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Surface roughness investigation and hardness by burnishing on titanium alloy

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Materials

ABSTRACT

Purpose: Burnishing is a chip less machining process in which a rotating roller or ball is pressed against metal piece. It is a cold working process and involves plastic deformation under cold working conditions by pressing hard. The burnishing process help to improve surface roughness and hardness.
Design/methodology/approach: The methodology adopted was using a multi roller on square titanium alloy material by designing various sliding speed/ spindle speed, feed rate and depth of penetration.
Findings: The roller burnishing is very useful process to improve upon surface roughness and hardness and can be employed. It will help to impart compressive stress and fatigue life can be improved. The titanium alloy is a difficult to machine material and burnishing is difficult process for this grade material. A low surface roughness and high hardness was obtained for the same spindle rotation, feed rate and depth of penetration.
Research limitations/implications: There are some limitations in increasing the operating parameters. It may develop flaw and micro cracks on the surface.
Originality/value: The value of the work lies in using the results for other researches to follow and further can be continued on fatigue life.
Keywords: Machining; Surface roughness; Technology devices and equipment

1. Introduction

Roller burnishing is cold working, chip less process which produces a smooth surface and surface hardness. A multi hardened rollers are pressed against a surface. The pressure generated by the rollers exceeds a plastic deformation stage and create a new surfaces. The machined surface consists of a series of peaks and valleys of irregular heights and spacing, the plastic deformation created by roller burnishing is a displacement of the material in the peaks which cold flows under pressure into the valleys. Grain structured is condensed, refined and compacted surface is smooth, harden and layer wearing than ground or honed surfaces. Titanium alloys are generally used for a component requires greater reliability, and therefore the surface integrity must be maintained [1]. Plastic deformation, micro-crack, phase transformation and residual stress effects are alterations in surface and sub-surface [2-6]. Machining of titanium alloys at higher cutting speed will cause rapid chipping at the cutting edge which leads to catastrophic failure of the cutting edge. To the best of our knowledge, unlike other machining process, little research work was done on vertical burnishing of materials.

2. Burnishing process

Most of the work on burnishing that has already been published was concerned with the effect of the burnishing process on surface roughness and surface hardness [7]. The changes in the surface characteristics due to burnishing will cause improvements in surface hardness, surface roughness, wear resistance, fatigue and corrosion resistance as claimed by many authors [8-11] which in turn improve corrosion resistance, wear resistance[9, 13-14], tensile strength [9], larger maximum residual stress in compression [15-17] and better roundness [18]. The Figure 1 shows a typical multi-roller burnishing tool used.

Table 1.
Chemical composition of Ti-6Al-4V

Al	V	Fe	C	Mo	Mn	Si	Ti
6.37	3.89	0.16	0.002	< 0.01	< 0.01	< 0.01	Remaining

Fig. 1. Multi-roller burnishing tool

3. Tool, material and equipments

A multi-roller burnishing tool is having hardened rollers fitted in a housing and are rotating freely in a horizontal axis. The rollers are projecting by 1 mm from housing surface and contain 8 rollers. Titanium alloy was cut from square block and machined to 45 x 45 x 120 mm in size. The initial surface hardness was 272 HV. The surface roughness was measured using Mitutoyo SJ 400 tester. A pinnacle vertical milling machine manufactured by Korean company was used. The surface hardness was measured using Highwood –digital micro hardness tester –make HWMMT-X3 manufactured by TTS unlimited INC, of Japan. The Vickers hardness was measured with 1000 kg load. Scanning Electron Microscope (SEM)-Joel -JSM 6380 LA was used to measure the deformed layer.

4. Results and discussions

4.1. Surface roughness

A.M. Hassan and A.M. Maqableh have identified that reduction in the surface roughness and the increase in hardness with increase in the initial hardness of the burnished work pieces [19]. The surface roughness before burnishing was 0.41 µm. At 700 spindle speed, surface roughness value was 0.22, 0.16, 0.18 and 0.14 µm with feed rate of 100 having depth of penetration of 0.20, 0.25, 0.30 and 0.35 mm respectively. As the depth of penetration was increased, more plastic deformation takes place. i.e. the peaks eased out which produced smoother surface and lower value. This is shown in the Figure 2. At 1050 spindle speed, the surface roughness was 0.13, 0.21, 0.15 and 0.14 µm with feed rate of 200 having depth of penetration of 0.20, 0.25, 0.30 and 0.35 mm respectively. This is shown in the Figure 3. At 1400 spindle speed, lower surface roughness of 0.11, 0.11, 0.14 and 0.11 µm was obtained with 300 feed rate having depth of penetration 0.20 to 0.35 mm in multiples of 0.05 mm respectively. This is shown in the Figure 4. The more depth of penetration easing out the surface and lower value obtained. The Figure 5 show graphical representation of results against 1750 spindle speed having 400 feed rate with 0.20, 0.25, 0.30 and 0.35 depth of penetration produced 0.13, 0.23, 0.18, 0.18 µm. These parameters produced rupture surface layer and hence high value of surface roughness.

4.2. Surface hardness

A.M. Hasan et al [8] stuided burnishing force or number of tool passes to certain limits increases the wear resistance of brass components under different rotating disc velcities or applied contact forces of the wear testing device. When a metal is continuously moving over a surface, a plastic deformation takes place. This produces work hardening effect and this surface is hard than other surface. The surface hardness is based on the initail surface hardness of the materials to be burnised [21]. The surface hardness is directly proportional to applied force. i. e. an increase in force increases the surface hardness. This is due to the increase of depth of penetration, increase in metal flow that leads to an increase in the amount of deformation and voids present in the metal. When the burnishing process continuously takes place for longer period of time, hardness of the disturbed layer of the surface increased significantly. At 700 spindle speed, surface hardness value was 302, 377, 298 and 313 HV having feed rate of 100 with depth of penetration of 0.20, 0.25, 0.30 and 0.35 mm respectively. Refer Figure 6. As the depth of penetration was increased from 0.20 to 0.35 mm in multiples of 0.05 mm surface become more work hardened and increased the surface hardness. When the spindle speed was 1050 with feed rate of 200, surface hardness value were 318, 337, 290 and 310 HV having depth of penetration 0.20, 0.25, 0.30 and 0.35 mm respectively. The depth of penetration has increased the work hardening effect and hence increases in surface hardness. This is shown in the Figure 7. At 1400 spindle speed having feed rate of 300 with depth of penetration of 0.20, 0.25, 0.30 and 0.35 mm, the hardness values are 381, 314, 330 and 298 HV respectively. The work surface become more hardened as the depth of penetration was increased. This is shown in the Figure 8. When the feed rate was increased to 400 at spindle speed of 1750, surface hardness values are 326, 389, 290 and 324 HV respectively having the same depth of penetration as before. This is shown in the Figure 9. Further deformations, by an increase in the depth of penetration or the number of burnishing roller passes, will only produce flacking on the surface with out any observable increase in hardness.

The surface hardness increases with increase in the depth of penetration. The increases the number of tool passes and/or burnishing force leads to an increase in the surface hardness [20]. S. Thamizhmanii et al [21] found that surface roughness improves by high spindle speeds, feed rate and depth of penetration on non-ferrous metals like aluminium, copper and brass materials. The heat generated at the deformation zone and friction zones over heat the tool and the work piece [22].

The white band in the Figure 10 shows the surface hardness achieved to a depth of 0.05 mm. The Figure 11 shows the plastic deformation that occurred by burnishing process after completion for the tests.

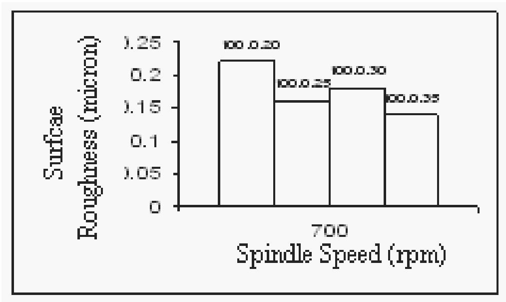

Fig. 2. Spindle speed Vs roughness

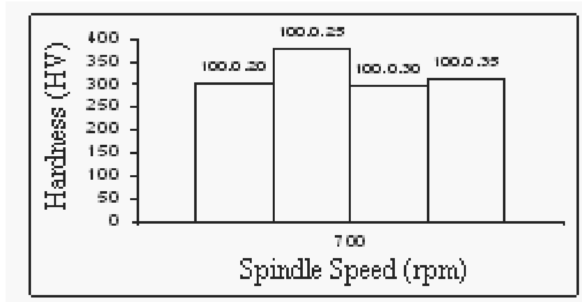

Fig. 6. Spindle rotation Vs hardness

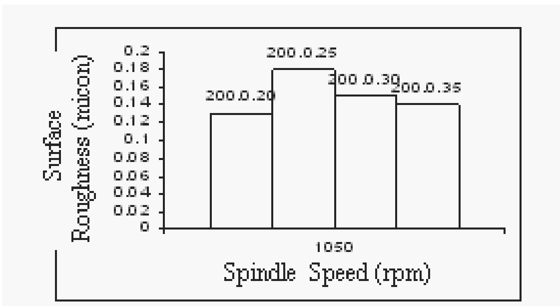

Fig. 3. Spindle rotation Vs roughness

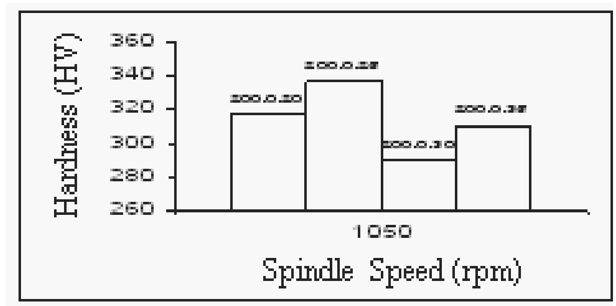

Fig. 7. Spindle rotation Vs micro hardness

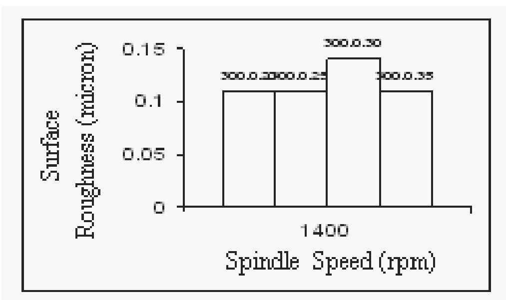

Fig. 4. Spindle rotation Vs roughness

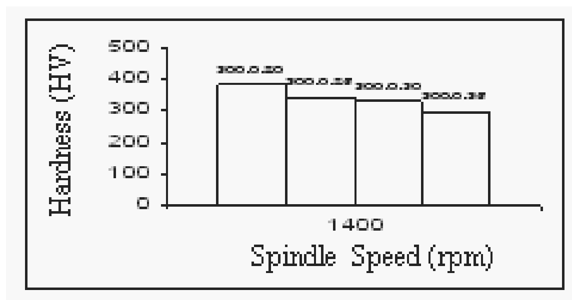

Fig. 8. Spindle rotation Vs micro hardness

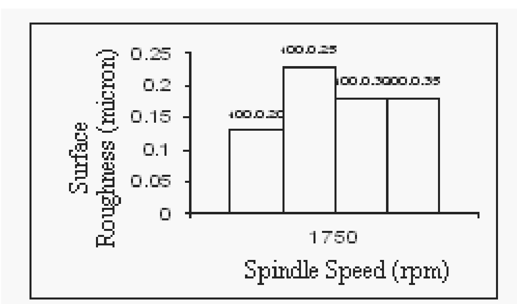

Fig. 5. Spindle rotation Vs roughness

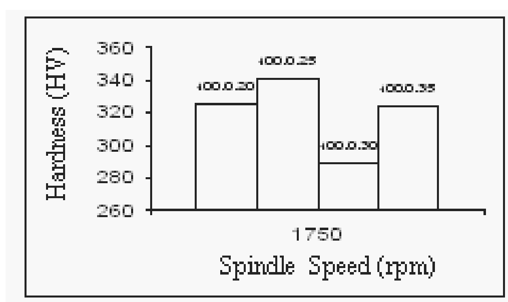

Fig. 9. Spindle rotation Vs hardness

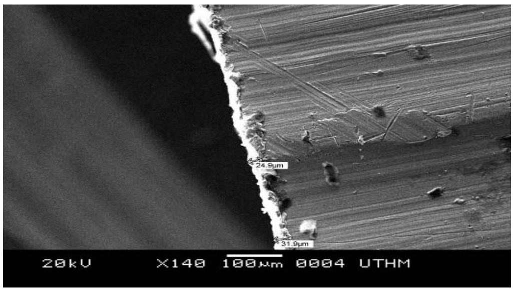

Fig. 10. SEM view on surface hardness

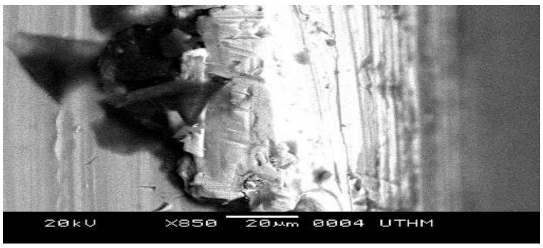

Fig. 11. SEM view on plastic deformation

5. Conclusions

The following conclusions were drawn based on the results by burnishing experiments on titanium alloy.

1. The test results produced significant improvement on surface roughness and surface hardness.
2. A lower surface roughness value obtained at spindle speed of 1400 having feed rate of 300 mm / min with depth of penetration of 0.35 mm.
3. The surface hardness also increased as the spindle speed, feed rate and depth of penetration was increased. A higher surface hardness value obtained at 1400 spindle rotation with 300 feed rate and 0.35 mm depth of penetration.
4. The more depth of penetration has increased the burnishing force on the surface and surface hardness increased.
5. This process has not produced any glassy or bright surface like other machining process due to poor machinability of the material and operating parameters can't be increased beyond certain limit due to formation of flaw and micro crack.
6. Further study can be extended on fatigue testing after burnishing process.

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