"PARAMETRIC OPTIMIZATION OF ROLLER BURNISHING PROCESS FOR SURFACE ROUGHNESS AND SURFACE HARDNESS THROUGH APPLYING FULL FACTORIAL DESIGN" - A REVIEW

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ABSTRACT

Now a days, manufacturing industry expected more service life of the components without increasing the production cost. This led to development improvised and versatile manufacturing processes that address these expectations. The service behaviour and life of the components depend mostly on the surface properties. For this reason, significant attention has been paid to the post-machining operations, because the conventional machining processes like turning, milling etc. produce surfaces with inherent irregularities and imperfections. So there is need for a surface finishing operation that nullifies these irregularities. **Burnishing** is one of the surface finishing process, which does not involve material removal, but improves the surface properties by deforming the surface plastically. Here SS410 steel is used for making shafts with good surface finish and hardness by the roller burnishing process. The present study aims to achieve high performance of roller burnishing machine, experiments is carry out to find effect of input parameter on output performance parameter. The experimental data will be optimizing by full factorial methodology, and conclude optimal set of parameter by Response surface methodology or Regression analysis.

1 INTRODUCTION

Technological revolution in the recent years increased in the expectation from the manufacturing industry. The expected service-life of the components has taken a long-leap, without increasing the production cost. So the engineers had to come up with improvised and versatile manufacturing processes that address these expectations. The service behaviour and life of the components depend mostly on the surface properties. For this reason, significant attention has been paid to the post-machining operations, because the conventional machining processes like turning, milling etc produce surfaces with inherent irregularities and imperfections. So there is need for a surface finishing operation that nullifies these irregularities and also improves other surface properties like hardness, corrosion resistance, wear resistance and fatigue life. These properties can be increased by utilizing surface plastic deformation (SPD) process, which does not involve material removal, but improves the surface properties by deforming the surface plastically, under compressive loads. Under this external load, the surface of the component is subjected to cold working. One such SPD process that has gained increasing acceptability in the manufacturing industry is burnishing. Burnishing is a surface modification process which produces a very smooth surface finish cylindrical surface. The tool may consist of one or more ball or roller. This process does not involve the removal of material from the work pieces.

All machined or other processed metal surfaces consist of a series of peaks and valleys which constitute the surface irregularities. The force applied by the burnishing tool forces the material from the peaks to flow into the valleys. This reduces the height of the peaks and depth of the valleys, thereby reducing the surface roughness.

Quality of surface is an important factor to decide the performance of a manufactured product. Surface quality affect product performance like assembly fit, aesthetic appeal that a potential customer might have for the product. A surface is defined as the exterior boundary of an object with its surroundings, which may be any other object, a fluid or space or combination of these. The surface encloses the object's bulk mechanical and physical properties. A surface is what we touch, when we held a manufactured object. Normally dimensions of the object are specified in its drawing relating the various surfaces to each other. These nominal surfaces, representing the intended surface contour of the manufactured part, are defined by line in the drawing (machine). The nominal surfaces of the object are represented by perfect straight lines, perfect circles, round holes, absolute perpendicularity and straightness. A variety of processes are used to make the designed parts. In totality the manufacturing result is wide variations in surface characteristics. It is important to know the technology of surface generation. Only then the root causes of deviations can be determined and fixed to get the good results. [1].

Burnishing process is considered as a cold working process, because the surface of the work piece is subjected to severe stress due to the planetary motion between the tool & work piece and the pressure applied by the tool. When this stress exceeds the yield strength of the material, it results in the plastic flow of the material from the peaks of the surface irregularities into the valleys, thereby reducing the surface roughness[2].

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

2 LITERATURE REVIEW

Branko Tadic (2015)[3] et all investigated on aluminium alloy EN AW-6082 (AlMgSi1) through ball burnishing of openings. Their primary goal was to achieve dimensional and geometrical accuracy of the openings. They has been used a specially designed stiff tool, the openings were widened by 0.06 mm on average, while the roundness and cylindricity errors were drastically reduced. In addition, the surface roughness was improved by 35%. They conducted FEM analysis to determine the stress field distribution in the work piece, as well as to approximate the residual stresses after the ball burnishing.

X. L. Yuan & Y. W. Sun (2015)[4] et all investigated the influence of roller burnishing parameters (i.e., spindle speed, burnishing depth, and burnishing feed) on the surface roughness and microhardness of TA2 alloy. The aim is to model the relations between some relevant process parameters and the surface performances of surface roughness and microhardness after roller burnishing, which can give an optimum combination of process parameters to produce desired surface roughness and microhardness.

Goutam D. Revankar(2014)[5] et all to optimize the process parameters during burnishing of titanium alloy (Ti–6Al–4V). They considered Ball burnishing process parameters such as burnishing speed, burnishing feed, burnishing force and number of passes to minimize the surface roughness and maximize the hardness. The lubricated ball burnishing experiments were planned as per L25 orthogonal array and signal to noise (S/N) ratio was applied to measure the proposed performance characteristics. The optimization results revealed that burnishing feed and burnishing speed are the significant parameters for minimizing the surface roughness, whereas burnishing force and number of passes play important roles in maximizing the hardness. The optimization results showed greater improvements in surface finish (77%) and hardness (17%) when compared to pre machined surfaces.

Masato Okada (2014)[6] et all conducted experiment on a novel roller burnishing method that achieves simultaneously rolling and sliding effects on the burnishing point to accomplish a finish with superior surface integrity using a commercially available roller burnishing tool. The circumferential surface of the work piece, which is rotated by the main spindle of the lathe. The sliding effect was obtained by changing the rotational axis of the burnishing roller with respect to the work piece. The processing characteristics of the method with an aluminium-based alloy work piece were evaluated to compare with the conventional method. They investigated influence of the burnishing conditions, such as the burnishing speed, thrust force, and feed rate. The thrust force and feed rate had a large influence on the burnished surface integrity, whereas the influence of the burnishing speed was minimal. They examined to the carbon steel for applicability of the proposed method.

K Saraswathamma (2014)[7] et all presented on Optimization of surface roughness in the Roller burnishing process using response surface methodology. Also they developed mathematical equation for future use by design engineer. They have been used process parameters burnishing speed, Feed and Interference for experiment work. They found that the Due to increase in feed, surface roughness increases. Results concluded that at a speed of 190 rpm, feed of 0.22 mm/rev and interference of 6 μm and also at 135 rpm, 0.32 mm/rev and 6 μm were obtained. The experimental results at the optimum process parameter combination confirm the effectiveness of the response surface models for optimum burnishing parameters.

Shu Yang (2014)[8] et all presented to investigate the effect of a severe plastic deformation (SPD) process, cryogenic burnishing, on the surface integrity modifications of a Co–Cr–Mo alloy due to the burnishing induced surface integrity properties. A set of experiments was conducted to investigate the influence of different burnishing parameters on distribution of grain size, phase structure and hardness of the processed material. They showed that the proper selection of burnishing conditions can significant improve the surface integrity of the Co–Cr–Mo alloy due to refined microstructure, high hardness, and favourable phase structure on the surface layer, which could potentially lead to advanced wear performance of such material. They revealed that the Microstructural changes with grain refinement in the surface layer were observed under both dry and cryogenic conditions. In addition to the cooling method, the thickness of the burnishing-influenced layer with grain refinement was also found to be dependent on the used depth of penetration and the burnishing speed.

Deepak Mahajan (2013)[9] et all survey on ball burnishing process and determine idea about various workpiece materials, various cutting tools and machine tools, process parameters lubricants, variable measured and methodology used as well as the prominent levels for each. To ensure reliable performance and prolonged service life of modern machinery, its components require to be manufactured not only with high dimensional and geometrical accuracy but also with high surface finish. The surface finish has a vital role in influencing functional characteristics like wear resistance, fatigue strength, corrosion resistance and power loss due to friction. Unfortunately, normal machining methods like turning, milling or even classical grinding can't meet this stringent requirement.

W. Grzesik (2013)[10] et all Producing high quality hardened parts using sequential hard turning and ball burnishing operations. The effects of burnishing can be additionally controlled by cryogenic pre-cooling of the work piece. In general, burnishing of hard turned surfaces results in substantial modifications of both surface and subsurface layer. As a result, after the hard machining of cryogenically pre-cooled workpiece, the microstructure does not change in comparison to initial quenching due to low cutting temperature. But, according to SEM analyses performed, the content of retained austenite decreases after cryogenic treatment and SL formation is less intensive.

P Ravindra babu (2012)[11] et all conducted experiment to arriving optimum burnishing parameters for a variety of materials with characteristic strength level (in the present case varied average micro hardness) the materials considered are EN series steels, AA6061 alloy, alpha–beta brass and the burnishing parameters evaluated include burnishing force, burnishing feed, burnishing speed and number of passes. They conducted based on a 2 and 3 level Taguchi's design experiment method. They showed that the Maximum burnishing depth happens to occur in 2^{nd} pass. However, it should be noted that the variation in burnishing depth with extent of burnishing is less pronounced in the present alloy as compared to EN series steels.

Feng Lei Li (2012)[12] et all reveals that the decrease of surface roughness is proportional to burnishing force to the 2/3 power in roller burnishing and to the 1/2 power in ball burnishing. The proportional constants are only determined by the yield stress of workpiece with geometrical parameters held constant, and have nothing to do with the elastic constants such as Young's modulus and Poisson's ratio used in Hertz theory. The lowest surface roughness and the optimum burnishing force can be obtained. The lowest surface roughness is proportional to the initial surface roughness, and burnishing can decrease the surface roughness of workpiece up to about 75% to 87.5% which depends only on the semi-angle of asperity. The above adopted assumptions, the conclusions worked out and the predicted results are verificated by the experiments and related literatures.

Malleswara Rao J. N. (2011)[13] et all various experiments are conducted 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.

J.N. Malleswara Rao (2011)[14] et all performed by applying a highly polished and hardened ball or roller with external force onto the surface of a cylindrical work piece. The burnishing process increases the surface hardness of the work piece, which in turn improves wear resistance, increases corrosion resistance, improves tensile strength, maintains dimensional stability and improves the fatigue strength by inducing residual compressive stresses in the surface of the work piece. In the present experimental work, both ball and roller burnishing tools are used. Experiments are conducted to study the performance of the ball and roller burnishing tools on lathe, along with the influence of number of burnishing tool passes on the surface roughness and surface hardness of brass specimens. The results revealed that improvements in the surface finish and increase in the surface hardness are obtained by the increase of the number of burnishing tool passes in both ball burnishing and roller burnishing on the brass specimens.

P Ravindra Babu (2008)[15] et all conducted experiment to investigated effect of internal roller burnishing on surface roughness and surface hardness of mild steel by varying the speed. They revealed that the Variation of surface finish and surface roughness by varying burnishing speed, keeping burnishing interference and burnishing feed as constant. Optimum increase in surface finish and SR was at 62 m/min. If speed is different than optimum value, increase in surface finish and SR is less. They also suggested that the same study can be extended to other metals, non-metals and composite.

Binu C. Yeldose (2008)[16] et all presented an investigation for the comparison of the effect of the uncoated and TiN coating by reactive magnetron sputtering on EN31 rollers in burnishing with varying process parameters such as burnishing speed, feed, 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 operation. The burnishing speed, feed, depth of cut and number of passes are the influencing parameters on the burnishing operation. The burnishing speed, 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.

S. Thamizhmanii, B. Saparudin, S. Hasan (2007)[17] et all observed that surface roughness has increased as the spindle rotation, feed and depth of penetration increased for aluminum, brass and copper. If the over lapping of the roller is maintained, and then it is possible to achieve lower surface roughness value. This is only possible where there is no fixed feed rate in the machine. The micro hardness also increased as the spindle speed, feed and depth of penetration increased for all the three non-ferrous metals. The work hardening effect has increased at higher operating parameters. There is some limitation to increase the depth of penetration. If the depth of penetration is increased the roller will act as cutting tool with larger nose radius and material removal takes place. The burnishing is good process to improve the surface roughness for metals where grinding is not possible due to wheel loading effect in material like aluminum etc.

H. Hamadache (2006)[18] et all investigated to develop a device for mechanical plastic deformation of structural Rb40 steel using ball and roller burnishing and to investigate the evolution of associated roughness, hardness and wear resistance. They found that roller burnishing provides optimal roughness results, particularly when initial surface quality is close to 3 µm. They obtained optimum roughness and hardness for a specific operating regime in which decisive parameters are the applied force as well as the number of passes. When considering roughness criterion, it is recommended to limit the number of passes to two while three passes are advised for a hardness basis. Rb40 steel superficial layers treated by either roller or ball burnishing behave as a grinded surface with an appreciable wear resistance.

3. CONCLUSION

From the literature review, it has been found that the several researchers has been worked on various burnishing operation through using various process parameter like burnishing speed, feed and burnishing force. Several researcher has been worked on same material is mild steel and aluminium with various process parameter. Also it has been found that the several researchers have been worked on surface roughness and surface hardness. Also it has been found that the very less literature have been done on the **SS410 steel material**. **SS410 steel material** are widely using in bolts, screws, bushings, nuts, shaft, pump and valve. Thus it has been decided to work on SS410 steel by using roller burnishing process. The 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.

4 REFERENCES

1]. Introduction to burnishing - Sodhganga shodhganga.inflibnet.ac.in:8080/jspui/bitstream/.../09_chapter%201.pdf

2]. ISO journal
iosrjournals.org/iosrjmce/papers/vol12issue3/...2/B012321623.pdf

3]. Branko Tadic, Sasa Randjelovic, Petar Todorovic, Jelena Zivkovic, Vladimir Kocovic, Igor Budak, Djordje Vukelic," Using a high-stiffness burnishing tool for increased dimensional and geometrical accuracies of openings, Precision Engineering (2015).

4]. X. L. Yuan & Y. W. Sun & L. S. Gao & S. L. Jiang," Effect of roller burnishing process parameters on the surface roughness and microhardness for TA2 alloy, Int J Adv Manuf Technol DOI 10.1007/s00170-015-8031-0 Springer-Verlag London (2015).

5]. Goutam D. Revankar , Raviraj Shetty, Shrikantha S. Rao, Vinayak N. Gaitonde," Analysis of surface roughness and hardness in ball burnishing of titanium alloy" Measurement 58 (2014) 256–268.

6]. Masato Okada, Shohei Suenobu, Kei Watanabe, Yorihiro Yamashita, Naoki Asakawa," Development and burnishing characteristics of roller burnishing method with rolling and sliding effects" Mechatronics (2014).

7]. K Saraswathamma, G Venkateswarlu, S Venkatarami Reddy," Optimization of surface roughness in the Roller burnishing process using response surface methodology and desirability function, International conference on Emerging Trends in Mechanical Engineering, ISBN: 978-93-82163-09-1,(2014).

8]. Shu Yang, Domenico Umbrello, Oscar W. Dillon Jr., David A. Puleo, I.S. Jawahir," Cryogenic cooling effect on surface and subsurface microstructural modifications in burnishing of Co–Cr–Mo biomaterial, Journal of Materials Processing Technology 217 (2014) 211–221.

9]. Deepak Mahajan, Ravindra Tajane," A Review on Ball Burnishing Process, International Journal of Scientific and Research Publications, Volume 3, Issue 4, (2013) ISSN 2250-3153.

10]. W. Grzesik, K. Z. ak," Producing high quality hardened parts using sequential hard turning and ball burnishing operations, Precision Engineering 37 (2013) 849– 855.

11]. P Ravindra Babu, K Ankamma, T Siva Prasad, A V S Raju and N Eswara Prasad," Optimization of burnishing parameters and determination of select surface characteristics in engineering materials" Indian Academy of Sciences *Sadhana* Vol. 37, Part 4, (2012), pp. 503–520.

12]. Feng Lei Li , Wei Xia, Zhao Yao Zhou, Jing Zhao, Zheng Qiang Tang," Analytical prediction and experimental verification of surface roughness during the burnishing process, International Journal of Machine Tools & Manufacture 62 (2012) 67–75.

13]. Malleswara Rao J, Chenna Kesava Reddy, Rama Rao P," The effect of roller burnishing on surface hardness and surface roughness on mild steel specimens, International Journal Of Applied Engineering Research, Dindigul Volume 1, No 4, (2011) ISSN 0976-4259.

14]. J. N. Malleswara Rao, A. Chenna Kesava Reddy and P. V. Rama Rao," Experimental investigation of the influence of burnishing tool passes on surface roughness and hardness of brass specimens, Indian Journal of Science and Technology ISSN: 0974- 6846 (2011).

15]. P Ravindra Babu, T Siva Prasad, A V S Raju and A Jawahar Babu," Effect of internal roller burnishing on surface roughness and surface hardness of mild steel, Journal of Scientific & Industrial Research Vol. 68, (2009), pp. 29-31.

16]. Binu C. Yeldose, B. Ramamoorthy," An investigation into the high performance of TiN-coated rollers in burnishing process, journal of materials processing technology 207 (2008) 350–355.

17]. S. Thamizhmanii, B. Saparudin, S. Hasan," A study of multi-roller burnishing on non-ferrous metals, Journal of achievements in materials and manufacturing engineering (2007).

18]. H. Hamadache, L. Laouar, N.E. Zeghib, K. Chaoui," Characteristics of Rb40 steel superficial layer under ball and roller burnishing, Journal of Materials Processing Technology 180 (2006) 130–136.