Comparative Study Of Ball And Roller Burnishing

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Abstract : Burnishing is a cold working, surface treatment process; it is a chip less process in which plastic deformation of surface non-uniformity occurs by applying pressure through a very hard roller or ball on a surface to generate a highly smooth and work-hardened surface. Burnishing is one processes which highly affect the surface roughness of metal. Burnishing improves the surface finish of the component along with surface properties of the component such as roughness, hardness, wear resistance, the fatigue strength of the material. It is a cost efficacious process, largely used in aerospace, biomedical and automobile industries to improve reliability and performance of the component.

***IndexTerms* – Burnishing, Surface Roughness, Surface Micro-Hardness, Compressive Residual Stresses.**

1. INTRODUCTION

In this cold-working process in which large contact pressure is applied on the surface of the work piece by a smooth roller or a ball burnishing tool to cause plastic deformation of surface irregularities without separating the material. The high burnishing pressure was greater than the yield strength causes roughness crest to flow towards the valleys which crush all the texture of the rough surface, resulting in smoother surfaces. The burnishing process produces a good surface finish, increases dimensional and shape accuracy, it improves surface hardness and also exerts residual compressive stresses at the metallic surface layers. The burnishing process is done to improve the surface finish of work pieces that have been previously machined. Figure 1 shows the actual mechanism of burnishing process of plastic deformation with the movement of burnishing tool over the work piece.

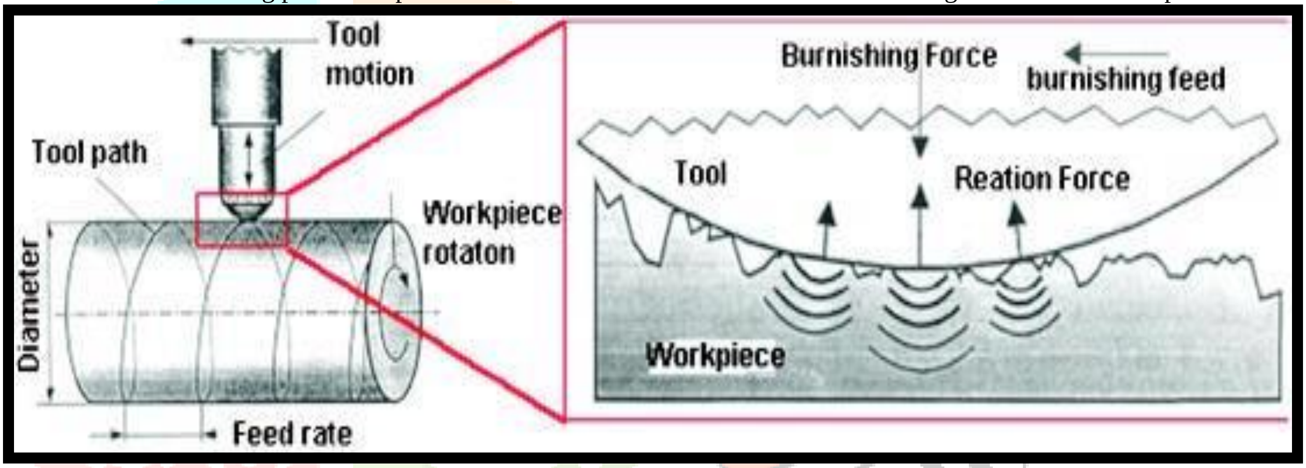

Fig.1 The mechanism of burnishing process

This process can be carried out using standard machines, such as lathe machine. Due to its high productivity, it also saves more production costs than other traditional processes such as super finishing, honing and grinding. Burnishing tools are also used for the sizing and finishing of surfaces.

2. CLASSIFICATION OF BURNISHING PROCESSES

Burnishing process can be typically classified into categories as:

I. Based on deformation element

a. Ball burnishing
  - i. Flexible
  - ii. Rigid

b. Roller burnishing

II. Based on the motion of the tool, on the surface.

a. Normal or ordinary

b. Impact

c. Vibratory

2.1 BALL BURNUSHING

The In this process, the deformation part is hard ball. Alumina carbide ceramic, cemented carbide, silicon nitride ceramic, silicon carbide ceramic, bearing steel is the material used for the ball. As ball acts as a tool in deforming 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 close to the ball on the work piece Fig.2 represents a schematic diagram of ball burnishing process.

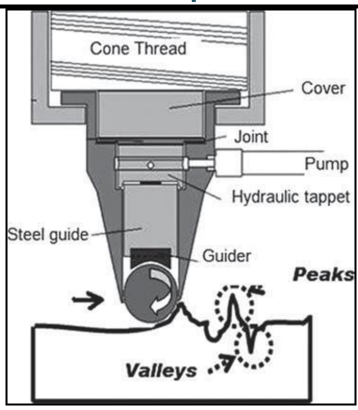

Fig.2 Ball burnishing

2.2 ROLLER BURNUSHING

Roller burnishing is a cold working process which produces a high quality of surface finish over a bored or turned metal surface. Roller burnishing involves cold working the surface of the work piece to improve surface structure. All machined surfaces have series of peaks and valleys of uneven height and spacing, the plastic deformation produces by roller burnishing, it is a displacement of the materials in the peaks in which cold flows into the valleys due to the pressure. This results in a mirror-like finish with a rigid, work hardened, wear and corrosion resistant surface.

3. LITERATURE REVIEW

3.1 ROLLER BURNISHING

M. W. Ingole, A. S. Bahedwar[6] had worked on the effect of lubricants on the surface finish of En8 material 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.

Taylan Altan, Partchapol Sartkulvanich[7] had studied on the FEM modeling in Cutting and Roller Burnishing, 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.

D. Lingaraju, K. Ramji[8] had done their work on roller burnishing process of polymer silica hybrid nanocomposites and observed that improvement in the surface strength mainly improves the fatigue behavior of work-piece under dynamic load. The properties of composites were upgrade 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, Nano silica was modified by 3-aminopropyltriethoxysilane and the hybrid Nano composite laminated by hand lay-up method. A low surface roughness and high hardness were 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.

Nikunj k Patel, Kiran A Patel[11] had 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.

R. Sadeler, M. Akbulut[12] had studied the formulation of experimental data based on a mathematical model for Al-2014 with a spherical surface burnishing tool. The authors are dealing with the effect of burnishing process on the aluminum alloy material 2014. Author's main purpose about this experimentation is used to gather information for formulation of a mathematical model for 6351 material operation. The authors observed that it is essential to correlate quantitatively various independent and dependent terms involved in this very intricate phenomenon. This correlation is nothing but a mathematical model as a design tool for such situation. The author's objective behind this was to minimize processing torque; energy and time with the constraints involved were bound values of π terms. The author's formulated LPP on the basis of the computed results. The computed result on the basis of dimensional analysis provides effective guidelines to the manufacturing engineering so that they can minimize E, Ra, and t for higher performances.

J.N. Malleswara Rao[13] had worked on finite element approach for the prediction of residual stresses in aluminum work pieces produced by roller burnishing. They calculate the residual stress using the numerical approach. Roughness is considered as a triangular asperity in this numerical approach. Before burnishing, the height of the triangle is considered as the roughness of the work piece. The normal force is acting on the peak of the asperity. The depth of deformed layer depends on the yield strength of the material (σy), normal load (Fn), and the asperity angle (α). They use the ANSYS12 to simulate the analysis process. The burnishing process is modelled as 2 D FEA and the surface roughness is considered as a triangular asperity with an included angle of α equal to 800. The height of the triangular asperity is considered as the surface roughness before burnishing which is taken as "a". Fig. 3 represents the triangular model for the numerical approach.

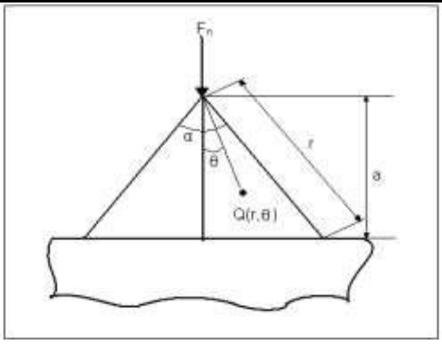

Fig.3 Coordinates of a point Q (r, θ) within a triangular asperity

N.S.M. EL-Tayeb[14] had worked on a forecast of burnishing surface integrity using radial basis function. They used the artificial neural network (ANN) and radial basic function (RBF) techniques to estimate the value of surface roughness. Artificial neural networks are calculated elements, which are based on the structure and function of the biological neurone. These networks have nodes or neurones, which are a report by differential equations. The nodes are interconnected layer-wise or intra-connected among themselves. Each node in the successive layer receives the inner product of synaptic weights with the outputs of the nodes in the previous layer when the vectors are binary or bipolar, hard-limiting non-linearity is used.

Fathi Gharbi[15] had worked on aluminum 1050A rolled sheet for improvement of ductility by a newly designed ball burnishing tool. He studied that the burnished surface had 48% improvement in ductility as compared with the unfurnished specimen. When the specimen is burnished with burnishing conditions of 200 N, 400 rpm, and 0.1 mm/rev. In this case, the yield strength, ultimate tensile strength, energy, and percent elongation at fracture for aluminum 1050A were 108.2 MPa, 125.16 MPa, 21.01 J, and 12.94%, respectively. In this case, the burnished specimen under the optimal conditions resists tensile well and its plasticity increases and as a result of this, the ductility in the material shows improvement.

Fritz Klocke[16] had studied the effect of process and geometric parameters on the surface layer state after roller burnishing of IN718, in this study they observed highly stressed components of modern aircraft engines, such as fan and compressor blades those have to satisfy dense requirements regarding durability and reliability. 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 very good surface quality. Hence to achieve a 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-increase measurements.

P. Ravindra Babu, K. Ankamma, T. Siva Prasad, A.V. S. Raju, N. Eswara Prasad[17] had done their study 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 parameters were selected for this study was speed, feed, depth of cut and number of passes. Results they got from the different experiments were compared with the theoretical method Taguchi method. Further, the 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.

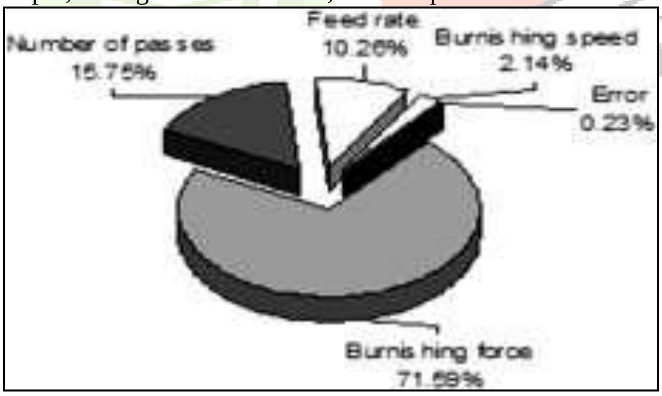

Fig.4 Contribution percentage of the burnishing parameters

N.S.M. El Tayeb, K.O. Low, P.V. Brevern[19] worked on the effect of roller burnishing contact width and burnishing orientation on the surface quality of Aluminum 6061. From there study it was observed that the optimum range of burnishing speed and force is of 250–420 rpm for 1mm roller contact width. Burnishing force above 220N is capable of decreasing the surface roughness by 35%. Below this limit, the surface roughness starts to decline plastically; Burnishing with smaller roller contact width (1 mm) is capable of improving the surface roughness up to 40%. Burnishing speed 110 rpm yields the highest improvement in hardness, as much as 30% increase. Increasing burnishing force had a negative impact on the wear resistance of burnished Aluminum 6061 surfaces.

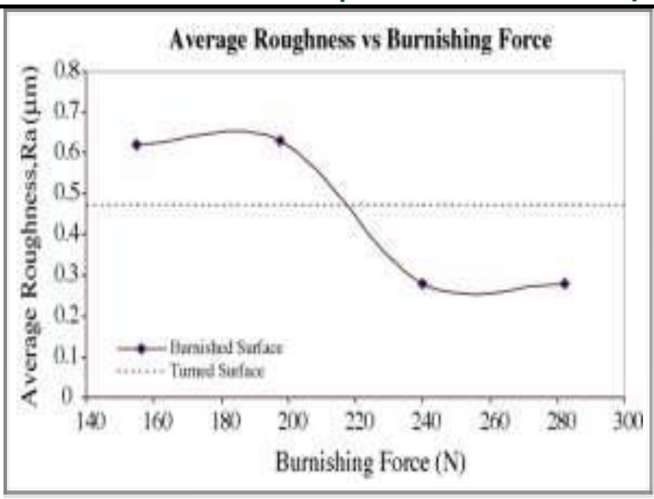

Fig.5 Burnishing force verses Average roughness

Malleswara Rao J. N, Rama Rao P.V.[20] had studied the effect of roller burnishing on surface hardness and surface roughness on mild steel specimen. From their study, it was seen that the 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. The maximum reduction in surface roughness is observed in first five passes on mild steel by roller burnishing operation.

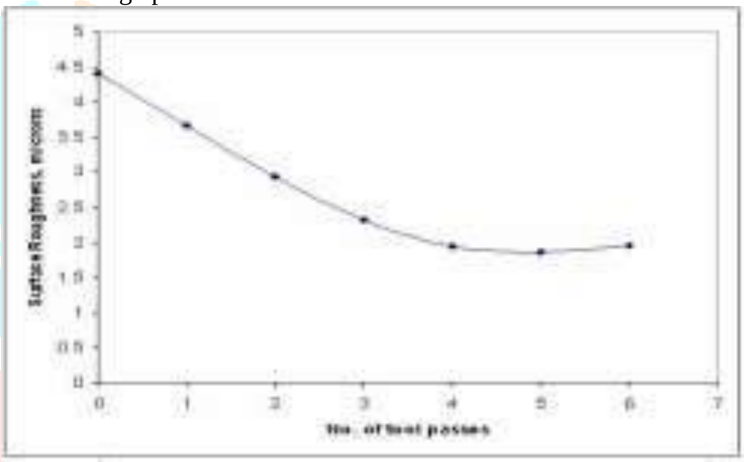

Fig.6 No of passes verses surface roughness

Khalid. S. Rababa, Mayas Mohammad Al-mahasne[23] had done look over the effect of roller burnishing on the mechanical behavior 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. The surface treatment is an important feature of all manufacturing processes. It has been used to impart certain physical and mechanical properties, such as appearance, corrosion, friction, wear and fatigue resistance. From there study they were observed that the most 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. SPD is one of the most effective representatives is the roller burnishing.

P. S. Kamble, V. S. Jadhav[26] had experimentally studied roller burnishing process on planetary type gear box, author employed internal roller burnishing tool to burnish the drilled hole. They were used the parameters-Speed, feed, and a number of passes were varied using taguchi method to examine the surface finish and micro hardness and ANOVA analysis are carried out and surface finish from 2.44 micron to 0.13 micron was achieved through internal roller burnishing.

P. R. Prabhu, S. M. Kulkarni, S. S. Sharma[28] had 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 the fractional design of experiments. The evaluation 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 a number of tool passes were the most using parameters, which have great effects on the work piece surface during the deep cold rolling process.

J. N. Malleswara Rao, A. Chenna Kesava Reddy, P. V. Rama Rao[29] 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. From the study, it was concluded 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 aluminum 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, aautomobiles manufacturing sector, production of machine tools, hydraulic cylinders.

3.2 BALL BURNISHING

B. B. Ahuja, U. M. Shirsat[22] they had worked on the parametric analysis of combined turning and ball burnishing process by carrying out experiments based on 23 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. They found the results of variance technique and the F-test. The analysis highlighted the significance of lubricant, force, and speed and feed on surface roughness and surface hardness.

Iolanda Elena Manole, Gheorghe Nagi[24] had worked on feed rate influence in the ceramic ball-burnishing process by an experimental work that concerned the effect of the burnishing parameters on the surface quality. The experimental study involved analyses of the burnishing process on the chromium-alloyed steel samples using a different tool, feed values and also different values for the radius of the ball burnishing. The experimental work followed a complete factorial plan that involved factors at different levels and evaluated the effect of the different burnishing system on surface roughness and form accuracy and also to develop an experimental relation that could predict the surface roughness.

Deepak Mahajan, Ravindra Tajane[27] They studied and takes the ball burnishing method as surface finishing method compared to another conventional method such as honing, lapping, super finishing. Ball burnishing process gives maximum efficiency in case of aluminum and steel work piece. Amongst the ball burnishing process parameters burnishing force, speed and feed were considered the most compared to ball material, No of revolutions and direction of burnishing. Micro hardness of work piece is also improved with ball burnishing process.

A.S. Maheshwari, Dr. R. R. Gawande[18] had investigated an surface hardness improvement of Titanium Alloy using Stiff Ball Burnishing process. They were considered mainly four parameters namely as; speed, feed, number of passes, depth of cut; to study effects on surface hardness. They used carbide as a tool(ball) material and experiment were carried out on CNC machine. To explore the effect of burnishing parameters on surface hardness of workpiece, the impirical mathematical model was developed and effects were investigated using RSM methodology.

To review the performance and to find the effect of each parameter on surface micro hardness, ANOVA table is generally used. From this experiment, the authors were concluded,

i. As speed, feed increases initial hardness increases and after that, it decreases.

ii. The most significant factor determine was a number of passes.

iii.Optimum results of surface hardness were achieved at, Number passes=3, Feed=300mm/min, DOP=0.5, Speed=900rpm

A. M. Hassan, A. M. Maqableh[1] had studied the effects of initial burnishing parameters on non-ferrous parts. They had used carbon chromium as ball material and two non-ferrous work piece materials, namely free machining Brass and cast Al-Cu alloy. They found that burnishing parameters such as 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 was concluded that the use of a lubricant in the burnishing process causes a general decrease in surface roughness and in the amount of the increase in surface hardness, but a change in the viscosity of the lubricant seems to have no significant effect on above two 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 surface roughness, and in the total amount of the increase in surface hardness.

M. H. El-Axira[2] had used newly designed internal ball burnishing tool to burnish the internal machined surfaces. The effect of four internal ball burnishing parameters (speed, feed rate, depth of penetration and number of passes) on surface roundness and surface micro hardness of a material by using response surface method (RSM). A remarkable improvement in roundness and surface micro hardness of aluminum alloy 2014 work piece has been got. The results show that from an initial roughness of about Ra 4μm, the specimen could be finished to a roughness average of 0.14 μm.

Aysun Sagbas[3] had studied the effect of the main burnishing parameters burnishing force, feed rate and a number of passes on surface hardness was examined using full factorial design and analysis of variance (ANOVA). Optimal ball burnishing parameters were determined after the experiments of the Taguchi's L9 orthogonal array. The burnishing parameters for surface hardness were the combination of the burnishing force at 200 N, a number of passes at 4, the feed rate at 0.25 mm/r. Also, they had studied on Al alloy 7178 with stainless steel ball using desirability function approach (DFA) and a quadratic regression model was developed to predict surface roughness using RSM with rotatable central composite design (CCD) and considered burnishing force, number of passes, feed rate and burnishing speed were as model variables. They found an absolute average error between the experimental and predicted values for surface roughness was 2.82%.

A. S. Maheshwari, Dr. R. R. Gawande[31] had studied the effect of the newly designed ball burnishing tool on the surface micro hardness of AA6351. They selected aluminum alloy because it widely used in automobile & aerospace sector due to properties like corrosion resistance, high strength to weight ratio high. They select the following process parameters- Feed, speed, depth of penetration and number of passes. Experiments were carried out on experimental design matrix. After the experiment they observe the effect of all parameters on surface micro hardness, from all the parameters the depth of penetration have maximum contribution upto 64.51% and with the depth of penetration number of passes also plays an important role in the improvement of surface micro hardness upto 30.85%.

R. Sadeler, M. Akbulut[9] had studied on the fatigue behaviour of AISI 1045 steel with the effect of ball burnishing parameters at varied pressures 100, 200 and 300 bars. The hard steel ball was hydrostatically forced towards the work piece, then from the results, they conclude that roughness improves with increasing pressure and also enhance both fatigue life of specimens for each pressure value.

El-Axir[10] had 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 they got the results that, from an initial roughness of about Ra 4μm, the specimen could be finished to a roughness average of 0.14μm. From the results it was concluded that increase in internal ball burnishing speed leads to a slight decrease in surface average roughness and also it concluded that, 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. Their study shows that a number of passes interact with both burnishing speed and burnishing feed. The greatest results obtained at both high number of passes with low burnishing speed and a high number of passes with low burnishing feed.

Ugur Esme[21] had done their work on the use of grey based taguchi method in ball Burnishing process for the optimization of surface roughness and micro hardness of AA 7075 aluminum alloy. From his work or study, it was observed that burnishing force has a maximum contribution of affecting the surface roughness. The contribution of burnishing force and no. of tool passes is more which 71.59% for force and 15.75% for no. of passes.

Fathi Gharbi[15] had worked on the effect of ball burnishing process on tensile properties of the material. It was seen that the tensile test curves for cold-rolled aluminum 1050A for different burnishing conditions are shown in Fig. As shown in Fig. burnishing aluminum 1050A plates can have a significant effect on its stress– strain behavior. The stress–strain behavior for aluminum 1050A remains more or less constant in the plastic zone. Depending on the burnishing force, the yield strength and the ultimate tensile strength may decrease or increase as compared with the unburnished condition. Fig. also shows that the plasticity increases with no increase in the stress. Both the energy and percent elongation at fracture increase with burnishing.

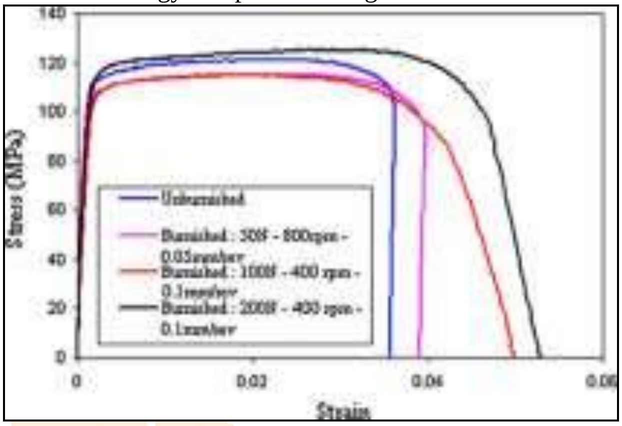

Fig.7 Stress–strain curves of tensile tests for burnished and unburnished specimens

A. S. Maheshwari, Dr. R. R. Gawande[30] were work on the role of burnishing process in manufacturing industry they consist of burnishing mechanism, burnishing loads and material used for burnishing also they studied the effect of various types of ball material and using that they got the best result for cemented ball burnishing load. They also consider the various burnishing parameters for the process.

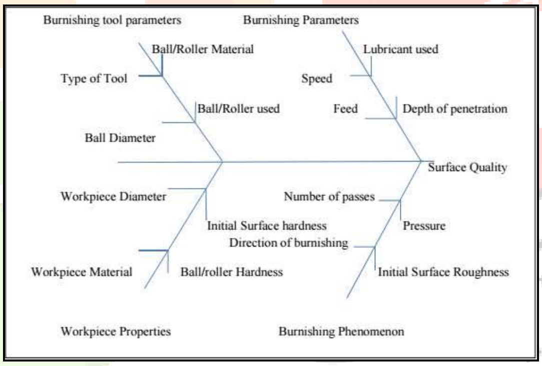

Fig.8 Fishbone Diagram for Burnishing Process

Table 3.1: Comparison between the ball and roller burnishing process

	Ball Burnishing	**Roller Burnishing**
Parameters	Speed, feed, Depth of penetration, Number of passes.	Speed, Feed, Number of passes, Burnishing Force
Burnishing Force	For the same material and same results of work piece it requires comparatively less amount of force.	For same work piece and same results comparatively, it requires more force.
Surface Finishing	Easy and effective for complex surfaces.	Comparatively difficult and less effective for complex surface.
	For EN8 steel Surface finish = 0.162 [32]	For EN8 steel Surface finish = 0.207 [32]
	For Brass, Surface Finish = 0.51 [11]	For Brass, Surface finish = 0.58 [11]
Surface Hardness	For the same hardness of workpiece comparatively less force required	For the same hardness of workpiece comparatively more force required

	For Brass surface hardness = 85 [20]	For Brass surface hardness = 83 [20]
Residual Compressive stresses	Comparatively less residual stresses produced in the ball burnishing	Comparatively high amount of residual stresses produce at the surface of the work piece
	Comparatively less plastic deformation.	Comparatively very high plastic deformation
	Type of contact between the ball and the workpiece improve the surface finishing of the work piece.	But it's the roller burnishing, width of the roller improves the surface finish. It is studied that smaller roller contact width is capable of improving SF up to 40%
	From the study, it was observed that ball burnishing is not that much of economical and it require a skilled operator.	From the study, it was observed that roller burnishing is comparatively economical and it doses not require a skilled operator.
	It gives a best and accurate surface finish on Al workpiece but comparatively takes a time.	It gives a better and accurate surface finish on Al workpiece in minimum time
	Mostly it gives the results of the surface finish, surface hardness, and fatigue life.	It also gives the results of the surface finish, surface hardness, fatigue strength but it also imparts some physical and mechanical properties like; corrosion resistance, wear, friction, wear resistance.
	Number of passes and depth of penetration gives the maximum effect compare to other parameters.	Number of passes and depth of penetration gives the maximum effect compare to other parameters.

4. Discussion & Conclusion

- Most of the authors studied burnishing on aluminum alloy, titanium alloy, brass and steel material. Burnishing parameters taken were; speed, feed, number of passes, depth of penetration and burnishing force.
- Residual stresses produced in the roller burnishing at the surface of the work piece is high compare to the ball burnishing so it gives good strength and wear resistance.
- Ball burnishing gives high surface finishing for the same material than roller burnishing.
- Surface hardness improvement by the ball burnishing is better to than the roller burnishing.
- Most of the authors took speed, feed, depth of penetration and number of passes as process parameters. From all this parameters depth of penetration and number of passes shows a more effect on the surface roughness and micro hardness of the material.
- Some authors take burnishing force as a process parameter it also shows maximum results surface roughness of metal.
- Most of the researchers investigated roller burnishing, very, few investigated into ball burnishing.
- The material used for the ball or roller was carbon chromium, ceramic, hard steel.
- Authors used different analytical methods for the study of burnishing and stress distribution in the material i.e. response surface method (RSM), finite element analysis method (FEM), desirability function approach (DFA), central composite rotatable design (CCRD).
- Also, they use the artificial neural network (ANN) and radial basic function (RBF) techniques to estimate the value of surface roughness.

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