A STUDY OF CONTROLLED PEENING PARAMETERS ON THE PROPERTIES OF MACHINED SURFACES

M. L. Neema and P. C. Pandey

Department of Mechanical and Industrial Engineering, University of Roorkee, Roorkee-247 672, India

ABSTRACT

This paper describes the results of controlled peening tests performed on 0.5% C steel workpieces. It has been found that peening results into better surface finish, hardness and low coefficient of sliding friction along with higher load carrying capacity.

KEYWORDS

Controlled peening, surface roughness, rebound surface hardness, response surface, dynamic coefficient of friction, oil retention property.

INTRODUCTION

Majority of working surfaces, for use in machines, are produced by conventional and unconventional metal removal processes. However, such processes often lead to certain types of surface alterations, such as plastic deformation of thin surface layer, tears, laps, recrystallization, phase transformation, micro and macro cracks, inducement of residual stresses etc. Increasing demands for high performance components have prompted the production engineers and metallurgists to develop improved tool materials and better processing techniques. Heat-treatment, burnishing,peening, shot peening are few of the methods that have been successfully used to improve the surface conditions for achieving better functional properties.

In this paper the authors have employed ball peening under controlled conditions on a turned surface. Peening parameters viz., peening frequency, ball diameter, force, feed and number of passes have been varied to study the changes in properties in respect of surface roughness and hardness. Experimental design technique known as response surface methodology, due to Box and Wilson (1951), has been employed to plan the experimental programme.

MATHEMATICAL MODELLING

From the experimental data obtained, it/possible to derive a second order response surface equation of the following form:

$$y_u = b_o + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ii} x_i^2 + \sum_{i<j} b_{ij} x_i x_j \qquad (1)$$

where y_u is the response of k variables and $b_o, b_1, \ldots$ etc. are the coefficients to be evaluated by the method of least squares from

$$b = (X'X)^{-1} X'Y \qquad (2)$$

where X is the matrix of independent variables and Y is the column matrix of logarithmic values of the observed response. The adequacy of the response eqn.(1) can be tested by standard F test.

PLANNING OF EXPERIMENTS

In order to plan the experiments for five variables, a central composite rotatable design (Box and Hunter, 1957) has been used. The levels of the variables are obtained from the logarithmic transforming eqn.(3)

$$x = \frac{2(\ln V - \ln V_{+1})}{\ln V_{+1} - \ln V_{-1}} + 1 \qquad (3)$$

where V_{+1} and V_{-1} are the chosen values of any variable V at +1 and -1 levels respectively.

Table 1 shows the scheme of experimentation from which the matrix X can be obtained (Peng,1967). Table 2 shows the range of parameters selected.

TABLE 1 Scheme of Experimentation

x_1	x_2	x_3	x_4	x_5	x_1	x_2	x_3	x_4	x_5	x_1	x_2	x_3	x_4	x_5	x_1	x_2	x_3	x_4	x_5
-1	-1	-1	-1	1	-1	-1	-1	1	-1	-2	0	0	0	0	0	0	0	0	-2
1	-1	-1	-1	-1	1	-1	-1	1	1	2	0	0	0	0	0	0	0	0	2
-1	1	-1	-1	-1	-1	1	-1	1	1	0	-2	0	0	0	0	0	0	0	0
1	1	-1	-1	1	1	1	-1	1	-1	0	2	0	0	0	0	0	0	0	0
-1	-1	1	-1	-1	-1	-1	1	1	1	0	0	-2	0	0	0	0	0	0	0
1	-1	1	-1	1	1	-1	1	1	-1	0	0	2	0	0	0	0	0	0	0
-1	1	1	-1	1	-1	1	1	1	-1	0	0	0	-2	0	0	0	0	0	0
1	1	1	-1	-1	1	1	1	1	1	0	0	0	2	0	0	0	0	0	0

TABLE 2 Range of Controlled Peening Parameters

Variables	Levels in coded form				
	-2	-1	0	+1	+2
x_1, Feed, mm/rev	0.07	0.10	0.14	0.20	0.28
x_2, Frequency, Hz	780	900	1040	1200	1385
x_3, Force, kgf	2.83	4.00	5.65	8.00	11.30
x_4, Ball dia., mm	6.35	9.52	12.70	15.87	19.05
x_5, No. of passes	1	2	3	4	5

EXPERIMENTAL WORK

Experimental work, consisting of a total of 32 observations was carried out on 0.5% C steel rods 75 mm in diameter and 600 mm long. These were turned to an initial surface roughness of approx. 3.3 μm CLA. Peening was done with the help of a specially designed device (Fig.1). It consisted of a cast iron base plate supporting a variable speed electric motor, an eccentric hub and a ring, and a sheave capable of providing variable throw to the peening head attached to the sheave. The peening ball, made of hardened steel (60 Rc) and ground to a high degree of finish was held against a strong spring. The whole assembly was mounted on the rear side of the cross-slide of a HMT Centre Lathe.

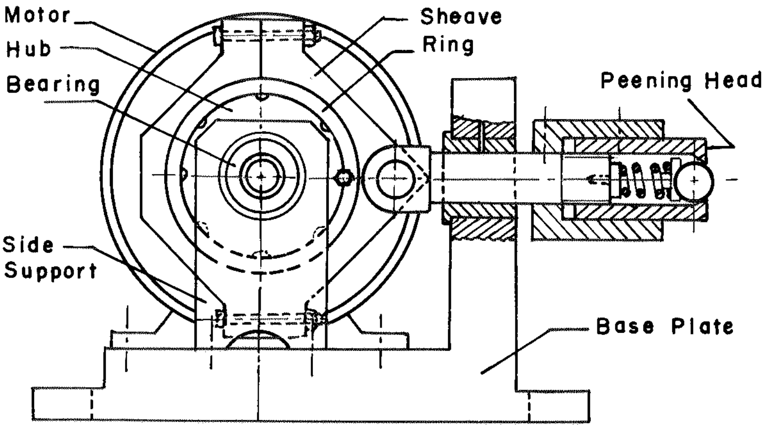

Fig. 1. Controlled peening device

For each test a length of 30 mm was peened and surface roughness value was measured with the help of Talysurf Model-10. For surface hardness measurement, a steel ball weighing 6 gmf was suspended as a pendulum of length 215 mm. The ball was allowed to hit upon the treated surface through an angle of swing of 78°. The number of rebounds as proposed by Herbert (Lessells, 1954) that the ball makes before coming to rest was taken as a measure of surface hardness. Table 3 shows the observations in respect of surface roughness and hardness.

TABLE 3 Observations

S.No.	CLA	H	S.No.	CLA	H	S.No.	CLA	H	S.No.	CLA	H
1	2.25	83	9	2.4	97	17	2.0	91	25	1.8	87
2	3.2	81	10	2.5	100	18	3.0	94	26	1.8	107
3	2.3	81	11	1.6	110	19	2.2	100	27	1.5	100
4	3.1	103	12	2.8	93	20	1.6	106	28	1.6	96
5	2.2	95	13	2.1	110	21	2.0	98	29	1.5	95
6	2.6	105	14	2.0	98	22	1.3	118	30	1.6	98
7	1.6	108	15	1.6	96	23	2.0	90	31	1.5	102
8	2.1	102	16	1.8	106	24	2.0	101	32	1.7	95

Initial Surface Roughness = 3.3 μm (CLA), Initial Hardness = 65 H

RESPONSE EQUATIONS

From the data, the regression coefficients in eqn.(1) were calculated using eqn.(2) and the response surface eqns.(4) and (5) obtained for

$$
\begin{aligned}
y=&0.442783+0.107086x_1-0.077005x_2-0.110106x_3-0.046251x_4-0.021284x_5\\
&+0.12501x_1^2+0.058348x_2^2+0.020479x_3^2+0.074327x_4^2+0.047987x_5^2+0.04603x_1x_2\\
&-0.046448x_1x_3-0.02627x_1x_4+0.027319x_1x_5-0.037963x_2x_3-0.007977x_2x_4\\
&-0.019182x_2x_5+0.011498x_3x_4+0.039638x_3x_4-0.0121x_4x_5 \qquad (4)
\end{aligned}
$$

$$
\begin{aligned}
y=&4.58423+0.007517x_1+0.018242x_2+0.047233x_3+0.033749x_4+0.05247x_5\\
&-0.016558x_1^2+0.010249x_2^2+0.02113x_3^2-0.00914x_4^2-0.00599x_5^2+0.007069x_1x_2\\
&-0.002586x_1x_3-0.02645x_1x_4-0.0003x_1x_5-0.01356x_2x_3-0.02064x_2x_4\\
&+0.0177x_2x_5-0.0351x_3x_4-0.00504x_3x_5-0.00122x_4x_5 \qquad (5)
\end{aligned}
$$

surface roughness and hardness respectively.

FRICTION FORCE MEASUREMENT

In order to get an idea of the coefficient of friction, friction force measurement during rolling contact can be carried out(Rabinowicz, 1966). In the present case, the dynamic coefficient of sliding friction for the peened workpieces was measured by means of a setup shown in Fig.2. In this case the sliding contact between test bodies was localised so that sliding occurs over a very narrow track. The friction coefficient obtained in this manner, is however, valid for lightly loaded systems only. The friction force, for the normal load applied was measured by compression of a spring and a calibrated dial gage.

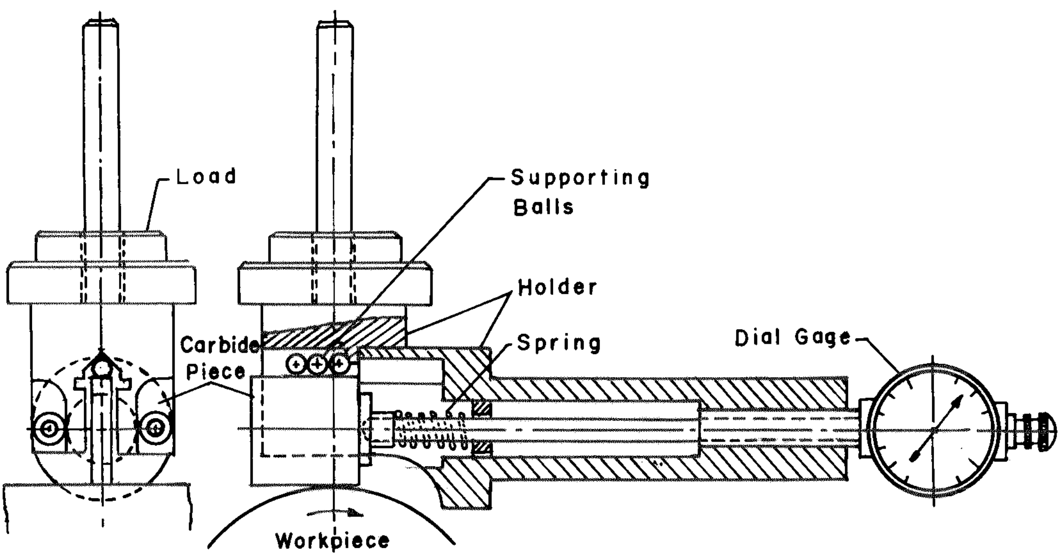

Fig.2. Friction force measuring device

RESULTS AND DISCUSSION

Figures 3 and 4 show the plots of eqn.(4) for feed and force only for different levels of process parameters indicated thereon. In these Figs. other parameters were fixed at zero level. It has been found that controlled peening, in general, leads to an improvement in surface finish for all levels of the peening parameters except with high feed or low force and high peening frequency. It can be seen that optimum peening frequency in majority of the cases lies in the range of 1050 to 1150 Hz for all levels of feed, force, ball dia. and number of passes. However, minimum surface roughness of the order of 1.5 μm CLA has been found with a feed rate of 0.14 mm/rev, 11.3kgf force, using 12.7 mm diameter ball with 3 or 4 number of passes.

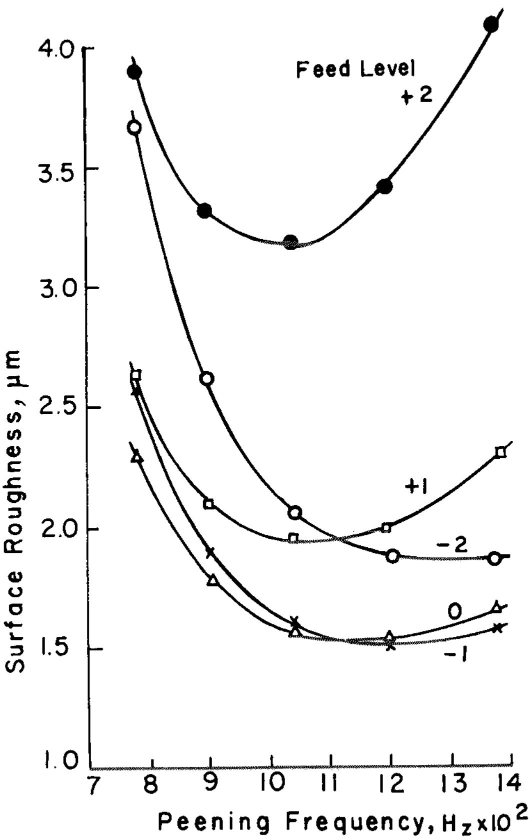

Fig. 3.

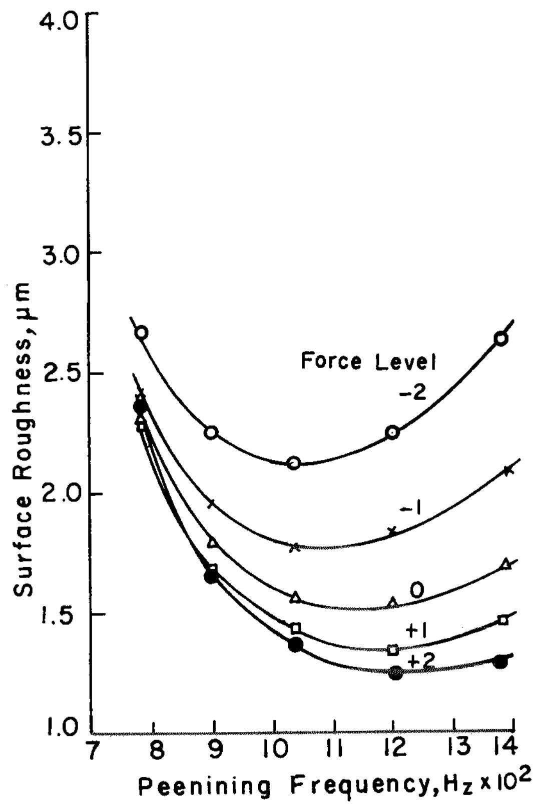

Fig. 4.

Similarly Figs. 5 and 6 were plotted from eqn.(5). A general improvement in surface hardness has been found to occur for all feeds and increasing peening force. From the point of view of finish and surface hardness, it has been observed from the analysis of data that in the present case a feed of 0.14 mm/rev, 11.3 kgf peening force with a ball of 12.7 mm diameter and higher number of passes at a peening frequency of 1150 Hz gives best results.

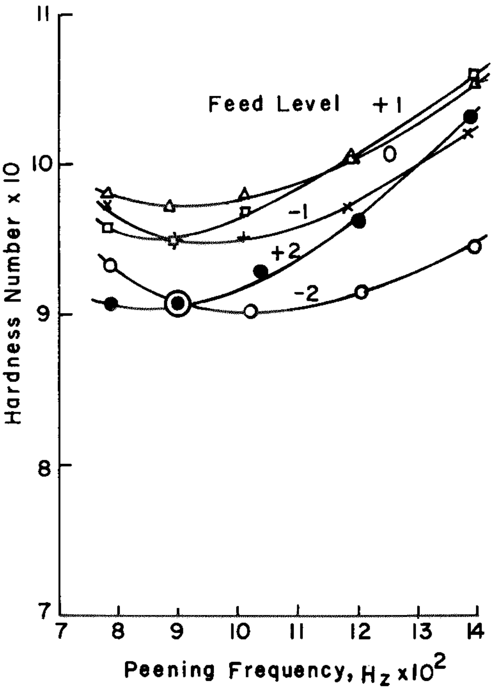

Fig. 5.

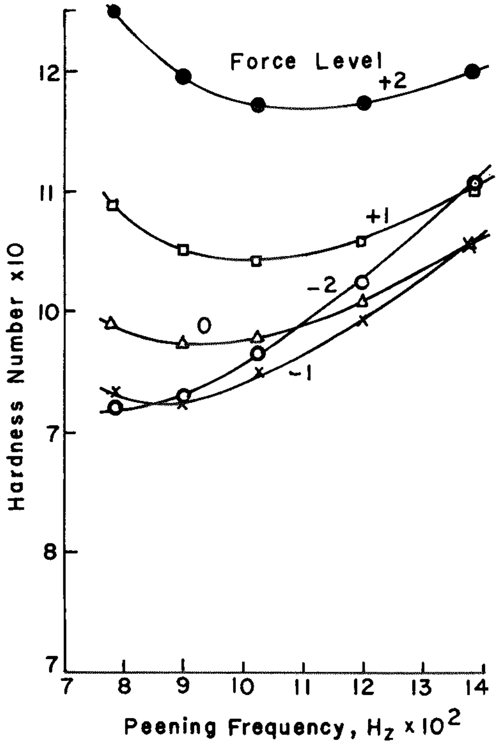

Fig. 6.

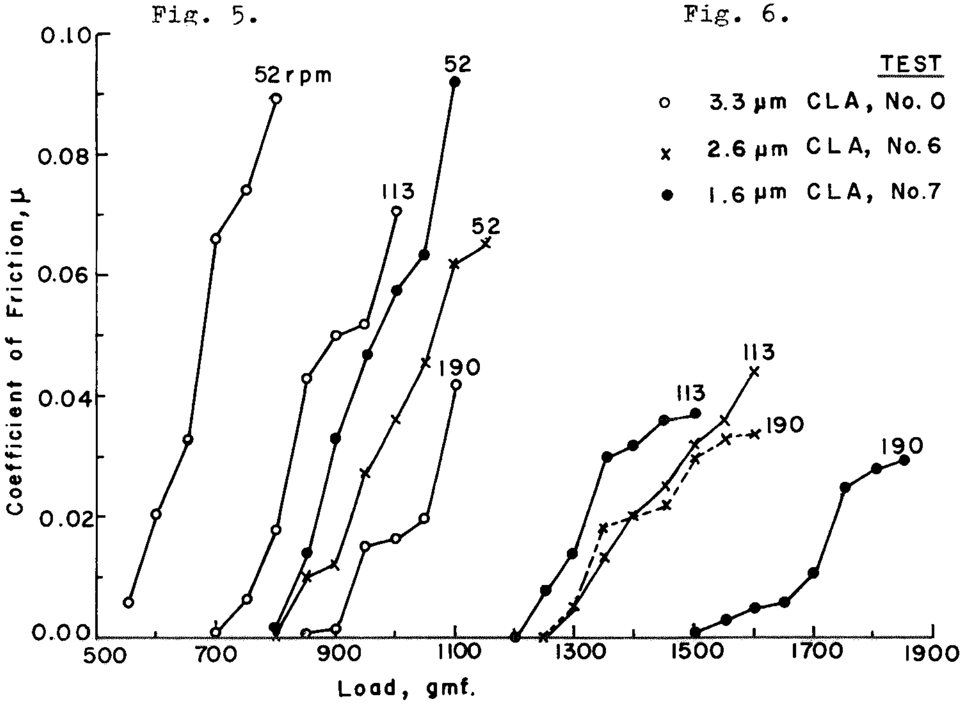

Fig. 7.

Figure 7 shows the results obtained from the friction force measuring device, using flood lubrication (SAE 30 Oil) at different speeds. It can be noticed that increase in rubbing speed and a decrease in surface roughness results into better load carrying capacity. This can be attributed to better oil retention properties even with smooth surfaces (Shneider, 1972) which is a special feature of this process.

CONCLUSIONS

Results show that controlled peening can be successfully employed as a post machining operation for improving surface characteristics of the machined components. In such an operation micro and macro surface irregularities are deformed plastically resulting into better surface finish, better surface hardness and improved friction characteristics. For the range of process parameters selected for experimentation in the present case a peening frequency of 1050 to 1150Hz with a ball diameter of 12.7 mm gives best results.

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