that the wear rate of shot peened sample in the initial intervals was significantly less than that of the unpeened samples. In later intervals, the difference in the wear rate amongst the peened and unpeened samples reduced and after a critical distance of ~1.7 km both the peened and unpeened samples exhibited almost same wear rate at each proceeding interval. This signified that the effect of shot peening towards wear response becomes inactive after a sliding distance of ~1.7 km. This further suggested that the overall improvement in the wear rate of shot peened samples was due to significant influence of peening

Table 1: Benefits of shot peening on duck foot sweep in field.

S. No.	Treatment type	Weight loss (g)	Relative wear resistance (R)	Costing (Rs.) (Sweep+HT+P)	Relative cost ratio (C)	Benefit in life extension (R/C)
1	Commercially available sweep	273	1.00	210	1.00	1.00
2	Shot peened sweep	246	1.10	210+6=216	1.02	1.08

in the initial stages of the wear which causes considerable decrease in the wear rate in the initial sliding period due to peening. In fact, a critical depth from the peening surface of the specimen got subjected to plastic deformation during peening and the influence of peening was limited to this depth only. After a certain distance (~1.7 km in the present study) the layer influenced by the shot peening got completely removed and thus, beyond this sliding distance, even the shot peened samples behaved similarly to the unpeened samples. This further suggested that in order to have continuous improvement in the wear resistance the materials could be shot peened intermediately during their operation. Commercially available duck foot sweeps (made of EN-45 steel containing 0.53%C, 1.7%Si, 0.79% Mn, 0.049% S and 0.017% P) were shot peened and tested for ploughing 50.12 ha in 109.45 h. The benefit obtained using shot penning technique is given in Table 1.

CONCLUSIONS

Following conclusions can be obtained from this study:

- Shot peening increased the hardness of the specimen (SAE 6150) from 150 Hv to 270 Hv but the maximum wear resistance was obtained at the hardness value of 190 Hv.
- The optimum peening intensity for maximum wear resistance was 0.17A for laboratory (SAE-6150) as well as in field tests (EN-45).
- Shot peening operation improved the wear resistance of medium carbon steel by 15% in laboratory tests for SAE-6150 steel and 10% for EN-45 in field condition.
- Based on laboratory data, the material could be re-shot peened intermediately after 1.7 km of its operation for getting continuous improvement in the wear resistance.
- Thus, shot peening is a simple and economic technique that can be adopted for soil engaging components of agricultural implements.

REFERENCES

Ajit Jain, 2001. Generalization of shot peening applications In: Sharma, M.C., editor, Shot Peening and Blast Cleaning, Proceeding of International Conference on Shot Peening and Blast Cleaning, *MACT, Bhopal*, India: 264-268.

Annonymous, 2005. Shot peening applications. Metal Improvement Company, Inc., Subsidiary of CURTISS Corporation Wright, http://www.metalimprovement.com/peening_process.php, Status 10th Aug. 2005.

Ferguson, S. A., Fielke, J.M. and Riley, T.W. 1998. Wear of cultivator shares in abrasive South Australian soil. Journal of Agricultural Engineering Research, 69: 99-105.

Fouvry, S., Fridrici, V., Langlade, C., Kapsa P. and Vincent, L. 2006. Palliatives in fretting: A dynamical approach. Tribol. Int., 39 (10), 1005-1015.

LidaKisuke 1996. Historical aspect of shot peening. In: Sharma, M.C. and Rautraray, S.K., editor, Proceeding of international conference on shot peening and blast cleaning, MACT, Bhopal, India, 26-29.

Rautaray, S.K. and Sharma, M.C. 1996. Appropriate shot peening technology for agricultural equipment. In: Sharma, M.C. and Rautraray, S.K., editor, Proceeding of international conference on shot peening and blast cleaning, *MACT, Bhopal*, India: 174-179.

Rautaray, S.K., 1997. Fatigue and wear characteristics of shot peened rotavator blade materials. Un-Published Ph.D. Thesis, Faculty of Engineering, *Barkatullah* Vishwavidyalaya, *Bhopal*, India : 60-61.

Salokhe, V.M. and Gee–Clough, D. 1988. Coating of Cage wheel lugs to reduce soil adhesion. *J. Agric. Engng Res.,* 41**,** 201-210.

Salokhe, V.M., Gee-Clough, D. and Tamtomo, P. 1991. Wear testing of enamel coated rings. *Soil & Tillage Research,* 21: 121-131.

Saxena, A.C. and Sharma, M.C., 2001. Wear of shot peened thresher pegs. In: Sharma, M.C., editor, Shot Peening and Blast Cleaning, Proceeding of International Conference on Shot Peening and Blast Cleaning, *MACT, Bhopal*, India: 281-287.

Singh, D and Saxena A. C, 2008. Status of metallurgical techniques practiced by agricultural machinery manufacturers for fast wearing components in India. Agricultural Engineering Today. Vol. 32(3) pp 17-20.

Yan, W., Fang, L., Sun, K. and Xu, Y., 2007. Effect of surface work hardening on wear behaviour of Hadfield steel. Materials Science and Engineering, A 460-461, 542–549.