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Parametric Analysis of Mild Steel Specimens Using Roller Burnishing Process

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ABSTRACT:- Burnishing, a cold working process, is a very simple and effective method of improving surface properties, which can easily be carried out using existing machines, such as lathe. With changing trends in manufacturing industry, special attention is given on surface finish along with dimensional accuracy and tight geometrical tolerances. Burnishing comes in mind as one of popular finishing process because it is completely chip-less as compared to other finishing processes such as grinding, honing etc. The purpose of the research was to demonstrate burnishing process on ferrous metals namely mild steel alloy. Parametric analysis was done using speed and feed rate as input parameters and surface roughness & surface micro hardness as response variables. Burnishing was performed using Hindustan machine tools (HMT) power lathe (NH 26 model).

KEYWORDS:- *Burnishing, surface finish, surface micro hardness, HMT*

I. INTRODUCTION

During recent years, considerable attention is being paid to the post-machining metal finishing operations such as burnishing which improves the surface properties by plastically deforming the surface layers of work surface at microscopic level (M.M. El-Khabeery and M.H. El- Axir, 2003). Burnishing is simple and effective finishing process for the improvement of surface properties such as surface finish, surface micro hardness, fatigue resistance etc (Hassan, A.M., 1997). Burnishing displaces the peaks or asperities into the valleys of the machined surface, thereby producing a smooth and compact surface. Burnishing mechanisms can be categorized into three main groups. First is the surface smoothing (geometrical) mechanism, the characteristic of which is mainly the decrease in surface roughness. Second is the surface enhancement (mechanical) mechanism, the characteristics of which are the introduction of compressive residual stress and cold-work hardening. Third being the microstructural (metallurgical) mechanism, the characteristics of which are the closure of crack, the change of texture orientation, the elongation and refinement of crystalline grain even to nanocrystallization by severe plastic deformation (Feng Lei Li *et al*, 2012). Burnishing tools are 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 of such application include valves, pistons of hydraulic or pneumatic cylinders, lawn and garden equipment components, shafts for pumps, shafts (Malleswara Rao J. N, 2011)

1.1 Classification of burnishing processes: Burnishing process has typically been categorized into two types.

a. Ball burnishing
b. Roller burnishing

Ball Burnishing: In this process the deformation element is hard ball. Alumina carbide ceramic, cemented carbide, silicon nitride ceramic, silicon carbide ceramic etc. are the popular materials being used for manufacturing of the ball (Mahajan & Tajane, 2013). Ball acts as tool for compressing the surface layers and there is point contact between tool and work piece. Fig.1 represents the scheme of ball burnishing process.
Roller Burnishing: It is a method of cold working the metallic surface in order to reduce compressive residual stresses and enhance surface roughness qualities. In roller burnishing process, the pressure exerted by the rollers exceeds the yield point of the work piece at the point of contact, which results in small plastic deformation of the surface structure of the work piece. All machined surfaces consist of a network of peaks and valleys which are not regular in height and spacing. Roller burnishing creates plastic deformation which displaces the material from the peaks of work piece by means of cold work under pressure into the valleys resulting in mirror-like finish with a tough, work hardened, wear and corrosion resistant work surface (Hassan, A.M., 1997). The process schematic has been shown as below in Fig.1

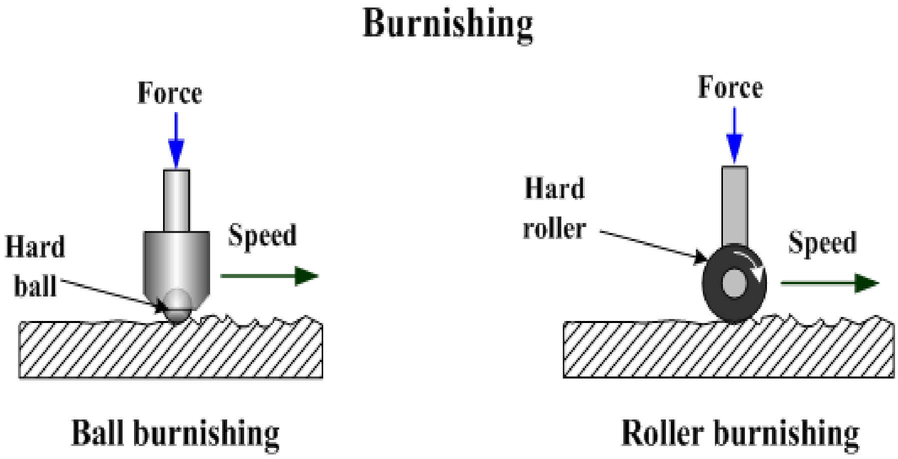

Fig.1 Schematic representation of ball and roller burnishing

1.2 Benefits of burnishing

1. Simple and highly productive operation which may be carried out in conventional machines (e.g. lathe).
2. May replace more complicated operations such as honing, lapping and grinding.
3. Requires low energy and torque since the pressure load is relatively low.
4. Does not produce chips, shavings, filings, turnings or dust.
5. Provides tight dimensional tolerances.
6. As compared to other processes tool wear is relatively less.

II. LITERATURE SURVEY

Axir, has investigated roller burnishing using RSM (response surface methodology) and took Steel-37 as work piece and a roller bearing having outside diameter of 22 mm and a width of 6 mm as tool. Using feed rate of 0.1 mm/rev., depth of cut 0.2 mm and spindle speed of 600 rpm respectively, he observed that the spindle speed, burnishing force, burnishing feed and number of passes have the most significant effect on both surface micro hardness and surface roughness. Recommended spindle speeds that resulted in high surface micro hardness and good surface finish were in the range from 150 to 230 rpm and also the residual stress was maximum near the surface (Axir, 2000).

Khaberry and Axir, have developed the experimental techniques for studying the influence of burnishing parameters on surface characteristics for some materials. To carry out the experimental work four input parameters were used, namely: burnishing speed, depth of penetration, burnishing time and initial hardness of the work piece materials. Three response parameters were selected, namely: Out-of-roundness, reduction in diameter and surface micro hardness; respectively. It was found that increase in burnishing speed of more than 1.5 m/s resulted in a considerable increase in out-of-roundness. The best results for surface micro hardness were obtained at low depth of penetration with high burnishing time or with high depth of penetration with low initial hardness of material (Khabeery & Axir, 2003)

Hryniewicz and Rokosz, have studied the corrosion behaviour of C-45 carbon steel after roller burnishing through electrochemical investigation results of the corrosion rate. Two different medias, based on sodium chloride as the corrosive agent, were applied for the electrochemical studies, with one of them, 3% NaCl water solution, imitating the synthetic sea water environment. It was found that the corrosion rate decreased many times after roller burnishing of initially prepared surface having regular projections on it (Hryniewicz and Rokosz, 2005).

Thamizhmanii *et al.*, have worked on multi-roller burnishing on non-ferrous metals where burnishing process was carried on lathe and vertical/horizontal milling machines with suitable fixtures to hold the work piece with various spindle rotations, feed rate and depth of penetration and it was identified that surface roughness of non-ferrous metals improved with high spindle rotations, high feed rate and depth of penetration respectively (Thamizhmanii *et al.*, 2007).

Thamizhmanii *et al.*, have worked on surface roughness investigation and hardness by burnishing on titanium alloy by using a multi roller burnishing tool on square titanium alloy material by designing various sliding speed/ spindle speed, feed rate and depth of penetration and concluded that the roller burnishing was very useful process in improving surface roughness and hardness and can be employed to impart compressive stress and high fatigue life (Thamizhmanii *et al.*, 2008).

Jawalkar *et al.*, have conducted experiments to find optimized values for enhancing the surface quality and hardness economically in the roller burnishing process. They have considered the input parameters as spindle speed, tool feed, number of passes and lubricants. The surface roughness and micro hardness were main response variables (outputs). The commonly used industrial material EN-8 was selected as a work piece for experimental purpose. It was concluded that the number of passes, feed and spindle speed contributed maximum for the *surface roughness* in burnishing of EN-8 material. Number of passes and speed contributed maximum in improving the surface hardness of EN-8 because of the work hardening effect (Jawalkar *et al.*, 2009)

Stoic *et al.*, have investigated on the machining efficiency of 34CrMo4 steel, using roller burnishing process. The experimental results showed that all smoothing outputs could be detected in all regimes. The measured data on surface roughness before and after roller burnishing process had been compared. It was found that surface roughness was significantly lower after roller burnishing. Experimental results and numerical modeling of roller burnishing offered great potential in improving the efficiency and part's quality (Stoic et al, 2010).

2.1 Some other relevant literature results can be tabulated as in below Table 1.

Sr. No	Process/Tool /Material	Key Results	Authors
1.	Roller burnishing on mild steel specimen.	It was found that surface finish and surface hardness increases with burnishing speed up to an optimum value of (62 mm/min) and then decreases with further increase in speed.	Babu et al. (2008)
2.	Roller burnishing on EN-24 steel using EN-31 roller tool.	It was observed that the performance of the tin-coated roller was superior to that of uncoated rollers in burnishing operation	Yeldose et al. (2008)
3.	Ball burnishing on Al alloy 2014 using carbon chromium steel ball as tool.	Results showed that from an initial roughness of about Ra 4 µm, the specimen could be finished to a roughness average of 0.14 µm.	Axira and Othmanb (2008)
4.	Roller burnishing on A53 steel.	Results showed that the corrosion potential and corrosion current decreased with increasing pressing force and reached a minimum value at about 80 N.	Qawabeha et al. (2009)
5.	Roller burnishing on different geometries.	Using FEA models quantitative prediction of the residual stress state was done.	Klocke et al. (2009)
6.	Roller burnishing on IN718 alloy.	Using roller burnishing high compressive residual stress, high strain hardening and excellent surface quality respectively were obtained.	Klocke et al. (2009)
7.	Ball burnishing on chromium-alloyed steel using ceramic ball as tool.	Using complete factorial plan, empirical relation was developed that could predict the surface roughness.	Manole and Nagi (2011)
8.	Ball burnishing on steel components.	Using ball burnishing fatigue life and wear resistance improved considerably.	Chaudhari et al. (2011)
9.	Roller burnishing on O1 alloy steel.	Using SPD, surface quality improved by 12.5%, ultimate tensile strength increased by 166 MPa and the percentage elongation of material increased by 13.6% respectively.	Rababa and Almahasne (2011)

III. EXPERIMENTAL SETUP

A properly planned and executed experiment can provide highly reduced data for collection and can avoid unnecessary experiments. It will save lot of resources which may be time, money, raw materials etc. In present study, parametric observation was made using speed and feed rate as process parameters and surface roughness and surface micro hardness as output or response variables. Experiments were performed using HMT power lathe (NH 26 model), making use of mineral oil as a lubricant. Lathe is shown in Fig.2. Burnishing operation was performed on mild steel specimen using roller burnishing tool. Fig.3 shows two different regions on mild steel specimen.

Fig.2 HMT power lathe for carrying out burnishing process.

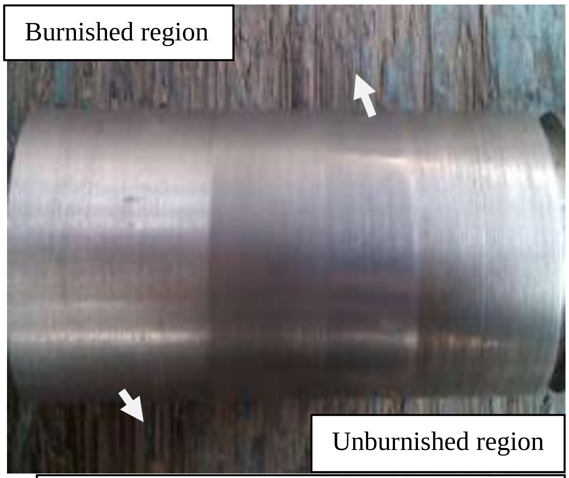

Fig.3 Different regions observed in mild steel specimen during burnishing process.

IV. RESULTS OF THE STUDY

3.1 Measurement of surface roughness values

In this study surface roughness and surface micro-hardness were the main response variables and the process parameter under consideration was the spindle speed. The material under consideration was mild steel. On experimental analysis, it was found that all the process parameters significantly affected the quality and surface finish of the work piece. The variation of surface roughness with spindle speed obtained during the trial is shown in the table 1 and fig.4.

Table 2: Variation of surface roughness with spindle speed

S.No.	Spindle speed (rpm) (along X-axis in graph)	Surface roughness (µm) (along Y-axis in graph)
1.	325	0.25
2.	420	0.21
3.	550	0.70

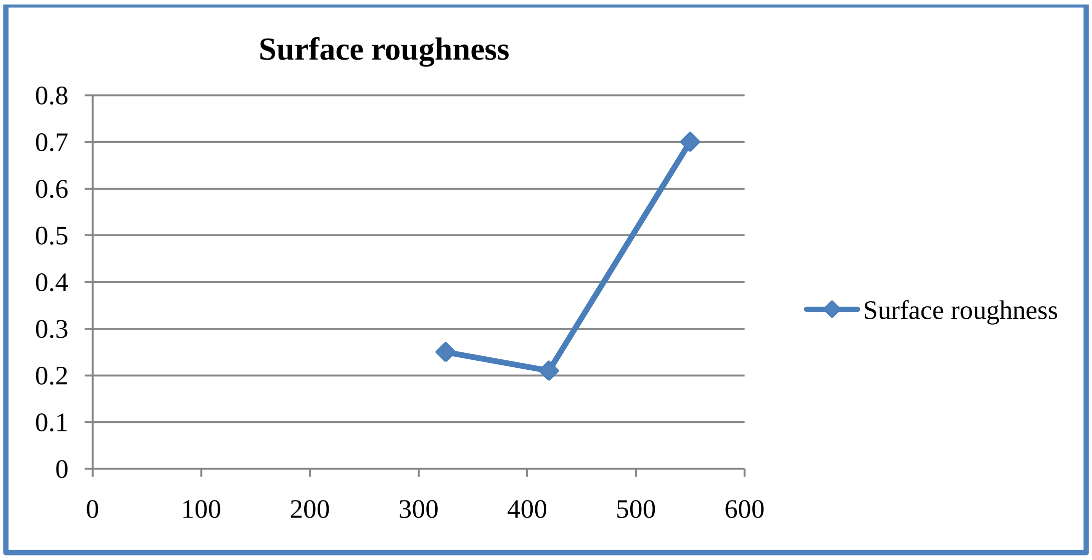

Fig.4 Trend line showing variation of surface roughness with spindle speed.

The variation in feed rate also affects the surface roughness of mild steel specimen as shown in Table 3 and Fig.5.

Table 3: Variation of surface roughness with feed rate

S.No.	Feed rate (mm/rev.) (along X-axis on graph)	Surface roughness (μm) (along Y-axis on graph)
1.	0.1	0.30
2.	0.2	0.25
3.	0.4	0.65

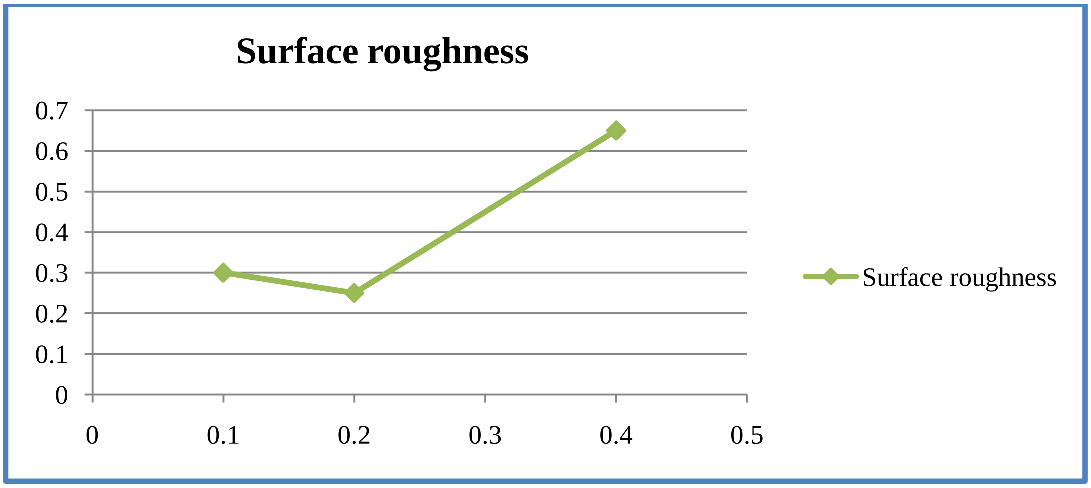

Fig.5 Trend line showing variation of surface roughness with feed rate.

3.2 Measurement of surface micro hardness values

In this phase experiments were conducted using roller burnishing tool on mild steel specimen to analyze the effect of variation in rpm on surface hardness. An increase in the burnishing force will increase the plastic deformation, as the penetration of roller is increased. It will lead to an increase in the internal compressive residual stress, which in turn causes a considerable increase in the surface hardness. Surface hardness decreases with increase in spindle speed and feed but there is a limit beyond which it is not possible to decrease the hardness due to work hardening effect. The Table 4 and Fig.6 represents the micro hardness against the spindle speed.

Table 4: Variation of micro hardness with spindle speed

S.No.	Spindle speed (rpm) (along X-axis on graph)	Surface hardness (HRB) (alongY-axis on graph)
1.	325	63
2.	420	61
3.	550	66

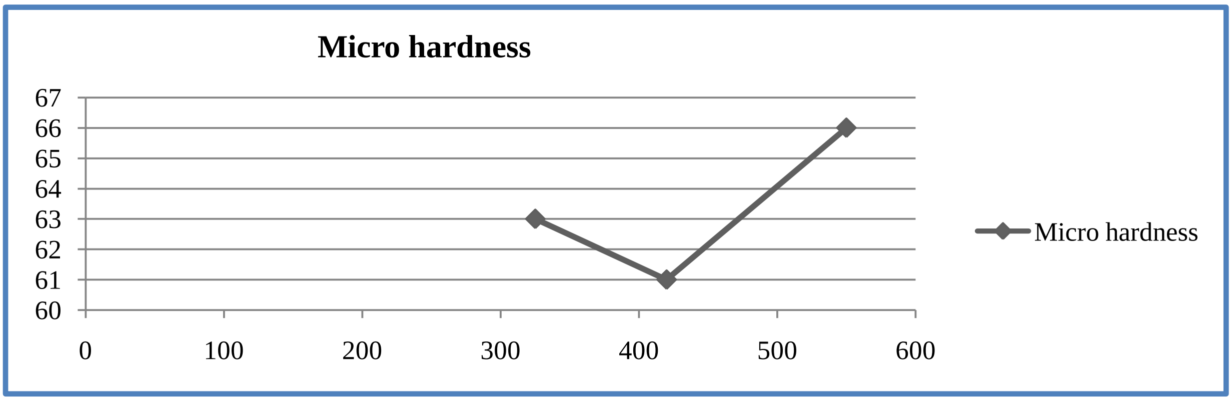

Fig.6 Trend line showing variation of surface micro hardness with spindle speed.

The variation in feed rate also affects the surface micro hardness of mild steel specimen as shown in Table 5 and Fig.7.

Table 5: Variation of micro hardness with feed rate

S.No.	Feed rate (mm/rev.) (along X-axis on graph)	Surface hardness (HRB) (along Y-axis on graph)
1.	0.1	62.5
2.	0.2	63
3.	0.4	66

Fig.7 Trend line showing variation of surface micro hardness with feed rate.

IV. CONCLUSIONS/RESULTS

Roller burnishing process for which the results are reported in this paper can be considered as one of the important processes for finishing of precision components. Through the conducted experiments on mild steel specimen, the following conclusions were drawn:

1. Roller burnishing produced superior surface finish with absence of feed marks of the burnishing tool on the burnished surface. The average surface roughness *Ra* obtained was 0.39 µm in burnishing, and finest *Ra* value observed was 0.21 µm (Table 2).
2. The process was useful in improving the quality of the burnished surface by selecting proper input parameters.
3. There was significant improvement in the surface micro hardness of mild steel specimen with increase in speed and feed rate. Best value of hardness obtained was 66 HRB at spindle speed of 550 rpm and feed rate of 0.4 mm/rev. respectively.
4. Since roller burnishing process improves bored or turned metal surface as well as the quality of surface roughness and surface hardness, so it can effectively be used in many fields such as automobiles manufacturing sector, production of machine tools, aerospace industries etc.
5. Since burnishing is completely chip-less process so there is no scrap produced while performing the experiments as compare to its counterparts like grinding, honing, lapping etc.

4.1 Future work/Research

Observing the various fruitful outcomes, it can be understood that this area of research has a vast scope for further research and experiments. By undergoing experiments a variety of materials as per their use in industry and applications. It may provide the associated sectors especially which calls better surface properties (like Space industry, Aeronautics and commodities sector etc.) with a hell of benefits.

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