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Experimental Investigation of the Influence of Burnishing Parameters on Surface Roughness and Surface Hardness of Aluminium Alloy 6061 T6 on CNC machine

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Abstract: **In this paper, ball burnishing as a mechanical surface treatment for improving productivity and quality of rotating shafts is presented. When this method is applied after conventional turning, the resulting process is rapid, simple and cost effective, directly applicable in lathes, CNC and turning centers of production lines. This process provides good surface finish, and surface hardness increment of the surface layer, which in turn improves wear resistance, increases corrosion resistance, improves tensile strength, maintains dimensional stability and improves the fatigue strength of the work piece.**

Results show that burnishing is an economical and feasible mechanical treatment for the quality improvement of rotating components, not only surface roughness but in surface hardness as well.

Keywords: Ball burnishing tool, CNC machine, Aluminium, Surface roughness, Surface Hardness.

1. INTRODUCTION

In today's manufacturing industry, special attention is given on surface finish along with dimensional accuracy and geometrical tolerance. Comparing with other finishing process such as grinding, honing, burnishing is chip less process. Burnishing is a cold working surface finishing process which is carried out on material surfaces to induce compressive residual stresses and enhance surface qualities. A burnishing tool typically consists of a hardened sphere which is pressed onto across the part being processed which results in plastic deformation of asperities into valleys. In burnishing process the 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.

The burnishing process, shown in Fig 1 is based on the rolling movement of a ball against the work piece surface, a normal force being applied at the tool. As soon as the yield point of the work piece material is exceeded, plastic flow of the original asperities takes place. This phenomenon leads to a smoother surface. At the same time, compressive stresses are induced in the surface layer, followed by strain hardening and a series of beneficial effect on 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.

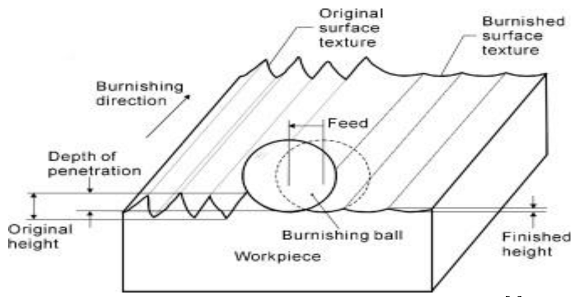

Fig 1 Schematic diagram of Ball Burnishing Process[9]

Burnishing is a cold working process in which plastic deformation occurs by applying a pressure through a ball or roller on metallic surfaces as shown in Fig 2. It is a finishing and strengthening process. Improvements in surface finish, surface hardness, wear resistance, fatigue resistance, yield and tensile strength and corrosion resistance can be achieved by the application of this process.

Burnishing is one of the important finishing operations carried out generally to enhance the fatigue resistance characteristics of components. Burnishing tools are used to impart a gloss or fine surface finish, often in processes that involve the cold working of metal surfaces. Burnishing tools are also used for the sizing and finishing of surfaces. Burnishing tool can be a roller or ball type.

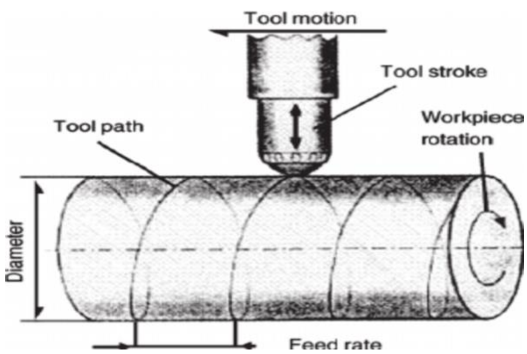

Fig. 2 Ball Burnishing Process [16]

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Burnishing process can be typically classified into two categories as:

1. Based on deformation element
    a. Ball burnishing
        i. Flexible
        ii. Rigid
    b. Roller burnishing
2. Based on the motion of the tool, on the surface
    a. Normal or ordinary
    b. Impact
    c. Vibratory

2. EXPERIMENTAL SETUP

2.1. Work piece material

In this work, Aluminium alloy 6061 T6 was used as a workpiece material. which were received as 40 mm diameter round bars. These bars are cut to suitable lengths of 200 mm and then turned to 38 mm diameter. Each work piece was divided into 5 regions of 30 mm each by a slot of 2 mm length and 2 mm depth. The chemical composition and mechanical properties of the material are shown in Tables 1 & 2.

Table 1
Chemical composition

%Si	0.918
%Fe	0.291
%Cu	0.072
%Mn	0.688
%Mg	0.871
%Cr	0.070
%Zn	0.031
%Ti	0.062

Table 2
Mechanical properties

Hardness, HV5	99.33
Ultimate Tensile Strength	275-375 MPa
Elongation %	4.0-16.0

This material is selected due to its importance in aeronautic/aerospace industries and also in automobile industries.

2.2. Ball Burnishing Tool

Many researchers have done their experiments by developing different types of burnishing tools like ball burnishing tool and roller burnishing tool and use them with conventional machine tools. But in our work we have made a tool which can be used in CNC machine as shown in Fig. 3. The design is made in such a manner that the tool is simple, cheaper and can be used easily.

Fig. 3 Ball Burnishing Tool

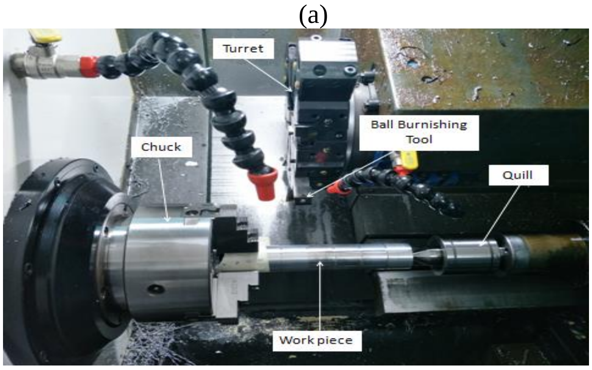
The burnishing tool designed shown above consists of parts namely ball, cover plate, main tool body and plate screw. The ball is made up of EN31 (High carbon alloy steel) having diameter 10 mm and the body is made up of mild steel. The design is made in consideration with the parameters in the work i.e. input parameters are Burnishing speed, Feed rate, Depth of penetration & Coolant and output parameters are Surface Roughness & Surface Hardness.

2.3. Machine Tool

2.3.1. CNC Machine

The Experiment was carried out on a Turn Master GF 165-A CNC Machine tool shown in Fig. 4

(a)



(b)

Fig. 4 (a) & (b) CNC machine tool

2.3.2. Roughness Tester

The roughness tester used for measuring surface roughness of aluminium bar is Mitutoyo SJ210 roughness tester shown in fig. 5 and its measurement range is -200µm to 160µm.

Fig. 5 Surface Roughness Tester

2.3.3. Hardness Tester

The Hardness Tester used for measuring Surface Hardness of aluminium bar is Vickers Hardness Testing Machine, shown in Fig. 6

Fig. 6 Surface Hardness Tester

3. EXPERIMENTATION

The Experiments were planned according to L27 orthogonal array, which has 27 rows corresponding to the number of experiments with 3 columns at 3 levels, as shown in Table 3.

Table 3 Parameters and their levels.

Parameters	Unit	Level 1	Level 2	Level 3
Burnishing Speed	mm/min	190	200	210
Feed rate	mm/rev	0.05	0.07	0.1
Depth of Penetration	Mm	0.05	0.075	0.1

4. RESULTS AND DISCUSSIONS

Initially the work piece was measured for its initial surface roughness and initial surface hardness i.e., initial surface roughness was 1.762 µm & Initial surface hardness was 99.33 HV5 and then the trial experiment was done shown in Table 4 and finally the Experiment was carried out with the parameters and levels mentioned in table 3 as shown in Table 5 & 6. And the work pieces after Burnishing are shown in Fig 7.

Fig. 7 Work pieces after Burnishing

Table 4

Trial Experiments

Speed (mm/min)	Feed (mm/rev)	Depth of penetration (mm)	Roughness (µm)
50	0.1	0.1	0.571
100	0.1	0.1	0.302
150	0.1	0.1	0.346
200	0.1	0.1	0.223
240	0.1	0.1	0.343
200	0.05	0.1	0.213
200	0.12	0.1	0.261
200	0.15	0.1	0.289
200	0.07	0.05	0.243
200	0.07	0.1	0.232
200	0.07	0.15	0.655

The roughness and hardness of the burnished aluminium was measured at each specified region with the help of the Mitutoyo SJ210 surface roughness tester & Vickers Hardness Testing Machine, and the average values of several measurements were reported for each region.

Table 5

Experimental data for Surface Roughness

Speed (mm/min)	Feed (mm/rev)	Depth of penetration (mm)	Surface Roughness (µm)
190	0.05	0.05	0.503
190	0.05	0.075	0.284
190	0.05	0.1	0.261
190	0.07	0.05	0.560
190	0.07	0.075	0.182
190	0.07	0.1	0.265
190	0.1	0.05	0.336
190	0.1	0.075	0.387
190	0.1	0.1	0.369
200	0.05	0.05	0.128
200	0.05	0.075	0.196
200	0.05	0.1	0.213
200	0.07	0.05	0.233
200	0.07	0.075	0.238
200	0.07	0.1	0.495
200	0.1	0.05	0.387
200	0.1	0.075	0.330
200	0.1	0.1	0.268
210	0.05	0.05	0.478
210	0.05	0.075	0.280
210	0.05	0.1	0.289
210	0.07	0.05	0.178
210	0.07	0.075	0.124
210	0.07	0.1	0.115
210	0.1	0.05	0.588
210	0.1	0.075	0.329
210	0.1	0.1	0.332

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Table 6
Experimental data for Surface Hardness

Speed (mm/min)	Feed (mm/rev)	Depth of penetration (mm)	Surface Hardness (HV5)
190	0.05	0.05	103.00
190	0.05	0.075	106.33
190	0.05	0.1	115.00
190	0.07	0.05	110.00
190	0.07	0.075	108.00
190	0.07	0.1	108.33
190	0.1	0.05	111.00
190	0.1	0.075	119.67
190	0.1	0.1	128.33
200	0.05	0.05	106.67
200	0.05	0.075	113.33
200	0.05	0.1	112.33
200	0.07	0.05	108.00
200	0.07	0.075	113.00
200	0.07	0.1	109.33
200	0.1	0.05	111.00
200	0.1	0.075	107.33
200	0.1	0.1	105.67
210	0.05	0.05	103.00
210	0.05	0.075	114.33
210	0.05	0.1	115.33
210	0.07	0.05	111.67
210	0.07	0.075	109.67
210	0.07	0.1	107.00
210	0.1	0.05	115.00
210	0.1	0.075	112.00
210	0.1	0.1	108.00

Effects of burnishing speed

The investigation into the effect of burnishing speed, during the ball burnishing process of aluminium found that initially, when the speed was increased, the surface roughness of the aluminium work piece decreases up to a certain limit. Then, with further increase in burnishing speed, the surface roughness increases. The possible reason of increase in surface roughness may be the chattering of the ball burnishing tool and the increase in temperature, which increases the possibility of material transformation between the burnishing ball and work piece interface. And in case of surface hardness of the burnished surface the hardness increases with the decrease in Burnishing speed and starts decreasing with the increase in Burnishing speed.

Effects of Feed rate

The investigation into the effect of Feed rate, during the ball burnishing process of aluminium found that initially, the surface roughness decreases with an increase in feed rate to a certain limit and then starts increases beyond that. In case of surface Hardness with an increase in feed rate the surface hardness increases.

Effects of Depth of penetration

An investigation of effect of depth of penetration on the surface roughness of aluminium rod shows that increase in the depth of penetration results in increase in burnishing force, which in turns decreases the surface roughness value to certain limit and then starts increases. In case of surface hardness, with the increase in depth of penetration the surface hardness increases to a certain limit and then starts decreases.

Effects of Coolant

An investigation of effect of coolant shows that during the working condition, due to the high speed and aluminium as work piece the temperature on the surface of aluminium increases and starts sticking on the surface of burnishing ball, which in turn increases the surface roughness. So, during burnishing process mist coolant is required.

Table 7
Optimum parameter values for surface roughness

Burnishing Speed (mm/min)	Feed rate (mm/rev)	Depth of penetration (mm)	Surface roughness (µm)
210	0.07	0.1	0.115

Table 8
Optimum parameter values for surface Hardness

Burnishing Speed (mm/min)	Feed rate (mm/rev)	Depth of penetration (mm)	Surface Hardness (HV5)
190	0.1	0.1	128.33

5. CONCLUSIONS

a. Burnishing speed & Feed rate are most affected parameters on surface Roughness.
b. Surface Hardness increases with decrease in Burnishing speed and increase in feed rate.
c. Burnishing with High speed & medium Feed rate gives better Surface Finish.
d. At Burnishing speed = 210 mm/min, Feed rate = 0.07 & Depth of penetration = 0.1, best surface finish obtained i.e., 115 µm.
e. At Burnishing speed = 190 mm/min, Feed rate = 0.1 & Depth of penetration = 0.1, best surface hardness obtained i.e., 128.33 HV5.
f. Due to the high heat generation at the surface of work piece, coolant is compulsory required.

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