Experimental Evaluation of Optimum Performance Parameters for Burnishing of Spur Gear

Milind Kulkarni[1] Ninad Dombre[2] Hrushikesh Vibhute[3] Ashutosh Kannawar[4] Prashant Karande[5]
[1]Professor
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]SKNCOE, Savitribai Phule Pune University-411041

Abstract— Out of the many available processes for surface finishing like honing, lapping, shaving, grinding the most economic and effective process is burnishing. Burnishing does not remove material from the work piece, it simply takes the material from the peaks and fills it into the valleys. Thereby reducing the average height of micro peaks and valleys present on the surface. This is exactly what reduces the average surface roughness of the burnished surface. This paper studies the burnishing process for gears. An experimental setup for burnishing of gears has been developed. Using the setup, gears of 50 mm diameter and 2.5 mm module were burnished. While burnishing the gears, the burnishing motor speed and the time of burnishing was varied, effect of variation of these two parameters on burnishing process has been studied in this paper. The optimum parameters for burnishing of spur gears obtained through experimentation have been put forth.

Key words: Experimental Evaluation, Spur Gear

I. INTRODUCTION

Gears are the most important elements of power transmission systems. Gears need to be smooth i.e. they need to have high surface finish in order to transmit power at minimum frictional losses. One of the cheapest methods to achieve a good surface finish is burnishing. Burnishing has been successfully implemented for finishing plane surfaces and cylindrical surfaces. This paper aims at applying the burnishing phenomenon to spur gears. In this paper, a gear burnishing setup has been developed. An experimental analysis of gear burnishing process has been put forth. The paper also gives the optimum parameters for burnishing of spur gears.

II. BURNISHING PRINCIPLE

Burnishing works on the principle of localized yielding. As we all know there is no perfectly plane surface in nature. All the surfaces have irregularities in the form of peaks and valleys when observed at micro level. In burnishing, hard roller is pressed and rolled over the surface to be burnished this causes stresses to generate in the surface. We adjust the burnishing conditions so that the stresses generated exceed the yield point and make the material deform plastically .This is called localized yielding. Because of localized yielding the material from the peaks flows into the valleys giving a smoother surface. This phenomenon is also applicable to gears. When a hard gear is rotated in mesh with soft gear at specific conditions, soft gear gets burnished. Burnishing also causes stain hardening of gears. Increasing its wear resistance and life.

III. GEAR BURNISHING

A. *Experimental Setup*

Main components of the setup are

1) Hard gear
2) Test gear
3) Bearings
4) Electric motor
5) Pneumatic cylinder

- Hard Gear: The hard gear is mounted on the motor. It is made up of heat treated plain carbon steel having hardness of 55 HRC .The gear has 20 teeth with the module of 2.5 mm.
- Test gear: The test gear is a mild steel gear with 20 teeth and 2.5 mm module. It is mounted on a vertical shaft supported in two bearings with the help of holding plates as shown in fig. 4.1. The test gear along with the bearing and the shaft is attached to end of the piston.

B. *Burnishing Setup Working*

As stated above, the gear burnishing setup works on the principal of localized yielding. For this yielding to take place the stresses exceeding the yield point of test gear material must be generated in the surface. This job is done by the motor, the motor while rotating the gears applies tangential force (Pt) on the test gear. The force responsible for burnishing of the gears is the normal force (Pn) which acts perpendicular to the tooth flank and acts along the pitch line of the gears.

IV. CALCULATIONS

For burnishing to take place properly, this force Pn must be properly adjusted. And from the force vector diagram of a general spur gear we know,

Normal force (Pn) =tangential force (Pt)/cosα (1.1)

Where α is the pressure angle of the gears i.e 20°.

Now using Hertz theory for contact stresses, we can calculate the tangential force required for burnishing .The contact stress needed to be generated should be equal to the yield strength of test gear material. In our experiment the test gear is made of mild steel, hence Syt= 250 MPa

According to hertz theory,

$$\sigma c^2 = \frac{1.4Ft}{bQDpsin\emptyset * cos\emptyset[\frac{1}{Ep}+\frac{1}{Eg}]} \quad (1.2)$$

Equation (1.2) gives the contact stresses generated between the two gears. Here the values in the formula are as follows

Width (b) = 10mm
Tooth factor (Q) = 1
Pitch circle diameter (Dp) = 50mm
Pressure angle (α) = 20°

Modulus of elasticity of test gear (E1) = 210Gpa
Modulus of elasticity of hard gear (E2) = 210Gpa

And σc is the contact stress that needs to be generated which is 250 MPa.

By putting these values in the equation (1.2), we get the required tangential force that needs to applied

After putting the values and calculating, we get tangential force (Ft) = 68.23 N.

The tangential force is to be supplied with the help of a motor. Hence a motor with accurate power rating needs to be chosen.

The required torque to be provided by the motor is given by-

Torque (T) =tangential forec (Ft)*pitch diameter (Dp)/2. (1.3)

When we substitute values, we get,

Torque (T) = 1.705 N-M

The estimated speed required for burnishing is roughly 600 rpm.

Hence a motor providing a torque = 1.705 newton-meter (N-M). at 500 rpm is to be chosen. From the equation (1.4) we calculate the required power of the motor as -

Power (P) = 2*π*burnishing speed in rpm(n)*torque(T)/60 . (1.4)

we put the values (1.4) we get the motor capacity of 90 Watts.

For taking care for the frictional losses at bearings, motor with a higher capacity of 150 Watts has been chosen.

V. FIGURES AND TABLES

For the experimental evaluation of optimum process parameters for gear burnishing, first the roughness readings for unburnished gears were taken. As the roughness value for each gear before burnishing was significantly different than the other specimen gears, each gear had to be tested before and after burnishing for its roughness value. To study the effect of burnishing speed on the surface finish of a gear, readings of % improvement in surface finish with variation in burnishing speed were taken. The speeds ranging from 100 rpm to 500 rpm i.e from 15.7m/min to 80m/min were taken into consideration. Similarly to study the effect of burnishing time on surface finish of a gear, % improvement in surface finish with respect to time of burnishing was observed. The burnishing time was varied from 1 min to 5min and the readings obtained are as follows.

Following table shows the readings taken after 4 min of burnishing at the corresponding speeds.

Burnishing speed (m/min)	Roughness (Ra) (before burnishing)	Roughness (Ra) after burnishing	% improvement in surface finish
15.7	1.240	.748	39.71
32	.886	.457	48.42
47	.598	.282	52.85
64.3	1.329	.517	61.11
70.3	.866	.360	58.39
79.2	1.458	.631	56.73

Table 1 Burnishing Readings After 4 Min

Burnishing speed(m/min)	After 1 minute of burnishing	After 2 minute of burnishing	After 3 minute of burnishing	After 4 minute of burnishing	After 5 minute of burnishing
	%improvement in surface finish				
15.7	20.12	28.71	35.75	39.71	40.29
32	24.18	35.36	38	48.42	46.35
47	30.19	39.78	45.87	52.85	53.26
64.3	36.33	45.13	53.48	61.11	61.03
70.3	35.52	43.81	51.03	58.39	60.37
79.2	34.18	42.95	49.5	56.73	58.76

Table 2: % Improvement In Surface Finish W.R.T. Variation In Burnishing Speeed

The graph of % improvement in surface finish with respect to speed of burnishing has been plotted below. Here X axis denotes the burnishing speed.

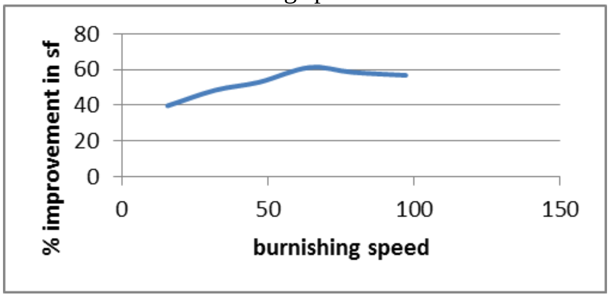

Fig. 1: Improvement in surface finish w.r.t burnishing speed

The plot shown above corresponds to the readings taken after 4 min of burnishing.

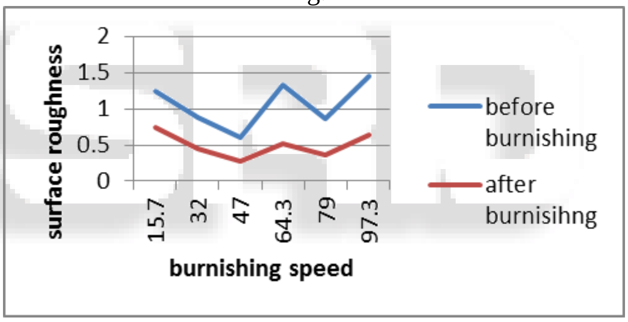

Fig. 2: Surface roughness before and after burnishing

Above plot shows the roughness readings of test gears before and after burnishing. The increasing improvement w.r.t. speed can clearly be seen.

The following plot shows the variation of improvement in surface finish w.r.t. time of burnishing.

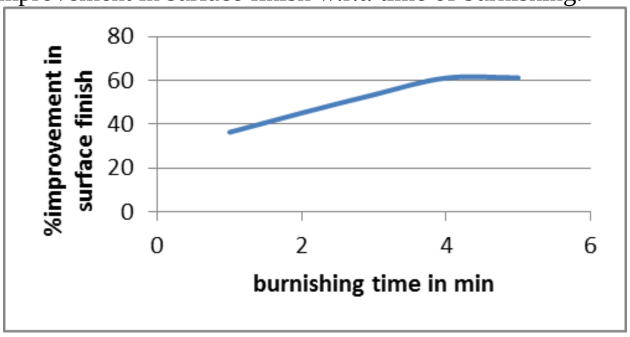

Fig. 3: graph of improvement in surface finish w.r.t. time of burnishing.

The image shown below is the gear burnishing setup developed. The image shows the pneumatic cylinder on which the test gear has been mounted, in mesh with the test gear is the hard which has roughness value of 0.157. the hard gear is heat treated plain carbon steel gear with hardness value increased to 55 HRC. The hard has been mounted on a high torque dc motor which is located directly below the hard gear. (not visible in the setup below).

Fig. 4: Experimental Setup for Gear Burnishing

VI. Results and Discussion

Burnishing was carried out from a speed ranging from 100 rpm to 500 rpm, this speed in rpm has been converted into m/min for better understanding and interpretation of the results. Also, the time for which burnishing was done, varies between 1min to 5 min.

As can be seen from tables I and II provided, that the % improvement in surface finish increases with the increase in burnishing speed and time. At smaller speeds and time periods of burnishing the improvement in surface finish is comparatively smaller, but as we increase the speed and time of burnishing there is considerable improvement in the surface finish. At the speed 64.3 m/min and 4 minutes of burnishing highest improvement in surface finish of 61.11 % was observed.

Thereafter any increase in burnishing speed does not give any appreciable improvement in surface finish. After 64.3 m/min of burnishing speed if we increase the speed further the % improvement decreases due to tooth slippage and higher impact. Similarly any increase in the time of burnishing after 4 min does not give special results because the already burnished surface tends to get strain hardened after 4 min hence it does not response to any further burnishing.

VII. Conclusion

From the experiment it is concluded that the burnishing speed affects the surface roughness value directly. At 64.3m/min maximum improvement in surface finish was observed, so it can be concluded that the optimum range of burnishing speed is between 60-65m/min. When burnishing is done at this speed for approximately 4 min maximum increase in surface finish of 61.11 % is observed. Similarly with increase in time of burnishing the surface finish improves up to a point, after that decreases. The improvement in surface finish of gears leads to reduced power transmission losses and lower noise levels. Burnishing also improves the hardness of gears through work hardening.

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