A THESIS ON

STUDY OF EFFECT OF DIFFERENT BURNISHING CONDITIONS ON SURFACE ROUGHNESS FOR A FLEXIBLE BURNISHING TOOL

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ABSTRACT

Burnishing is a very simple and effective method for improvement in surface finish and can be carried out using existing machines, such as lathe. Quality of Surface is an important factor to decide the performance of a manufactured product. For better quality surface finish the main factor is surface roughness. On account of its high productivity, it also saves more on production costs. Moreover, the burnished surface has a high wear resistance and better fatigue life. The lower value of roughness gives higher surface finish for the manufactured product. Now in present scenario different processes like grinding, honing, super finishing, polishing, burnishing etc are used to reduce the value of surface roughness. Burnishing is one of the processes which majorly affect the surface roughness. The levels of input process parameters are selected on basis of one factor at a time experiment are Depth of cut, burnishing feed, burnishing speed and number of passes.

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Declaration

This is to declare that the project “STUDY OF EFFECT OF DIFFERENT BURNISHING CONDITIONS ON SURFACE ROUGHNESS FOR A FLEXIBLE BURNISHING TOOL” and related audit was carried out by the authors under the supervision of PROF. DR. MD. NURUL ABSAR CHOWDHURY, Professor, MCE Dept, IUT.

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LIST OF SYMBOLS

R_a………..Algorithmic surface roughness

V………..Burnishing speed

C………Depth of cut

F……….Burnishing feed

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Surface enhancement is well known as one of the most important methods to improve product performance by improving surface properties, such as surface hardening, which can be traced back to thousands of years. Surface enhancement techniques, such as thermal, thermo chemical, and mechanical techniques, have prospered greatly since the early twentieth century.

The studies of mechanical surface treatments increasingly focused on surface and subsurface characteristics in industrial fields, such as shot peening, ultrasonic shot peening, and ball-burnishing which induced the highest and deepest maximum residual stress. As a quite sufficient mechanical process in applications of dynamic loading, modern burnishing was applied in the early part of last century in the U.S., in which the history may need to be verified for some different introductions in literatures. Altenberger introduced this burnishing process which was carried out in the U.S. on the axes of Ford T vehicle in the 1920s and later on the axes of trains in the 1930s. However, the recent researches reported by Luca and Sorin indicated that it was introduced in the United States in the 50s of the last century after it was applied first in Germany in the twenties of the last century and then USSR.

1.2 BURNISHING

Burnishing is a cold work that employs plastic deformation of a surface layer in order to improve surface characteristics, such as surface finish and hardness of a work piece. As a no chip process in the environmental benefit, it is essentially a forming operation that occurs on a small scale in which strain hardening is induced to improve the surface strength and hardness with mirror like surface finish and high compressive residual stress in the surface layer, resulting in better fatigue life.

The plastic deformation produced by roller or ball burnishing is a displacement of the material in which the tool pushes the materials at the surface from the peaks into the valleys under the normal force against the surface over the yield point of materials in Figure 1-1. The compressive residual stresses induced in the surface layer enhance fatigue performance and mitigate stress corrosion cracking. In contrast, the tensile stresses reduce fatigue life and tend to surface cracking. Moreover, burnishing process also transform tensile residual stresses into compressive residual stresses in the surface zone. Under certain conditions, it provides a manufacturing alternative to grinding, precision turning, and honing operations with a cheaper cost that only for surface finish there was about 8-15 times less expensive than grinding. Burnishing is widely used on various materials such as steels, aluminum alloys, titanium alloys, magnesium alloys, cobalt-chromium alloy and brass. The applications involve about soft materials and hard materials (up to 65 HRC) in manufacturing automotive crankshafts, inner and outer bearing races, bogies axles, etc. In recent years, the burnishing process is employed increasingly to the aerospace, medical, and nuclear industries.

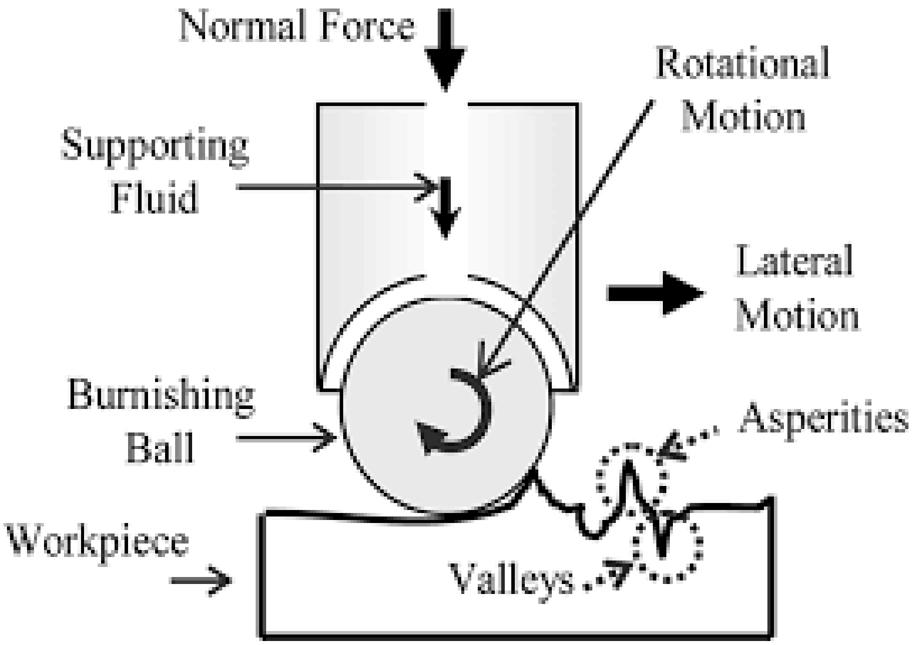

Fig 1-1: Plastic deformation by burnishing

1.3 BURNISHING TYPES

A burnishing tool clamped in the conventional or CNC machine can work similarly as the turning process for cylindrical work piece in a lathe or for flat work piece in a milling machine, in which the parameter can be set up usually depending on properties of work piece, such as hardness, and the objectives of works such as surface roughness and residual stress. Based on the tip movement related to the tool holder, burnishing can be simply classified into three basic types including

- Roller burnishing process
- Ball burnishing process
- Slide burnishing process

In views of burnishing tool motion with the frequency of oscillation, three types of burnishing can be achieved due to the magnitude of frequency, namely

- Vibratory burnishing process
- Sonic burnishing process
- Ultrasonic burnishing process

By combining the burnishing process with other processes, some new hybrid types were created, e.g., Laser-assisted burnishing which employed a laser beam just ahead of a burnishing tool in order to soften hard materials for burnishing, cryogenic burnishing for studies in grain size refinement and phase transformation by cooling the burnished area.

Compared to slide burnishing with the pure sliding motion, roller and ball burnishing processes are rolling types which are the most popular due to their simplicity, great techniques, and economic advantages for decades.

1.3.1 Roller Burnishing

In roller burnishing, a roller or rollers are forced in rotation or planetary rotation over a machined surface seen in Figure 1-2

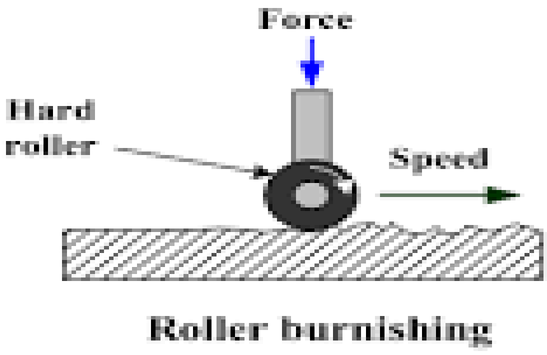

Fig 1-2: Roller burnishing process

1.3.2 Ball Burnishing

Ball burnishing with its characteristics of free rotation has two types, mechanical and hydrostatic springs, used in the industry. The mechanical spring tool is simple and easy to use just like turning tools or mill cutters; however, the main disadvantage of mechanical spring is obvious for the need of spring adjustment or changing, following the load variation.

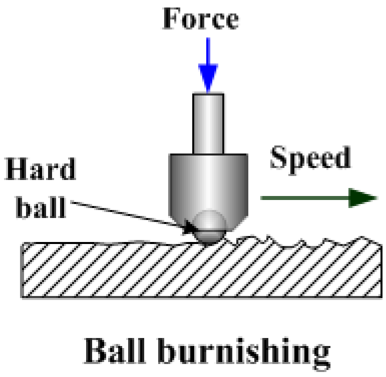

Fig 1-3: Ball burnishing process

In contrast, the main advantages of hydrostatic spring include a constant load (pressure easily adjusted), hydrostatic film kept between the ball and bearing seat, and overflow fluid to lubricate the work piece, which makes the hydrostatic tool little wearing and is suitable for manufacturing and also is employed in the overwhelming majority of literatures. For hard materials (over 45 HRC), a literature [1] indicated a single-point burnishing tool as the most effective due to reasonable normal forces.

1.3.3 Slide Burnishing

In slide burnishing, the tip of the tool is fixed to slide purely over the work piece with significant friction forces in both directions which may cause two drawbacks including rapid tool wear and particular scaly surface. Some studies showed that slide burnishing with cylindrical tools was more productive than that with ball-shaped tools in which very similar values of surface roughness Ra were obtained [2, 3].

In this study, the tool was designed as a ball burnishing method, and it was mounted on tool post which was perpendicular to the work piece so that it only burnished a portion of the outer surfaces to achieve desirable products.

1.4 OBJECTIVES

The objective of the study is to reduce surface roughness of mild steel alloy using ball burnishing process.

The objective of the study is to introduce the possible ball burnishing surface finish process of a free form surface plastic deformation.

The objective of the study is to roughness minimization of the work piece.

CHAPTER 2

Literature Review

2.1 INTRODUCTION TO PLASTIC DEFORMATION

It is well known that plastic deformation in crystals occurs by dislocation slips [4, 5]. A dislocation, namely a linear crystal imperfection, was proposed independently by Orowan, Polanyi and Taylor in 1934, generally with part edge and part screw dislocation [8]. Almost all the metals are polycrystalline [6]. In the early stages of plastic deformation, work hardening or strain hardening by the increase of stress with plastic deformation is mainly induced by dislocation pile-up due to stuck dislocations across a grain through a narrow transition zone or grain boundary as an effective slip barrier. The dislocation interactions then appear as the increase of dislocation density which is responsible for a higher hardening rate always in a polycrystalline metal than in a single crystal, so yield strength controlled by dislocation interactions only exists in the later stages of deformation [4]. Altenberger [1] introduced that deep rolling could result in the microstructures with dislocation cell structures, nano-crystallites, twinning, or phase transformations. Due to the bcc crystal lattice in 17-4 PH steel, it can be suggested that dislocation cell structures are preferred after ball burnishing.

2.2 BALL BURNISHING ON SURFACE INTEGRITY

Recently, many investigations about the burnishing processes were focused on ball burnishing process which could be due to its advantages [4, 10, 14]. Figure 2-1 shows the surface characteristic during ball burnishing process. In addition, an increasing tendency for machining hard steels is to employ ball burnishing as the finish process [7]. Manajan et al. [8] reported that most studies involving ball burnishing focused on effects of process parameters, mainly pressure (force), speed, and feed, followed by number of passes, ball diameter, lubricant, etc., on surface integrity.

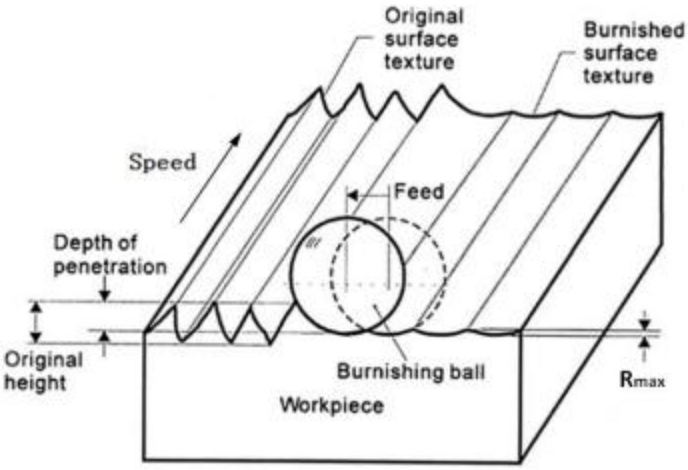

Figure 2-1 Sketch of ball burnishing process [13].

2.3 STUDIES ON SURFACE ROUGHNESS

The effect of ball burnishing on surface roughness probably is the most commonly reported in literature reviews. The most parameters are concerned with pressure (or force), feed, and speed, in which pressure and feed usually have significant effects on surface roughness as opposed to the effect of speed which may be negligible [9, 14].

Burnishing speed has a wide range introduced from 3 to 300 m/min [4] or between 10 and 250 m/min [13]. Luca et al. [4] recommended that usually values were lower than 150 m/min otherwise resulting in rougher surfaces which were also mentioned in the literature [12], and much lower speeds should be taken for rigid indentation tools. The value of 150 m/min also was introduced as the maximum established by the burnishing tool manufacturer [15]. Sagbas [16] and Tadicet al. [17] showed the speed had no significant influences on surface roughness on mild steel alloy which implied the feasible choice of maximum speed to save time.

Feed rate is also a very important factor for surface roughness because it is directly related to the surface profile which is highly dependent on tool contact geometry.

For number of passes, a previous research [25] revealed that a sufficiently good surface

could be achieved by a single pass even though two or more passes might be better, which involved several steels with hardness from 31-52 HRC. Using a maximum force, one pass was suggested [4, 17]. For hardened steels, one pass was effective [4]. For soft materials, generally two or three passes resulted in the best surface finish [18, 19, 20, 21, 22] even though some cases preferred four passes on brass [24, 25], which was believed that a high number of passes could deteriorate surface finish due to over-hardening and consequently flaking of the surface layers [23].

For lubricant, it is more interesting to use machining coolant because of the burnishing process following machining. Machining coolant (emulsion of 3-5% oil in water) which is an emulsion of 5% oil in water. Another study [15] employed an emulsion coolant of 3% oil in water. Nevertheless, many investigations focused on other lubricants such as SAE engine oil, kerosene, and diesel [26]. Hassan et al. [9] applied several lubricants by different viscosities from 8 to 413 mm^2/s (at 40°C), respectively, to mechanical ball surface roughness or on hardness during the change of viscosity of lubricants.

CHAPTER 3

EXPERIMENTAL SETUP

3.1 SUITABLE BURNISHING CONDITIONS FOR MILD STEEL

Work piece: Cylindrical bars
Length 120-300 mm

Diameter 30-45 mm

No of Passes: 1-7

Feed: .05-.44 mm per rev

Speed: 10-60 m per min

3.2 EXPERIMENTAL PLANNING

Variable	Constant	Exp 01	Exp 02	Exp 03	Exp 04
Speed (m/min)	Feed, Depth of Cut, No of pass	56.6	38.5	23.5	15
Feed (mm/min)	Speed, Depth of Cut, No of pass	.38	.24	.12	.095
Depth of Cut (mm)	Speed, Feed, No of pass	.5	.75	1	1.25
No of pass	Speed, Feed, Depth of Cut	1	2	3	4

Table 3.1: Experimental Planning

3.3 WORKPIECE

The raw material was mild steel machining quality solid cylindrical bar at Φ 34 mm × 5 mm cut at 20 mm length. The work pieces were turned by facing and center drilling and then were clamped on the lathe machine which includes three-jaw chuck, dead center, and tool turret.

The turmimg parameters were controlled with a speed of 360 RPM, feed of 0.24 mm/rev and depth of cut of 1mm.

Finally, the average roughness was 3.62 µm.

In addition, three extra turned samples were stored for the next step.

Figure 3.1: Work piece

3.4 BURNISHING PROCESS

The burnishing processes were carried out in the same lathe without unclamping the

Turned work pieces by using a ball burnishing tool mounted on the turret just next to the turning insert. The burnishing tool was set up just like the figure below against the work piece edge under an applied pressure.

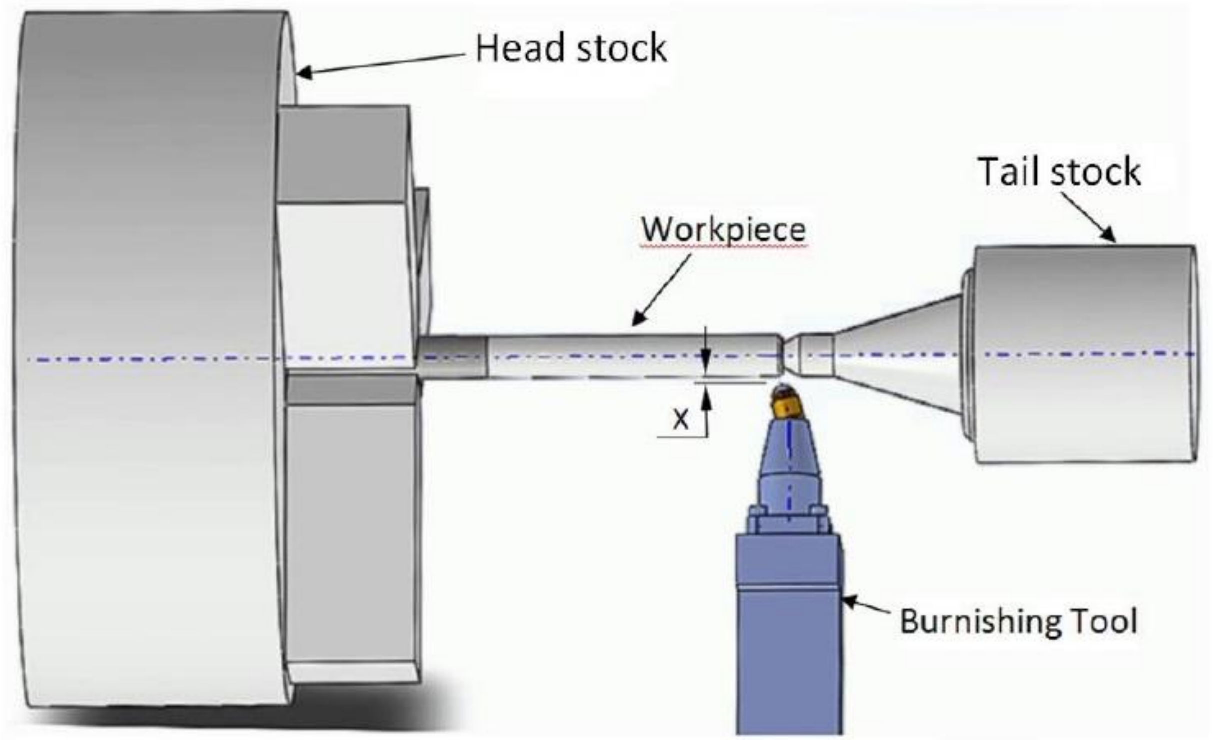

Fig 3.2: Sketch of ball burnishing process

Fig 3.3: Burnishing tool

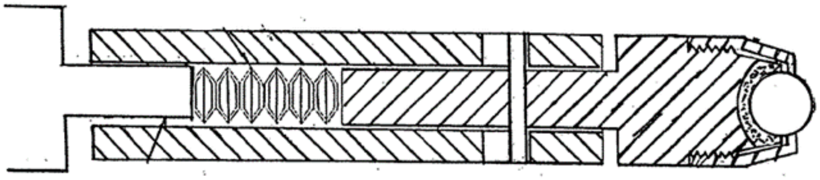

Fig 3.4: Schematic diagram of burnishing tool

3.5 SURFACE ROUGHNESS MEASUREMENT

The values of mean surface roughness (Ra) before and after burnishing were measured by Mitotoyo surface roughness tester. Cleaning work was necessary to avoid the contamination by air before measurements. For each work piece, the average R_a was obtained by three measurements conducted along the longitudinal direction at different positions.

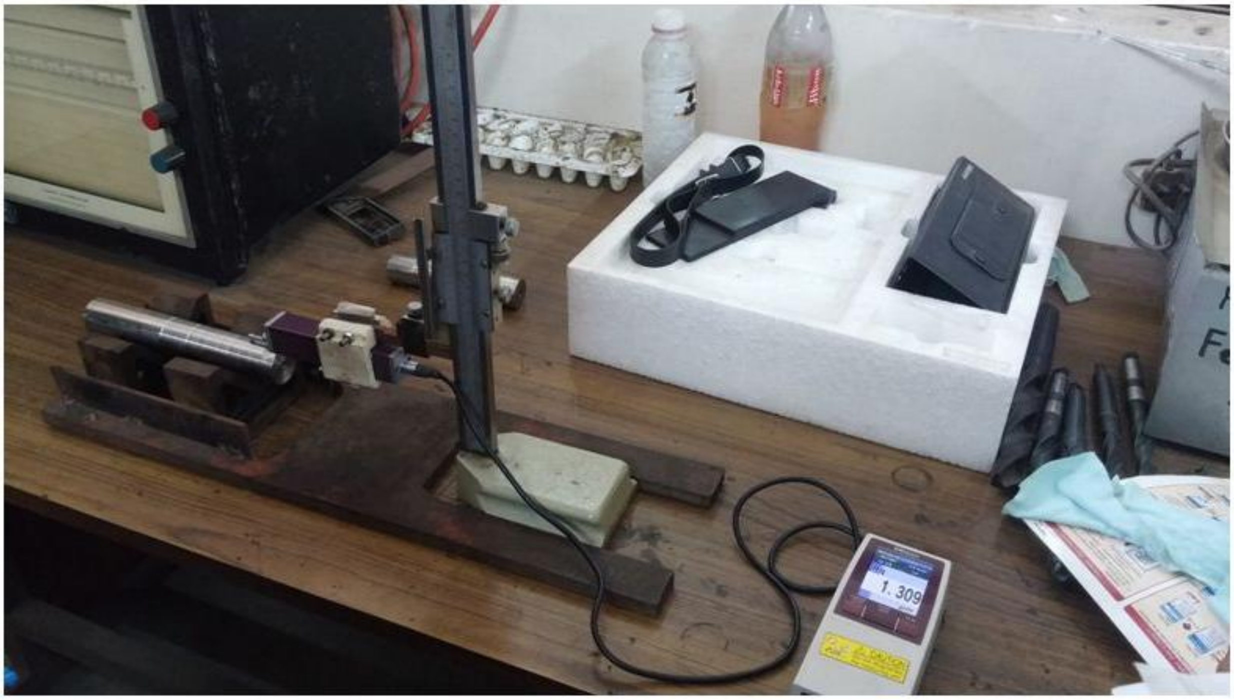

Fig 3.5: Measuring the surface roughness with Mitutoyo surface roughness tester

CHAPTER 4

Experimental Data

4.1 SPEED VS ROUGHNESS

Initial Roughness- 4.5 Ra-µm

Constant Parameters:

Feed-0.24 mm per min

Depth of Cut- 1 mm

No of pass- 1

`

Table 4.1: Experimental values for surface roughness against variable RPM

RPM	Speed V	V/V_o	Roughness Ra-µm	Average Roughness, µ Ra-µm	μ/μ_o
530	56.6	3.78	2.647	2.64	.6
			2.671		
			2.602		
360	38.45	2.57	1.476	1.564	.35
			1.609		
			1.608		
220	23.5	1.57	1.7	1.703	.38
			1.635		
			1.775		
140	14.95	1	3.587	3.376	.75
			3.301		
			3.24		

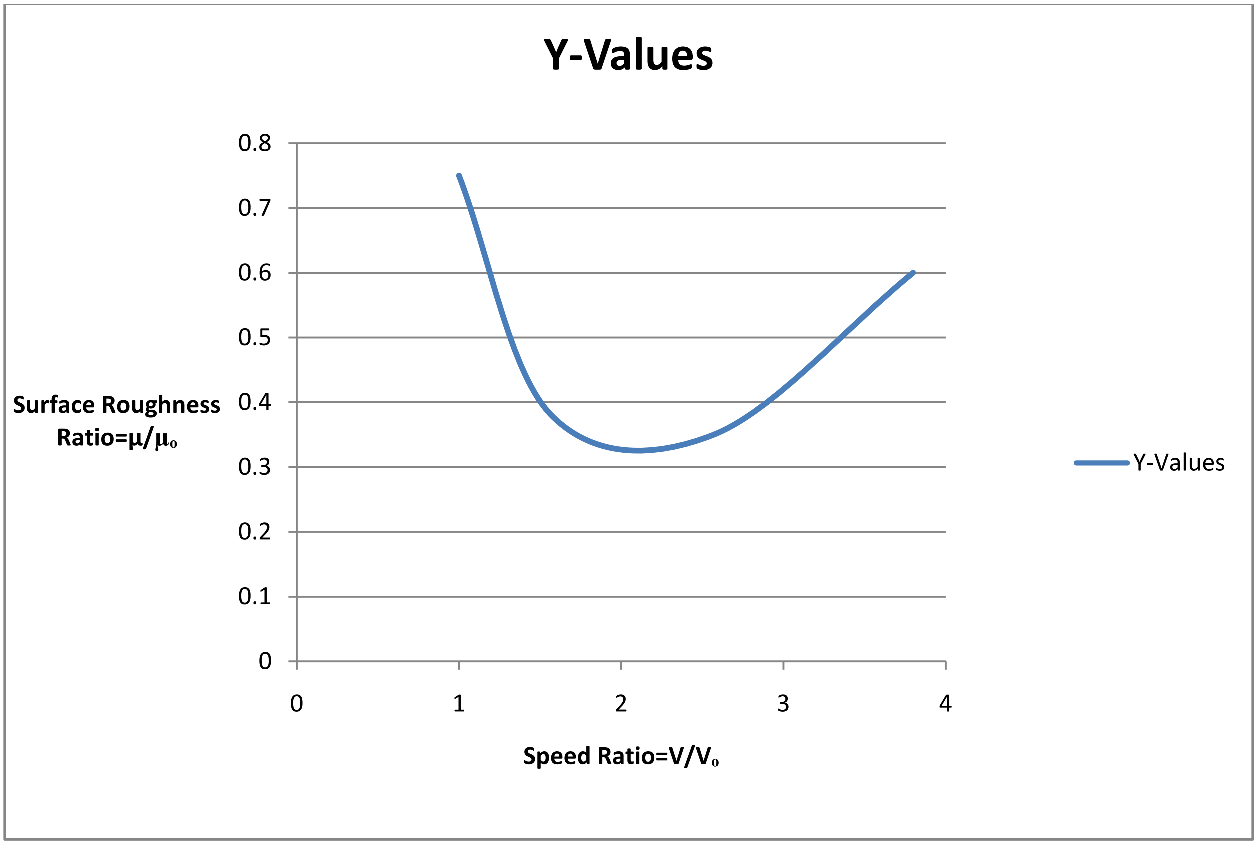

Fig 4.1: RPM vs surface roughness graph

4.2 DEPTH OF CUT VS ROUGHNESS22

Initial Roughness- 2.21 Ra-µm

Constant Parameters:

Feed- 0.24 mm per min

RPM- 360

No of pass- 1

Table 4.2: Experimental values for surface roughness against variable depth of cut

Depth of Cut C	C/C_o	Roughness Ra-µm	Average Roughness, µ Ra-µm	μ/μ_o
0.5	1	1.285	1.304	.6
		1.231		
		1.397		
0.75	1.5	2.162	1.939	.877
		1.803		
		1.852		
1	2	1.98	1.711	.77
		1.6		
		1.554		
1.25	2.5	1.465	1.446	.65
		1.338		
		1.535		

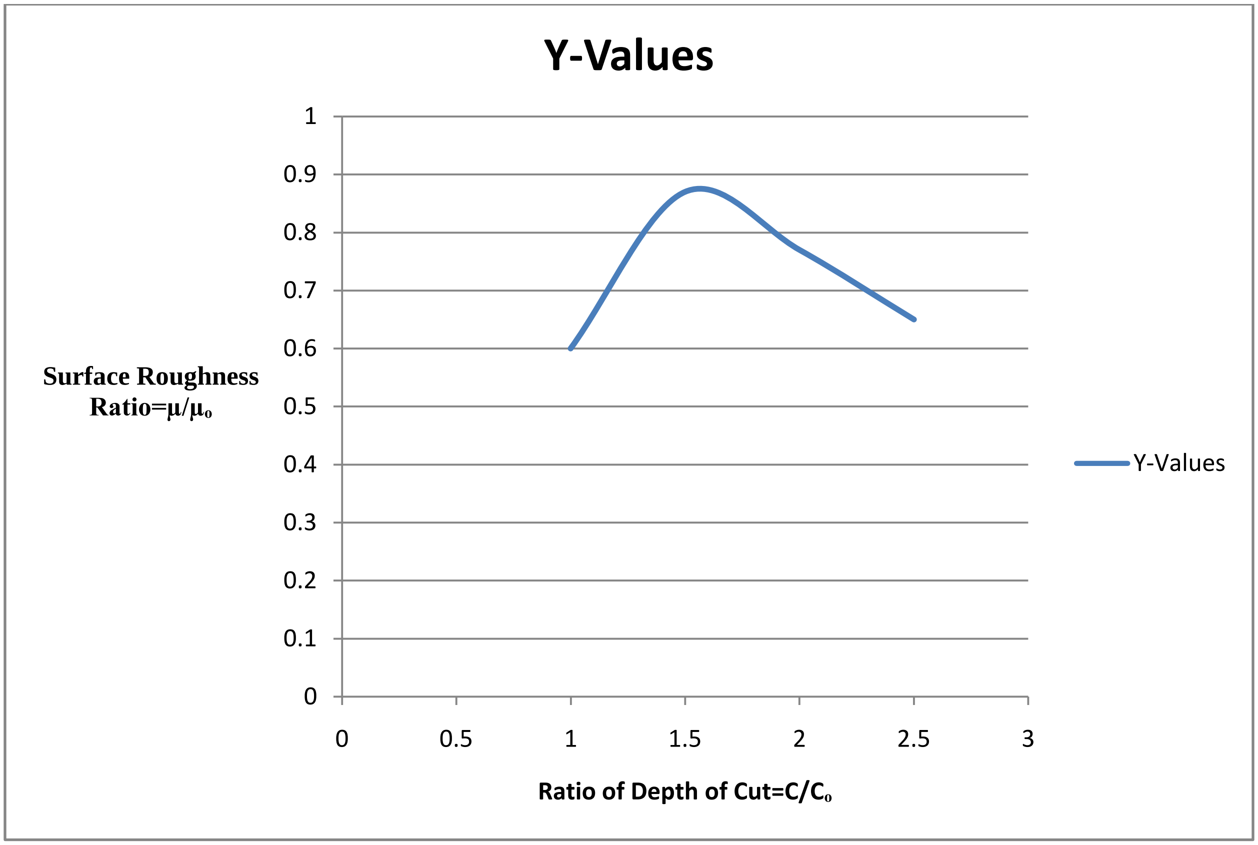

Fig 4.2: Depth of cut vs surface roughness graph

4.3 FEED VS ROUGHNESS

Initial Roughness- 2.0 Ra-µm

Constant Parameters:

Depth of Cut- 1 mm

RPM- 360

No of pass- 1

Table 4.3: Experimental values for surface roughness against variable feed

Feed F	F/F_o	Roughness Ra-µm	Average Roughness, µ Ra-µm	μ/μ_o
0.38	4	1.79	1.827	.9135
		1.988		
		1.703		
0.24	2.5	1.735	1.76	.88
		1.892		
		1.652		
0.12	1.25	0.74	0.782	.782
		0.876		
		0.73		
0.095	1	0.735	0.652	.326
		0.6		
		0.621		

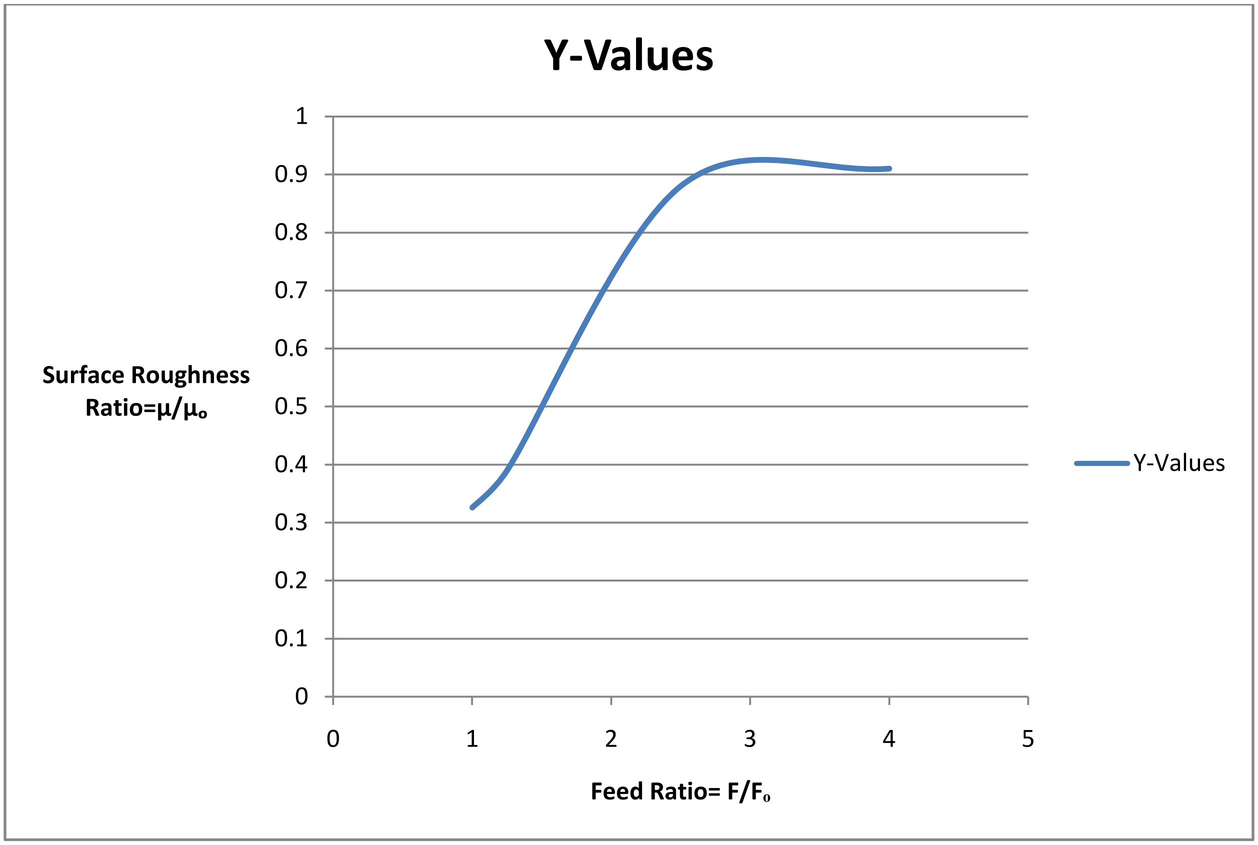

Fig 4.3: Feed vs surface roughness graph

4.4 NO OF PASSES VS ROUGHNESS

Initial Roughness- 5.78 Ra-µm

Constant Parameters:

Feed- 0.24 mm per min

RPM- 360

Depth of Cut- 1

Table 4.4: Experimental values for surface roughness against variable no. of pass

No of Pass	Roughness Ra-µm	Average Roughness, µ Ra-µm	μ/μ_o
1	4.9	5.148	.9
	5.35		
	5.196		
2	4.423	4.671	.816
	4.25		
	5.34		
3	2.463	2.761	.48
	3.121		
	2.7		
4	3.085	2.8	.49
	2.596		
	3.272		

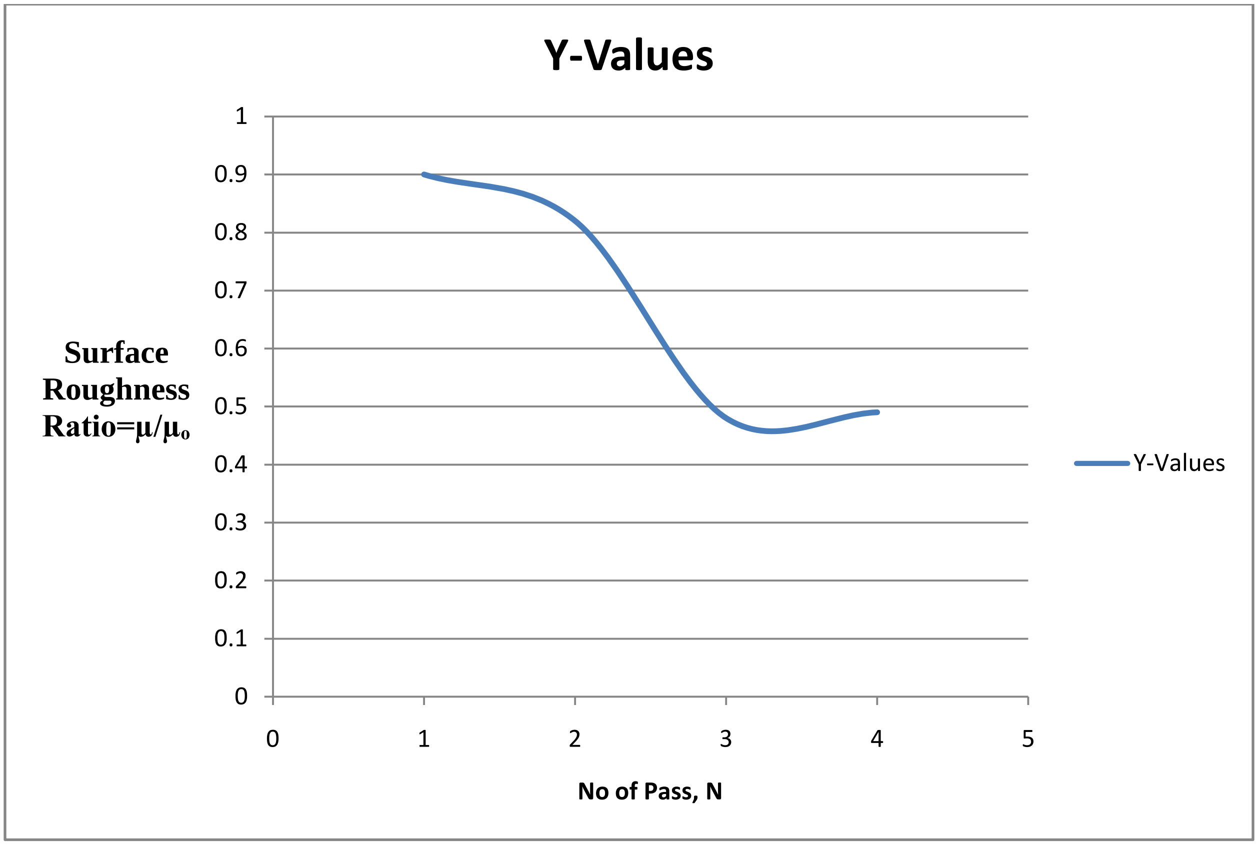

Fig 4.4: No. of pass vs surface roughness graph

CHAPTER 5

CONCLUSION & FUTURE WORK

5.1 CONCLUSION:

- Surface roughness decrease with increase in speed up to 360 RPM (approximately) and further gets increases with increasing speed. It’s due to possible chattering of the burnishing tool and the increase in temperature, which increases the possibilities of material transformation between the burnishing ball work piece interfaces start to have a decisive effect.
- Surface roughness decreases with decreasing feed. When feed rate is low the distance between successive traces will be small.
- Surface roughness varies with the depth of cut used. We found that it is wise to keep the depth of cut minimum as it will have a less effect on the job piece dimension.
- Surface roughness decreases with increasing in number of passes. After a particular number of passes, the surface layer becomes highly work-hardened, and then roughness increases a bit with number of passes. The optimum number of passes for mild steel is 3/4.

5.2FUTURE PLAN

- We can compare the changes in surface roughness with different diameter of ball used in the tool and find the suitable one. To design a tool which will be able to deal with variety of diameter, we must design a flexible ball holder.
- Changes in surface roughness with respect to changes in force applied in the work piece might be considered.
- The changes in hardness and residual stress of the material with changes in different parameters may be evaluated. This will help to select the required conditions even more.
- The whole experiment may be done with wider range in the parameters. That will help us to get a more specific and accurate decision.

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