

An Experimental Work on Multi-Roller Burnishing Process on Difficult to Cut Material – Titanium Alloy

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Abstract

Burnishing is a cold working and chipless machining carried out to improve surface roughness, surface hardness, fatigue, compressive stress and corrosion resistance by using sliding speed, feed rate and depth of penetration. The process smooth out peaks valleys on the surface. This paper described the process carried out by multi-roller burnishing fitted in housing and rotated freely in a horizontal axis. The work material used was Titanium alloy Ti-6Al -4V. The process produced good surface roughness and hardness at high rotation of spindle coupled with high feed rate and high depth of penetration.

Keywords: Burnishing, Plastic deformation, Surface hardness, Surface hardness.

1. INTRODUCTION

During recent years, considerable attention are being paid to the post metal finishing operations, such as burnishing process, which improves the surface characteristics by plastic deformation [1]. Burnishing is a cold working process, in which the metal near a machined surface is displaced from protrusion to fill the depressions [2]. Along with good surface roughness, the burnishing process has additional advantages over other machining processes, such as increased surface hardness, corrosion resistance, and fatigue life as result of producing compressive residual stress. Burnishing distinguishes itself from chip-forming finishing, processes such as grinding, honing, lapping and super finishing which induce residual tensile stresses at the machined surface layer [3]. The burnishing is a simple and cheap process, requiring little time and no skill required to operate to obtain a high quality surface finish [4]. A simple burnishing process by ball and roller are shown in the Fig. 1- (a) and (b) respectively. The burnishing process can be carried out by simple designed tool with conventional machines like lathe or vertical milling machine depending on the process. Roller burnishing is similar to ball burnishing process where as multi hardened rollers are pressed against a surface. The pressure generated by the rollers exceeds a plastic deformation stage and create a new surface. The machined surface consists of a series of peaks and valleys of irregular heights and spacing, plastic deformation created by roller is a displacement of the material in the peaks which cold flows under pressure into the valleys. Grain size is condensed, refined and the compacted surface is smooth, hardened and layer wearing than ground or honed surfaces. It was suggested by many researchers that an improvement in wear resistance can be achieved by burnishing [5-6]. Rajasekariah and Vaidyanathan [7] studied the influence of several parameters of ball burnishing such as the diameter of the ball, feed rate, the burnishing force and the initial surface roughness on the finish, surface hardness and wear resistance of steel components.

2. EXPERIMENT DETAILS

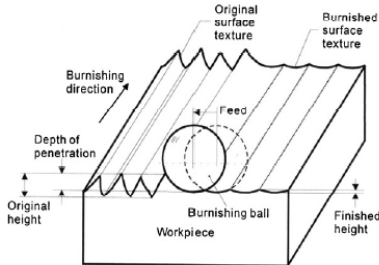
A multi roller burnishing tool are hardened rollers fitted in a housing and are rotates freely in a horizontal axis. The rollers project by 1 mm from housing surface. The tool used have 8 rollers and as shown in the Fig.2 (a). The process of vertical roller burnishing is shown in the Fig. 2-(b). The work material used was Titanium alloy Ti-6Al-4V. Ti- 6Al-4V material was cut from stock of material and machined to 45 x 45 x 120 mm. The surface of the work material was skin ground to have smooth surface before burnishing. The surface roughness was measured by using Mitutoyo SJ 400 tester. The micro hardness was measured by digital micro hardness tester make –HWMMT–X3 manufactured by M/s TT unlimited INC, of Japan. The plastic deformation was measured by Scanning Electron Microscope (SEM) Joel 6380 LA. A Pinnacle vertical milling machine was used for burnishing process. Before the experiment was conducted the initial surface roughness and hardness were recorded. The initial surface roughness measured was 0.41 microns and hardness 270 HV. The operating parameters are the spindle speeds of 700, 1050, 1400 and 1750 RPM, 100, 200, 300 and 400 mm/ min as the feed rate and depth of penetration (DOP) of 0.20, 0.25, 0.30 and 0.35 mm.

3. RESULTS AND DISCUSSIONS

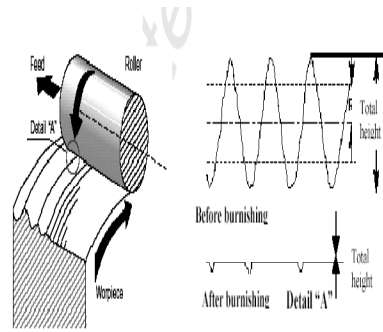
3.1. Surface roughness

The Fig.1 (a) and (b) show typical ball and roller burnishing process respectively. The Fig. 2 shows multi roller burnishing tool used for this experiments. The Figs. 3 to 6 show the feed rate against surface roughness for depth of penetration of 0.20, 0.25, 0.30 and 0.35 mm for various spindle rotation 700, 1050, 1400 and 1750. Hassan and Maqableh [8] have identified that reduction in the surface roughness and the increase in hardness with increase in the initial hardness of the burnished work material. The plastic deformation of asperities depends on the normal force, and mechanical properties of the work piece materials, as well as geometric characteristics of the original asperities. The initial surface roughness before burnishing was 0.41 μm . At feed rate of 100 with DOP 0.20 mm having the spindle speed of 700, the surface roughness obtained was 0.25 μm with sudden reduction of

approximately 40 % from the initial roughness value. As the depth of penetration was increased to 0.25, 0.30 and 0.35 mm for the same operating parameters, the surface roughness values are 0.17, 0.19, and 0.13 microns respectively. The reductions in percentages are 58 %, 53 % and 68 % for 0.25, 0.30 and 0.35 DOP respectively. As the DOP was increased, the deformation of material taken place and peaks and valleys were reduced. This is shown in the Fig. 3. At feed rate of 200 at spindle rotation of 1050 with DOP of 0.20, 0.25, 0.30 and 0.35 mm, the roughness values are 0.15, 0.18, 0.15 and 0.14 microns respectively. This is shown in the Fig.4. The percentage difference between 100 and 200 feed rate was 40 %, 0.10 %, 21 % and 7. Figs. 5 and 6 show the roughness values at feed rate of 300 and 400 mm/min for spindle rotation of 1400 and 1750 rpm. The roughness values are 0.12, 0.13, 0.14 and 0.13 microns for feed rate 300 and for the feed rate of 400 mm/min, values are 0.12, 0.24, 0.18 and 0.18 microns. As the feed rate was increased to 400 mm/min, there was deterioration surface roughness and the deformation was ineffective. i.e. the peaks and valleys again formed. The higher the depth of penetration by the roller, the peaks and valleys reduced and better surface finish is obtained. It was not advisable to further deepen the penetration which may lead to micro-cracks on the surface which may not be seen by the naked eye. It was clear that depth of 0.20 mm is the better option to get good surface finish even though, 0.25, 0.30 and 0.35 mm DOP produced almost same effect. Consequently an indication that surface roughness started to increase. The ideal operating parameters are spindle rotation of 1400 rpm; feed rate of 300 mm/min and depth of penetration 0.20 mm.



(a)



(b)

Fig.1. Schematic diagram of burnishing process – (a) ball and (b) – roller [11-12]

3.2. Surface hardness

Hassan [9] studied burnishing force or number of tool passes to certain limits increases the wear resistance of brass components under different rotating disc velocities or applied contact forces of the wear testing device. When a metal is continuously moving over a surface, plastic deformation takes place. This produces work hardening effect and produce harder surface than other surfaces. The surface hardness is directly proportional to applied force, i.e. an increase in compressive force increases surface hardness. This is due to the increase in depth of penetration, increases in metal flow that leads to an increase in the amount of deformation and voids present in the metal. When the burnishing process continued for a longer period of time, hardness of the disturbed layer of the surface increased significantly. The heat produced at the deformation zone and friction zones overheat the tool and work material [10]. The surface hardness is based on the initial surface hardness of the work materials to be burnished [11–12]. Figs. 7 to 10 show the surface hardness against depth of penetration. When a metal is continuously moving over a surface, a plastic deformation takes place. This produces work hardening effect and this surface is harder than other surface. The hardness of distributed layer increased significantly. At feed rate of 100 with DOP of 0.20, 0.25, 0.30 and 0.35 mm, the surface hardness increased 308, 375 302 and 323. Between the initial hardness and this test, the hardness values increased by 12%, 28%, 10% and 16% for DOP of 0.20, 0.25, 0.30 and 0.35 mm respectively. When the depth of penetration was 0.25 the hardness value was 375 for feed rate of 100 at 700 spindle rotation. This is shown in the Fig.8.

This is similar to number of passes. It was clear that there was decrease in the surface hardness at spindle rotation of 1050 with feed rate of 200 mm/min with the same DOP as that of 100 mm/min. At feed rate of 300 with spindle rotation of 1400 rpm, the hardness values were increased to 388, 375, 360 and 350 HV.

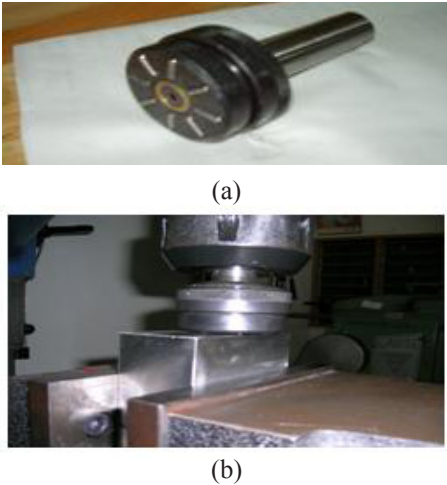


Fig.2. Multi-roller burnishing tool and vertical roller burnishing process

This was due to initial surface hardness before burnishing. At 400 feed rate, the hardness values are 330, 355, 290 and 310 which is far below from the hardness as shown in figure 8. Any further increase in the DOP will only produce flaking effect on the surface with out any increase in hardness. This is shown in the Fig.9. From Fig. 10, it is understood that high surface hardness value was possible by 1400 spindle rotation with feed rate of 300 , m/min at DOP of 0.25 mm. Fig.11 shows the SEM view on deformation taken at spindle rotation of 1400 for feed rate of 300 with 0.2 DOP.

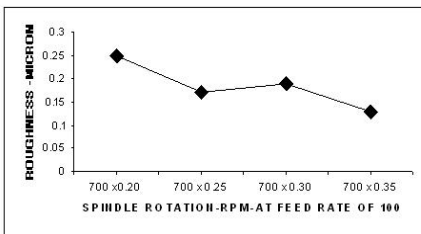


Fig.3. Feed rate Vs Roughness at 700 RPM

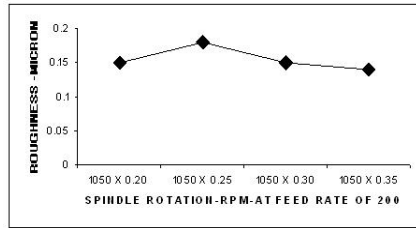


Fig.4. Feed rate Vs Roughness at 1050 RPM

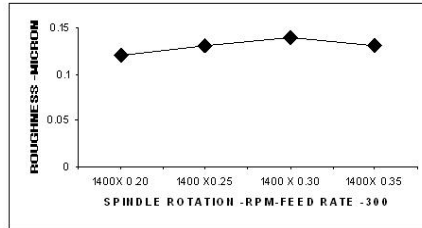


Fig.5. Feed rate Vs Roughness at 1400 RPM

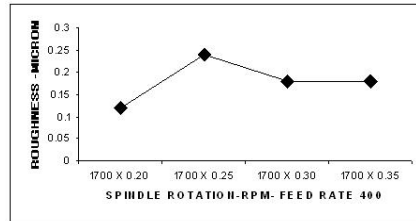


Fig.6. Feed rate Vs Roughness AT 1700 RPM

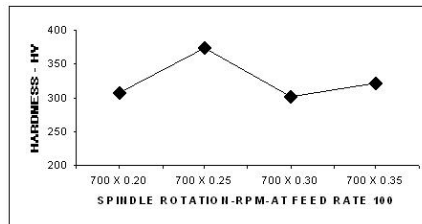


Fig.7. Feed rate Vs Hardness – 700 RPM

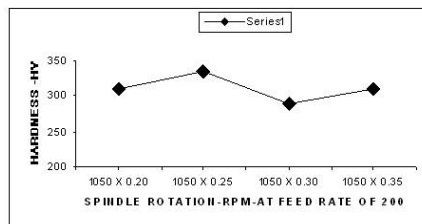


Fig.8. Feed rate Vs Hardness-1050 RPM

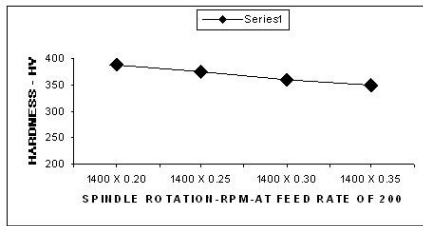


Fig.9.Feed rate Vs Hardness -1400 RPM

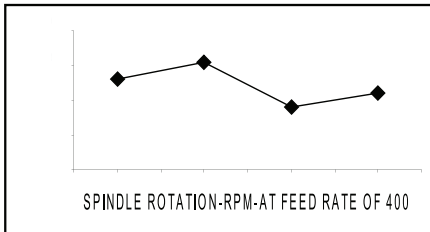


Fig.10.Feed rate Vs Hardness -1750 RPM



Fig.11.Deformation of material

4. CONCLUSION

The following conclusions were drawn from the multi-roller burnishing process on Titanium alloy.

01. At 1400 spindle rotation with feed rate of 300 mm/min at 0.30 DOP produced low surface roughness value.
02. The depth of penetration increased the burnishing force on the surface and hardness was also increased. High surface hardness of 388 HV was obtained at 1400 spindle rotation with feed rate of 300 mm/min at depth of penetration of 0.20 mm.
03. High Depth of penetration smooth out peaks and valleys.

This produced more plastic deformation on the surface and in turn produced good surface roughness and more hardness.

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