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Design and fabrication of new type of dynamometer to measure radial component of cutting force and experimental investigation of optimum burnishing force in roller burnishing process

J. Naga Malleswara Rao[1], A. Chenna Kesava Reddy[2] and P.V. Rama Rao[3]

[1]*Department of Mechanical Engg., VR Siddhartha Engg., College, Vijayawada-520 007, AP*
[2]*Department of Mechanical Engg., JNTU College of Engg., Hyderabad - 500 085, AP*
[3]*Department of Mechanical Engg., Mahatma Gandhi Institute of Technology, Hyderabad - 500 075, AP, India*
jnmr15827@yahoo.co.in

Abstract

In this work, an attempt has been made to design and fabricate a new type of dynamometer to measure radial component of cutting force using strain gauges. Dynamometer is required to measure the components of cutting force in any metal cutting process. The dynamometer has been calibrated and tested for performance. It is used in roller burnishing experiment on aluminum work piece under various conditions. In roller burnishing, a hard roller is pressed against a rotating cylindrical work piece and parallel to the axis of the work piece on lathe. Optimum values of burnishing force and the corresponding surface roughness value (R_a) are obtained for different lubricant applications in roller burnishing operation. This dynamometer can be manufactured at a low cost and it can be used for tests on lathe in metal cutting laboratories and engineering colleges.

Keywords: Dynamometer, strain gauges, roller burnishing, surface roughness value R_a, burnishing force.

Introduction

In order to analyze the roller burnishing operation on a quantitative basis, certain observations must be made. One of the important observations is the measurement of components of cutting force. A dynamometer (Shaw, 1969) is used to measure forces that occur in metal cutting or any other operation. Cutting force is one of the parameters which play a great role in machining and for obtaining better surface qualities like surface finish, surface roughness and accuracy of dimensions. Hence, it is required to measure components of cutting force (King & Foschi, 1969) in three mutually perpendicular directions in turning operation. In burnishing, the component of cutting force in radial direction plays a dominant role. The other components of forces i.e., feed component (in x-direction) and tangential component (in z-direction) can be neglected. This is because burnishing removes no material, but it only compresses the surface. Thus, to measure radial component of force (in y-direction), a single component lathe tool dynamometer is designed and fabricated for the present work.

Design and fabrication of dynamometer

In this work, a new type of dynamometer is fabricated with bonded electrical strain gauges (Beckwith & Lewis Buck, 1982). Four strain gauges (122 ohms resistance and 2.1 gauge factor of 10 mm x 10 mm size) are bonded with araldite on the strain ring and connected in the form of a wheat stone bridge. The strain ring is shown in Fig. 1. The bridge circuit diagram for measuring the radial component of cutting force is shown in Fig. 2 along with colour codes of the terminals. The electrical wires are connected to the ends of the strain gauges by soldering. Fig. 3 shows the photograph of the dynamometer mounted on the fixture showing the components and the internal connections. The roller burnishing tool is fixed in the tool holder by clamping screws.

Design principle

Overall dimensions of the dynamometer are arrived at keeping in view its fixation on the cross slide of the Condor' precision lathe, manufactured by Gedee Weiler, Coimbatore. The centre distance of the slots on cross slide is 114 mm and the height of centres above the cross slide is 84.5 mm for this lathe. A fixture is designed and fabricated to fix the dynamometer on the cross slide, as shown in Fig. 4. The detailed drawings of the dynamometer are shown in Fig. 5.

Calibration

Fig. 6 shows the testing of the single component lathe tool dynamometer (Levi, 1972). The dynamometer is kept on a firm base resting on the rear plate so that axis of the tool holder is oriented vertically. A loading fixture if fabricated. DC 3 volts supply is given as excitation to the bridge. The dynamometer is loaded (P) vertically in steps of 10 kgf and the corresponding output voltage (milli volts) from the bridge is measured by means of HIL 2100 digital multi meter, Hindustan Instruments Ltd., Gurgaon. The results are shown in Table 1. A Calibration chart for radial component of cutting force (in y-direction) is drawn and shown in Fig. 7. This curve is drawn between load in kgf on x- axis and corresponding output voltage (mv) on y-axis. In the actual experiments conducted with burnishing tools in action with the work pieces, the output

Table 1. Variation of output voltage with increase of load on dynamometer

Load P kgf	0	10	20	30	40	50	60	70	80	90
Output voltage (V) mv	1.60	1.71	1.83	1.96	2.07	2.19	2.30	2.42	2.54	2.66

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voltage (mv) gives measurement of the burnishing force from the calibration chart (Bhattacharyya, 1984).

Experimental set up

The aluminum work piece is held in between centres on lathe. Dynamometer is fixed on the cross slide of the lathe. The experimental set up is shown in Fig. 8. To conduct experiments with roller burnishing tool aluminum round bar is selected as work piece. The aluminum work piece is shown in Fig. 9.

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 centres of lathe and it is driven through the lathe dog. A high speed steel single point tool is kept in the tool post of the lathe and work piece is turned to have 6 steps.

In the present experiments, roller having outside diameter 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 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 set screws. Input voltage of 3 V DC is given to the bridge circuit of dynamometer.

Output voltage is measured by a digital multi meter (milli voltmeter). Fig. 11 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. The dynamometer, tool, aluminum work piece, etc. are shown clearly in Fig. 12.

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. 13. Centre line average (CLA) 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).

Experiments with roller burnishing tool on aluminium workpiece

Experiment No. 1: Variation of surface roughness (R_a) with burnishing force:

Aluminum work piece is initially turned to 40 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. 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. The work piece is burnished with various forces. The results are given in Table 2. Fig, 14 shows graph drawn between burnishing force (kgf) and surface roughness value R_a (microns).

Table 2. Variation of surface roughness with burnishing force

Step	1	2	3	4	5
Burnishing force, kgf	8	16	25	34	42
Final R_a (microns)	2.52	1.96	1.69	1.61	1.72

Initial surface roughness value, Ra = 3.60 microns.

Experiment No. 2: Variation of surface roughness (R_a) with burnishing force, by applying SAE 40 Engine oil (Servo, Indian Oil make) as lubricant:

Aluminum work piece is initially turned to 39.6 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 Ra 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. SAE 40 engine oil is applied on the work piece continuously. Various burnishing forces are applied on the work piece at different steps. The results are given in Table 3. A graph is drawn between burnishing force (kgf) and surface roughness value R_a (microns), which is shown in Fig. 15.

Table 3. Variation of surface roughness with the application of SAE 40 engine oil

Step	1	2	3	4	5
Burnishing force, kgf	8	16	25	34	42
Final R_a (microns)	2.48	1.86	1.40	1.32	1.47

Initial surface roughness value, Ra = 3.60 microns.

Variation of surface roughness (Ra) with burnishing force, by applying Kerosene oil as lubricant:

Aluminum work piece is initially turned to 39.3 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 Ra 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. Kerosene oil is applied on the work piece. Various burnishing forces are applied on the work piece at different steps. The results are given in Table 4. A graph is drawn between burnishing force (kgf) and surface roughness value R_a (microns), which is shown in Fig. 16. The variation of surface roughness with

Table 4. Variation of surface roughness with burnishing force in the presence of lubricant (kerosene oil)

Step	1	2	3	4	5
Burnishing force, kgf	8	16	25	34	42
Final R_a (microns)	1.98	1.25	0.90	0.72	0.80

Initial surface roughness value, Ra = 3.60 microns

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Fig. 1. Strain ring
(All dimensions are in mm only)

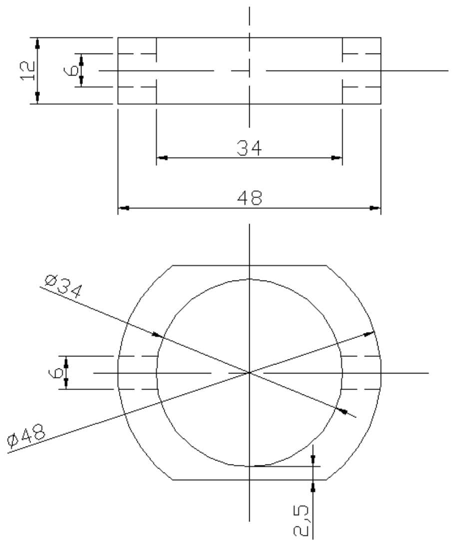


Fig. 3. Photograph of dynamometer

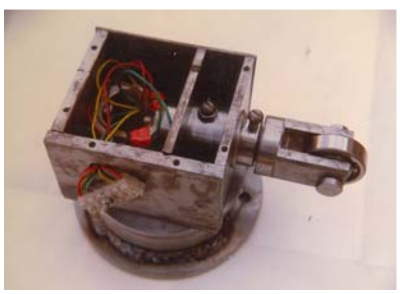


Fig. 5. Detailed drawings of dynamometer.

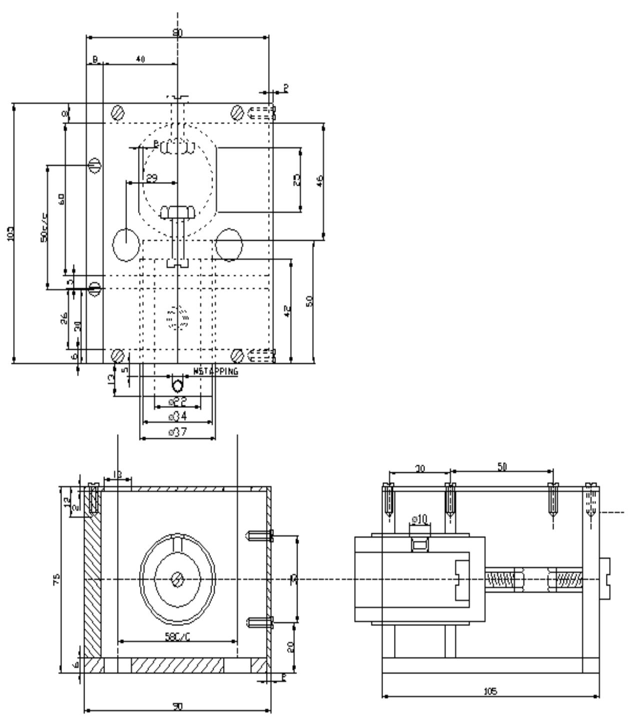


Fig. 2. Four arm bridge circuit.

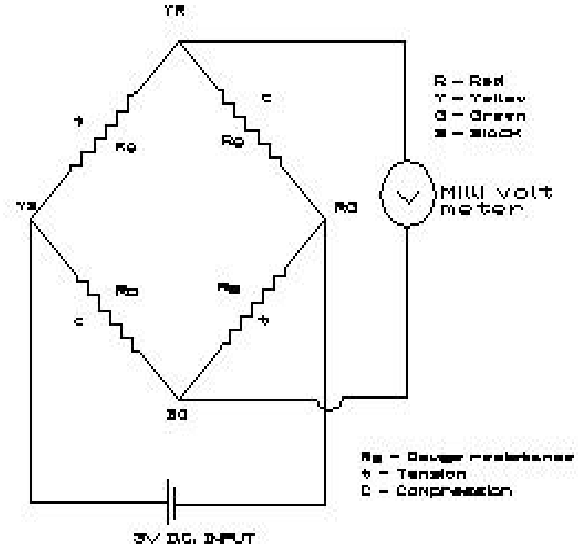


Fig. 4. Fixture to fix the dynamometer on the cross slide of lathe

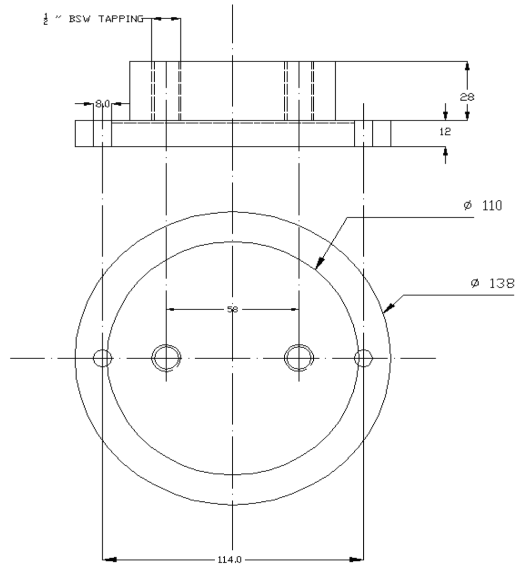
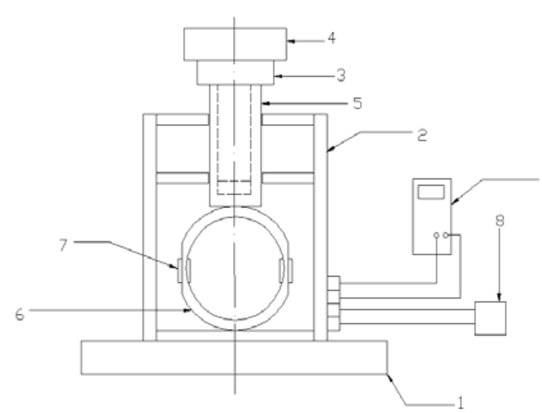


Fig. 6. Calibration set up of dynamometer



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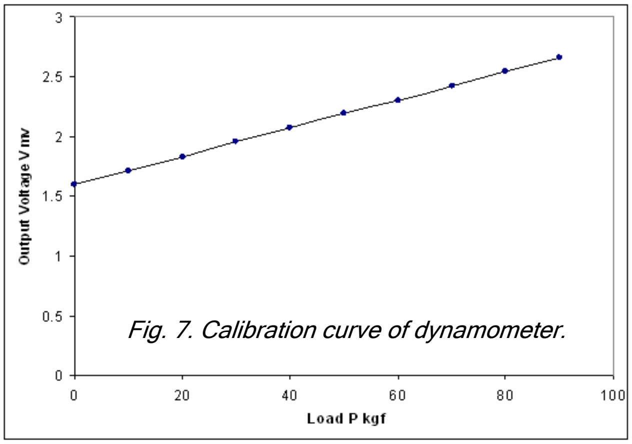

Fig. 7. Calibration curve of dynamometer.

Fig. 8. Experimental set up with roller burnishing tool.

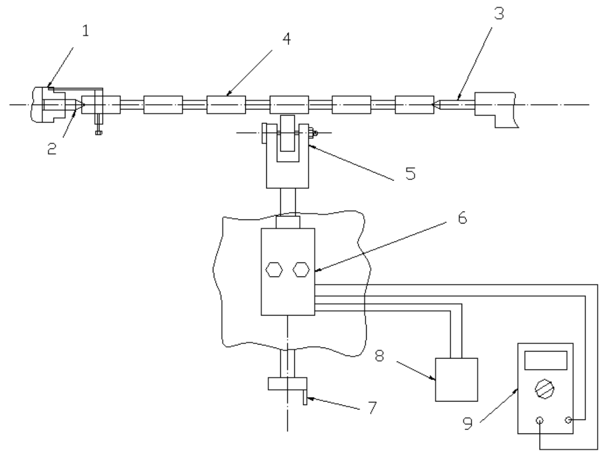

Fig. 9. Aluminum work piece for roller burnishing (all dimensions are in mm only)

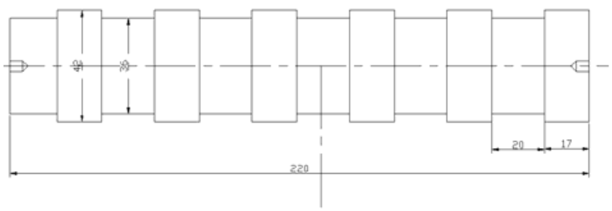

Fig. 10. Roller burnishing tool assembly

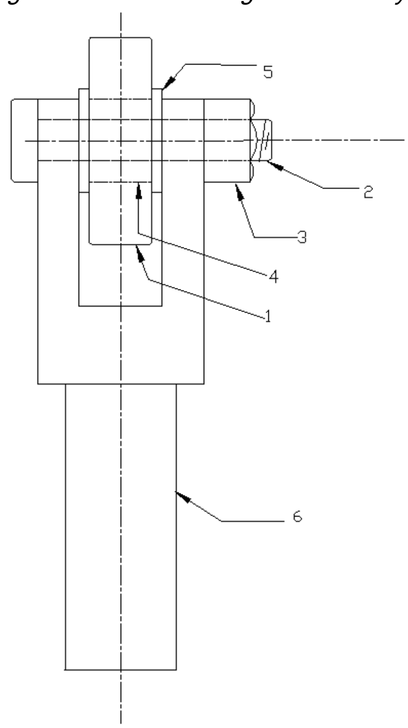

Fig. 11. Photograph of experimental set up of roller burnishing process on lathe

Fig. 12. Photograph showing close up view of experimental set up on lathe

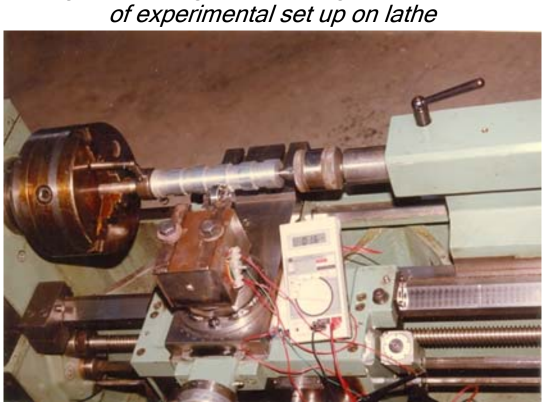

Fig. 13. Surftest - 211 model surface roughness tester

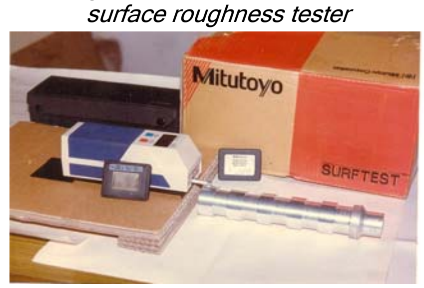

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Fig. 14. Variation of surface roughness with burnishing force

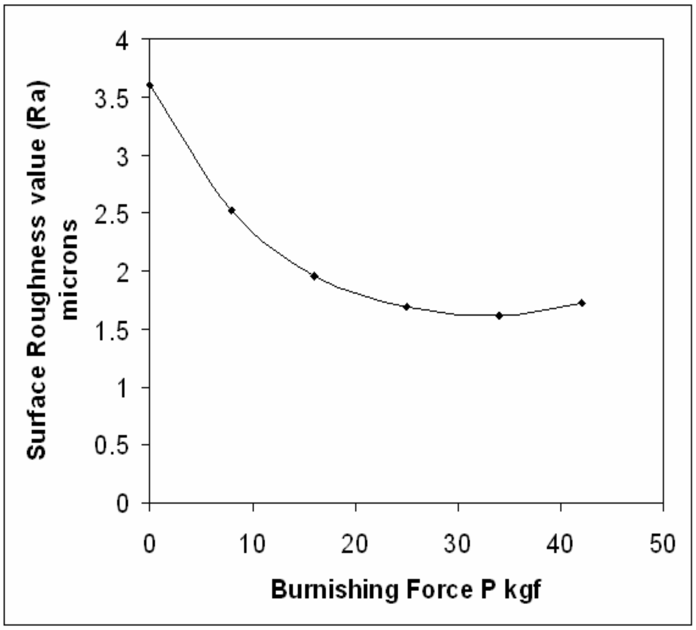


Fig. 15. Variation of surface roughness with burnishing force by the application of SAE 40 engine oil

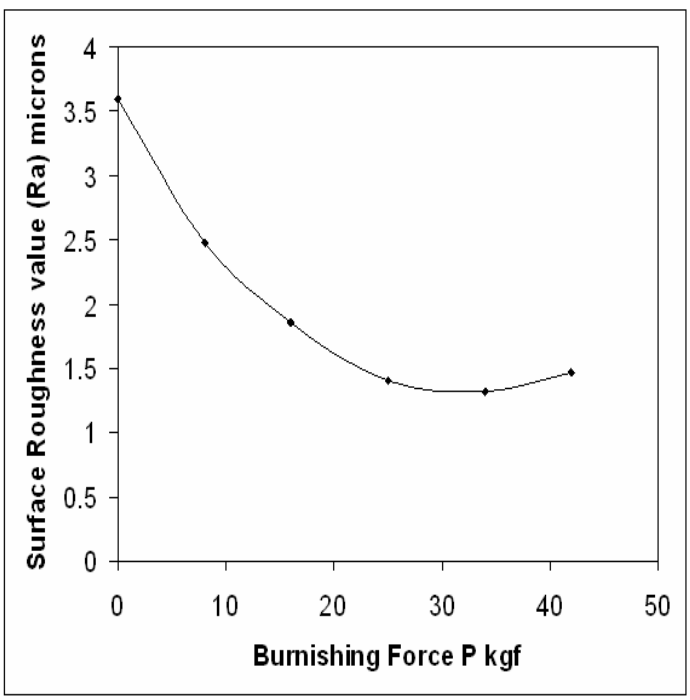


Fig. 16. Variation of surface roughness with burnishing force in the presence of lubricant (kerosene oil)

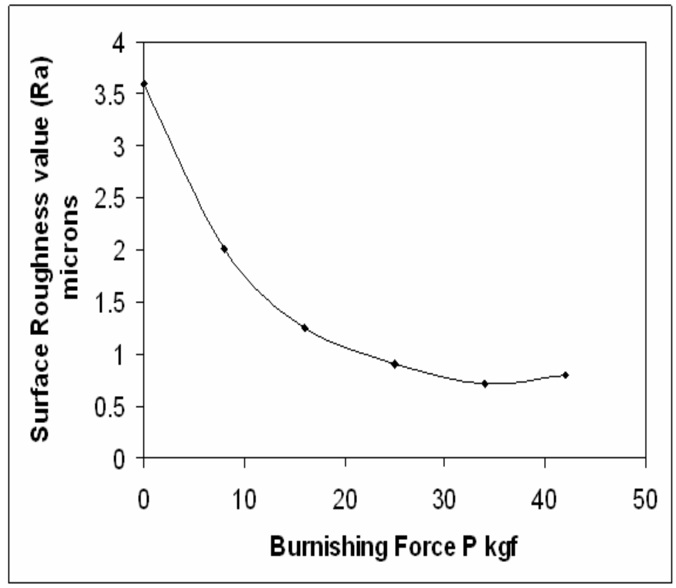
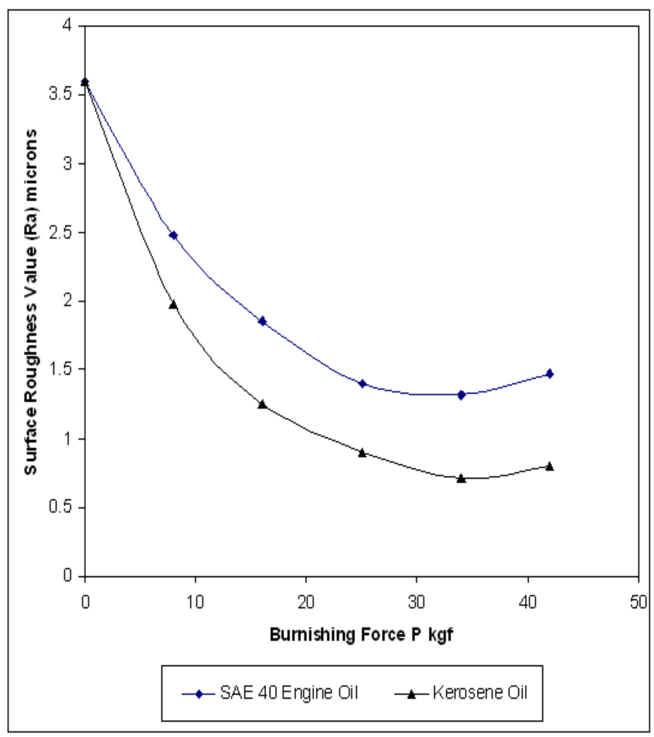


Fig. 17. Variation of surface roughness with burnishing force in presence of lubricants (SAE 40 engine oil & kerosene oil).



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burnishing force in the presence of lubricants (SAE 40 Engine Oil and Kerosene oil) is shown in Fig. 17.

Results and discussions

Variation of surface roughness with burnishing force:

By roller burnishing (Murthy & Kotiveerachary,1981), the variation of surface roughness with burnishing force on aluminum work piece is shown in Fig.13. It is observed from the graph that as the burnishing force increases, the surface roughness decreases up to an optimum value of force (Shneider Yu, 1967). 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 (Hassan, 1997). The result of optimum value of the burnishing force is given below.

From experiment 1 and Fig. 14 in roller burnishing on aluminum work piece, for a constant burnishing speed 17.6 m/min, and constant feed rate 0.060 mm/rev, the optimum value of burnishing force is observed be 34 kgf.

Variation of surface roughness with burnishing force in the presence of lubricants:

By roller burnishing, the variation of surface roughness with burnishing force in the presence of SAE-40 engine oil and kerosene oil is presented in Fig. 15, 16 &17. It is observed from the graphs that surface roughness decreases with burnishing force. Higher reduction in surface roughness is observed when burnishing in the presence of lubricants (Thamizhmnaii, 2008). 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, whereas 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 oil (SAE 40 engine oil) in order to get higher reduction in surface roughness.

Conclusions

- The new type of dynamometer so fabricated has been tested under both static and dynamic conditions with proven satisfactory performance.
- This dynamometer can be fabricated at a low cost and it can be used for tests on lathe in metal cutting laboratories and engineering colleges.
- Roller burnishing produces better and accurate surface finish on work pieces in a smaller time. It is an economical process, where skilled operators are not required.
- It is required that the lubricant has considerable effect on roller burnishing process. There will be higher reduction in surface roughness with increased burnishing force, in the presence of lubricant than in dry condition. A light oil such as kerosene oil produces better surface finish values than heavy oils such as SAE 40 engine oil on aluminum work piece.

References

1. Beckwith TG and Lewis Buck N (1982) Mechanical measurements. 5th ed., Oxford & IBH Publi. Co., New Delhi.
2. Bhattacharyya, A (1984) Metal cutting-theory and practice. Central Book Publi., Calcutta.
3. Hassan AM (1997) The effects of ball and roller burnishing on the surface roughness and hardness of some non-ferrous metals. *J. Mat. Proces.Technol*. 72, 385-391.
4. King B and Foschi RO (1969) Cross ring dynamometer for direct force resolution into three orthogonal components. *Int. J. Machine Toll Design Res*. 4, 345-356.
5. Levi R (1972) Multi component calibration of machine tool dynamometer. *J. Engg. Industry*. 11. 1067-1072. Murthy RL and Kotiveerachary B (1981) Burnishing of metallic surfaces – a review. *Precision Engg*. 3, 172-179.
6. Shaw MC (1969) Metal cutting principles. 3rd ed. Oxford & IBH Publ. Co., New Delhi.
7. Shneider Yu G (1967) Characteristics of burnished components. *Mech. Tooling*. 38(1), 19-22.
8. Thamizhmnaii S, Bin Omar B, Saparudin S and Hassan S (2008) Surface roughness investigation and hardness by burnishing on titanium alloy. *J. Achiev. Mat. Manuf. Engg*. 28 (2), 139-142.