INTERNATIONAL JOURNAL OF APPLIED ENGINEERING RESEARCH, DINDIGUL
Volume 1, No 4, 2011

RESEARCH ARTICLE ISSN - 0976-4259

The effect of roller burnishing on surface hardness and surface roughness on mild steel specimens

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ABSTRACT

Roller burnishing tool is used for the experimental work of the present study on a specially fabricated mild steel specimen. In roller burnishing, a hard roller is pressed against a rotating cylindrical work piece and parallel to the axis of the work piece. Burnishing is essentially a cold forming process, in which the metal near a machined surface is displaced from protrusions to fill the depressions. In the present work, various experiments are conducted to investigate the effect of burnishing force and number of tool passes on surface hardness and surface roughness of mild steel specimens. The results show that improvements in the surface roughness and increases in surface hardness were achieved by the application of roller burnishing with mild steel specimens. The results are presented in this paper. Roller burnishing produces better and accurate surface finish on Aluminum work piece in minimum time. Roller burnishing is an economical process, where skilled operators are not required. This process can be effectively used in many fields such as Aerospace Industries, Automobiles Manufacturing sector, Production of Machine tools, Hydraulic cylinders, etc.

Keywords: Roller burnishing, dynamometer, surface roughness value R_a, burnishing force, burnishing speed, surface hardness and mild steel.

1. Introduction

Roller burnishing helps users to eliminate secondary operations for substantial time and cost savings, while at the same time improving the quality of their product. Roller burnishing is a method of producing an accurately sized, finely finished and densely compacted surface that resists wear. Hardened and highly polished steel rollers are brought into pressure contact with a softer work piece. As the pressure exceeds the yield point of the work piece material, the surface is plastically deformed by cold- flowing of subsurface material.

A burnished surface is actually smoother than an abrasively finished surface of the same profilometer reading. Profilometers measure roughness height. Abrasive metal removal methods lower the roughness height. But, they leave sharp projections in the contact plane of the machined surface (Murthy R. L., 1981). Roller burnishing is a metal displacement process. Microscopic "peaks" on the machined surface are caused to cold flow into the "valleys", creating a plateau-like profile in which sharpness is reduced or eliminated in the contact plane. The burnished surface will therefore resist wear better than the abraded surface in metal-to-metal contact, as when a shaft is rotating in a bushing.

There are two types of burnishing processes. i. Ball burnishing and ii. Roller burnishing. The ball materials are hardened alloy steel, carbide, diamond, etc. The roller material is hardened alloy steel. In this paper, experiments with Roller burnishing tool are presented. Residual compressive stresses are induced on the surface of the burnished components, which results in fatigue resistance and improvement in wear resistance quality (Shneider, 1967). The schematic of Roller burnishing process with indication of residual stress conditions developed by the process is shown in Figure 1.

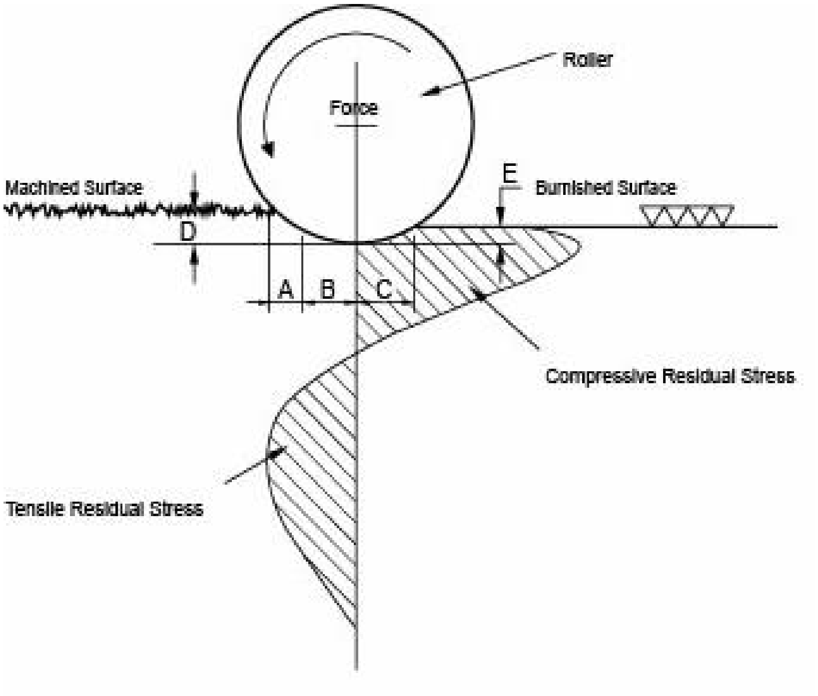

Figure 1: Schematic of Roller burnishing process.

Wear has important technological and economical significance because it changes the shape of the work piece, and the tool and the interference. Burnishing is considered as a cold working process which can be used to improve surface characteristics. Surface roughness and hardness plays an important role in many areas and is factor of great importance for the functioning of machined parts. The effects of ball and roller burnishing on the surface roughness and hardness of some non- ferrous metals were presented by many researchers (Hassan, A. M., 1997). Investigations of surface roughness and hardness on titanium alloy using a roller burnishing tool were carried out by many authors and the results were presented (Thamizhmnaii, S., 2008). Research work has been carried out to investe the surface roughness produced by Ball burnishing, with varying burnishing parameters (Loh, N. H., 1991). Discussions on the application of experimental design in ball burnishing has been presented by many scientists (Loh, N. H., 1993). It was suggested by many investigators that an improvement in wear resistance can be achieved by burnishing process.

2. Practical Applications of Roller Burnishing

Roller burnishing was first applied in American industry in the 1930s to improve the fatigue life or railroad car axles and rotating machinery shafts. By the 1960s, roller burnishing was more widely applied, particularly in the automotive industry, as other process advantages were recognized. The primary benefits, related to part quality, are as follows:

- ✓ Accurate size control (tolerances within 0.0005 inch or better, depending on material types and other variables).
- ✓ Surface finished (typically between 1 to 10 micro inches R_a).
- ✓ Surface hardness (by as much as 5 to 10 % or more).

Roller burnishing has long been used on a wide variety of automotive and heavy equipment components (construction, agricultural, mining and son on), including piston and connecting rod bores, brake system components, transmission parts and torque converter bubs. Burnishing tools are also now widely applied in non-automotive applications for a variety of benefits; to produce better and longer-lasting seal surfaces; to improve wear life; to reduce friction and noise levels in running parts; and to enhance cosmetic appearance. Examples include valves, pistons of hydraulic or pneumatic cylinders, lawn and garden equipment components, shafts for pumps, shafts running in bushings, bearing bores, and plumbing fixtures.

2.1 Advantages of Roller Burnishing

1. Roller burnishing is a faster, cleaner, more effective and more economical method of sizing and finishing parts to exacting specifications.
2. Fantastic Mirror like surface finish.
3. Consistent dimensional tolerance and Repeatability.
4. Single pass operation offers very less cycle time.
5. Increases the surface hardness of components.
6. Reduces the reworks and rejections.

2.2 Materials and Method

2.2.1 Roller Burnishing Tool

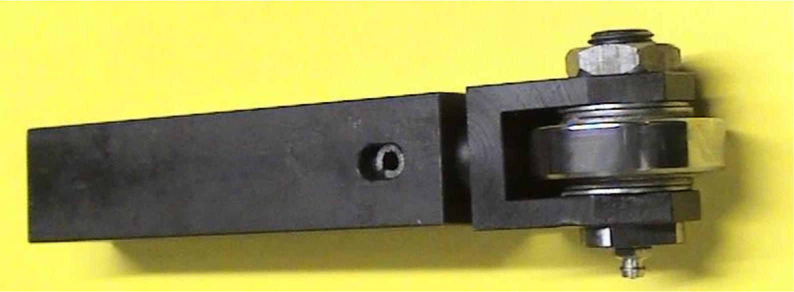

Figure 2: Roller burnishing tool assembly.

The Roller burnishing tool used is shown in Figure 2. It consists of the parts, such as Roller, Special bolt, Nut, Bush, Washers and Shank. The shank is fixed in the dynamometer and it is tightened with two bolts. The Roller has got the following chemical composition: Fe 97.003, Si 0.18, Mn 0.26, Ni 0.12, Cr 1.44, C 0.99, S 0.007. The Roller has the following properties. Surface roughness value R_a = 0.12 µm, Hardness = 61 HRC.

2.3 Experimental Setup

The Roller burnishing tool is fixed on the Lathe. The experimental set up is shown in Figure 3. It consists of the following parts. 1. Three jaw chuck 2. Live center 3. Dead center 4. Mild Steel work piece 5. Roller Burnishing tool 6. Dynamometer fixed to the cross slide of Lathe 7. Hand wheel for cross slide 8. Input power to the Dynamometer ix. Strain indicator. Figure 4 shows Roller burnishing operation on lathe.

2.4 Test Specimens

Burnishing experiments are conducted on turned mild steel work piece, which is ductile and available commercially in the form of round bars. The mild steel work piece is specially fabricated, as shown in Figure 5. All the dimensions are shown in millimeters in the figure. First, the work piece is held in 3- jaw chuck of lathe and facing operation is completed on both sides and centre drilling is completed on both the faces. Then, the work piece is held in between centers of lathe and it is driven through the lathe dog. A high speed steel (H. S. S.) single point cutting tool is fixed in the tool post of the lathe and work piece is turned to have 6 steps and grooves in between them. In actual experiments, by applying different parameters on each step, this long work piece can be utilized as 6 different work pieces.

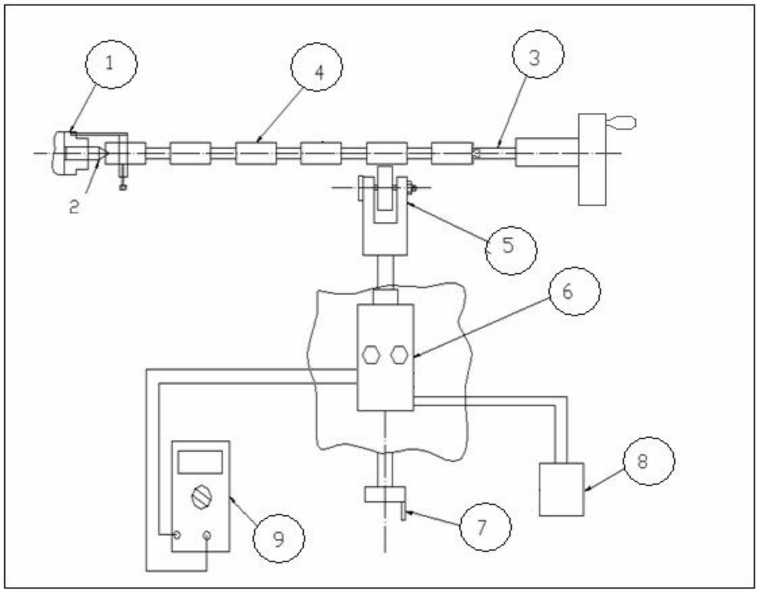

Figure 3: Experimental set up of Roller burnishing operation on lathe.

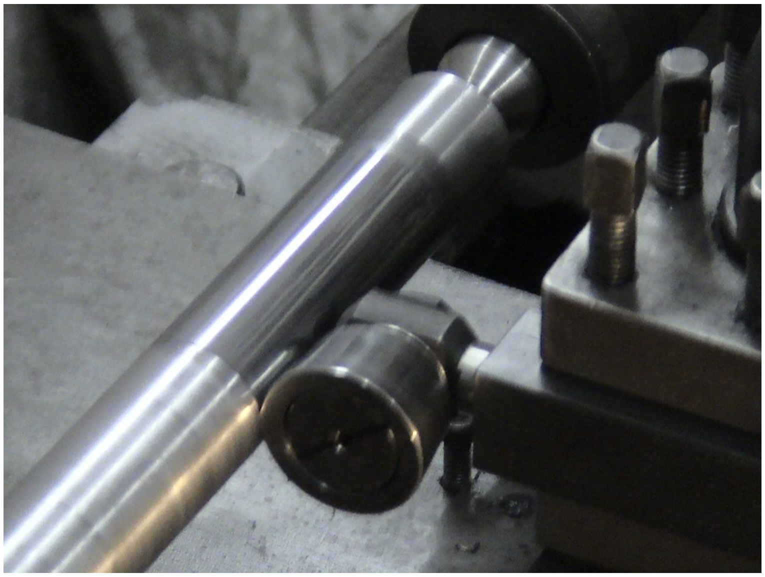

Figure 4: Roller burnishing operation on lathe.

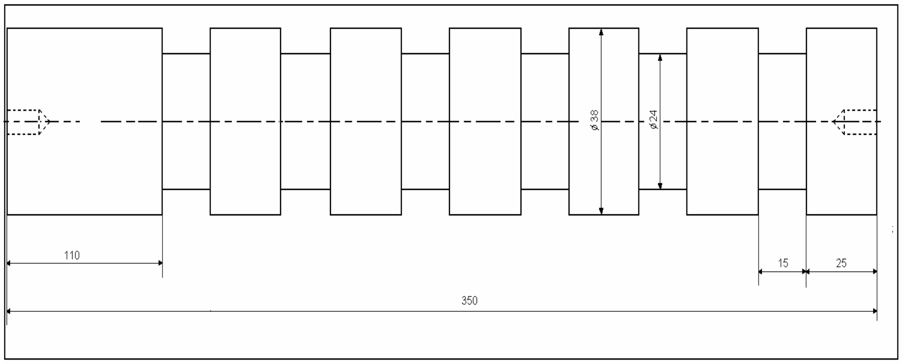

Figure 5: Mild Steel Work piece for Roller Burnishing.

In the present work, roller having outside diamante of 40 mm and 12 mm width is used for roller burnishing. The tool post and compound rest are removed from the lathe. Dynamometer together with its fixture is held on the cross slide of Condor lathe, Gedee Weiler make, Coimbatore and it is tightened with two fixing bolts. The roller burnishing tool assembly is kept in the tool holder of dynamometer and it is held rigidly by two bolts. Burnishing Force i.e., radial component of cutting force (in y- direction) is measured by dynamometer.

2.5 Measurement of Surface Roughness Values

A repetitive or random deviation from the nominal surface which forms the pattern of the surface is known as surface texture. It includes roughness, waviness, flaws, etc. Waviness is due to the geometric errors of machine tool and varying stiffness of the machine tool.

Roughness is due to the inherent kinematic differences of the cutting process. Various parameters of surface roughness i. e. R_a, $R_{z,}$ R_{max} are measured by using Surface Roughness Tester, as shown in Figure 6. Centre line average (C. L. A.) or R_a value is the arithmetic average roughness height.

Figure 6: Photograph of Surface Roughness Tester

3. Experiments with Roller burnishing tool and Mild steel work piece

3.1 Experiment No. 1: Variation of surface hardness with burnishing force

Mild Steel work piece is turned to 27.8 mm diameter with high speed steel single point tool in lathe with a spindle speed of 280 rpm and feed rate of 0.060 mm/rev. The initial surface roughness value R_a is measured with surface roughness tester 'Surftest – 211, Mitutoyo, Japan make. A roller of 40 mm outside diameter is fixed in roller burnishing tool assembly. Constant burnishing speed 12 m/min (140 rpm of spindle) and constant feed rate 0.060 mm/rev are maintained throughout the experiment. The step at the extreme right side of the work piece which is near the dead centre is denoted as step no. 1. Minimum value of burnishing force is applied on the step no. 1 of the work piece. An increased burnishing force is applied on the step no. 2, as we proceed towards the left side of the work piece, i. e. towards live centre. Like this, each step is regarded as a separate work piece. The grooves separate the steps. These Roller burnishing experiments are conducted on five steps of the aluminum work piece with five different values of burnishing force. The final surface hardness (HRB) is measured. The results are given in Table 1. Figure 7 shows the graph drawn between burnishing force (kgf) and surface hardness (HRB).

Table 1: Variation of surface hardness with burnishing force:
Initial surface hardness = 65 HRB.

S. No.	1	2	3	4	5
Burn. Force, kgf.	8	25	42	60	85
Hardness, HRB.	66	68	70	69.75	69.25

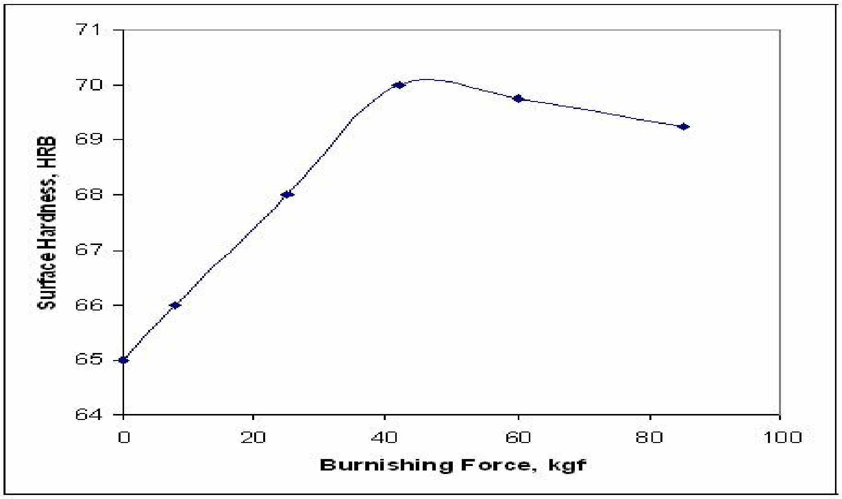

Figure 7: Variation of burnishing force (kgf) and surface hardness (HRB).

3.2 Experiment No. 2

3.2.1 Variation of surface roughness (R_a) with number of burnishing passes

Mild Steel Work piece is turned to 28.5 mm diameter with high speed steel single point tool on lathe with a spindle speed of 280 rpm and 0.060 mm/rev feed rate. The initial surface roughness value R_a is measured. A roller of external diameter 40 mm is used in the roller burnishing tool assembly. Constant spindle speed of 140 rpm (burnishing speed 12.5 m/min), constant feed rate of 0.060 mm/rev and constant burnishing force of 16 kgf are maintained throughout the experiment. The first step of the work piece is burnished in one pass, the second step is burnished in two passes, and so on. The resultant surface roughness value, R_a is measured. The results are shown in Table. 2. A graph is drawn between number of burnishing passes and surface roughness value, R_a (μm), as shown in Figure 8.

Table 2: Variation of surface roughness R_a with number of burnishing passes
Initial surface roughness value, R_a = 4.42 μm

S. No.	1	2	3	4	5	6
No. of tool passes	1	2	3	4	5	6
Final R_a, μm.	3.67	2.95	2.33	1.94	1.87	1.96

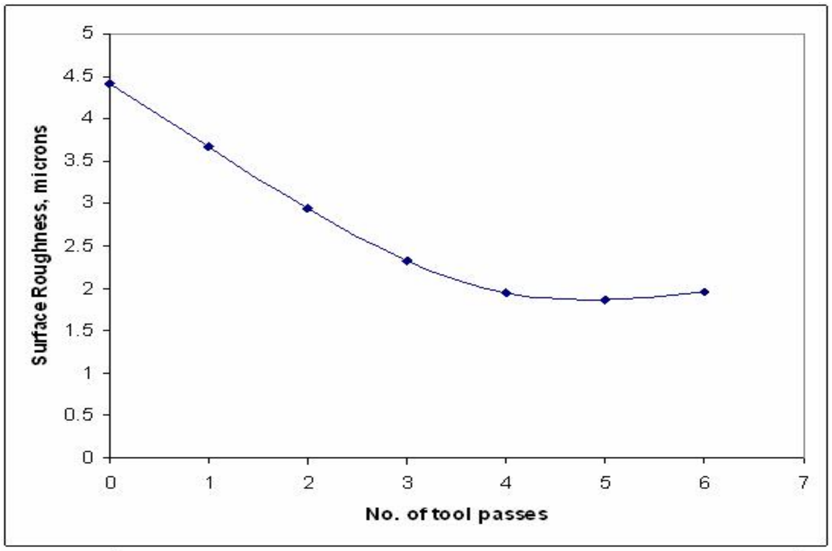

Figure 8: Variation of surface roughness (R_a) with number of burnishing passes.

4. Results and Discussion

4.1 Experiment No. 1

4.1.1 Variation of surface hardness with burnishing force:

The variation of surface hardness with burnishing force is shown in Fig. 8 for mild steel by roller burnishing. It is observed that surface hardness increases with increase in the burnishing force. This is mainly due to the increased plastic deformation of micro irregularities with high burnishing forces. There is an optimum burnishing force, beyond which the surface hardness decreases. Higher work hardening of surface layer will lead to flaking effect, which is the main cause for decrease in surface hardness with higher and higher burnishing forces. The burnishing force which gives maximum surface hardness for mild steel by roller burnishing operation is 42 kgf, at a speed of 12 m/min and feed of 0.060 mm/rev.

4.2 Experiment No. 2

4.2.1 Variation of surface roughness (R_a) with no. of burnishing passes:

The variation of surface roughness with number of burnishing passes is studied keeping the other burnishing conditions (speed, feed and force) constant and the results are shown in Fig. 9 for mild steel work piece by roller burnishing process. It is observed from the graph that maximum reduction in surface roughness is observed in the first five passes. Beyond five passes, there is not much improvement in the surface finish in the present experiment. In each number of pass, the burnishing force is being applied on the deformed asperities of the previous operation. Then, there will be a further deformation in the asperities in each number of pass; thereby the surface roughness will decrease with number of passes. After a certain number of passes, as the surface layer is highly work hardened due to repeated contact of the tool, further deformation of asperities at the same burnishing force is not so considerable. Thereby, there is not much improvement in surface finish after a certain number of passes.

5. Conclusions

1. The surface hardness of mild steel specimens increases with increase in the burnishing force up to 42 kgf. Further increase of burnishing force results in the decrease of surface hardness on mild steel specimens. The maximum surface hardness obtained is 70 HRB.
2. Maximum reduction in surface roughness is observed in first five passes on mild steel by Roller Burnishing operation.

6. References

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