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ROLLER BURNISHING-A Literature Review of Developments and Trends in Approach to Industrial Application

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ABSTRACT— ***Burnishing is a cold working, surface treatment; chip less process in which plastic deformation of surface irregularities occurs by exerting pressure through a very hard and smooth roller on a surface to generate a highly smooth and work-hardened surface. Roller burnishing is an economical process, where skilled operators are not required. This paper presents the reviews of different works in the area of burnishing and tries to find out latest developments and trends available in industries in order to minimize the total equipment cost and result in high production rate, with accuracy and without considerably increasing existing inventories.***

Keywords— Roller Burnishing, Surface Finish, Burnishing tool, Surface Roughness.

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1. INTRODUCTION

The Machining operations are used to produce required Dimensions by removing excess material from a blank in the form of chips. The work piece is subjected to intense mechanical stress and localized heating by tools having one more shaped cutting edges. Each cutting edge leaves its own mark on the mechanical surface. Also the work piece and tool together with the machine on which they are mounted form a vibratory system liable to random, forced or induced vibration. Due to these reasons, the surface of the machined component is more or less damaged [P.N. Sundararajan, (2009)]. The ball burnishing process is done to improve the surface finish of work pieces that have been previously machined [Rodriguez et al. (2011)].Surface finish and surface integrity are the terms used to denote the degree of such damage. To answer this Burnishing is capable of producing surface finish of 0.2-0.8 ra, µm. Burnishing, a plastic deformation process, is becoming more popular as a super finishing process. The selection of the burnishing parameters to reduce the surface roughness and to increase the surface hardness is especially crucial because of the non-linear characteristic of the burnishing parameter.[John and Vinayagam (2011)]

1.1 Classification of Burnishing

a. Ball Burnishing

b. Roller Burnishing

The above two types are explained below,

1.2 Ball Burnishing

In this method, machined surfaces are burnished by a ball burnishing tool. The experimental work is carried out on a lathe machine or milling machine. The ball burnishing process is done to improve the surface finish of work pieces that have been previously machined [Rodriguez et al. (2011)]

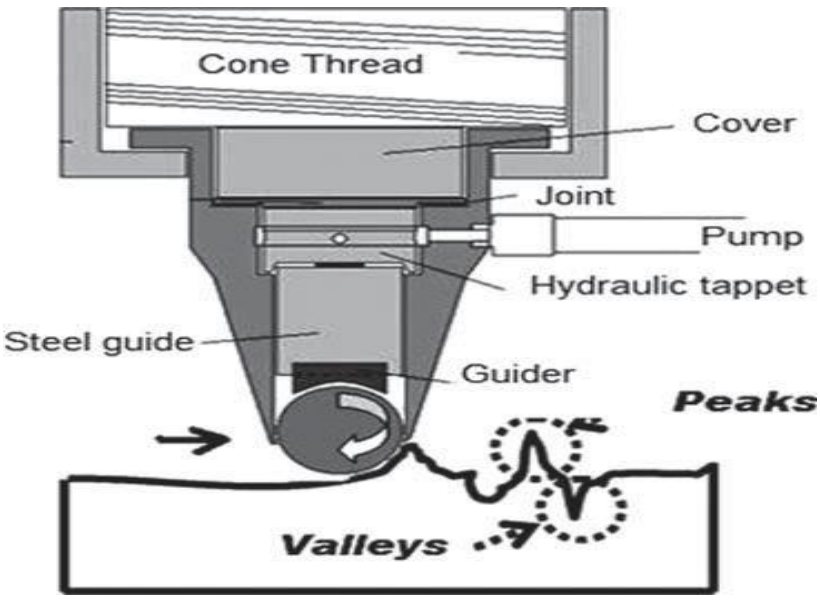

Figure 1: Ball burnishing process for surface finishing

In case of ball burnishing process best roughness values are also obtained on the surface of smaller radius and in case of higher feed rates. In the case of the direction of burnishing, the measurements in the parallel direction to the milling feed rates are smaller for the perpendicular burnishing and in the perpendicular direction to the milling process. The lower roughness values were obtained in the burnishing parallel to the milling feed rates. Rodriguez et al. (2011)]

1.3 Roller Burnishing

Roller burnishing is a cold working process which produces a fine surface finish by the planetary rotation of hardened roils over a bored or turned metal surface. Roller burnishing involves cold working the surface of the work piece to improve surface structure [P.N. Sundararajan, (2009)].

As all machined surfaces have series of peaks and valleys of irregular height and spacing, the plastic deformation created by roller burnishing is a displacement of the materials in the peaks in which cold flows under pressure into the valleys. This results in a mirror-like finish with a tough, work hardened, wear and corrosion resistant surface.

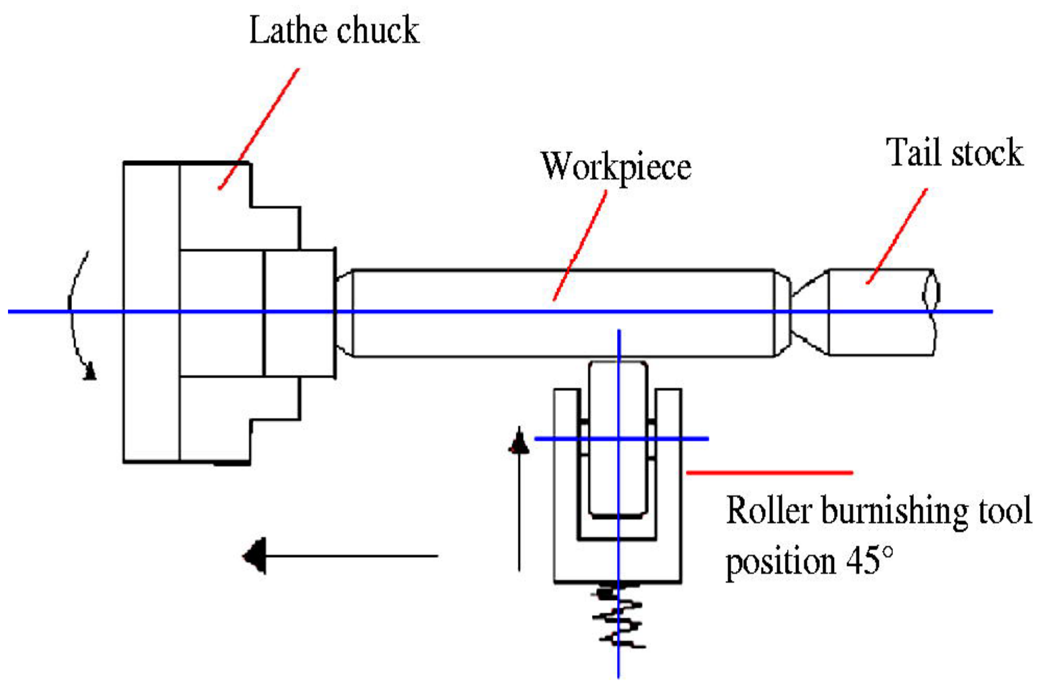

Figure 2: Roller burnishing process for surface finish of Outer Diameter

1.4 Pre-machining of the work piece

The work piece must be prepared for the roller burnishing with the right stock allowance and the right surface finishing rate. The amount of the stock allowance depends from the job conditions, the material properties, the wall thickness of the part, the type of the machined surface and the quality of the desired surface finishing. The following chart shows typical stock allowances for internal and external burnishing. However, because of the number of variables involved, these references should be considered only not binding. An exact stock allowance can be established by tests. It is important never to burnish parts with too much stock allowance: a roller burnishing in such conditions reduces the life of the tool but can also produce flaking of the burnishing surface. High ductility materials have an elongation of more than 18% and hardness less than RC 25. They include annealed steel, aluminum, brass, bronze. Low ductility materials have an elongation less that 18% and a hardness of max. RC 45. [62]

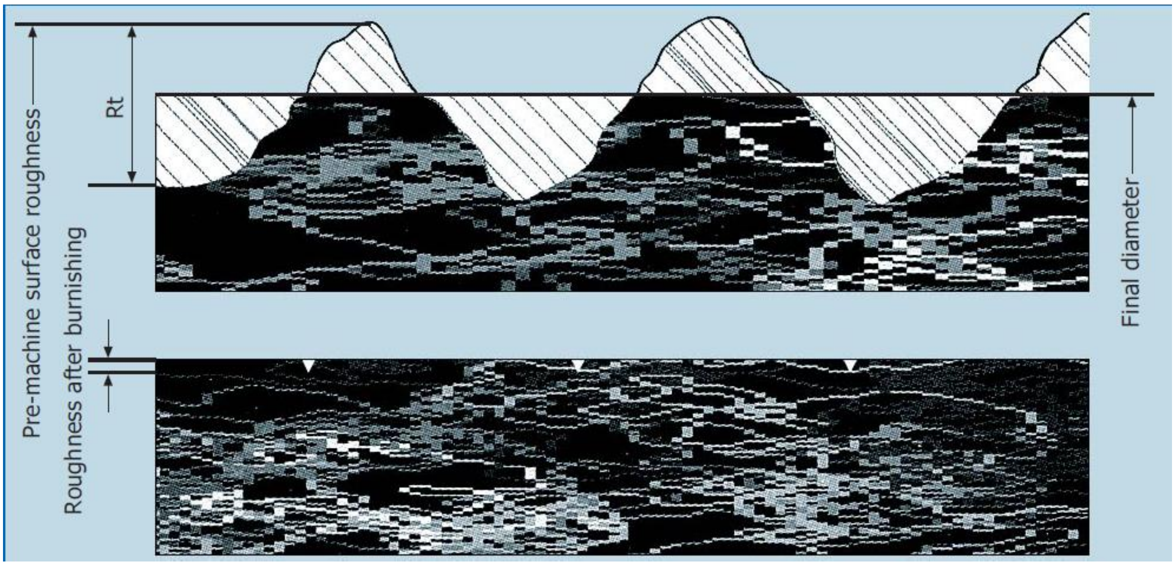

Figure 3: Surface profile before and after roller burnishing

Table 1: Stock allowance –Surface finishing chart

Work piece size range mm		Inside surfaces					Outside surfaces				
		Stock allowance mm	Surface finish Ra (Rt)				Stock allowance mm	Surface finish Ra (Rt)			
			Machined		Roller Burnish			Machined		Roller Burnish	
			Ra	(Rt)	Ra	(Rt)		Ra	(Rt)	Ra	(Rt)
High Ductility Material	3-12	0.010	2	(8)	0.2	(1)	0.010	2	(8)	0.2	(1)
		0.017	3.1	(12)	0.2	(1)	0.015	2.5	(10)	0.2	(1)
	12-25	0.017	1.5	(6)	0.2	(1)	0.012	2	(8)	0.2	(1)
		0.040	3.1	(12)	0.2	(1)	0.025	4.5	(18)	0.2	(1)
	25-50	0.025	1.5	(6)	0.2	(1)	0.017	2.5	(10)	0.2	(1)
		0.050	3.1	(12)	0.2	(1)	0.025	4.5	(18)	0.2	(1)
	50-165	0.040	1.5	(6)	0.2	(1)	0.025	3.1	(12)	0.2	(1)
		0.075	5	(20)	0.2	(1)	0.050	10.1	(20)	0.2	(1)
Low Ductility Material	3-12	0.010	2	(8)	0.4	(2)	0.008	1.5	(6)	0.4	(2)
		0.017	2.5	(10)	0.4	(2)	0.012	2.3	(9)	0.4	(2)
	12-25	0.017	2.2	(9)	0.4	(2)	0.012	2.5	(10)	0.4	(2)
		0.025	3.1	(12)	0.4	(2)	0.018	3.5	(14)	0.4	(2)
	25-50	0.025	3.1	(12)	0.4	(2)	0.012	2.5	(10)	0.4	(2)
		0.040	4.5	(18)	0.4	(2)	0.025	4.5	(18)	0.4	(2)
	50-165	0.040	3	(12)	0.4	(2)	0.020	3.1	(12)	0.4	(2)
		0.050	5	(20)	0.6	(3)	0.035	5	(20)	0.4	(2)

Also the internal surface quality plays an important role in the part performance. Internal surfaces of non-ferrous materials are difficult-to-finish due to many problems encountered in grinding which is optimum for ferrous metals. Internal burnishing process is believed to be more suitable since it eliminates sticking, wheel dulling and overheating. [Axir et el. (2006)]

2. AIMS AND OBJECTIVES OF THE WORK

The aim of this study is to minimize the workloads and increasing the quality of machining by latest technologies available for producing high grade of surface finish.

The aims and objectives of the present study are as follows:-

- To reduce production cost and improve productivity
- To improve efficiency of production systems where high machining accuracy and high grade surface is required.
- To study the latest technologies available and adaptability of burnishing in modern production systems.

3. LITERATURE REVIEW

Burnishing methods have become the topic of research in the "recent period. Many researchers investigated and formulated the methodologies of Burnishing which has helped in optimizing production with high accuracy and surface finish. Research and development efforts over the last decade have resulted in improvement and increased effectiveness of processes.

The literature on burnishing methods has been reviewed thoroughly and has been presented and discussed below:

Hassan and Maqableh (2000) [1] studied the effects of initial burnishing parameters on non-ferrous components. They have used Carbon chromium as ball material and two non-ferrous work piece materials, namely free machining Brass and cast Al-Cu alloy and found that the initial burnishing parameters such as initial surface roughness and hardness of the work piece, the ball diameter of the burnishing tool, use of different lubricants have significant effects on the burnishing process. In the same work two types of lubricants were used to study the effect of lubricant in the burnishing process. As a result of this study it was concluded that the use of a lubricant in the burnishing process causes a general reduction in surface roughness and in the amount of the increase in surface hardness, but change in the viscosity of the lubricant seems to have no significant effect on either of the above-mentioned properties. They concluded that an increase in initial surface roughness will cause an increase in the final surface roughness of the ball burnished work pieces, but it has no effect on the surface hardness of these metallic work pieces. An increase in the initial surface hardness will cause a decrease in the reduction of surface roughness, and in the total amount of the increase in surface hardness.

Axir (2000) [2] published his work on an investigation of roller burnishing by using RSM method and taking Steel-37 as work piece and a roller bearing having outside diameter of 22 mm and a width of 6 mm, using feed rate as 0.1mm/rev. depth of cut 0.2mm, spindle speed 600 rpm RSM) and he concluded a good correlation between the experimental and predicted results derived from the model Thus, used the proposed procedure, the optimum roller burnishing conditions obtained to control the surface responses of other materials. It was shown 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, tend to have many interactions and recommended spindle speeds that resulted in high surface micro hardness and good surface finish are in the range from 150 to 230 rpm and also the residual stress is at a maximum near the surface and decreases with an increase in the depth beneath surface.

Khabeery and Axir (2001) [3] worked upon the experimental techniques for studying the effects of milling roller-burnishing parameters on the surface integrity. They have used 6061-T6 Aluminum alloy work piece to investigate the effect of roller-burnishing upon surface roughness, surface micro hardness and residual stresses. They have used response surface method (RSM) with the Box and Hunter method to investigate the effect of the burnishing process parameters. In order to determine the independent, interactive, and higher-order effects of the different variables on the burnished surface roughness, hardness and maximum residual stress, a special technique called Group Method of Data Handling (GMDH) is used in this work. They concluded that the mathematical models for burnishing responses (mean roughness, burnished surface micro hardness, and maximum residual stress) are identified by GMDH considering burnishing speed, depth of penetration and number of passes. The literature study shows that the increasing both the number of passes and the burnishing depth of penetration causes the changes in mean roughness, surface micro hardness and maximum residual stress. Also they concluded that the burnishing speed should not exceed about 120m/min to obtain high surface quality.

An experimental analysis was undertaken by Nemat and Lycons (2001) [4] on ball burnished mild steel and aluminum using a purpose built burnishing tool. The analysis was designed to assess the effects of burnishing feed, force and speed and the number of tool passes on the surface roughness and surface hardness of mild steel and an aluminum work piece. In some cases, experiments showed that improvements of as much as 70% in surface quality were obtained when varying the mix of parameters.

Martin (2002) [5] investigated the computational evaluation of the roller burnishing process to address the permanent deformation needed to introduce a desirable residual stress state. The analysis used a series of incrementally applied pressure loadings and finite element methodology to simulate the behavior of a roller burnishing tool. Various magnitudes of applied pressure loadings coupled with different size plates and boundary conditions were examined to assess the degree and depth of the residual compressive stress state cold working. Both kinematic and isotropic hardening laws were evaluated.

Ingole and Bahedwar (2002) [6] published work on the effect of lubricants on the surface finish of En8 specimens Using 23 factorial designs, in terms of surface roughness, model equations. The burnishing parameters considered were speed, feed and force and the other parameters were kept constant.

Axir and Khabeery (2003) [7] presented the work on influence of orthogonal burnishing parameters on surface characteristics for various materials. They used 2014 Aluminum alloy, Brass, and three carbon steel materials; namely, A387, grade 2; A285, grade C and A455, type 1 as work piece materials and steel roller burnishing tool and concluded that the output responses of the burnished surfaces are mainly influenced by the four parameters used, namely: burnishing speed, depth of penetration, burnishing time and initial hardness of the work piece materials. The literature Review show that an increase in burnishing speed leads to a decrease in both the percentage of micro hardness increase and change in work piece diameter, whereas the increase in burnishing speed more than 1.5 m/s results in a considerable increase in out-of-roundness. The authors have concluded that an increase in depth of penetration leads to a considerable increase in both surface micro hardness and change in work piece diameter, whereas it causes a decrease in the out-of-roundness. The best result for out-of-roundness was obtained by applying high depth of penetration with low burnishing time.

Shiou and Chen (2003) [8] have presented their work on free form surface finish of plastic injection mold by using ball-burnishing process. In this study PDS5 tool steel was used as work piece material and three types of ball materials with diameter of 10mm, namely tungsten carbide ball (WC), steel ball coated with chromium (CrC), and tungsten carbide ball coated with titanium nitride (TiN), were used as ball material for ball burnishing tool. Four burnishing parameters, namely the ball material, burnishing force, burnishing speed and feed were selected as the experimental factors of Taguchi's design of experiment to determine the optimal burnishing parameters. They concluded that optimal burnishing parameters for the plastic injection mold steel PDS5 were the combination of the tungsten carbide ball, the burnishing speed of 200mm/min, the burnishing force of 300N, and the feed of 40μm. The surface roughness Ra of the specimen can be improved from about 1 to 0.07μm by using the optimal burnishing parameters for plane burnishing. The Vickers hardness scale of the tested specimen was improved from about 338 to 480 after ball-burnishing process where hardened layer thickness was about 30μm. By applying the optimal burnishing parameters for plane burnishing to the surface finish of the freeform surface mold cavity, the surface roughness improvement of the injection part on plane surface was about 62.9% and that on freeform surface was about 77.8%.

A work on modeling of metal cutting and ball burnishing, prediction of tool wear and surface properties was presented by Yen (2004) [9] In this work, the effect of different cutting edge designs (hones and chamfer geometries) on the cutting variables and process mechanics was first investigated using Finite Element Method (FEM) cutting simulations. Then, an FEM-based methodology involving nodal wear rate calculations were developed to predict the progression of tool wear geometry during cutting the surface enhancement generated by ball burnishing, which is used following machining to improve surface finish and provide a surface layer of compressive residual stresses. For a successful ball burnishing process, the selection of process parameters (burnishing pressure, ball diameter, speed, and feed rate) needs to be optimized. In this research, a full 3-D FEM analysis model and a simplified 2-D model were developed for this purpose and the predictions of residual stresses were evaluated with limited experimental data. For the 2-D model, the strong elastic recovery of the burnished surface caused contact with the ball around its trailing end during unloading, making the simulation like a series of "indenting" cycles. Furthermore, the effects of the initial plastic strain and residual stresses in the machined surface, as opposed to uniform bulk material, were analyzed.

Ghani et al. (2004) [10] have studied the application of Taguchi method in the optimization of end milling parameters by using hardened steel AISH H13 as work piece material and TiN coated P10 carbide tool.. They found that Taguchi method was suitable to evaluate the milling parameters cutting speed, feed rate and depth of cut. In the same work an orthogonal array, signal-to-noise (S/N) ratio and analysis of variance (ANNOVA) are employed to analyze the effect of milling parameters. As a result of this study the optimal combination for low resultant cutting force and good surface finish are cutting speed, low feed rate and low depth of cut. Also other significant effects such as the interaction among milling parameters are also investigated by using Taguchi method. They concluded Taguchi method is suitable to solve the stated problem with minimum number of trails as compared with a full factorial design. They concluded that the Taguchi's robust design method is suitable to analyze the metal cutting problem as described in that paper. Conceptual S/N ratio and Pareto ANOVA approaches for data analysis draw similar conclusion. In end milling, use of high cutting speed (355m/min), low feed rate (0.1mm per tooth) and low depth of cut (0.5mm) were recommended to obtain better surface finish for the specific test range. Low feed rate (0.1mm per tooth) and low depth of cut (0.3mm) lead to smaller value of resultant cutting force the specific test range.

Ahuja et al. (2004) [11] worked on parametric analysis of combined turning and ball burnishing process by carrying out experiments based on 2^3 factorial designs on turn master T-40 lathe. They studied that the effect of the combined turning and two balls burnishing parameters on the surface roughness and surface hardness of aluminum specimen. The results were analyzed by the variance technique and the F-test. Analysis highlighted the significance of lubricant, force, and speed and feed on surface roughness and surface hardness.

Preve et al. (2005) [12] worked on overview of low plasticity burnishing for mitigation of fatigue damage mechanisms for low plasticity burnishing that provides thermally stable compression and can be performed in conventional machine shop environments on CNC machine tools. Low plasticity burnishing enables the extension of component service lives fatigue limited by various damage mechanisms including foreign object damage (FOD), corrosion fatigue, pitting, and fretting and improved corrosion fatigue.

Hryniewicz and Rokosz (2005) [13] studied the corrosion behaviour of C45 carbon steel after roller burnishing through electrochemical investigation results of the corrosion rate carried out by means of a method known as the electrochemical impedance spectroscopy (EIS). Two different media, 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. The electrochemical investigation results revealed the effect of burnishing operation on the corrosion resistance of the carbon steel studied and was found that the corrosion rate may be decreased many times after roller burnishing of initially prepared surface having regular projections on it.

Axir and Ibrahim (2005) [14] worked on the surface characteristics after center rest ball burnishing. In this study, the center rest was used as a super-finishing tool by replacing the three original adjustable jaws of the center rest with three ball burnishing tool. They concluded that an increase in burnishing speed up to 1.5m/s leads to a decrease in both the burnished surface roughness, out-of-roundness, and change in work piece diameter whereas the increase in burnishing speed more than 1.5m/s result in an increase in both surface roughness and out-of-roundness. The literature Review show that an increase in burnishing feed up to 0.12mm/rev leads to a decrease in surface roughness and roundness also the best results for the surface roughness and roundness were obtained at burnishing force of 150N and burnishing feed 0.12mm/rev. surface roughness and surface roundness was obtained using the center rest burnishing tool applying one ball or three balls

Status of FEM Modeling in Cutting and Roller Burnishing was studied by Altan et al. (2006) [15] in this work he focused on FEM Modeling of Roller Burnishing Process and Proposed 2D FEM model for hard roller burnishing that showed reasonable accuracy for residual stress predictions in both tangential and axial directions. Magnitudes and variations of residual stresses over the depths agree quite well with the experiments.

Hamadache et al. (2006) [16] worked on the characteristics of Rb-40 steel superficial layer under ball and roller burnishing by using M20 carbide cutting tool and Rb-40 steel as work piece material. They concluded that for Rb-40 steel, roller burnishing provides roughness optimal results, particularly when initial surface quality is close to 3μm. For the same study it was found the optimum roughness and hardness are obtained for a specific regime whose decisive parameters are the applied force as well as the number of burnishing tool passes. Based on roughness, it was recommended to limit the number of passes to two whereas for the highest hardness, it was advised to go up to three passes while associating an effort of 150N.The literature Review shows that increase of revolutions and feed rate are not desirable for surface roughness and surface hardness. Superficial layers of Rb40 steel treated by roller and ball burnishing behave like ground surfaces and shows an appreciable wear resistance.

Axir et el. (2006) [17] Studied the inner surface finishing of aluminum alloy 2014 by ball burnishing process, using 8 mm carbon chromium balls for the internal burnishing process for this purpose the predicted five different surface profile parameters caused by internal- ball burnishing process parameters namely; burnishing speed, feed, depth of penetration, and number of passes and it was observed that from an initial roughness of about Ra 4 μm, the specimen could be finished to a roughness average of 0.14 μm. The burnishing speed, feed and number of passes have the most significant effect on all surface profile parameters.

The effect of burnishing parameters on steel fatigue strengths were experimentally demonstrated by Swirad (2007) [18] in this work main focus was on possibilities of sliding burnishing with cylindrical elements made of diamond composite with ceramic bonding phase. Author identified that technology of sliding burnishing with cylindrical elements of diamond composite can be used in very simple and uncomplicated way for smoothing machining of various types of material and cylindrical elements are easier to manufacture and easier to grind, which reduces the costs of their production, when the contact zone 'tool machined object' will wear, it can easily grinded in this way it was possible to extend its life several dozen times. Author showed the distinctly advantageous effect of diamond burnishing with cylindrical elements on the improvement of the fatigue strength of the steel 40HM.

Thamizhmanii et al. (2007) [19] worked on multi-roller burnishing on non-ferrous metals where the 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 the authors identified that the surface roughness on various no-ferrous metals improved by high spindle rotations with high feed rate and depth of penetration and also observed that Due to high spindle rotations with multi roller in action, the vibration of the equipment could not be controlled. Some mechanisms have to be devised to reduce the vibrations. However, it is not in the scope of this research.

Tayeb et al. (2007) [20] investigated the influence of roller burnishing contact width and burnishing orientation on surface quality and tribological behavior of Aluminum 6061. In this study Aluminum 6061 used as work piece material and carbon chromium rollers with different roller contact widths were used in a burnishing tool with interchangeable adapters for ball and roller for the purpose of the experimental tests. Here optimum ranges of burnishing speed and force were identified to be 250-420 rpm for 1mm roller contact width. They found Burnishing with smaller roller contact width (1mm) is capable of improving the surface roughness up to 40%. Mean-while, surface morphologies revealed that using roller with larger contact width 1.5 and 2mm, the surface deteriorates with excessive plastic deformation. Burnishing force above 220N is capable of decreasing the surface roughness by 35%. Below this limit, the surface roughness starts to deteriorate plastically. In the same study the Burnishing speed 110 rpm yields the highest improvement in hardness, as much as 30% increase. However, the improvement diminishes as higher burnishing speeds are applied. The authors have found that the friction coefficient of burnished surfaces is dependent on the surface roughness. Low friction coefficient corresponds to low surface roughness, which may be attributed to less mechanical interlocking of asperities and entrapped debris. In this study the SEM examination of the worn surface reveals that interposing lubricant during Tribo-test acts as a cooler and polishing agent, resulting in smoother surface compared to the burnished surface. Under dry contact condition, burnished surface using smaller roller contact width produces the lowest friction coefficient. Increasing burnishing force has a negative impact on the wear resistance of burnished Aluminum 6061 surfaces.

Altan et al. (2007) [21] developed 2D & 3D FEM model that was used to study the effect of process parameters burnishing pressure & feed rate on surface finish and residual stresses. The simulation results were evaluated and compared with the experimental data. Results showed that the established FEM model could predict the residual stresses and provide useful information for the effect of process parameters, both FEM and experiments shows that burnishing pressure has most influence, where high burnishing pressure produces less roughness and more compressive residual stresses at the surface.

A work on the effect of ball burnishing on heat- treated steel and Inconel-718 milled surface was presented by Lopez et al. (2007) [22] in this work authors have taken studied the burnishing system and its main parameters are taken in to account considering their influence over surface roughness and it is concluded that using large radial width of cut in the previous end milling operation ,together with small radial width of cut during burnishing produced high grade of surface finish and compression cold working was higher and deeper in the Inconel-718 than in steel case.

A work was presented by Thamizhmanii et al. (2008) [23] 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 is very useful process to improve upon surface roughness and hardness and can be employed to impart compressive stress and fatigue life can be improved. The titanium alloy is a difficult to machine and burnishing is difficult process for this grade material also flaws and micro cracks on the surface of work piece were developed by increasing burnishing parameters.

Babu et al. (2008) [24] worked on effects of internal roller burnishing on surface roughness and surface hardness of mild steel and observed that in internal burnishing process, surface finish and surface roughness of M.S material increased with increase in burnishing speed due to repeated deformation of surface irregularities with increased burnishing speed, and also surface finish and surface hardness increases with burnishing speed up to an optimum value (62m/min)and then decreases on further increase in speed.

Axir et al. (2008) [25] studied the inner surface finishing of aluminum alloy 2014 by ball burnishing process. They used 8mm carbon chromium steel ball material and aluminum alloy 2014 work piece material and reviled that from an initial roughness of about Ra 4μm, the specimen could be finished to a roughness average of 0.14μm. As a result of this study it was concluded that an increase in internal ball burnishing speed leads to a slight decrease in surface average roughness. They concluded that an increase in internal burnishing feed leads to a decrease in surface average roughness, reaching a minimum value at burnishing feed of (0.15-0.25mm/rev). A further increase in burnishing feed causes an increase in average roughness. Also the best result for average roughness is obtained when applying high depth of penetration. The literature survey show that number of passes interacts with both burnishing speed and burnishing feed. The best results obtained at both high number of passes with low burnishing speed and high number of passes with low burnishing feed.

Axir et al (2008) [26] worked on the improvements on out-of-roundness and micro hardness of inner surfaces by internal ball burnishing process. In this study they have used Aluminum alloy 2014 work piece and carbon chromium steel balls were used and concluded that an increase in burnishing speed leads to considerable reduction in out-of-roundness, however, it has no significant effect on surface micro hardness. The recommended burnishing feeds that resulted in high surface micro hardness and a considerable reduction in out-of-roundness were in the range from 0.2 to 0.35 mm/rev. In the same study the best results for surface micro hardness were obtained at depth of penetration in the range from 0.025 to 0.045mm whereas for the out-of-roundness was obtained after application of high depth of penetration. In this literature study, a simple and adequate experimental design, response surface methodology (RSM), with the Box and Hunter method were used to investigate the effect of the burnishing speed, burnishing feed, depth of penetration, Number of passes of internal ball burnishing process on the work material characteristics.

Yeldose et al. (2008) [27] presented a work on comparison of effect of uncoated & Tin coated by reactive magnetron sputtering on EN31 rollers in burnishing with varying process parameters such as burnishing speeds, feeds, burnishing force, number of passes upon surface roughness of EN24 steel work material. It was observed that the performance of the Tin-coated roller is superior to uncoated rollers in burnishing operations. The burnishing speeds, feeds, depth of cut and number of passes were considerably influencing parameters on the burnishing operation. The burnishing speeds, burnishing force and number of passes are having almost equal importance on the performance of the roller in burnishing, particularly with reference to the surface finish of the components produced.

Shiou and Cheng (2008) [28] worked on Ultra precision surface finish of NAK80 mould tool steel using sequential ball burnishing and ball polishing processes at the spindle speed 14000, 18000 rpm, feed 20.60 mm/min, and polishing force (N) 60/0.392 120/0.817 240/2.695 depth of penetration 60/0.396, 120/0.817 using Taguchi’s L18 orthogonal table, analysis of variation (ANOVA), and the full factorial experiments. They observed based on the Taguchi’s L18 matrix experimental results, that the optimal plane surface spherical polishing parameters for the plastic injection mould steel NAK80, were the combination of the spindle speed of 22,000 rpm, the abrasive of Sic with grid no. 10,000 (1.5 m in diameter), the feed of 120 mm/min, the step over of 40 m, and the depth of penetration of 240m (polishing force of 2.695 N). The surface roughness Ra of the burnished specimens was improved from about 0.08min average to 0.016min average using the optimal spherical polishing parameters. Applying the optimal plane surface ball burnishing and spherical polishing parameters sequentially to the surface finish of the mound cavity of a spherical lens, the surface roughness value on the polished surface Ra = 0.020m in average, was observed.

Jawalkar and Walia (2008) [29] presented a work on the experimental investigations into micro hardness in roller burnishing processes on EN-8 and aluminum specimens using design of experiments, Roller burnishing being a specialized super finishing process, as in any such processes, it improved the surface finish to a very high degree inherently.

Axira and othmanb (2008) [30] presented a work on the inner surface finishing of aluminum alloy 2014 by ball burnishing process. They have used 8mm carbon chromium steel ball material and aluminum alloy 2014 work piece and found that from an initial roughness of about Ra 4μm, the specimen could be finished to a roughness average of 0.14μm. As a result of this study it was concluded that an increase in internal ball burnishing speed leads to a slight decrease in surface average roughness. Also they found that Inner surface finishing of non-ferrous metal which are difficult-to grind with conventional grinding-could be carried out successfully using the proposed internal ball burnishing tool. The technique is simple, easy to apply and economical, an increase in internal ball burnishing speed leads to a slight decrease in surface average roughness.

A work was presented by Qawabeha et al. (2009) [31] on Influence of roller burnishing on surface properties and corrosion resistance in steel and to study, the influence of Rb on corrosion resistance in A53 MH increases with increasing the applied force and the percentage improvements are found to be 12, 24, 28, 35 and 65 percent for 40, 60, 80, 100 and 120N Rb pressing forces, respectively. Weight losses in general resulted in an optimum value at about 80N. Corrosion potential and corrosion current decrease with increasing pressing force and reached a minimum at about 80N.

A work was presented by Klocke et al. (2009) [32] on innovative FE-Analysis of the roller burnishing process for different geometries, which are able to provide quantitative prediction of the rime zone state of roller burnished work pieces. These FE-models are verifiable through the comparison of calculated residual stress state with the experimental results of roller burnishing tests.

Jawalkar and Walia (2009) [33] Studied the of roller burnishing process on En-8 specimens using design of experiments and concluded that Roller burnishing produces superior surface finish with absence of tool feed marks. The average (μm Ra) value observed is 0.21 and the finest is 0.13 also no change in surface integrity was reported on micro structure and Number of passes, feed and spindle speed contribute maximum for surface roughness in burnishing for En-8.

A work was presented by Rodriguez et al. (2009) [34] on ball burnishing process to improve surface roughness by designing an experimental setup to investigate what are the process parameter controls that developed. Surface roughness parameters, Ra and Rt, in the direction of step (perpendicular to the tool feed) by presenting the Pareto charts and a response surface for the Ra and Rt in the direction of the step and concluded that the e values of the average superficial roughness (Ra), decrease in the pieces tested, after burnishing and the surface roughness values are different depending on the technical parameters with which the operation is conducted.

A work on Optimization of roller burnishing process for aluminum using taguchi technique was published by Sundararajan (2009) [35] in this work a roller burnishing tool is used to perform roller burnishing process on Aluminum 63400 material under different parameters and different burnishing orientations. The impact of burnishing force, burnishing feed, number of passes and step over on the surface roughness and surface hardness are investigated and It was found that burnishing force of 1200N, burnishing feed of 200mm/min, step over 1mm and number of pass 3 is capable of improving surface finish. Roller burnishing process also enhances the hardness of burnished Aluminum 63400. The Taguchi analysis of results concluded that the optimal combinations for good surface finish were at the burnishing force 600N, the burnishing feed 200mm/min and the step over 1mm for third number of pass.

Babu et al. (2009) [36] presented a work on two internal roller burnishing tools to perform roller burnishing process on mild steel at different speeds. The variation of surface finish and surface hardness were observed by varying speed, optimum increase in surface finish and surface hardness was at 62m/min. If speed is different than optimum value increase in surface finish is less.

Basak et al. (2009) [37] carried out experiments using fuzzy model. Aluminum alloy (AL 7075 T6) was burnished using and varying different burnishing parameters such as number of revolution, feed, number of passes, and pressure force with burnishing apparatus. Using the experimental results a fuzzy logic model was used to achieve the best parameters for the burnishing process. The fuzzy model prediction suggested that the most suitable values for minimum surface roughness were the pressure force of 200 N, and a feed 0.1mm/rev with two tool passes. These results obtained from the fuzzy model were highly consistent with the experimental results except for a small deviation in the case of surface hardness value for 0.2 mm/rev of feed & 400N of applied force. The results concluded that fuzzy logic resulted to be the suitable technique that may be efficiently used to optimize burnishing process.

Klocke et al. (2009) [38] presented a work on influence of process and geometry parameters on the surface layer state after roller burnishing of IN718, in this work they analyzed highly stressed components of modern aircraft engines, such as fan and compressor blades those have to satisfy stringent requirements regarding durability and reliability. The induction of compressive residual stresses and strain hardening in the surface layer of these components has proven as a very promising method to significantly increase their fatigue resistance. The required surface layer properties were achieved by the roller burnishing process, which is characterized by high and deeply reaching compressive residual stresses, high strain hardening and excellent surface quality. In order to achieve defined state of the surface layer, the determination of optimal process parameters for a given task requires an elaborate experimental set-up and subsequent time-consuming and cost-extensive measurements.

Prabhu et al. (2010) [39] studied the Influence of deep cold rolling and low plasticity burnishing on surface hardness and surface roughness of AISI 4140 steel and focused on the surface roughness and surface hardness aspects of AISI 4140 work material, using fractional factorial design. The assessment of the surface integrity aspects on work material was done, in order to identify the predominant factors amongst the selected parameters and it was observed that by using LPB process surface hardness has been improved by 167% and in DCR process surface hardness has been improved by 442%. It was also found that the force, ball diameter, number of tool passes and initial roughness of the work piece are the most pronounced parameters, which has a significant effect on the work piece’s surface during deep cold rolling and low plasticity burnishing process.

Stoic et al. (2010) [40] investigated fine machining efficiency of 34CrMo4 steel using roller burnishing tool. Experimental results identified that all smoothing outputs can be detected in all regimes. Roughness measured data before and after roller burnishing process were compared and it was concluded that surface roughness is significantly lower after roller burnishing as compared to the specimen without burnishing process performed upon them.

Korzynskia and Pacanab (2010) [41] presented the work on the Centre less burnishing and influence of its parameters on machining effects by using 41Cr4 steel as specimen and burnishing rollers made of 100Cr6 bearing steel using rotation speed 100 rpm and obtained results by using 24 plan matrix and surface roughness tests. They concluded that the center less burnishing can be easily applied as a surface finish method without any major technological problems it is possible to achieve a surface roughness Ra within 0.25–0.50m. After center less burnishing, the average surface roughness (Ra) was three to six times smaller than that of the surface which was turned. Due to burnishing, there forms an isotropic surface and the height of surface irregularities gets reduced as well as the values of the rest of the surface topology indices after center less burnishing were fairly good. Based on the empirically derived mathematical models and its graphic interpretations, the hardness of the studied work pieces before center less roller burnishing does not significantly affect the result of burnishing while quenched and tempered work pieces (HB = 340daN/mm2) showed very good surface condition after burnishing.

Zhanga et al. (2010) [42] worked on the effects of roller burnishing on fatigue properties of the hot rolled Mg– 12Gd–3Y magnesium alloy taking spindle speed as 36 $^{\mathrm{min1}}$, rolling forces between 50 to 300 N. They observed from experiments that roller burnishing improved fatigue strength of the Mg–Gd–Y alloy significantly. After Rb, the fatigue strengths increased from 150and 155 MPa, to 225 and 210MPa in the as-rolled alloy and the T5 heat-treated alloy, corresponding to the improvements in fatigue life of about 50% and 36%, respectively. Due to the larger process, compressive residual stresses were induced and deformation degree increased, the effect of RB in the as-rolled alloy is superior to that in the T5-treated alloy, Fatigue cracks in the Mg–12Gd–3Y alloy as the roller burnished condition nucleated in subsurface. In addition, facets of the cleavage plane were observed in the crack nucleation area.

Investigation of Roller Burnishing Process on Aluminum 63400 Material was experimentally presented by John and Vinayagam (2011) [43] in this work an experimental program to study the influence of different burnishing conditions on both surface roughness and hardness: namely, burnishing force, feed, step-over and number of passes is demonstrated and responses of surface methodology are used to optimize the burnishing parameters.

Surface finish enhancement by frictional stir burnishing was studied by Sasahara (2011) [44] in this work main focus was on developing frictional stir burnishing, which is surface reforming technique using general-purpose machine tools, and establishing a working process based on the technique. Frictional stir burnishing employs general-purpose machine tools with rotating tools such as machining centers and integrated machine tools to reform surfaces, and so the reforming can start immediately after machining. It requires no dedicated surface reforming equipment, and is expected to save setup time and reduce the number of manufacturing processes.

A work on improving the surface finish of concave and convex surfaces using a ball burnishing process was published by Rodriguez et al. (2011) [45] In this article they presented the results of tests performed with on the work pieces with a convex or concave surface of two different materials: aluminum A92017 and steel G10380. These results are compared to those measured in the work pieces before being burnished and it was concluded that in case of aluminum 92017 work pieces direction of the burnishing process related to the milling feed rate is also relevant in curved surfaces and in case of steel 1038 work pieces. The prior peak height produced by the milling process is the parameter value that affects more the indexes of surface roughness. The feed rate has no influence whatsoever, because this material has a high coefficient of self-hardening.

Manole and Nagi (2011) [46] worked on feed rate influence on burnishing degree in ceramic ball-burnishing process by an experimental work that concerned the influence of the burnishing parameters on the processed surface quality. The experimental study involved analyses of the burnishing process on the chromium-alloyed steel samples using different tool feed values and also different values for radius of the ball burnishing. The experimental work followed a complete factorial plan that involved factors at different levels and evaluated the effect of different burnishing regimes on surface roughness and form accuracy and also to develop an empirical relation that could predict the surface roughness.

Chaudhari et al. (2011) [47] Investigated micro and macro properties of ball burnished components and it was identified that besides giving a good surface finish, burnishing process also increases micro hardness of the components (8-9), improvement in the fatigue life (14-5) and wear resistance. Burnishing is a chip less finishing method, which employs a rolling tool, pressed against the work piece, in order to achieve plastic deformation of the surface layer and the possibility of burnishing steel components with high hardness was proven.

Rao et al. (2011) [48] worked on the effect of roller burnishing on surface hardness and surface roughness on mild steel specimens by conducting experiments to investigate the effect of burnishing force and number of tool passes on surface hardness and surface roughness of mild steel specimens. The results show that improvements in the surface roughness and increases in surface hardness were achieved by the application of roller burnishing with mild steel specimens. Roller burnishing produces better and accurate surface finish on Aluminium work piece in minimum time. Roller burnishing is an economical process, where skilled operators are not required. This process can be effectively used in many fields such as Aerospace Industries, Automobiles Manufacturing sector, Production of Machine tools, Hydraulic cylinders, etc.

Khalid and Mayas (2011) [49] investigated the effect of roller burnishing on the mechanical behaviour and surface quality of O1 alloy steel the main aim of this study is to enhance the mechanical properties and micro hardness of the surface of O1 steel using the roller burnishing process. In manufacturing processes, surfaces and their properties are as important as the bulk properties of the materials. Surface treatment is an important aspect of all manufacturing processes. It has been used to impart certain physical and mechanical properties, such as appearance, corrosion, friction, wear and fatigue resistance. Widely used methods of finishing treatment that create necessary parts with the given roughness usually do not provide optimum quality of the surface. Therefore, methods of Surface Plastic Deformation (SPD) are used. One of the most effective representatives is the roller burnishing.

Rababa and Almahasne (2011) [50] worked on effect of roller burnishing on the mechanical behavior and surface quality of o1 alloy steel at the burnishing speeds 63 to 160 mm/min, burnishing depth- ranging from 0.05 to 0.25 mm. Widely used methods of finishing treatment that create necessary parts with the given roughness usually do not provide optimum quality of the surface, Therefore, methods of Surface Plastic Deformation (SPD) was used and they founded that RB process has a large effect on the micro hardness of O1 alloy steel, the stress of material increased by about150 MPa, The improvement percentage on the surface quality was 12.5%and the ultimate tensile strength increased by 166

MPa ,the percentage elongation of material also increased by 13.6%.

Lingaraju and Ramji (2011) [51] presented a work on roller burnishing process of polymer silica hybrid nanocomposites and observed that increase in the surface strength mainly improves the fatigue behaviour of work-piece under dynamic load the properties of composites were improved using fillers in the size of nano level as reinforcement. Fillers like Nano silica provide better performance with some treatment, such as chemical modification to the surface, than natural structure. In this work, nanosilica was modified by 3-aminopropyltriethoxysilane and the hybrid Nano composite laminated by hand lay-up method. A low surface roughness and high hardness was obtained for the same spindle rotation, feed rate and depth of penetration by the burnishing process and it was observed that It was better to select low speeds because the deforming action of the burnishing tool was greater and metal flow is regular at low speeds. The recommended spindle speeds that resulted in high surface micro hardness and good surface finish are in the range from 22.57m/min.

Prabhu et al. (2011) [52] published their work on an experimental investigation on the effect of deep cold rolling parameters on surface roughness and hardness of AISI 4140 steel by using fractional factorial design of experiments. The assessment of the surface integrity aspects on work material was done, in terms of identifying the predominant factors amongst the selected parameters, their order of significance and setting the levels of the factors for minimizing surface roughness and maximizing surface hardness. It was found that the ball diameter, rolling force, initial surface roughness and number of tool passes were the most pronounced parameters, which have great effects on the work piece's surface during the deep cold rolling process. A simple, inexpensive and newly developed DCR tool, with interchangeable collet for using different ball diameters, was used throughout the experimental work.

Grzesik (2012) [53] presented the experimental results of the role of ball burnishing in improving of the surface integrity produced in finish hard machining of hardened 41Cr4 steel. Author characterized surface integrity in two standardized sets of 2D and 3D roughness parameters, the distributions of micro hardness, residual stresses and the microstructure of the sub layer which were examined using SEM/EDS technique. This study revealed that ball burnishing performed on hard turned surfaces improved not only surface roughness but also resulted in better service properties compared to those generated by CBN hard turning.

A work was presented by Dzionk and Przybylski (2012) [54] on Surface waviness of components machined by burnishing method. Author evaluated cylindrical surfaces burnished on the basis of waviness ratio and concluded that surface waviness ratios were found about 40% greater in case of surface after burnishing than in the case after turning.

Kamble and Jadhav (2012) [55] Experimentally studied Roller burnishing process on plain carrier of planetary type gear box author employed internal roller burnishing tool to burnish the drilled hole Speed, feed, and number of passes were varied using taguchi method to examine the surface finish and micro hardness and anova analysis is carried out and Surface finish from 2.44 micron to 0.13micron was achieved through internal roller burnishing.

Babu et al. (2012) [56] presented a work on Optimization of burnishing parameters by DOE and surface roughness, microstructure and micro hardness characteristics of AA 6061 aluminum alloy in T6 condition .The burnishing process parameters studied in this investigation include depth of cut, speed, feed, and number of tool passes. The data obtained from systematically conducted burnishing experiments was correlated with theoretical design using Taguchi method. Further, surface characterization was conducted using optical microscopy and XRD studies that were employed to estimate the micro hardness and magnitude of residual stress. The study revealed a one-to-one correlation between various burnishing parameters and a peak in all the three parameters, viz. burnishing depth, average micro hardness and compressive residual stress levels.

A work was presented by Babu et al. (2012) [57] on Optimization of burnishing parameters and determination of select surface characteristics in engineering materials by technological solutions for the surface modifications based on burnishing of some of the commonly employed engineering materials. The effects of various burnishing parameters on the surface characteristics, surface microstructure, micro hardness are evaluated, reported and discussed in the case of EN Series steels (EN 8, EN 24 and EN 31), Aluminum alloy (AA6061) and Alpha-beta brass. The burnishing parameters considered for studies principally are burnishing speed, burnishing force, burnishing feed and number of passes. Taguchi technique is employed in the present investigation to identify the most influencing parameters on surface roughness and to identify the optimal burnishing parameters and the factors for scientific basis of such optimization.

A work on Integrity of surfaces finished with ultrasonic burnishing was presented by Huuki and Laakso (2012) [58] .in this work they studied the residual stresses produced in two 34CrNiMo6-M tempering steel qualities of different hardness. The magnitude of stresses was examined using the hole drilling method and the hardness, surface quality of the finished work piece was measured and the results highlighted that the ultrasonic burnishing not only treated material on the surface efficiently but also deformed the material deeper, producing compressive residual stresses in the work piece. The hardness increased after finishing and surface quality improved significantly. The Roundness of the work piece was improved and dimensional changes were negligible.

A work on cryogenic burnishing of *co*-cr-mo biomedical alloy for enhanced surface integrity and improved wear performance was published by Yang (2012) [59] in this work author investigated the effect of a SPD process, cryogenic burnishing, on the surface integrity modifications of a *Co-Cr-Mo* alloy, and the resulting wear performance of this alloy due to the burnishing-induced surface integrity properties through a systematic experimental study that was conducted to investigate the influence of different burnishing parameters on distribution of grain size, phase structure and residual stresses of the processed material. The wear performance of the processed *Co-Cr-Mo* alloy was tested via pin-on-disk wear tests. The results from this work showed that the cryogenic burnishing has significant improved the surface integrity of the *Co-Cr-Mo* alloy which would finally lead to advanced wear performance due to refined microstructure, high hardness, compressive residual stresses and favorable phase structure on the surface layer. A finite element model (FEM) was developed for predicting the grain size changes during burnishing of *Co-Cr-Mo* alloy under both dry and cryogenic conditions and a new material model was used for incorporating flow stress softening and associated grain size refinements caused by the dynamic recrystallization.

Patel and Patel (2013) [60] presented a review of Parametric Optimization of Process Parameter for Roller Burnishing Process. A roller burnishing tool is used to perform roller burnishing process under different parameters. There are so many parameters which can be optimized for better performance of surface roughness and surface hardness. It has been used to impart certain physical and mechanical properties, such as friction, corrosion, wear and fatigue resistance. Roller burnishing is an economical process, where skilled operators are not required.

Esme et al. (2013) [61] worked on predictive modeling of ball burnishing process using regression analysis and neural network by focusing on two techniques, namely regression and neural network techniques, for predicting surface roughness in ball burnishing process. Values of surface roughness predicted by the two techniques were compared with experimental values. Also, the effects of the main burnishing parameters on surface roughness were determined. Surface roughness (R_a) was taken as response (output) variable and burnishing force, number of passes, feed rate, and burnishing speed were taken as input parameters. Relationship between the surface roughness and burnishing parameters was found out for direct measurement of the surface roughness.

4. DISCUSSION

From the Review of literatures it is found that Burnishing can be used almost all types finishing operations in industries. From the literature Review following points needs to be discussed:-

- Experiments on Burnishing parameters showed that depth of penetration and burnishing time are the most important parameters controlling the values of both out-of-roundness and change in work piece diameter.
- An increase in burnishing speed leads to a considerable reduction in the micro hardness index.
- The results showed that in case of Aluminum Alloy 2014 from an initial roughness of about Ra 4 μm, the specimen could be finished to a roughness average of 0.14 μm through ball burnishing.
- In internal burnishing process surface finish and surface hardness increases with burnishing speed up to an optimum value (62 m/min) and then decreases.
- Experiments revealed that the burnishing effectively improves surface finish, depth of burnishing, micro hardness and compressive residual stresses.
- Cold deformation of peaks to valleys on surface results with higher surface hardness. Depending on material ductility, peaks of the soften materials are more deformed.The possibility of burnishing steel components with high hardness is recommended
- Experiments showed that surface waviness ratios were about 40% bigger in case of surface after burnishing than in case of surface after turning. Burnishing elements with a surface designed to reduce waviness decrease only short term waviness.
- The surface roughness on various no-ferrous metals improved by high spindle rotations with highfeed rate and depth of penetration.
- The investigations of corrosion behavior of C45 carbon steel after roller burnishing indicate a significant effect of the low plasticity operations, much more greater than surface finish itself the corrosion resistance of carbon steel after roller burnishing has increased several times in comparison with the results obtained without any burnishing.
- Ultrasonic burnishing improves surface roughness by 90% also Residual stresses in work piece increased significantly, 400% by average.
- Roller burnishing produces superior surface finish with absence of tool feed marks on E-8 specimen of steel, the average (μm Ra) value observed is 0.21 and the finest is 0.13.
- Roller burnishing process has a large effect on the micro hardness of O_1 alloy steel, effect on the surface roughness of O_1 alloy steel. The improvement percentage on the surface quality was 12.5%.

- The durability and reliability of highly stressed turbine components can be increased by hardening of the surface layer, which can be achieved by roller burnishing.
- Ball burnishing process creates a shiny, smooth surface for low feed rate and larger diameter of the ball.
- The rolling force play an important role in enhancing the hardness of the treated specimens which in turn will have an influence in improving the fatigue life of the component. Higher the surface hardness higher will be the residual compressive stress, and thus higher the fatigue life of the component.
- The deep compression produced with low cold working by LPB has been shown to resist thermal relaxation at turbine operating temperatures far better than conventional shot peening.
- Roller burnishing has a positive effect on the surface roughness of O_1 alloy steel. The improvement percentage on the surface quality was 12.5%.
- Experiments show that surface hardness of mild steel specimens increases with increase in the burnishing force up to 42 kgf. Further increase of burnishing force results in the decrease of surface hardness on mild steel specimens. The maximum surface hardness obtained is 70 HRb.
- Frictional stir burnishing had found its usefulness in the manufacturing of aircraft and automobile components, and molds, these products often undergo surface deformation in a separate process after machining. With the application of frictional stir burnishing, surface reforming can be started immediately after cutting.
- The technology of sliding burnishing with cylindrical elements of diamond composite can be used in very simple and uncomplicated way for smoothing machining of various types of materials.
- Ball burnishing of hard steel parts produced surface profiles with sharp regular peaks which are visibly flattened by subsequent ball burnishing. In consequence, surfaces with lower surface roughness, Ra parameter below 0.2 mm was produced
- Many researchers carried out experiments on external work piece by single roller burnishing tool. It is also observed that roller burnishing also gives better result in drilled hole.
- Experiments showed that before burnishing micro hardness found 377Hv and after burnishing it increases up to 528Hv in case of steel.

5. CONCLUSION

From the critical literature Review it is concluded that there is a wide applicability of Roller Burnishing that improves bored or turned metal surface quality by improving surface roughness and surface hardness. This process can be effectively used in many fields such as Automobiles Manufacturing sector, Production of Machine tools, Aerospace Industries, thermal and hydro power plants components, for ships and submarines etc due to the following advantage offered by roller burnishing processes.

- Burnishing is capable of generating very high degree of surface finish ranging from 0.2 Ra, µm to 0.8 Ra, µm.
- Very close and consistent dimensional tolerance can be achieved in several thousand components by using Burnishing Tools also assembly problems are totally eliminated since part dimensions are maintained within tolerances.
- Since the roller burnishing process is a single pass operation manufacturing cycle times can be considerably reduced.
- Roller burnishing operation is cold rolling process; work hardening takes place on the cold worked surface. Roller Burnishing resulting in better wear resistance
- High repeatability finish sizing tolerance can be achieved easily by conventional machining methods.
- Generation of high repeatable sizing minimizes rework and rejection during the assembly process thus saving time and cost.

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