The Role of Ball Burnishing Process in Manufacturing Industry: A State-Of-The-Art Survey

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ABSTRACT- Burnishing is a chip-less surface enhancement technique used to improve the surface finish of the part along with other surface qualities like surface hardness, tensile strength, corrosion resistance, dimensional stability etc., Burnishing process employs a rolling ball or roller burnishing tool which pressed against the work piece, in order to achieve plastic deformation of the surface layer. It is a cost effective process, mostly used inaerospace, biomedical, and automobile industries to improve reliability and performance of the component. Ball burnishing is one type burnishing process used to make desired surface features on parts. In ball burnishing process, the performance characteristics of the products depends on burnishing process parameters, burnishing tool, and properties of work-piece material. The present study focuses to review the recent advancements in ball burnishing process. The concluding remarks have also been made from the work.

KEYWORDS-*Burnishing process, Ball burnishing process, Burnishing process parameters, Surface quality, Surface roughness*

INTRODUCTION

Nowadays manufacturing industries are showing more attention towards making products with good dimensional precision and fine surface treatments on advanced materials. To improve part quality, traditional secondary surface treatments such as honing, grinding, lapping, etc., are used in many industrial purposes [1]. But these techniques are chip removal processes, its performance highly depends on skill and experience of the operator [2]. Ball burnishing process is an innovative chip-less process which was introduced to overcome problems with chip generating processes for obtaining better surface qualities on products [3]. Ball burnishing is a cold working process in which plastic deformation occurs by applying a pressure through a very hard and smooth ball on a work-piece surface, used to produce fine surface finish without material loss, in short processing time [4].

Ball burnishing is a post finishing operation (also called assurface finish treatment process) used to improve the surface roughness by ball burnishing tools. The schematic diagram of ball burnishing process is given in Fig.1.Ball burnished tool is a highly polished one whichis pressed against pre-machined surfaces to plastically deform peaks into valleys. Ball burnishing operation becoming more beneficiary process compared other conventional processes because it useful to enhancement in surface values include increase in surface hardness, reduction in surface roughness, the production of compressive residual stresses which are favorable for cold work hardening of the surface, improves tensile strength and corrosion resistance, also maintains dimensional stability fatigue life as result of the produced compressive residual stress [5, 6].Burnishing is the plastic deformation of a surface due to sliding contact with another object. Visually, burnishing smears the texture of a rough surface and makes it shinier. Burnishing may occur on any sliding surface if the contact stress locally exceeds the yield strength of the material. Ball burnishing processes are most used for many of the industries like automobile, aircraft, defense, spacecraft, railways, textile, machine tool, motors and pump industry, hydraulic and pneumatic farm equipment, home appliances etc.

Ball burnishing is also called as ballizing process, is most common type of burnishing process, in which a burnishing tool runs against the workpiece and plastically deforms its surface. The workpiece may be at ambient temperature, or heated to reduce the forces and wear on the tool. The tool is usually hardened and coated with special materials to increase its life. Ball burnishing, or ballizing, is a replacement for other bore finishing operations such as grinding, honing, or polishing. A ballizing tool consists of one or more over-sized balls that are pushed through a hole. The tool is similar to a broach but instead of cutting away material, it plows it out of the way.

Ball burnishing is also used as a deburring operation. It is especially useful for removing the burr in the middle of a through hole that was drilled from both sides. Ball burnishing tools of another type are sometimes used in CNC milling centres to follow a ball-nosed milling operation: the hardened ball is applied along a zig-zagtool path in a holder similar to a ball-point pen, except that the 'ink' is pressurized, recycled lubricant. This combines the productivity of a machined finish which is achieved by a 'semi-finishing' cut, with a better finish than obtainable with slow and time-consuming finish cuts. The feedrate for burnishing is that associated with 'rapid traverse' rather than finish machining.

Plastic flow of the original asperities occurs when the yield point of the work-piece’s material is exceeded. In this way, asperities are flattened. Compressive stresses are also induced in the surface layer, giving several improvements to mechanical properties. Burnishing can improve both the surface strength and roughness. The increase of surface strength mainly serves to improve fatigue resistance under dynamic loads.

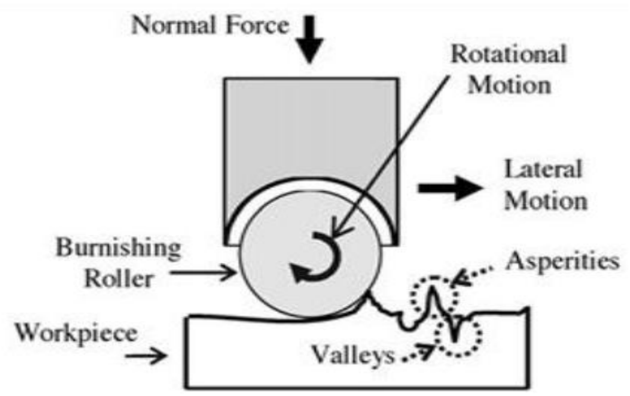

Fig 1: Ball Burnishing Mechanism

LITERATURE REVIEW

Rodriguez et al.,[5]investigated the influences of burnishing factors like speed, feed, burnishing force on residual stress values, surface hardness, roughness and fatigue life in ball burnishing of mild steel. Researchers identified from their work that output responses are highly depend on correct selection of input process parameters. Sagbas[4] studied the effects of burnishing force, no. of passes, feed rate and burnishing speed on surface roughness in ball burnishing of aluminum alloy materials. They used response surface methodology and desirable function approach to predict the better surface roughness value. Author suggested from work that minimum or less no. of passes and low level of burnishing force are good for obtaining better surface roughness.Revankar et al.,[6] analyzed the ball burnishing process to control the input parameters: burnishing speed, feed & force and no. of passes, to optimize surface finish and hardness of titanium alloy (Ti-6Al-4V) material. They had been used Taguchi methodology approach to illustrate the factor significances on output measurements. Gomez et al.[7]Made an comparative analysis between the ball burnishing assisted with vibration compared to a non-assisted conventional process. Researchers considered number of lateral passes, burnishing force, lateral width and vibrations as input parameters and surface quality is as output response. They found better surface roughness in vibration assisted ball burnishing compared with other conventional ball burnishing. They concluded that vibration assisted burnishing is advantageous to obtain good surface finish.

Chomienne et al.**[**8] analyzed the influences of speed, feed and number of passes on surface roughness, residual stress, micro hardness in ball burnishing martensitic stainless steel. Researchers applied the finite element model on experimental data to validate predicted output responses. Again Kiran et al.[9] also made an experimental analysis on ball burnishing of aluminum material to study the factor (i.e. spindle speed, feed & number of passes parameter) effects on surface roughness. Mathematical model had been developed to made relationships between the input parameters and output response. Again John et al.[3] had planned to study and validate the ball burnishing of D3 tool steel material using CNC lathe using finite element analysis. They considered speed, burnishing force and feed as control parameters and surface roughness, residual stress, micro hardness & roundness as performance characteristics. They found considerable improvement in output responses from their analysis.

Hiegemann et al.[10]had developed an analytical model for a ball burnishing process to predict the surface roughness of thermally sprayed coating after a post treatment. They improved surface roughness of part by systematic experimental and modeling of the ball burnishing process. Patel et al.[11] optimized the performance characteristic hardness of aluminum alloy in conventional lathe machine with burnishing process parameters: speed, feed rate, burnishing force and number of passes using Taguchi method. Significant parameters were identified by analysis of variance technique. The optimum parametric condition had also been obtained by Taguchi method. They stated from their study is that Taguchi methodology is very useful to optimize the ball burnishing process.

CASE STUDY

Aluminum materials are very important for many industrial purposes like aircraft designs, trucks, railway cars, bicycle, space crafts, cans, foil, frame, manufacturing of medical apparatus, chemical industries, decorative applications, for making various spare parts for automotive vehicles, etc., due to its excellent material properties. For producing aluminum parts with fine tolerances, grinding operation, shot peening, or hand polishing operations are preferred due its low machinability, as all these processes are metal removal techniques. At the same time burnishing process which is non-metal removal process is highly preferred for improving the surface qualities like surface roughness of aluminum products. Surface roughness is considered as quality parameter which used to describe the quality of the any machined or manufactured part. Good surface finish on the part increases its reliability. It also useful increase the product life time by decreasing coefficient of friction and by increasing corrosion resistance, etc.

El-Axirand El-Khabeery [12]had reported an article for studying the effects of input parameters on surface roughness of aluminum alloy in ball burnishing operation. The main effect plots of surface roughness (Fig.2) taken from the reference [12], to study the significances of process parameters on surface roughness of aluminum alloy. From the Fig.2, it is evident that surface roughness is decreasing with increase of parameters: speed and number of passes. Better surface roughness value found at low levels of speed and minimum number of levels. With increase of depth of cut, R_a value improved initially and then increased as found from Fig.2. Better surface roughness value obtained with increase of feed rate up to 80 μm/rev and worsen little bit at 100μm/rev as seen from the Fig.2. The most significant parameters can be found from the main effects plots, if difference is higher between the minimum and maximum limits of each factor, higher the effect on corresponding parameter. From the Fig.2, it is noted that speed is the most significant parameter for surface roughness of ball burnishing of aluminum alloy material. Next is number of passes, followed by feed rate and depth of cut.

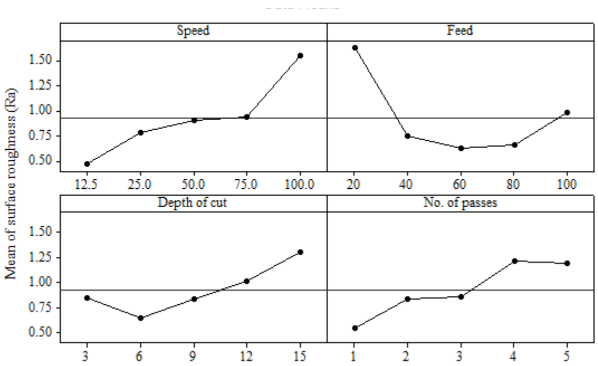

Fig 2: Main effect plots for surface roughness of aluminum alloy FDM [12]

The information regarding the various aspects of ball burnishing of different materials are limited, more extensive research is required to perform the process economically. For studying, analyzing, modeling and optimizing the ball burnishing process systematic techniques are required. Some of statistical tools like Taguchi method, full factorial design, response surface methodology (RSM) can useful for conducting experimental studies. The significances of parameters can be studied by analysis variance and signal-to-noise ratio. Mathematical modeling of responses and input parameters can be made by regression analysis and RSM techniques. Traditional optimization techniques like genetic algorithm (GA), simulated annealing algorithm (SAA); and advanced optimization algorithms such as teaching learning based optimization (TLBO) approach, jaya algorithm optimization, African buffalo optimization (ABO), etc., can be applied to conduct the ball burnishing process more reliably, economically, predictably.

CONCLUSIONS

The followings are the conclusions drawn from the present study:

i. Advanced manufacturing industries focusing to produce high quality parts from advanced materials
ii. Burnishing process is important non-metal removal process
iii. Burnishing process can conducted two types: roller burnishing and ball burnishing
iv. Ball burnishing is an surface treatment process used to make high levels of performance characteristics on parts
v. Ball burnishing process is highly affected by correct selection of parametric combination, other factors.
vi. The surface roughness is important response to describe the quality levels of any machined part
vii. Surface roughness of aluminum alloy in ball burnishing is most influenced by burnishing parameters
viii. Speed is the most influential factor of surface roughness of aluminum burnishing
ix. From the study it is found that systematic analysis is required to perform the ball burnishing process economically.

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