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Evaluation of Optimum Values of Surface Roughness on Aluminum Work Piece using Roller Burnishing

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Abstract

In Burnishing, a hard ball or 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, a Roller burnishing tool is designed and fabricated. The aluminum work piece is held in between the centers of lathe, and it is driven through the drive dog. Various experiments are conducted to investigate the variation of surface roughness (R_a) with respect to the variation of burnishing feed rate and burnishing force in the presence of different lubricants. 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 Aerospace technology applications and to finish Aircraft components.

Keywords: Roller burnishing, dynamometer, strain gauges, surface roughness value R_a, burnishing force, burnishing speed, feed rate.

Introduction

Burnishing is one of the important finishing operations carried out generally to enhance the fatigue resistance characteristics of components. Burnishing is not a metal cutting process. In burnishing process, chips are not produced. It is essentially a cold forming process, in which the metal near a machined surface is displaced from protrusions to fill the depressions. In a typical burnishing set up, a ball or a roller is pressed against a rotating cylindrical work piece and parallel to the axis of the work piece.

The surface material is progressively compressed, then plasticized as the resultant stresses reach a steady maximum value and finally the work piece gets better surface finish. The principal action takes place in a central plasticization zone, where the material in both the peaks and valleys becomes plastic and the material flow is induced down both the flanks of the surface protrusions, filling the depressions. Since this action is only local, the overall geometry of the work piece is not generally changed.

Due to the work hardening of the surface during burnishing, there will be a hardened layer on the surface and it is expected to increase the fatigue resistance of the component. Apart from improvement in surface finish and fatigue strength, burnishing process imparts improved wear and corrosion resistance. 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.

Burnishing is most often performed on internal and external diameters. The schematic of Roller burnishing process with indication of residual stress conditions developed by the process is shown in Fig.1.

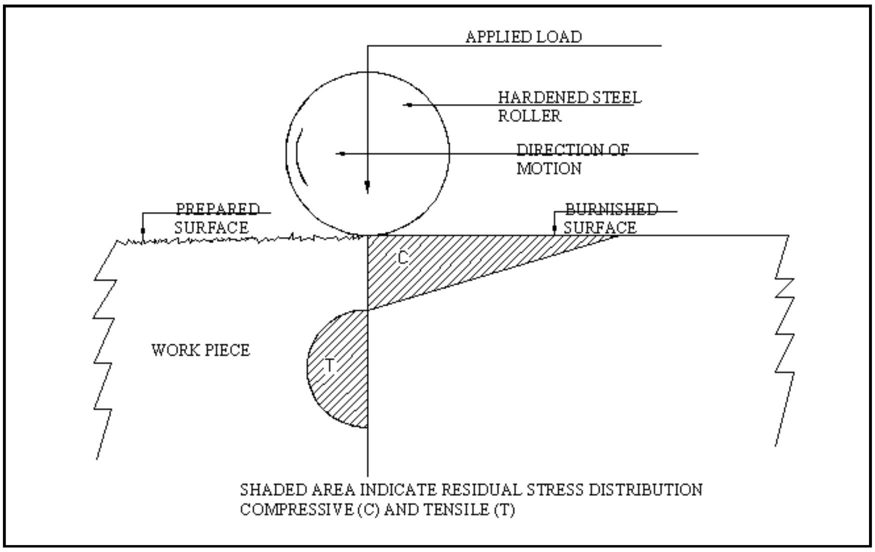

Figure 1: Schematic of Roller burnishing process.

Literature Review

Yu. G. Shneider [1] studied the characteristics of burnished components. Wear has important technological and economical significance because it changes the shape of the work piece, and the tool and the interference. R. L. Murthy [3] et al discussed the types and working methods of burnishing process. 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. N. H. Loh [4] et al presented the investigations on the surface roughness produced by Ball burnishing. A. M. Hassan [5] et al explained the effects of ball and roller burnishing on the surface roughness and hardness of some non- ferrous metals. It was suggested by many investigators that an improvement in wear resistance can be achieved by burnishing process. S. Thamizhmnaii [6] et al presented the surface roughness and hardness investigations on titanium alloy using a roller burnishing tool.

Parameters affected by Burnishing

Because of plastic deformation in burnishing operation under cold working conditions, the work piece surface is work hardened. The surface hardness increases considerably. Also, the metal flows on the surface of the work piece during burnishing operation. Due to this flow of metal, any burrs, scratches, micro cracks, etc. on this surface of the work are filled up. As a result, the number of stress raisers on the surface decreases, there by increasing the fatigue strength of the work piece. Because of improvement in the surface hardness and surface finish, the surface would become resistant to corrosion and wear.

Industrial Applications of Roller Burnishing

Typical applications for the Roller Burnishing process includes production of components for the hydraulic industry, where a precise sealing surface is required. The seal is often produced by an O- ring or rubber seal rubbing over the surface of a hardened steel shaft. The roller burnishing method meets the need for a strong part at a precise size and most importantly a quality surface finish that eliminates fluid leakage. Whether the requirement is close tolerances or superior surface finish, roller burnishing may be the tool that satisfies the machining needs. Roller burnishing operation is applied to finishing inner diameters of holes, taper seats for line contact and better wear resistance, inner diameters and outer diameters of hydraulic cylinders, grease pit lifts and hydraulic elevator cylinders, pistons for hydraulic systems, face seals, spherical seats, recesses (internal and external), fillets, sizing (sleeve bearings for proper fit), press fits, assembly jobs involving flooring and crimping often on components too delicate to withstand impact, and outer diameters of bearing surfaces of crank shafts. Several components in steering mechanisms in the automobile sector are finished economically by roller burnishing process. Also, majority of the components used in aircraft industry and aerospace technologies have got limitations with respect to weight. Hence, for such applications, light weight materials preferred are aluminum and its alloys. These materials are finished conveniently by roller burnishing process.

Benefits of Roller Burnishing

In Roller burnishing, tool marks are rolled out. The size of parts can be changed as little as 0.002 mm in one pass in a few seconds. The grain structure is condensed and refined and compacted surface is smoother, harder and longer wearing than ground or honed surfaces. Hence, the corrosion resistance of burnished surface is higher than the open surfaces produced by grinding or honing. Due to the plastic deformation by this operation, residual compressive stresses are included in the surface of the component. The compressive stresses greatly increase the strength properties and fatigue life of the component. Thousands of parts can be finished with little or no burnishing tool wear. Setting up of the burnishing tool takes less than minute time. Unskilled operators can produce close tolerance. Hence, there is great saving in the wages of workers.

Roller Burnishing Tool

A Roller burnishing tool is designed and fabricated as shown in Fig. 2. It consists of the following parts. i. Roller ii. Special bolt iii. Nut iv. Bush v. Washers vi. Shank. The shank is fixed in the dynamometer and it is tightened with two bolts. The chemical composition of Roller material is given below:

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

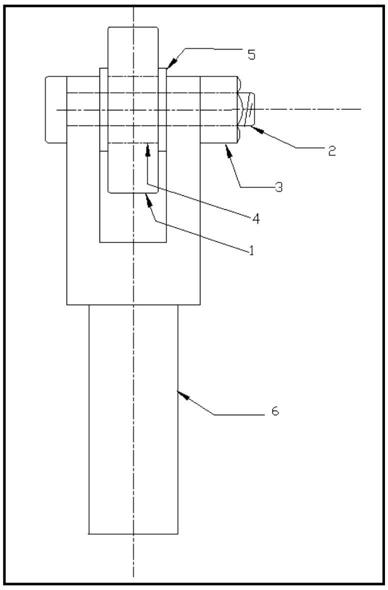

Figure 2: Roller Burnishing Tool assembly.

Experimental Set Up

The Roller burnishing tool is fixed on the Lathe. The experimental set up is shown in Fig. 3. It consists of the following parts. i. Three jaw chuck ii. Live center iii. Dead center iv. Aluminum work piece v. Roller Burnishing tool vi. Dynamometer fixed to the cross slide of Lathe vii. Hand wheel for cross slide viii. Input power to the Dynamometer ix. Strain reader.

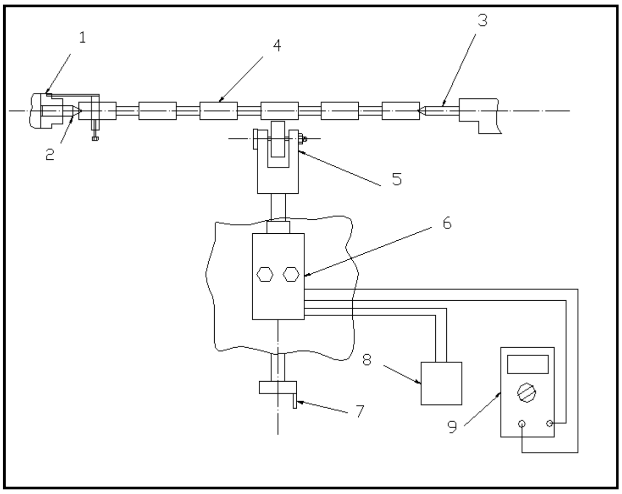

Figure 3: Experimental set up with Roller burnishing tool.

Burnishing experiments are conducted on turned aluminum work piece, which is very ductile, corrosive resistant, good conductor and available in the form of round bars. The chemical composition of aluminum specimen (wt %) is given below:

Al 93.73, Cu 5.34, Fe 0.3, Si 0.05, Mn 0.55, Zn 0.03

To conduct experiments with roller burnishing tool, a round bar made of aluminum material is chosen as work piece material. The aluminum work piece is specially fabricated, as shown in Fig. 4. All the dimensions are shown in millimeters in this figure.

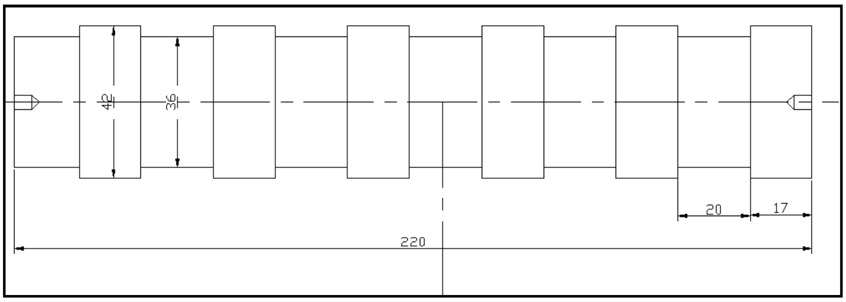

Figure 4: Aluminum Work piece for Roller Burnishing.

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.

In the present work, roller having outside diamante of 40 mm 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.

Fig. 5 shows the photograph of the experimental set up when roller burnishing tool with 40 mm diameter roller burnishes an aluminum work piece in Gedee Weiler Condor lathe.

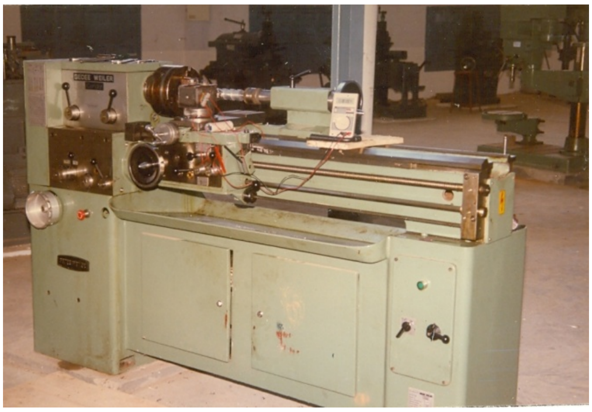

Figure 5: Photograph of experimental set up of Roller burnishing process on lathe.

The dynamometer, Roller burnishing tool, aluminum work piece, etc. are shown in the close up view clearly in Fig. 6.

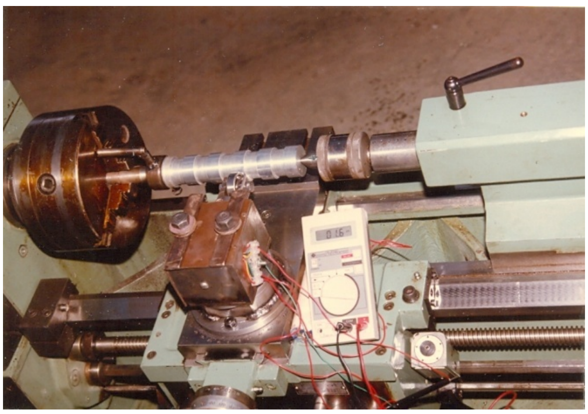

Figure 6: Photograph showing close up view of experimental set up on lathe.

Measurement of Surface Roughness Values

Repetitive or random deviations 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 – 211 Mitutoyo, Japan make, as shown in Fig. 7. Centre line average (C. L. A.) or R_a value is the arithmetic average roughness height. Average height difference between the five highest peaks and five lowest valleys within the traversing length are called peak to valley height (R_z).

Figure 7: Photograph of 'Surftest – 211 model' Surface Roughness Tester.

Experiments with Roller Burnishing Tool on Aluminum Workpiece

Experiment No. 1: Variation of surface roughness (R_a) with burnishing feed rate: Aluminum work piece is initially turned to 41.4 mm diameter with high speed steel single point tool in lathe with a spindle speed of 350 rpm and 0.082 mm/rev feed rate. The initial surface roughness value R_a is measured on surface roughness tester 'Surftest – 211), Mitutoyo, Japan make. A roller of 40 mm outside diameter is used in roller burnishing tool assembly. Constant burnishing force of 8 kgf is applied on the work piece. Constant spindle speed 220 rpm is maintained for work piece diameter 41.4 mm (i.e. constant burnishing speed of 28.6 m/min). 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 feed rate is set on the lathe and roller burnishing operation is completed on the step no. 1 of the work piece. An increased feed rate is set for 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 feed rate. Surface roughness values, R_a (microns) are measured on all the steps after finishing is completed by roller burnishing. The results are given in Table 1.

Table 1: Variation of surface roughness with burnishing feed rate: Initial surface roughness value, Ra = 1.22 microns.

Step No.	1	2	3	4	5
Feed mm/rev	0.024	0.041	0.060	0.082	0.103
Final R_a (microns)	0.65	0.41	0.31	0.36	0.44

Fig. 8 shows the graph drawn between burnishing feed rate (mm/rev) and surface roughness value, R_a (microns).

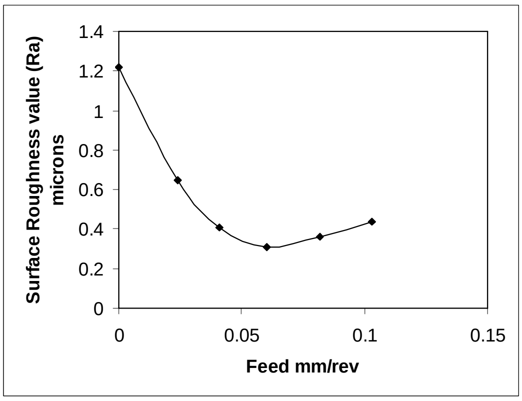

Figure 8: Variation of surface roughness with burnishing feed rate.

Experiment No. 2: Variation of surface roughness (R_a) with burnishing force, in the presence of different lubricants

Aluminum work piece is initially turned to 40 mm diameter with high speed steel single point tool on lathe with a spindle speed of 350 rpm and 0.082 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 18m/min) and constant feed rate of 0.060 mm/rev is maintained throughout the experiment. A lathe tool dynamometer is used to measure the burnishing force. It is radial component of cutting force. It is y- component and it acts along the radial direction of the work piece. Various steps of the Aluminum work piece are burnished with different values of burnishing forces. The same experiment is repeated six times. First, the work piece is burnished in dry condition, without using any lubricant. Later on, the following five lubricants are thoroughly applied on the work piece during the burnishing operation.

Grease. ii. SAE 140 Gear oil. iii. SAE 40 Engine oil. iv. Diesel oil. and v. Kerosene oil.

The final surface roughnesss value, R_a is measured in all these experiments. The results are shown in Table. 2. A graph is drawn between burnishing force (kgf) and surface roughness value, R_a (microns), as shown in Fig. 9.

Table 2: Variation of surface roughness R_a with burnishing force (kgf) in the presence of different lubricants.
Roller burnishing on Aluminum work piece.
Initial surface roughness vlaue, R_a = 3.50 microns.
Constant burnishing feed =0.060 mm/rev.
Constant burnishing speed=17.5 m/min.

Step No.	1	2	3	4	5
Burnishing Force (Kgf)	8	16	25	34	42
Final R_a (Dry Burnishing)	2.71	2.09	1.78	1.68	1.84
Final R_a (Grease)	2.32	1.66	1.28	1.18	1.31
Final R_a (SAE 140 Gear oil)	2.06	1.51	1.17	1.04	1.14
Final R_a (SAE 40 Engine oil)	1.94	1.32	0.96	0.87	0.98
Final R_a (Diesel oil)	1.83	1.19	0.87	0.71	0.83
Final R_a (Kerosene oil)	1.66	0.97	0.69	0.58	0.64

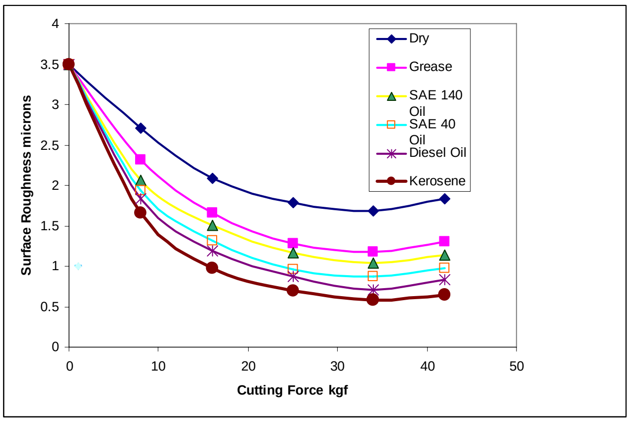

Figure 9: Variation of surface roughness (R_a) with burnishing force (kgf) in the presence of different lubricants.

Results and Discussions

Variation of surface roughness with burnishing feed rate

By roller burnishing, variation of surface roughness with burnishing feed rate on aluminum work piece is shown in Fig.8.

It is observed from the graph that as the feed rate increases, the surface roughness value decreases, and after reaching a minimum feed rate, the surface roughness value increases. The reason for this is explained below. At lower feed rates, the filling up process may not be effective due to higher adhesion conditions. At higher feed rates, there may not be an effective match between the wave front and the burnishing action at the trailing portion of the burnishing zone. Further, increased vibrations at higher feed rates also cause surface finish deterioration. Also, there will be no burnishing action at all at higher burnishing feeds, because of insufficient time for pressing the protrusions. This is happening in the case of roller burnishing. The result of optimum value of feed rate is given below:

From experiment No.1 and Fig.8 in roller burnishing operation on aluminum work piece, for a constant burnishing speed 28.6 m/min, and constant burnishing force 8 kgf; the optimum value of burnishing feed rate is found to be 0.060 mm/rev.

Variation of surface roughness with burnishing force, in the presence of different lubricants

By roller burnishing, the variation of surface roughness with burnishing force on aluminum work piece is shown in Fig.9. It is observed from the graph that as the burnishing force increases, the surface roughness decreases up to an optimum value of force. Beyond the optimum force, the surface roughness increases. The reason for this is explained below.

If the burnishing force is increased after a certain optimum value, due to the higher work hardening of the surface layer, flaking of the surface will take place, thereby the surface roughness increases. The optimum burnishing force depends on the initial roughness of the surface and the initial surface hardness of the material. The result of optimum value of the burnishing force is given below.

From experiment no.2 and Fig 9, in roller burnishing on aluminum work piece, for a constant burnishing speed 17.6 m/min, and constant feed rate 0.060 mm/rev, in dry condition, the optimum value of burnishing force is observed be 34 kgf.

It was observed that surface roughness decreases with burnishing force. Higher reduction in surface roughness is observed when burnishing in the presence of lubricants. The reason for this is explained below. The lubricants in metal deforming and metal cutting processes will provide the lubricating and cooling effects. Therefore, for the same force application in the presence of lubricants, the deformation will be more, thereby higher reduction in surface roughness. The contact conditions in metal cutting and metal deforming processes are quite different from those encountered in normal engineering situation. In metal deforming (burnishing), the ratio between the real and apparent area of contact is very close to unity, where as in normal sliding contacts, the true area of contact is less than 1 % of the apparent area of contact. Also, the contact pressure at the tool is very high in burnishing. Under such conditions, there is no possibility of full fluid film formation at the contact zone of the tool and the work piece. Hence, the mode of lubrication is only boundary lubrication and therefore the chemical property of the lubricant is more important than the physical property of the lubricant. Hence, kerosene oil is found to be better oil for use in burnishing aluminum than high viscous oils (such as SAE 40, SAE 140 and grease), in order to get higher reduction in surface roughness.

Conclusions

By selecting optimum values of burnishing feed rate and burnishing force and appropriate lubricant, we can get better value of surface finish on aluminum work piece by Roller burnishing process. By using a lighter cutting fluid such as Kerosene oil, a better surface finish will be resulted.

Roller burnishing produces better and accurate surface finish on aluminum work piece in a smaller time. It is an economical process, where skilled operators are not required. Also, roller burnishing process can be easily performed on lathe, with semi skilled operators.

The roller burnishing process as finishing process is not only technically viable but also has commercial potential. A required surface roughness can be obtained by proper selection of the process parameters. This process can be effectively used in Aerospace technology applications and to finish Aircraft components.

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