Optimization Parameters of Ball Burnishing Process for Surface Roughness

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Abstract— Burnishing is a plastic deformation process; it has become more popular as finishing process. Thus, it is especially crucial to select the burnishing parameters reduce surface roughness. In the present study, the investigation of surface roughness on ball burnishing parameters will be carried out on Aluminium alloy. The Taguchi method of surface roughness parameters (Ra) is developed considering the conditions as burnishing force (5,15,25 kgf), number of tool passes (1,3,5), feed rate (0.068,0.1,0.205 mm/rev.) and burnishing speed (45,120,300 rpm). Optimal ball burnishing parameters were determined after the experiments of the Taguchi orthogonal array. This model has better surface roughness prediction capability and applicability to effective selection of burnishing parameters for better quality products.
Keywords: Ball Burnishing; Taguchi Method; Surface Roughness; Burnishing Force; Feed Rate; Burnishing Speed

I. Introduction

Burnishing is a surface modification process which produces a very smooth surface finish by the planetary rotation of a tool over a bored or turned 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.

Burnishing process can be broadly classified into two types based on the geometry of the tool. They are

- Ball burnishing
- Roller burnishing

There are several forms of burnishing processes, the most common are roller burnishing and ball burnishing (a subset of which is also referred to as ballizing). In both cases, a burnishing tool runs against the workpiece and plastically deforms its surface. In some instances of the latter case (and always in ballizing), it rubs, in the former it generally rotates and rolls. 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-zag toolpath in a holder similar to a ball-point pen, except that the 'ink' is pressurised, 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 feed rate for burnishing is that associated with 'rapid traverse' rather than finish machining.

Roller burnishing, or surface rolling, is used on cylindrical, conical, or disk shaped workpieces. The tool resembles a roller bearing, but the rollers are generally very slightly tapered so that their envelope diameter can be accurately adjusted. The rollers typically rotate within a cage, as in a roller bearing. Typical applications for roller burnishing include hydraulic system components, shaft fillets, and sealing surfaces. Very close control of size can be exercised.

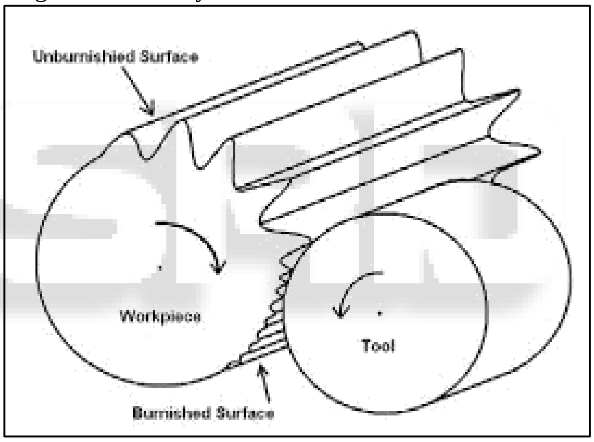

Fig. 1: Basic operation of burnishing

II. Literature review

M Babic, V Kocovic, D Vukelic, G Mihajlovic, M Eric and B Tadic [1] reveals that Numerous research results indicate that the finishing processing of metal materials using ball burnishing has positive effects from the aspect of surface roughness decrease to the hardness increase in the surface layers of the processed materials. Little research has been devoted to this type of processing for nonmetal materials. This paper presents research results related to the influence of ball burnishing processing on the hardness increase of a wooden element. It was determined that the hardness can be increased up to three times for processing of wood using this technology.

Harshal Patel and Ketan Sathavara [2] reveals that flame sprayed thermal coating is approach to improve wear as well as overall life of workpiece. but this type of coating have inherent irregularities and defects like micro cracks that cause energy dissipation and surface damage. To Overcome These Complications, Conventional Finishing Processed Such As Grinding have been traditionally employed.

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However, since this methods essentially depend on chip removal to attain the desired surface finish, these machining chips may cause further surface abrasion and geometric tolerance problem especially if conducted by unskilled operators. Burnishing is a cold forming process in which initial asperities are compressed beyond yield strength against load. The surface of the material is progressively compressed, then plasticized as resultant stresses reach a steady maximum value and finally wiped a superfine finish. This paper is deals with the thermal spray flame coating is used to increase wear as well as overall life of component and post machined by ball burnishing to achieve smaller surface roughness value and improving surface hardness.

P. N. Patel, N.B. Patel and T. M. Patel [3] reveals that optimization of newly design ball burnishing tool is used carried out experiment on conventional lathe machine with burnishing process parameters using taguchi analysis method. The work piece and ball materials used is Aluminium Alloy 6061 and high chromium high carbon with 8mm diameter. The levels of input process parameters are selected on basis of one factor at a time experiment are burnishing force, burnishing feed, burnishing speed and number of passes.

J. A. Travieso-Rodríguez, G. Dessein, and H. A. González-Rojas [4] reveals that the ball burnishing process is done to improve the surface finish of workpieces that have been previously machined. In this article we present the results of tests performed with this process that was applied to workpieces with a convex or concave surface of two different materials: Aluminium A92017 and steel G10380. An experiment to do the tests was designed. The results of measurements of surface roughness are presented in this paper as well. These results are compared to those measured in the workpieces before being burnished. After that conclusions are drawn about the improvement of surface roughness applied to the workpieces through the ball burnishing process.

III. Process Parameters

There are many process parameters that control the operation and outcome of burnishing process. Each of these parameters has to be optimized and controlled to get the best possible results. The most important parameters are:

– Burnishing force
– Speed
– Feed
– Number of tool passes
– Tool diameter and material
– Lubricant

The details of these parameters and their effect on burnishing process are discussed below.

A. Burnishing Force:

The force with which the tool is pressed against the work pieces is termed as burnishing force. This force acts normally on the work piece surface. The amount of force is controlled by the depth of penetration of the tool. Burnishing force is the most important and critical parameter of the burnishing process, because the surface roughness obtained depends on the force with which the tool is pressed against the work piece. The applied force should be high enough to deform or yield the surface asperities and make the material flow from the peaks into the valleys of the surface irregularities. The amount of force required to burnish a material largely depends on its yield strength.

B. Speed:

The speed with which the work piece is rotated during burnishing is called speed. In flat surface burnishing, where the work piece is static and the tool is rotated, the speed is referred to the rotational speed of the tool. Speed is generally measured in revolutions per minute (rpm) or meters per minute (m/min). Speed of rotation should be chosen based on the strength and dimensions of the work piece.

C. Feed:

It is the velocity at which the tool is fed or advanced along the work piece. It is expressed in the units of distance per one revolution of the work piece. Feed rate is dependent on the surface finish required. Lesser the feed rate more will be the surface finish, up to certain limit. So the feed rate should be optimized to obtain better surface finish.

D. Number of Tool Passes:

It is the number of times burnishing process is repeated on the same work piece, at the same set of parameters. In many cases repeated burnishing may be needed to improve the surface finish. In some cases, the number of tool passes may go up to 5, depending on the strength of the work piece material.

E. Tool Diameter and Material:

The size and material of the tool (roller or ball) also has effect on the surface finish of the burnished work piece. The material of the tool should be chosen such that it has higher hardness and toughness than the workpiece material.

F. Lubricant:

As burnishing is a chip-less operation and the amount of heat generated is also less, the influence of lubricant on the process outcome is also very less. In some cases burnishing can be done even in the absence of lubricant. But it is advisable to use any less viscous lubricant, for ease of movement of the bearings and rollers.

IV. Outcomes

The selected input and output parameters and factors with level values after research and analysing the facts comes from the literatures and the books.

Input Parameters	Output Parameters
Burnishing Force (kgf)	Roughness (micro meter)
No. of Tool Passes	
Feed Rate (mm/rev.)	
Burnishing Speed (rpm)	

Table 1: Input and Output Parameters

Factor	Level 1	Level 2	Level 3
Burnishing Force (kgf)	5	15	25
No. of Tool Passes	1	3	5
Feed Rate (mm/rev.)	0.068	0.1	0.205
Burnishing Speed (rpm)	45	120	300

Table 2: Factors with levels value

Run	Burnishing Force (kgf)	No. of Tool Passes	Feed Rate (mm/rev.)	Burnishing Speed (rpm)	Roughness (Ra)
1	25	1	0.205	120	0.41
2	5	5	0.205	300	0.4
3	15	4	0.205	45	0.393
4	5	1	0.068	45	0.42
5	25	5	0.1	45	0.38
6	25	4	0.068	300	0.33
7	5	4	0.1	120	0.414
8	15	1	0.1	300	0.42
9	15	5	0.068	120	0.39

Table 3: DOE Table of Ball burnishing Process for Roughness

From that basis the final equation for roughness in the terms of the input parameters was as follow:

Roughness = 0.37+ (0.49 * A) – (0.10 * B) – (0.15 * C) – (0.18 * D) – (0.24 * A * B) – (0.18 * A * C) + (0.092 * B * C)

Where,
A = Burnishing Force
B = No. of Tool Pass
C = Feed Rate
D = Burnishing Speed

Sr. No.	Population Size	Burnishing Force (kgf)	No. of Tool Passes	Feed Rate (mm/rev.)	Burnishing Speed (rpm)	Response
1	20	24.95	3.68	0.065	298.92	0.3369
2	50	25	4	0.068	300	0.33211
3	100	25	4	0.068	300	0.313476

Table 4: GA done after Ball Burnishing Machining Process for Roughness

It is concluding that after machining process roughness is minimum for particular parameter, and get parameter for the same. So, the optimized values for both are as below:

Sr. No.	Output Parameter	Burnishing Force (kgf)	No. of Tool Passes	Feed Rate (mm/rev.)	Burnishing Speed (rpm)	Response
1	Roughness	25	4	0.068	300	0.313476

Table 5: Optimized values for Roughness

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