SHOT PEENING TO REDUCE FATIGUE AND WEAR IN TILLAGE IMPLEMENTS

Rautaray SK and Sharma MC
MACT, Bhopal, India

ABSTRACT

The work presented in this paper describes the effect of shot peening on fatigue and wear characteristics of low carbon steel being carburised, hardened and tempered. A comparison was made of the results obtained through two methods of surface treatments on a low carbon steel and of the specimen with similar blade material. The investigation mainly addressed to findout the percentage improvement in fatigue strength, fatigue life and wear resistance of the specimen with surface work hardened layer induced by shot peening. The results showed that the specimens being shot peened after carburising, hardening and tempering have given improved fatigue and wear performance with overall economy as compared to other treatments tested in the study.

KEY WORDS

Fatigue, Wear, Carburising, Hardness, Economy

INTRODUCTION

Critical components of tillage equipment are either those coming into direct contact with the soil or some vital parts of a mechanism. The former are exposed to abrasive wear and sometimes impact, therefore, requiring certain level of hardness to be wear resistant but at the same time in order to withstand impact those have to have adequate toughness. The later are exposed to adhesive wear impact and fatigue which require certain level of hardness, toughness and fatigue resistance. The consequences of impact, fatigue and wear are serious in terms of both replacement cost (parts, labour and down time) and its effect on timeliness of field operations. Several investigators [Moore (1) and Richardson (3)] have reported that for a given material the amount of wear decreases when its hardness exceeds to that of abrasives. Despite the importance of hardness a compromise with toughness is also needed to avoid excessive impact damage. Therefore, the materials used in tillage equipment require strength and toughness to resist distortion and impact and hardness to resist fatigue and wear.

In general steels used for tillage equipment are often costly although they possess adequate strength and toughness but those have been found much softer than soil abrasives and so have poor fatigue/wear resistance. Since extremes of hardness and toughness are incompatible in a single material by the process of heat treatment alone a combination of treatments such as carburising, hardening, tempering and shot peaning have been carried out for an optimal compromise which would provide possibly a solution to reduce wear, impact and fatigue failure. Further with these treatments on a low grade low cost steel the required mechanical properties may be achieved which may not necessiate use of costly steels for manufacture of tillage equipment. The current work [Rautaray (2)] is aimed at widening the application of shot peening in agricultural equipment to reduce cost during manufacturing and to reduce the risk of damage due to wear, impact and fatigue during field operation.

The scope and objective of this paper is to findout the effect of shot peening on fatigue and wear characteristics of carburised-hardened-tempered low grade steel for manufacture of rotavator blades.

MATERIALS AND METHODS

Wear is mainly due to abrasion where as impact and fatigue are due to loading conditions. The factors which lead to wear, impact and fatigue on rotavator blades can be broadly classified as soil factor, material factor and physical/operating factor. Soil factors include compactness of soil, soil temperature, scouring property, crop roots, trash etc. These factors since very complex were kept constant as far as possible. Physical/operating parameters include shape, sharpness, angle of approach, and speed of operation and these were maintained in the test setup simulating quite closely to real field conditions. The material factors such as chemical composition, method of heat treatment and hardness are considered important ones which affect the performance of blades. The treatments applied to specimen, test set up developed and experimentation followed are described as follows:

Fatigue testing machine

Fatigue tests in bending with rotation was carried out. The specimen was fastened at one end by the machine grip such that a cantilever bending moment was applied through the bearing to the critical section of the specimen. As the specimen rotated at constant speed (2880 rpm) the stress in a point on its surface changed sign twice during one rotation. The stress however attained maximum value at the critical section where fracture occured.

Wear test setup

A wear test setup was developed to move the blade specimens in a circular path under controlled conditions, (Table 1). The mean radius of path followed by the blades was measured and corresponding to the rpm of the blade holder, the average speed of operation was measured to be 2.3 Km/h. Standard river sand being graded $\leq$ 2.36 mm was used in the test. Average depth of sandbed was kept 100 mm. The blades were operated at a depth of 50 mm.

Table 1 **Brief specification of wear test setup**

Sl. No.	Components	Particulars
1.	Sand / soil tank	Shape : Circular Dia at outer wall (mm) = 500 Height of wall (mm) = 150 Thickness of wall (mm) = 04
2.	Electric motor	3-phase, 1 hp, 1440 rpm
3.	Gear reduction unit	Worm and Gear, ratio 01:42
4.	Blade holding fixture	No.2 (each with 2 blades), rpm= 34
5.	Compaction cum covering roller	No.2, Dia(mm)= 260, Width (mm)= 66, Weight (kg)= 35

Test specimen

Fatigue test specimens (Fig.1a) were prepared as per standard dimensions. The dimensions of wear test specimen are shown in Fig.1(b). Both the specimens were prepared with similar surface finish (average roughness of the centre line, Ra varied from 0.5 to 1.2 μm. The chemical composition and mechanical properties of the test specimens are given in the following table.

Table 2 **Chemical composition and mechanical properties of test specimens**

Element	C	Si	Mn	P	S
% in fatigue sample	0.18	0.32	0.83	0.014	0.026
% in wear sample	0.19	0.30	0.81	0.017	0.022
% in actual blade	0.67	0.29	0.80	0.016	0.030

Mechanical Properties	Fatigue sample	Wear sample	Actual blade
UTS, Mpa	577.79	632.30	1004.20
Y.S., Mpa	231.13	223.18	185.95
% Elongation	10.17	7.74	1.20
Hardness, HRC	30.00	33.10	51.80

Heat treatment of specimen

After machining, the specimens were carburised at 930 degree C for 4 h, then taken out and directly quenched in water. Finally the specimens were tempered at 350 degree C for 30 min. The average surface hardness values after being heat treated were found to be HRC 43.2 and HRC 44.8 for fatigue and wear specimens, respectively. The average depth of carburising layer was found to be 0.65 mm. The microstructure of the surface layer were found to be martensite and retained austenite.

Shot peening of specimens

Syphonic type pneumatic shot peening machine was used for peening the test specimens. Saturation curves were established on Almen `A' strip to determine peening intensity and peening time. The peening parameters employed are given in Table 3.

Table 3 Shot peening parameters employed

Sl. No.	Parameters	Value
1.	Compressor air pressure, Mpa	0.589
2.	Nozzle diameter, mm	6.000
3.	Stand off, mm	80.000
4.	Shot size, mm	0.825 (S-330)
5.	Shot hardness, HRC	45
6.	Angle of peening, degree	90
7.	Average mass flow rate, Kg/h	350
8.	Peening time, Sec.	30
9.	Peening intensity, mm `A'	0.25
10.	Coverage, %	98-100
11.	Surface roughness before peening (Ra), μm	0.75
12.	Surface roughness after peening, (Ra, μm	1.30

Experimental design

The fatigue and wear specimens were tested for the following treatments

T1	Virgin (as received)
T2	Virgin - Shot peened (0.25 mm `A'
T3	Carburised - Hardened - Tempered
T4	Carburised-Hardened-Tempered - Shot peened (0.25 mm `A')
T5	Actual / similar blade material

Experimental procedure

For fatigue testing, after calculating load for unit bending stress the specimens were loaded at different stress levels. The life of the specimen at a given stress level was measured in terms of number of cycles to failure considering 10000000 cycles is the maximum limit. When the specimen did not fail within 10000000 cycles it was then taken as survived. Based on above, median fatigue limit was estimated as per ASTM STP 731

For wear testing, the test blades being cleaned were weighed and their dimensions measured. The blades were then fitted to the fixtures randomly and allowed to run in a sand bed. After 100 h of run the blades were takenout, cleaned, weighed and their dimensiosn measured.

RESULTS AND DISCUSSION

Fatigue behaviour

The summary of fatigue test results is given in Table 4.

Table 4 Fatigue strength and fatigue life of test specimens

Treatments	Fatigue strength		Fatigue life (cycles	
	Median estimate, Mpa	% improvement over virgin	Stress level, Mpa	Relative improvement, %
T1	225.24	-	235.75	-
T2	289.38	28.48	235.75	499
T3	370.03	64.28	324.16	302
T4	527.39	129.78	412.56	1785
T5	436.34	93.72	491.15	384(-)

The results showed that there have been considerable improvement of fatigue strength in T4 as compared to virgin. Further by virtue of shot peening at 0.25 mm `A' the improvement in fatigue strength has been found to be 42.52% over T3 and 20.86% over T5. Comparing the improvements in fatigue life, it was found that the life of the specimens have increased significantly even at higher stress levels by virtue of combination treatments. When compared to T5 at 491.15 Mpa the improvement in fatigue life was found to be 384% more in T4 and justified the beneficial effect of shot peening.

Wear characteristics

Percentage mass wear and volume wear of blades in sand bed for different duration of test run are given in table 4 and 5, respectively. It was found that mass wear in T1 was the maximum followed by T2, T3 and T4, respectively. Similar trend was observed for hourly % mass wear and % mass wear per Km of run.In other words the reduction of % mass wear in T4 over T1, T2 and T3 were found to be the lowest after each test runs of different durations. Further comparing the results of T4 with T5, it can be seen that % mass wear has been found to be decreased after each test run which may be due to the benefits of shot peening after carburizing, hardening and tempering the surfaces. In general % mass wear has been found to be increased with time of run in each treatment. However, in T4 the rate of increase was found to be the lowest more specifically at the initial stages, as compared to other treatments tested in the study. Analysis of the results of the dimensional wear (Table 5) show that, loss in Vol. was the least in T4 as compared to T1, T2 & T3 after each test run of different durations and it was found to be advantageous even over the volume wear of actual blade specimen (T5).

Table 4 Mass wear of test blades in sandbed

Sl. No.	Treat-ment	Initial mass of blades, g	% mass wear after 24 h of run	% mass wear after 48 h of run	% mass wear after 72 h of run	% mass wear after 96 h of run
1.	T1	55.23	1.47 (0.061) [0.026]	5.28 (0.110) [0.047]	8.46 (0.117) [0.051]	11.95 (0.124) [0.054]
2.	T2	54.14	0.86 (0.035) [0.015]	5.08 (0.105) [0.046]	7.84 (0.109) [0.047]	11.18 (0.116) [0.050]
3.	T3	52.95	0.51 (0.017) [0.007]	3.12 (0.065) [0.028]	6.21 (0.086) [0.037]	10.64 (0.110) [0.048]
4.	T4	52.86	0.12 (0.005) [0.002]	2.24 (0.047) [0.020]	4.14 (0.057) [0.025]	6.26 (0.065) [0.028]
5.	T5	53.98	0.44 (0.018) [0.007]	3.08 (0.064) [0.027]	6.16 (0.086) [0.037]	9.04 (0.094) [0.040]

() : Figures show hourly percentage wear on mass basis
[] : Figures show percent wear on mass basis per Km of run

Table 5 Volume wear (mm^3) of test blades in sand bed

Sl. No.	Treat-ments	Initial dimensions (mm)			% Vol. wear after different test run (h)			
		L	W	T	24	45	72	96
1.	T1	48.60	31.10	5.40	6.64	16.42	22.81	25.89
2.	T2	48.65	31.14	5.42	5.62	15.46	20.68	24.56
3.	T3	47.80	31.52	5.20	4.38	80.96	12.46	15.36
4.	T4	47.80	31.64	5.35	3.16	6.42	10.92	12.42
5.	T5	47.85	31.54	5.86	3.88	7.92	11.84	13.38

Economics of shot peening

Economic comparison between low carbon steel with combinations of treatments and high grade steel (actual/similar blade material) were made. The unit cost of specimens were calculated considering the costs in different treatments and purchase price of steels. The low carbon steel after being carburised, hardened, tempered and shot peened (0.25 mm `A') was found to be economical as it could save 67.2% cost when compared to costly high grade steel.

Discussion

The improved performance of shot peened surface may be attributed due to the fact that the microstructure on the surface layer of specimen which were carburised - hardened - tempered - shot peened turned to be finer than those which were only carburised - hardened and tempered. Due to the work hardened layer induced by shot peening the dislocation density could possibly increased which resulted in surface hardening effect. The surface layer of specimen being shot peened after carburising - hardening - tempering became shot peening work hardening layer and its average surface hardness has been found to be raised to HRC 53.6.

CONCLUSIONS

Shot peening of blades after carburising - hardening - tempering offered great potential for increasing fatigue strength and fatigue life and for reducing the severity of abrassive wear in soil engaging components due to formation of shot peened surface work hardened layer.

Low carbon steel with combination of treatments has been found to be advantageous in terms of overall life and economy as compared to costly high grade steels.

REFERENCES

1. Moore MA and Kings FS, *Abrasive wear of brittle solids,* Wear, 60, 123-140, 1980.

2. Rautaray SK, *Fatigue behaviour of shot peened power blades used in agricultural machinery*, Ph.D. Research, Deptt. of Mech. Engg., MACT, Bhopal, India, 1992.

3. Richardson RCD, *The wear of metals by relatively soft abrasives,* Wear, 11, 245-275, 1968.

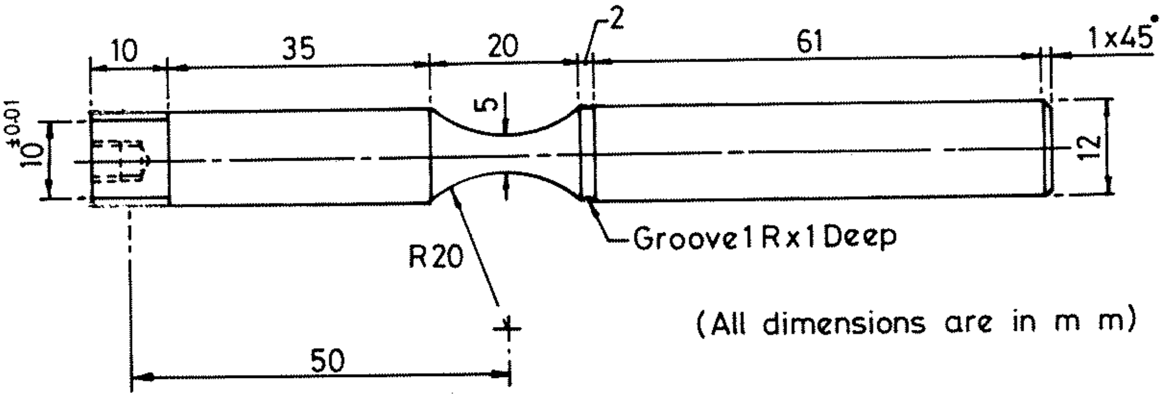

Fig.1(a) Fatigue specimen for round samples

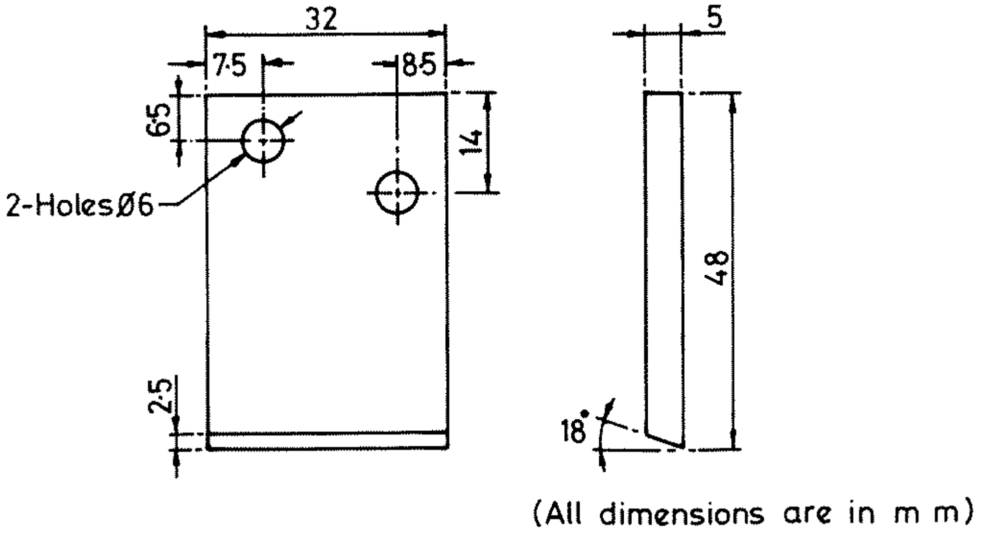

Fig. 1(b) Wear test specimen