STUDY OF THE EFFECT OF EXTERNAL VIBRATION ON SURFACE ROUGHNESS AFTER BURNISHING BY A VIBRATION ASSISTED FLEXIBLE BURNISHING TOOL

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CERTIFICATE OF RESEARCH

This is to certify that the work presented in this thesis paper is the outcome of the research carried out by the candidates under the supervision of Dr. Nurul Absar Chowdhury, Professor of Mechanical & Chemical Engineering. It is also declared that, neither this thesis nor any part thereof has been submitted anywhere else for the award of any degree or any judgement.

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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 saves also 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 manufacture red 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 process which majorly effect the surface roughness. The levels of input process parameters are selected on basis of one factor at a time. Experiment of depth of cut, burnishing feed, burnishing speed and number of process.

Burnishing process has many advantages over the other finishing processes, the improvement of the surface roughness through the burnishing process generally ranged between 40% and 90% [11-13]. Compressive stresses are also induced in the surface layer, giving several improvements to mechanical properties. Burnishing can improve both the surface strength and roughness [14].

Dedicated To

To our respected mentor

Prof. Dr. Nurul Absar Chowdhury

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R_a	Algorithmic surface roughness
V	Burnishing speed
V_o	Turning Speed
C	Depth of cut
C_o	Depth of cut during Turning Operation
F	Burnishing feed
F_o	Feed rate during Turning Operation
μ	Average roughness
μ_O	Initial roughness after Turning Operation

CHAPTER 1 : INTRODUCTION

1.1 OVERVIEW

To ensure reliable performance and prolonged service life of modern machinery, its components require to be manufactured not only with high dimensional and geometrical accuracy but also with high surface finish. The surface finish has a vital role in influencing functional characteristics like wear resistance, fatigue strength, corrosion resistance and power loss due to friction. Unfortunately, normal machining methods like turning, milling or even classical grinding can't meet this stringent requirement.

Current industry demands mechanical components with a high fatigue resistance and low friction ratio. This demand grows larger with the necessity of the manufacturing components requiring compressive residual stress in deep layers, high hardness and low surface roughness. Surface enhancement offers a variety of benefits ranging from increased life to cost reduction when properly designed and optimized for the material and application. Strength and life can be increased without changing either the material or the component design. Common service damage can be completely mitigated by placing the damaged layer in compression. Whether it is optimizing conventional shot peening for maximum production at minimal cost, or developing novel LPB® solutions for improved damage tolerance, Lambda's extensive experience and unique combination of applied stress modeling, residual stress measurement, surface treatment design, and performance testing capabilities are applied to each project to realize these benefits. Surface enhancement techniques, such as thermal, thermo chemical and mechanical techniques have prospered since the early twentieth century.

Some of the benefits of surface enhancement to introduce a deep stable surface layer of residual compression are as follows:

- Fatigue Life Extension
- Damage Tolerance Improvement
- Mitigating Manufacturing Damage
- Stress Corrosion Cracking and Corrosion Fatigue
- Weight Reduction
- Material Substitution

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 application of dynamic loading, modern burnishing was applied in the early part of last century in the U.S.A, 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.A on the axles of Ford T vehicles in the 1920's and later on the axles of trains in the 1930's.However, the recent researches reported by Luca and Sorin indicated that it was introduced in the U.S.A in 1950's of the last century after it was applied first in Germany in the 1920's of the last century and then USSR.

1.2 BURNISHING

Finishing processes are commonly used to improve the surface finish of the machined components. These processes can be classified as chip removal process such as grinding and chip less process such as burnishing [1-3]. Burnishing is considered as a cold- working finishing process, differs from other cold- working, surface treatment processes such as shot peening, and sand blasting etc., in that it produces a good surface finish. The burnishing process consists of pressing hardened steel rolls or balls into the surface of the work piece and imparting a feed motion to the same. Also, burnishing is economically beneficial, because it is a simple and less costly process, requiring less time. Semi-skilled operators are enough to obtain a high-quality surface finish. 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 process has many advantages over the other finishing processes, the improvement of the surface roughness through the burnishing process generally ranged between 40-90%.

In the process the deformation element is hard ball. Alumina carbide ceramic, cemented carbide, silicon nitride ceramic, silicon carbide ceramic, bearing steel is the material used for ball. As ball acts as tool in deformation the surfaces layer, for the given normal force it gives high specific pressure, more fatigue strength, micro hardness & depth of work hardening layer as compared to roller burnishing. As there is a point & rolling friction between the ball & the work piece, the deformation zone is located adjacent to the ball on the work piece.Fig.1.1 represents scheme of ball burnishing process.

Burnishing tools are also now widely applied in nonautomotive 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.

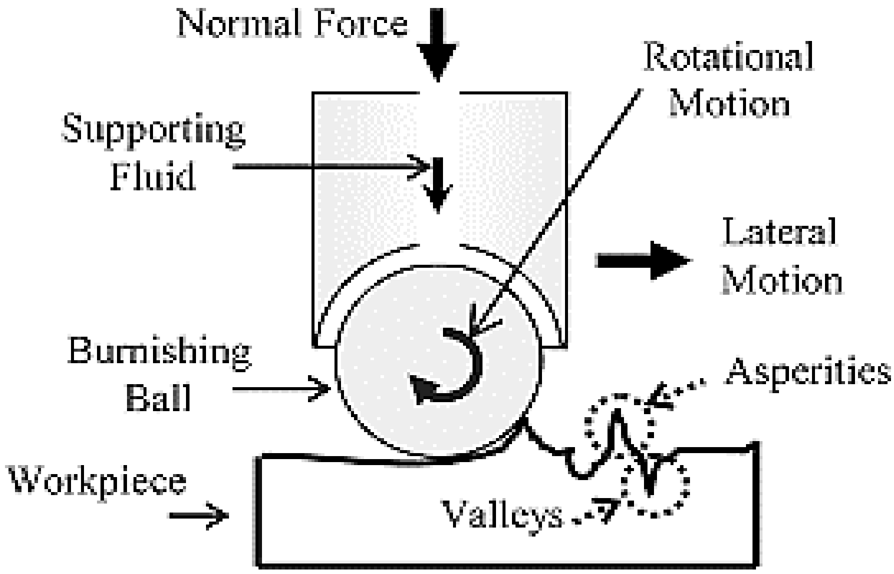


Figure 1.1 : Plastic Deformation by Burnishing Process

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 the properties of work piece, such as hardness, and the objective 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 pure sliding motion, roller and ball burnishing process are rolling types which are the most popular due to their simplicity, great techniques, and economic advantage for decades.

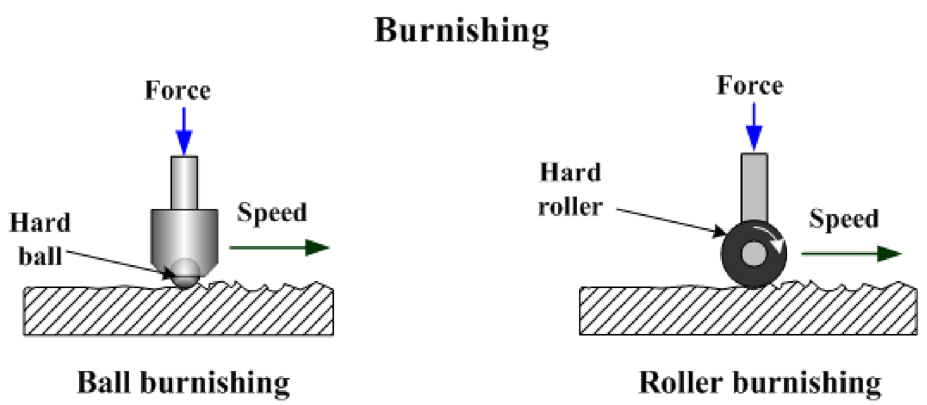


Figure 1.2 : Plastic Deformation by Burnishing Process

1.3.1 ROLLER BURNISHING

Roller burnishing is a method of cold working metal surfaces to induce compressive residual stresses and enhance surface roughness qualities. The tooling typically consists of a hardened sphere or cylindrical roller. These tools are pressed onto/across the part being processed. The part (or the tool in some applications) must be moving at a constant rate of speed, for example in the case of roller burnishing a part on a lathe, the part is spinning and the burnishing tool is moved across the surface as a constant rate; therefore, producing a very consistent finish across the part. Another application is thrust bearing surfaces of some production crankshafts. A dual roller (cylindrical) tool is moved into the thrust bearing journal of a crankshaft, while the crankshaft is spinning the tool is indexed (so each roller is perpendicular to the thrust surface while backing each other up) deforming the surfaces. So the diameters of each roller added together (compensated for elastic deformation) equals the finish dimension of the thrust bearing

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

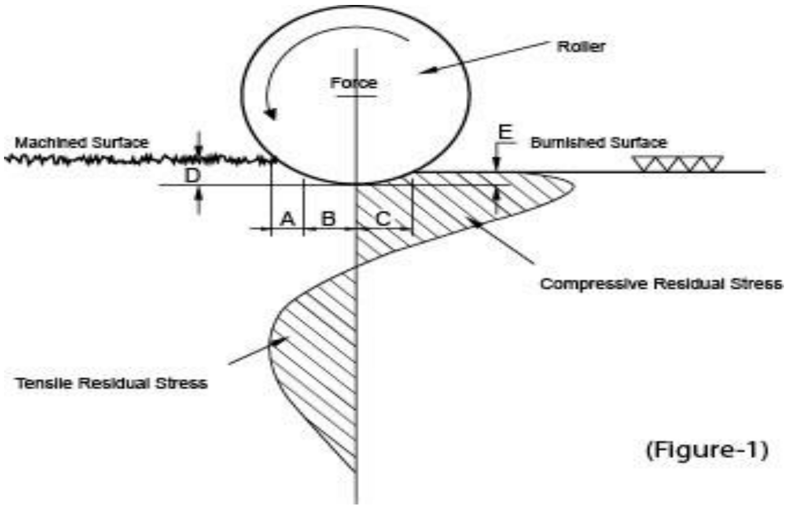


Figure 1.3 : Roller Burnishing Process

1.3.2 BALL BURNISHING

Ball burnishing with its paper 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.

In contrast, the main advantage 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 is also employed in the overwhelming majority of literatures. For hard materials (over 45 HRC), a literature indicated a single-point burnishing tool as the most effective due to reasonable normal forces.

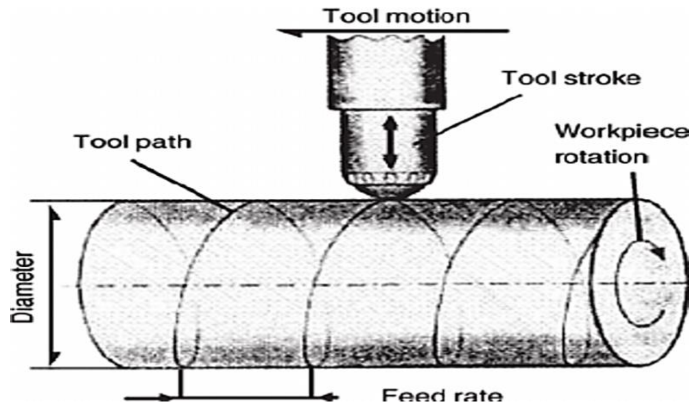


Figure 1.4 : Ball Burnishing

1.3.3 SLIDE BURNISHING

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

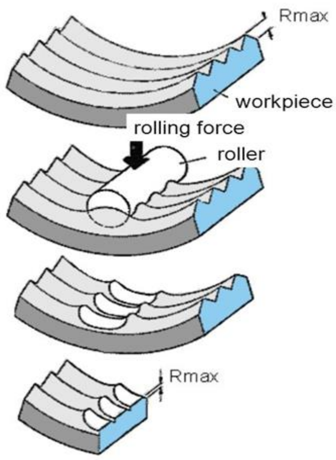


Figure 1.5 : Slide Burnishing

In this study, the tool was designed as a ball burnishing methods, and it was mounted on tool post which was perpendicular to work piece so that it only burnished a portion of the outer surface 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 vibrational effects on ball burnishing surface finish process of a free form surface plastic deformation and to roughness minimization of the work piece.

Then, this paper aims to study the behavior of a ball-burnishing vibration-assisted tool. To do that, firstly the design of the tool through the study of its fundamental parts is described. Analysis of the elements which provide the vibration via a physical model is made. This is why they are the essential elements for the tool operation.

1.5 SCOPES AND LIMITATIONS

The scopes of the study is to develop a new ball burnishing tool with the assistance of vibration from an external source which will help to achieve target plastic deformations at the peaks and valleys of layer of surface roughness.

As there is no specified tool for this operation, the suggested tool can perform only in certain criteria's. So, development study should be carried out efficiently.

CHAPTER 2 : LITERATURE REVIEW

2.1 INTRODUCTION TO PLASTIC DEFORMATION

It is well known that plastic deformation in crystals occurs by dislocation slips. 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. Almost all the metals are polycrystalline. In this early stages of 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 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. Altenberger introduces that deep rolling could result in the microstructure with dislocation cell structure, Nano-crystallites, twinning, or phase transformation. Due to bcc crystal lattice in 17-4 PH steel, it can be suggested that dislocation cell structures are preferred after ball burnishing.

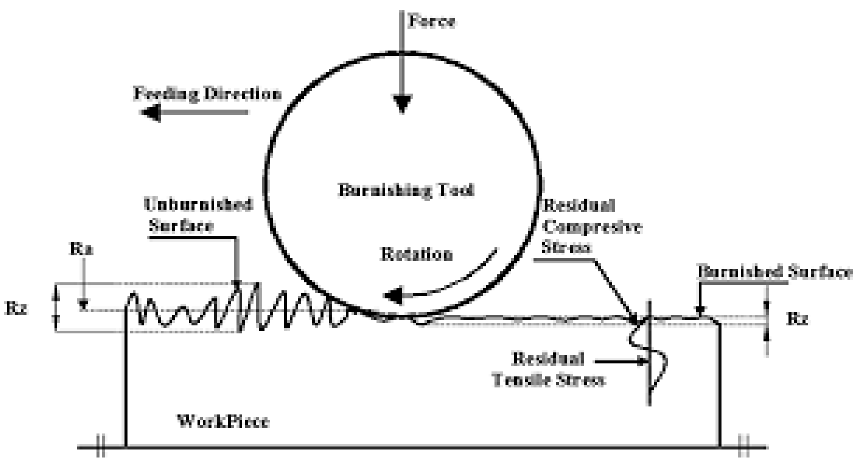


Figure 2.1 : Plastic Deformation during burnishing process

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 advantage [4, 10, 14]. Figure 2-1 shows the surface characteristics during ball burnishing process. In addition, an increasing tendency for machining hard steel is to employ ball burnishing as the finish process [7]. Manajan et al. [8] reported that most studies involving ball burnishing focused on effect of process parameters, mainly pressure (force), speed and feed, followed by number of passes, ball diameter, lubricant, etc., on surface integrity.

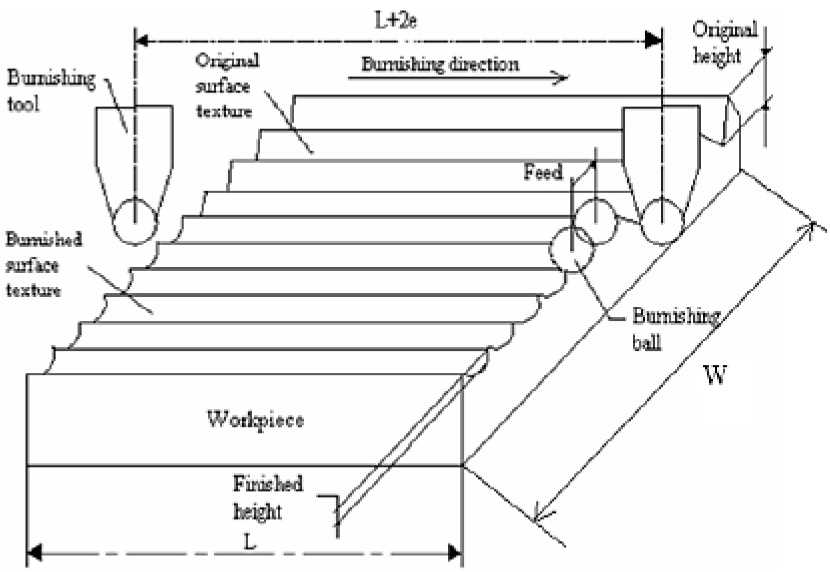


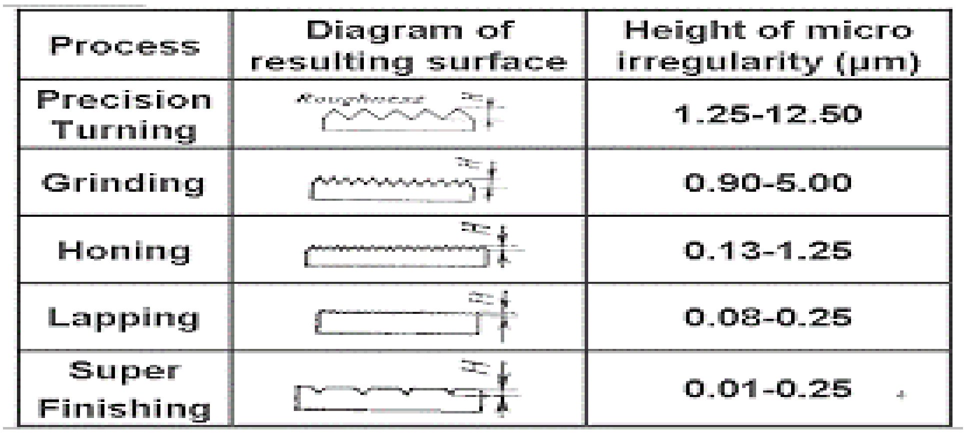
Figure 2.2 : Surface condition during Ball Burnishing

Burnishing tools are also now widely applied in nonautomotive 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

2.3 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 300m/ min [4] or between 10 and 250 m/min [13]. Luca et al. [4] recommended that usually values were lower than 150m/min otherwise resulting in rougher surface 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 manufacture [15]. Sagbas [16] and Tadicet al. [17] showed that speed had no significant influences on surface roughness on mild steel alloy which implied the feasible choice of maximum speed save time.



Process	Diagram of resulting surface	Height of micro irregularity (μm)
Precision Turning		1.25-12.50
Grinding		0.90-5.00
Honing		0.13-1.25
Lapping		0.08-0.25
Super Finishing		0.01-0.25

Figure 2.3 : Irregularities rise from different surface finishing process

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 hardness 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 passes could deteriorate surface finish due to over-Harding and consequently flanking of the surface layer [23].

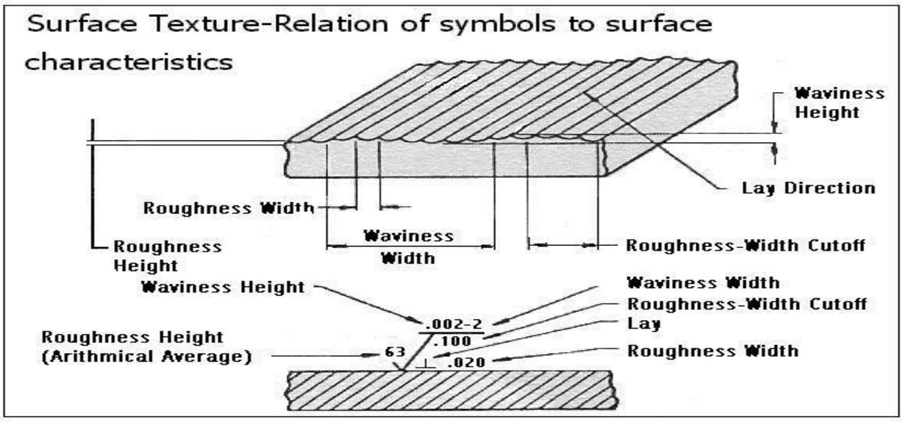


Figure 2.4 : Surface Texture Relations

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).

Nevertheless, many investigations focused on other lubricants such as SAE engine oil, kerosene, and diesel [26]. Hasan et al. [9] applied several lubricants by different viscosities from 8 to 413 mm^2/s (at 40 degree C), respectively, to mechanical ball surface roughness or on hardness during the change of viscosity of lubricants.

2.4 VIBRATION ASSISTED BALL BURNISHING

Rodriguez et al. [12] analyzed the behavior of this operation in a turning process, comparing the surface results of pieces mechanized through a turning operation and others finished through to ball burnishing. Surface roughness, hardness and compressive residual stresses were analyzed. Burnishing caused Ra up to 0.3 mm, an increase of 60% in hardness, and residual stresses of approximately 350MPa. As shown in referenced papers, this process has also been studied and evaluated by our group. We have shown the influence of burnishing on surface finishing, hardness and changes in the compressive stress map. The compressive force involved in the burnishing process is crucial for obtaining positive results. The material deformation is constrained by a certain limit determined by its properties, so acting on these during the burnishing process is necessary to attain better results. An alternative method to modify the way the material is deformed during the burnishing process is 80 assisting with a vibrational source. Vibration helps in increasing the velocity with which dislocations move and allows a better internal restructuring of the material’s microstructure while it is deforming [13, 14]. These considerations lead us to believe that a **vibration-assisted ball-burnishing process**

(VABB) is comparable to a conventional process and justifies the study presented in this paper. Furthermore, we have found nothing in the literature that has shown the existence of vibration-assisted burnishing tools.

The following hypotheses are addressed in this study:

1. Are the values of surface roughness affected by vibrations in a burnishing process?

2. Does the VABB process increase the superficial hardness of work pieces compared to the values obtained 95 by the conventional burnishing process?

3. Does the VABB change the compressive residual stress map in the external layers of the material, achieving higher values at deeper levels compared to values obtained through the conventional burnishing process?

2.5 EFFECT OF VIBRATION ON PLASTIC DEFORMATION

Through the vibration-assisted process, a greater dislocation movement of the material work piece is achieved. This allows us to work on harder materials with less force, and even improve the results of the process [3].
Today in the market there is no tool that uses the assistance of a vibration, to make a ball-burnishing process. This is the reason why a prototype tool capable of performing the above process has been designed and manufactured. This is the main contribution of this work.

- As there is a **point & rolling friction** between the ball & the work piece, the **deformation zone** is located adjacent to the ball on the work piece.
- When the **yielding point** is reached, the material deforms to a certain extent. The yield strength is not a purely intrinsic property of a material.
- The **yield strength** may change if the **deforming process** is being assisted by an **external source of vibration** (Kozlov et al. 1995).
- The phenomena is called **acoustoplasticity** and occurs when a vibrating force adds its effect to that of a deforming force, and contributes to the deformation of the material's structure. That way, **dislocations** of its **microstructure** reallocate more easily, and that translates into a decrease of the yield point. In other words, the material can be deformed by the application of **smaller forces**.

CHAPTER 3 : DEVELOPMENT STUDY

3.1 GENERATING VIBRATION

In this study, the VABB tool was designed by simply spot welding a mild steel hub onto it. There is two slots milled into it which the Vibration motors mount. The vibration motor generates vibration around 11 H_z spinning around at 250 RPM. The motors are operated at 12 Volts generating maximum power. Variable voltage adapter was connected as the power supply.

3.2 VIBRATION ASSISTED TOOL DESIGN

To characterize this tool, the following assumptions were made:

- The amplitude and frequency of the vibration that is directly generated by the Vibration motor force is generated by D.C current.
- The deformations of the surface are in an elastic regime, therefore, the material properties such as Young's modulus and Poisson's ratio are considered constant.
- The tool should work in a resonant mode whose frequency must be estimated

3.3 CONVENTIONAL V/S VABB TOOL

The VABB process has already been tested by the authors, obtaining very positive results. Comparing mechanical properties of specimens burnished with and without vibrations .Introducing vibrations into the process R_a is improved about 70% in the case of aluminum and about 50% in the steel, when the burnishing is performed with vibrations. Micro hardness also shows a 6% improvement in aluminum and 5% in the steel, residual stresses are also better at around 10% for aluminum and 8% for steel.

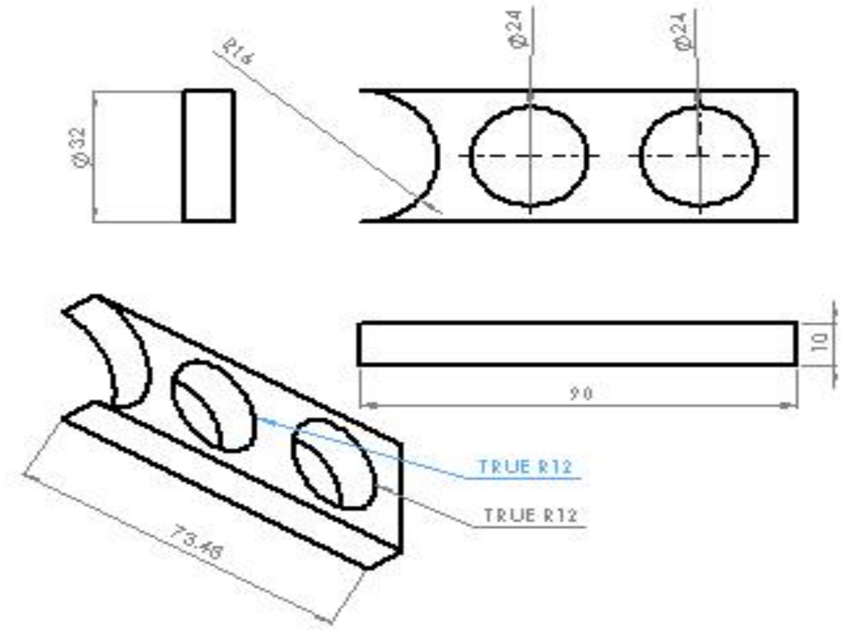


Figure 3.1 : VABB Tool Hub

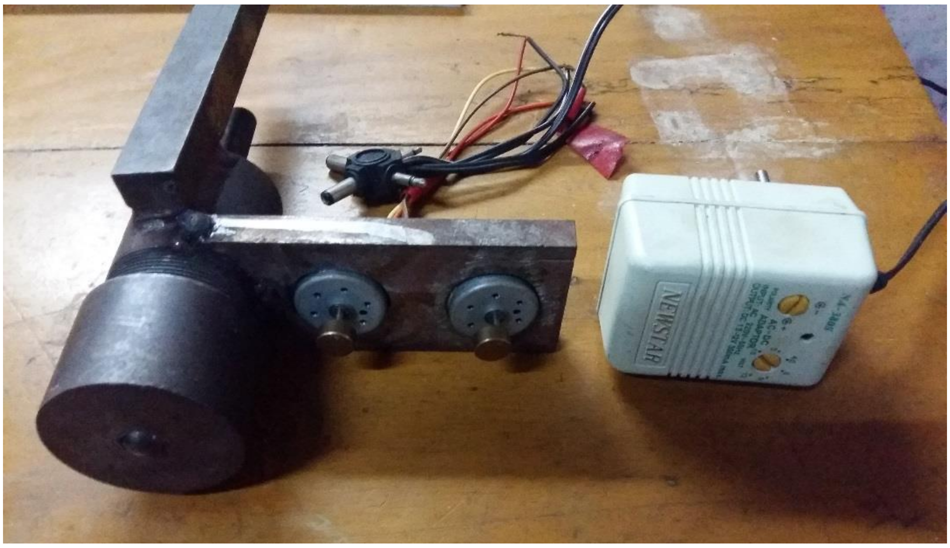


Figure 3.2 : VABB Tool

3.4 PARAMETERS AFFECTING THE STUDY

Some parameters had to be selected for the advancement of the study. The parameters were selected on the basis of importance which yielded positive results for the other authors. The Parameters are:

- Burnishing Speed
- Depth of Cut of the tool
- Feed Rate
- No. of tool passes

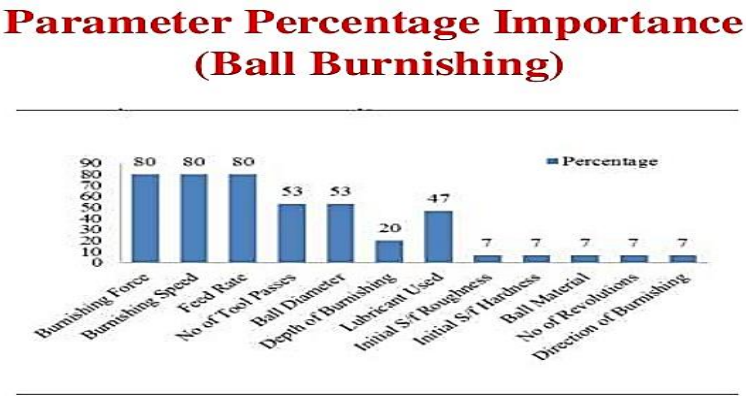


Figure 3.3 : Importance of Parameters

3.5 MEASUREMENT OF VIBRATIONAL PARAMETERS

The frequency and the amplitude of the VABB tool was measured by an Android application Seismograph. The obtained data was further analyzed and appropriate data was evaluated.

CHAPTER 4 : EXPERIMENTAL SETUP

The burnishing process is conducted on test specimens prepared by turning and alcohol was used to clean the specimens after turning. The cleaning of the ball was carried out continuously in order to prevent any hard particles from entering the contact surface between the tool and specimen.

The specimen to be burnished is clamped by the three-jaw chuck of the lathe and guided from other side by the lathe tailstock. The burnishing process was applied after turning without releasing the specimen from the lathe chuck to keep the same turning alignment.

Initial dry turning conditions were unified for all specimens as follows:

Cutting speed= 56.6 m/min., depth of cut =1 mm, feed rate= 0.24 mm/rev., and tool nose radius of 0.2 mm.

In this work, produced surface roughness, were measured after turning and burnishing process.

With the VABB tool these data's were obtained from the tool post of the lathe machine

Parameter	Without VABB	With VABB
Frequency	5.82 H_z	12.43 H_z
Amplitude	0.345 m	0.109 m

4.1 SUITABLE BURNISHING CONDITIONS FOR MILD STEEL

Work piece: Cylindrical bars

Length: 120-300mm

Diameter: 30-45 mm

No. of Passes: 1-7

Feed: 0.5-.44 mm per rev

Speed: 10-60 m/min

4.2 EXPERIMENTAL PLANNING

Table 4.1 : Experimental Planning

Variable	Constant	Exp 1	Exp 2	Exp 3	Exp 4
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	0.38	0.24	0.12	0.095
Depth of cut(mm)	Speed, Feed, No. of Pass	0.5	0.75	1	1.25
No. of Pass	Speed, Feed, Depth of Cut	1	2	3	4

4.3 WORKPIECE

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

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

Finally, the average roughness was 5.571 Ra-µm.

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

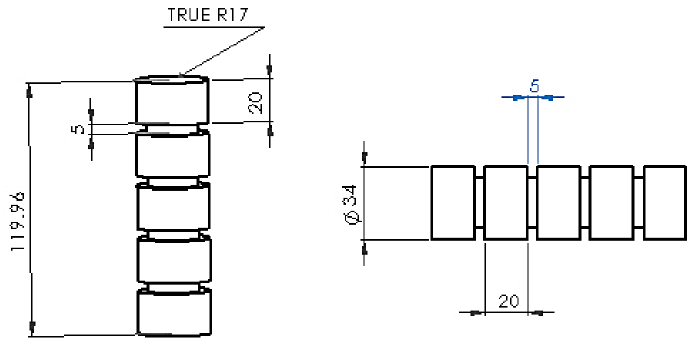


Figure 4.1 : Work piece for experiment

4.4 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.

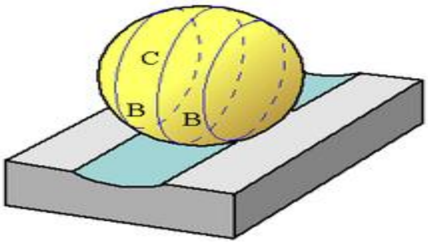


Figure 4.2 : Burnishing Process

4.5 SURFACE ROUGHNESS MEASUREMENT

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

Figure 4.3 : Mitotoya Surface Roughness Tester

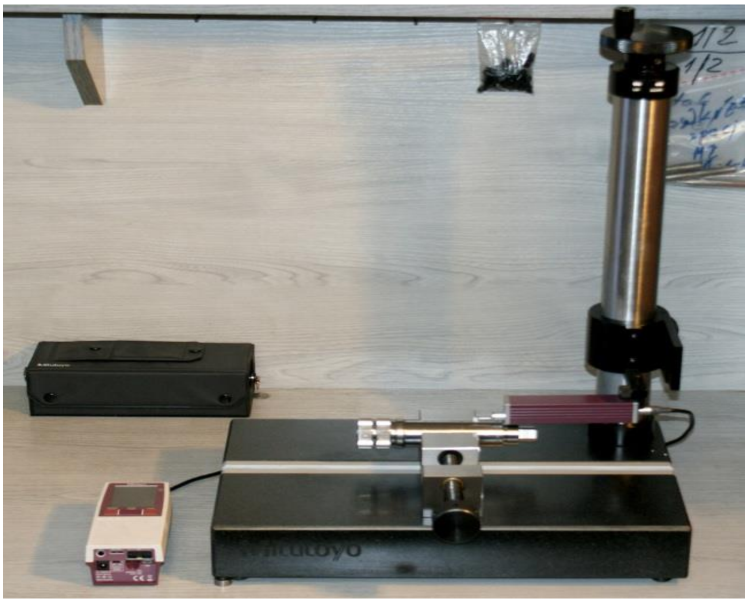


Figure 4.4 : Measuring the surface roughness with Mitotoyo surface roughness tester

CHAPTER 5 : EXPERIMENTAL DATA

5.1 SPEED V/S ROUGHNESS

Initial Roughness, $\mu_o = 5.57$ µm

Constant Parameters:

Feed – 0.24 mm/min

Depth of Cut – 1 mm

No. of Pass – 1

Table 5.1: 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	1.472	7.915	7.453	1.338
			7.311		
			7.145		
360	38.45	1	7.071	7.29	1.308
			7.300		
			7.518		
220	23.5	0.611	5.018	5.101	0.915
			5.295		
			4.990		
140	14.95	0.388	4.527	4.24	0.761
			3.909		
			4.303		

5.2 SPEED V/S ROUGHNESS (VABB)

Initial Roughness, $\mu_o = 5.327$ µm

Constant Parameters:

Feed – 0.24 mm/min

Depth of Cut – 1 mm

No. of Pass – 1

Table 5.1 : Experimental Values for surface roughness against variable RPM (VABB Tool)

RPM	Speed V	V/V_O	Roughness Ra-µm	Average Roughness, µ Ra-µm	μ/μ_o
530	56.6	1.472	6.386	6.405	1.202
			6.570		
			6.260		
360	38.45	1	5.325	5.219	0.979
			5.217		
			4.917		
220	23.5	0.611	3.834	3.691	0.693
			3.7		
			3.514		
140	14.95	0.388	7.169	7.059	1.325
			7.073		
			6.993		

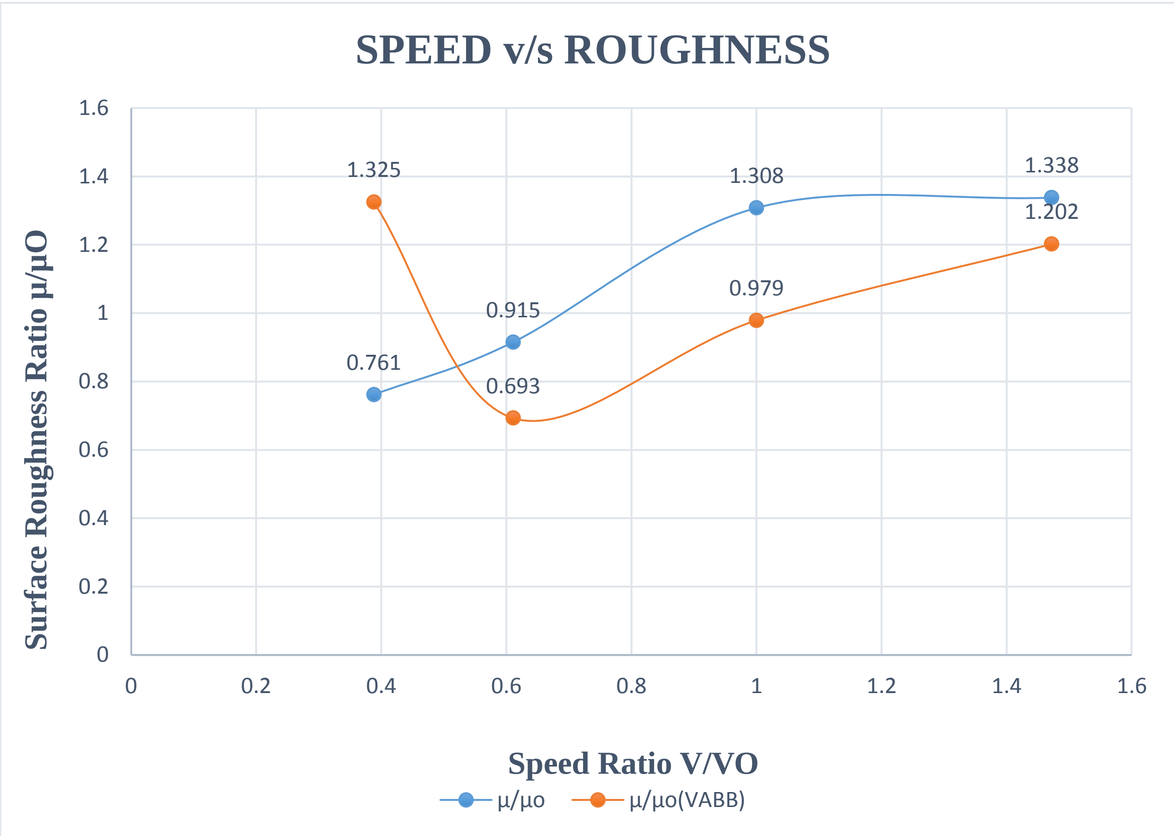


Figure 5.1 : RPM v/s Surface Roughness

5.3 DEPTH OF CUT V/S ROUGHNESS

Initial Roughness – 4.8 Ra-µm

Constant Parameters:

Feed – 0.24 mm/min

RPM – 360

No. of Pass – 1

Table 5.2 : Depth of Cut v/s Roughness

Depth of Cut C	C/C_o	Roughness Ra-µm	Average Roughness, µ Ra-µm	μ/μ_o
0.5	0.5	5.392	5.314	1.107
		5.150		
		5.421		
0.75	0.75	5.370	5.439	1.133
		5.513		
		5.434		
1	1	4.364	4.371	0.91
		4.321		
		4.227		
1.25	1.25	3.113	3.062	0.637
		2.828		
		3.246		

5.4 DEPTH OF CUT V/S ROUGHNESS (VABB)

Initial Roughness – 7.05 Ra-µm

Constant Parameters:

Feed – 0.24 mm/min

RPM – 360

No. of Pass – 1

Table 5.3 : VABB Depth of Cut v/s Roughness

Depth of Cut C	C/C_o	Roughness Ra-µm	Average Roughness, µ Ra-µm	μ/μ_o
0.5	0.5	7.346	6.937	0.983
		6.648		
		6.818		
0.75	0.75	4.708	4.682	0.664
		4.433		
		4.907		
1	1	2.988	2.919	0.414
		2.766		
		3.008		
1.25	1.25	3.076	2.835	0.402
		2.670		
		2.760		

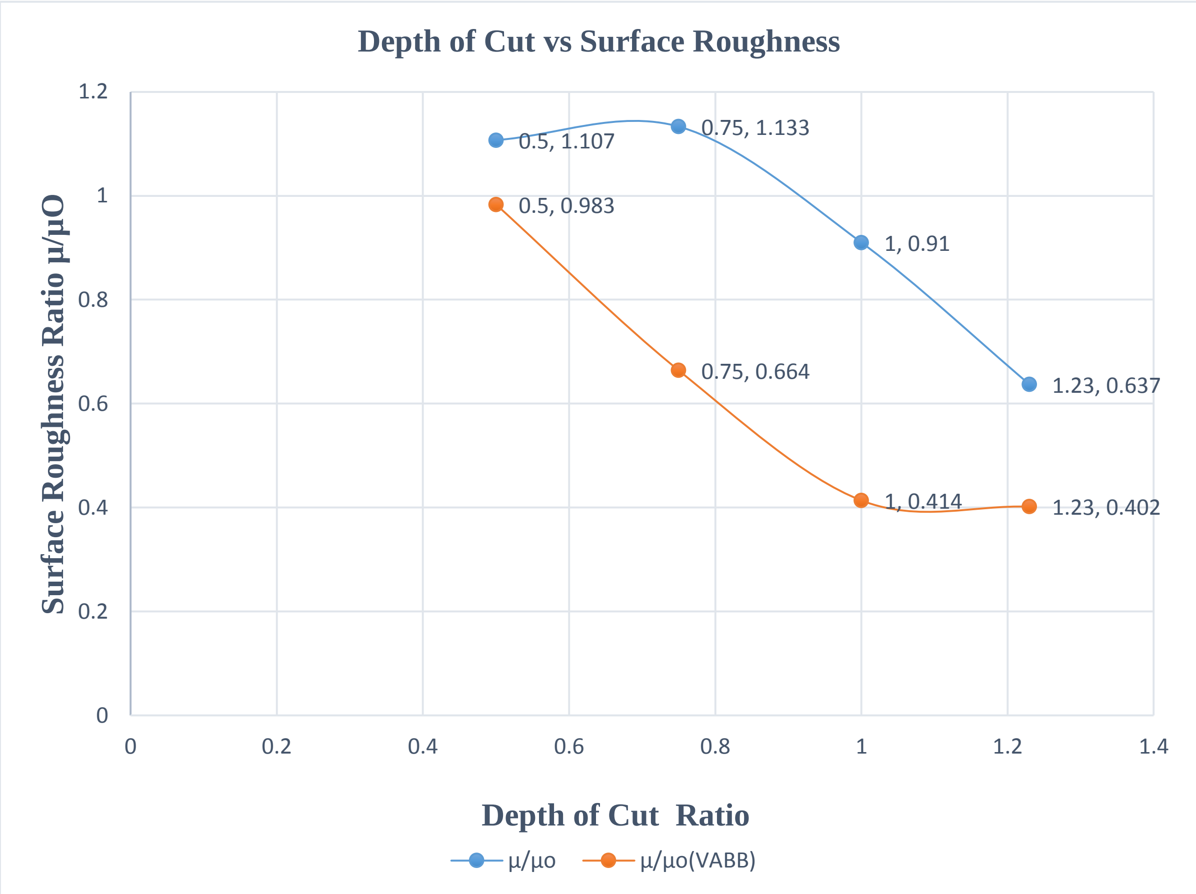


Figure 5.2 : Depth of Cut vs Surface Roughness Graph

5.5 FEED V/S ROUGHNESS

Initial Roughness – 6.27 Ra-µm

Constant Parameters:

Depth of Cut – 1mm

RPM – 360

No. of Pass- 1

Table 5.4 : Feed v/s Roughness

Feed	F/F_o	Roughness Ra-µm	Average Roughness, µ Ra-µm	μ/μ_o
0.38	1.58	6.732	6.406	1.021
		6.744		
		5.792		
0.24	1	4.680	4.669	0.744
		4.736		
		4.592		
0.12	0.5	4.378	4.013	0.64
		4.367		
		3.296		
0.095	0.395	2.110	2.252	0.403
		2.497		
		2.971		

5.6 FEED V/S ROUGHNESS (VABB)

Initial Roughness – 5.712 Ra-µm

Constant Parameters:

Depth of Cut – 1mm

RPM – 360

No. of Pass- 1

Table 5.5 : Feed v/s Roughness (VABB)

Feed	F/F_o	Roughness Ra-µm	Average Roughness, µ Ra-µm	μ/μ_o
0.38	1.58	2.669	2.53	0.444
		2.490		
		2.441		
0.24	1	2.886	2.687	0.471
		2.468		
		2.709		
0.12	0.5	5.462	5.271	0.92
		5.127		
		5.224		
0.095	0.395	5.830	5.967	1.046
		5.921		
		6.151		

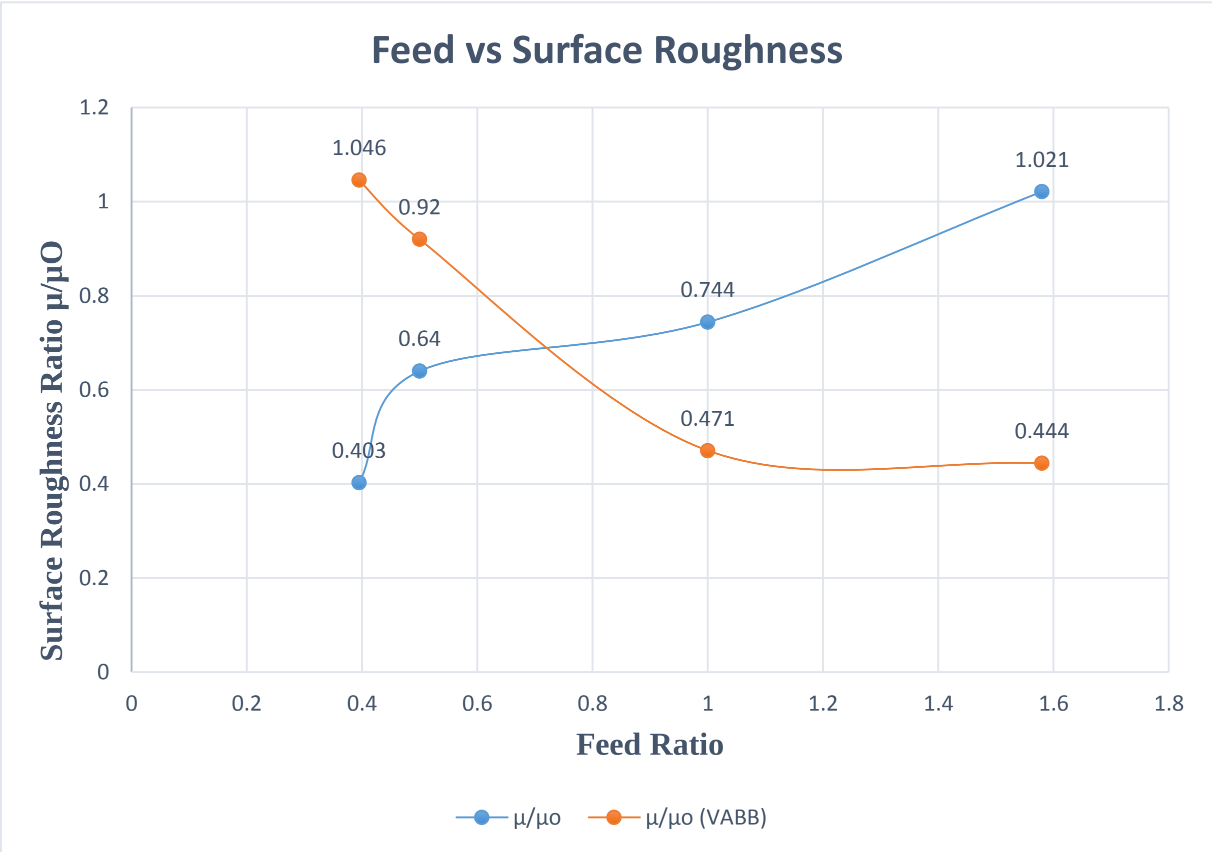


Figure 5.3 : Feed vs Surface Roughness Graph

5.7 NO. OF PASS V/S ROUGHNESS

Initial Roughness- 5.78 Ra-µm

Constant Parameters:

Feed -0.24 mm/min

RPM- 360

Depth of Cut -1mm

Table 5.6 : No. of Pass v/s Roughness

No. of Pass	Roughness Ra-µm	Average Roughness, µ Ra-µm	μ/μ_o
1	4.9	5.148	0.9
	5.35		
	5.196		
2	4.423	4.671	0.816
	4.251		
	5.342		
3	2.463	2.761	0.48
	3.121		
	2.7		
4	3.085	2.8	0.49
	2.596		
	3.272		

5.8 NO. OF PASS V/S ROUGHNESS (VABB)

Initial Roughness- 5.78 Ra-µm

Constant Parameters:

Feed -0.24 mm/min

RPM- 360

Depth of Cut -1mm

Table 5.7 : No. of Pass v/s Roughness (VABB)

No. of Pass	Roughness Ra-µm	Average Roughness, µ Ra-µm	μ/μ_o
1	4.517	4.551	0.787
	4.724		
	4.412		
2	3.121	3.213	0.555
	3.427		
	3.091		
3	2.463	2.387	0.412
	2.512		
	2.216		
4	3.391	3.555	0.615
	3.761		
	3.514		

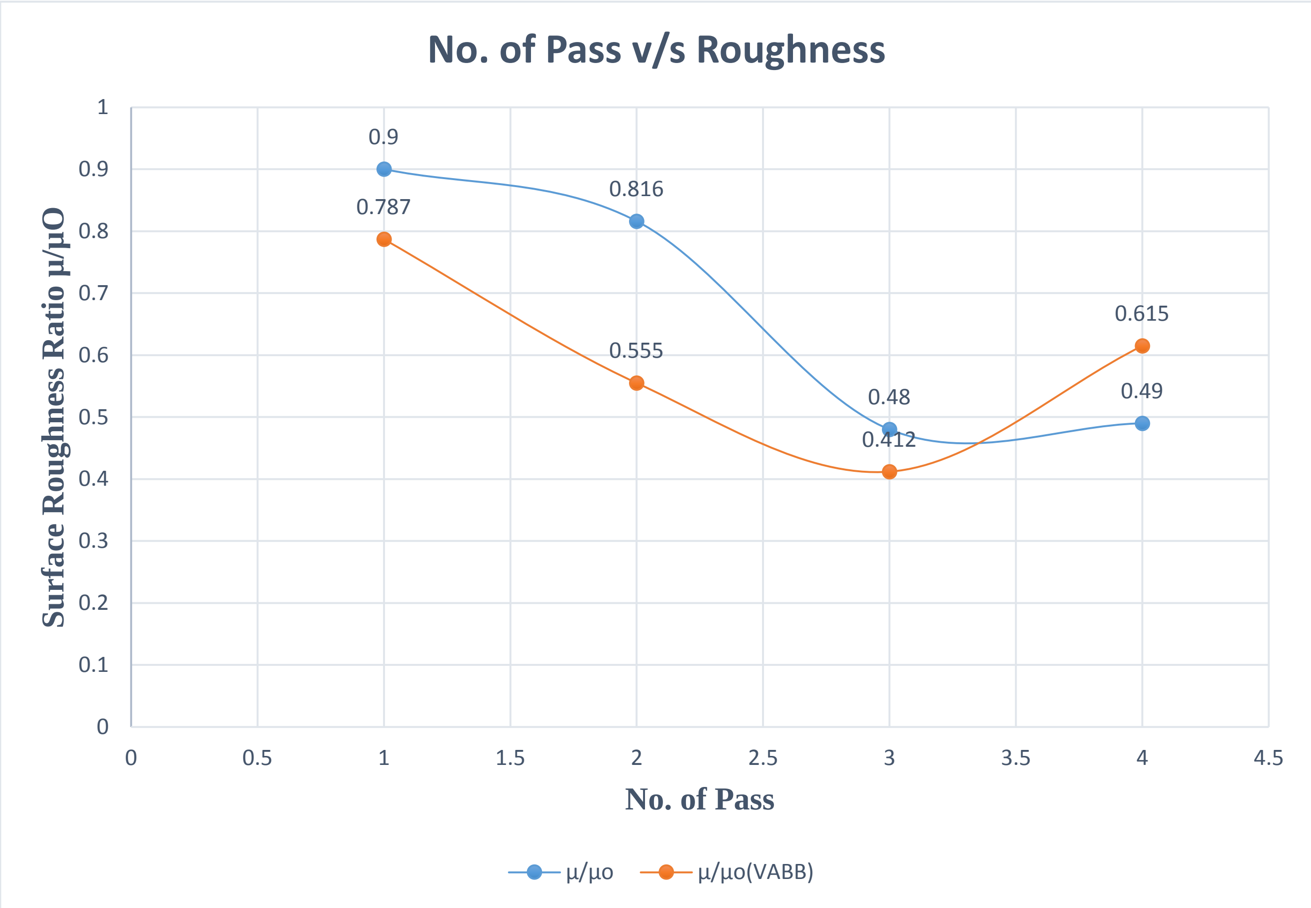


Figure 5.4 : No. of Pass v/s Roughness (VABB)

CHAPTER 6 : CONCLUSION & FUTURE WORK

6.1 CONCLUSION

1. The ball-burnishing vibration-assisted process has been studied. The changes of surface roughness results obtained when using the vibrations to assist the process, compared to when performing the process without being assisted has been also analyzed.

2. It is a prototype tool and the first experimental results show improvements compared to conventional burnishing process on surface roughness parameters evaluated.

3. Surface roughness decrease with increase in speed up to 360 RPM and further gets increased with increasing speed. It’s due to possible chattering of the burnishing tool and increase in temperature, which increases the possibilities of material transformation between the burnishing ball work piece interfaces start to have a decisive effect.

4. With the application of the VABB tool, it is seen that surface roughness decreases at a higher rate than conventional one in the range of 220-360 RPM.

5. Surface roughness varies with the depth of cut used. We have found that the best surface finish can be obtained by the VABB tool when depth of cut is limited to 0.5-1 mm.

6. Surface roughness decreases with increasing in no. 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. With the VABB tool, surface roughness is reduced in just 1-2 pass whereas conventional method takes up to 4 passes.

6.2 FUTURE PLAN

- First of all, to get the optimum values, a new and more reliable Vibration assisted ball burnishing tool can be designed. Piezoelectric transducers or magnetic transducers can be used as vibration generator.
- We can compare the changes in surface roughness with different diameter of balls used in the tool and find the suitable one. A flexible tool should be designed where balls of different diameters and different materials can be easily set.
- Changes in surface roughness with respect to changes in force applied in the work piece must be considered.
- The changes in hardness and residual stresses 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 of parameters. That will help us to get a more specific and accurate decision.

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