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A study of multi-roller burnishing on non-ferrous metals

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ABSTRACT

Purpose: The burnishing is chip less machining which can be used to improve the surface roughness and surface hardness on any metal work piece. The purpose of the research was to demonstrate the multi roller burnishing process on non ferrous metals namely Aluminum, Brass and Copper to improve surface roughness and surface hardness.

Design/methodology/approach: The experiments were carried on non-ferrous metals in a vertical milling machine with various spindle rotations, feed rate and depth of penetration.

Findings: The surface roughness on various no-ferrous metals improved by high spindle rotations with high feed rate and depth of penetration.

Research limitations/implications: Due to high spindle rotations with multi roller in action, the vibration of the equipment could not be controlled. Some mechanisms have to be devised to reduce the vibrations. However, it is not in the scope of this research.

Practical implications: The experiments were conducted with out coolant and this is added advantages for the environment and pollution free.

Originality/value: The burnishing process can be carried in a lathe and vertical/ horizontal milling machines with suitable fixtures to hold the work piece. The research can be continued on hard metals with varying hardness to find the surface roughness improvement. It is an eye opening for researchers to continue.

Keywords: Machining; Multi-roller burnishing; Surface roughness; Micro hardness

1. Introduction

Wear has important technological and economical significance because it changes the shape of the work piece, and the tool and the interference [1]. Burnishing is considered as a cold working process which can be used to improve surface characteristics. Surface roughness and hardness plays an important role in many areas and is factor of great importance for the functioning of machined parts [2]. Most of the work on burnishing that has already been published was concerned with the effect of the burnishing process on the surface roughness and surface hardness. It was suggested by many investigators that an improvement in wear resistance can be achieved by burnishing [3-4], but very little actual work has been done in this direction. Rajasekariah and Vaidyanathan [5] studied the influence of several parameters of ball burnishing such as the diameter of the ball, the feed, the burnishing force and the initial surface finish on the finish, surface hardness and wear resistance of steel components. The burnishing process can be achieved by applying a highly polished and hard roll on to a metallic surface under pressure. This will cause the peaks of the metallic surface to spread out permanently, when the applied burnishing pressure exceeds the yield strength of the metallic material, to fill the valleys [6]. Refer Figure 1. The surface of the metallic material is smoothed out and because of the plastic deformation the surface become work hardened, and the material left with a residual stress distribution, that is compressive on the surface [7]. The process improves surface hardness, surface quality, maximum compressive residual stress, higher wear resistance, good surface roughness, and better roundness, improves tensile strength and improvesfatigue strength by inducing compressive stress on the surface of the work piece [8-14]. The parameters affecting the surface finish are: burnishing force, feed rate, ball or roller material, number of passes, work piece materials, and lubrication, machine stability and tool stability [15]. To ensure quality of machining products and to reduce the machining costs and increase the machining effectiveness, it is very important to select the optimal machining parameters [16]. Burnishing also generates heat during due to rubbing between roller/ball and work pieces. The heat generated at the deformation zone and friction zones over heats the tool and the work pieces [17].

2. Experimental details

2.1. Multi–roller burnishing tool

Situation makes necessary to look for new tool designs or more cheaply for combinations of cutting parameters and types of tools that optimize the machining parameters [18].The burnishing tool was commercially available in the market. Refer Figure 2. This is vertical burnishing tool having 8 rollers fitted. The rollers are freely rotating in the horizontal axis. The burnishing tool can be used to maximum depth of 1mm. Each roller is acting like cutting edge with same depth of penetration.

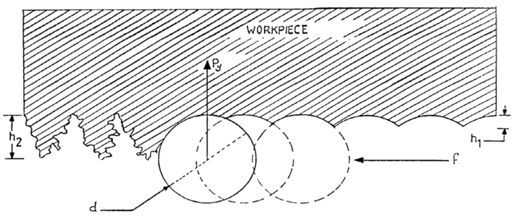

Fig. 1. Schematic diagram of burnishing process

Fig. 2. Multi-roller burnishing tool

2.2. Benefits of roller burnishing

Parts size can be changed as little as 0.002 mm in one pass in a matter of seconds. Tool marks are rolled out. Grain structure is condensed and refined and compacted surface is smoother, harder and longer wearing than ground or honed surfaces. As a result the corrosion resistance of burnished surface is higher than the open surfaces produced by grinding or honing. Due to plastic deformation by this operation, residual compressive stresses are included in the surface of the part. The compressive stresses greatly increase the strength properties and fatigue life of the part. Thousands of parts can be finished with little or no burnishing tool wear. Setting up of the burnishing tool takes less than minute time. Unskilled operators can produce close tolerance.

2.3. Other equipments

The PBM – VS 300 milling machine was used. This machine is having fixed spindle speeds and feed rates. The available spindle and feed rate were used to complete the experiment. The surface roughness was measured using Mitutoyo make SJ-301 and micro hardness was measured using HMV -2000 tester. Three types of non ferrous work pieces namely Aluminum, Brass and Copper were used. These three materials are commercially available as square bars. The initial size of all the materials was 45 mm square and 100 mm long. The surfaces are initially machined and their surface roughness and hardness were recorded. The initial surface roughness and hardness are given in the Table 1. In order to study the effect of burnishing process, the operating parameters range was collected from the machine catalogue. The burnishing parameters are shown in the Table 2. The work piece was held in a universal vice and parallelism is maintained all over the area. Maintaining parallelism give uniform depth of penetration. The width of the tool clears the width of work piece so that no foreign material present during the burnishing process.

Table 1.
Initial Roughness and Hardness of work pieces

Material	Surface roughness Ra in µm	Hardness HRB
Aluminum	0.20	39
Brass	1.83	53
Copper	0.20	16

Table 2.
Burnishing parameters

Spindle Speed (RPM)	Feed (mm / min)	Depth of Penetration (mm)
607	95	0.05
958	130	0.10
1541	200	0.15

3. Results and discussion

3.1. Surface roughness

Steel work piece on its final surface roughness after burnishing, showing that the final burnished surface increased with increase in the initial roughness of the work piece considered

[19]. The surface roughness can be increased with increasing the burnishing force or by number of passes to certain limit. The surfaces starts to deteriorate, as the surface of the metal is over work hardened due to the plastic deformation caused by the burnishing force or the number of tool passes exceeding the limits [1]. An experiment was conducted by computer integrated system to improve the surface roughness by ball burnishing process for plastic injection mould cavity [15]. Various researchers have done work on ball burnishing and limited work was done with multi-roller burnishing. The Figure 3, 4 and 5 represents the surface roughness for aluminum, brass and copper respectively.

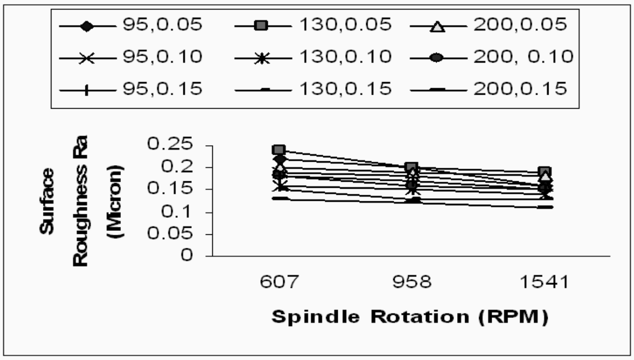

Fig. 3. Spindle Rotation Vs Surface Roughness for Aluminum

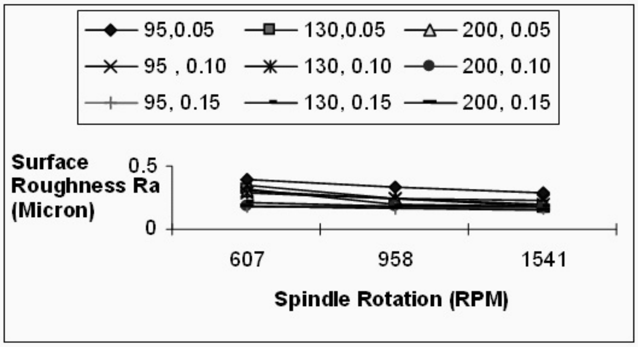

Fig. 4. Spindle Rotation Vs Surface Roughness for brass

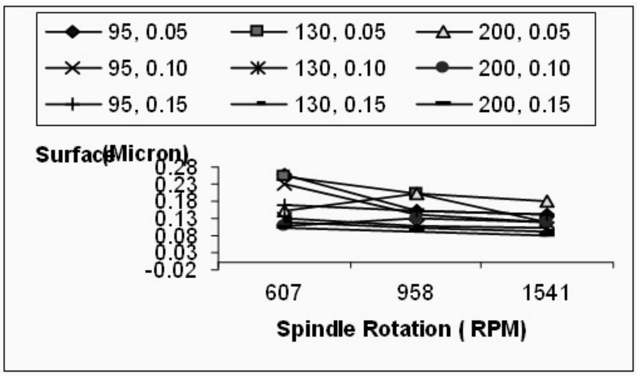

Fig. 5. Spindle Rotation Vs Surface Roughness for copper

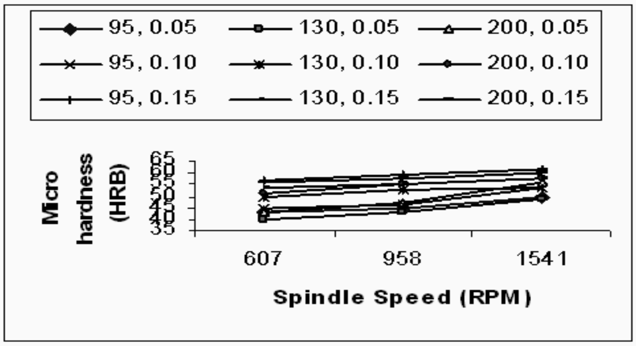

Fig. 6. Spindle Rotation Vs Surface Roughness for Aluminum

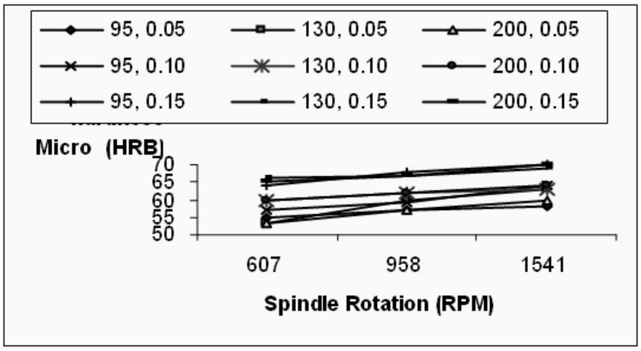

Fig. 7. Spindle Rotation Vs Micro hardness for brass

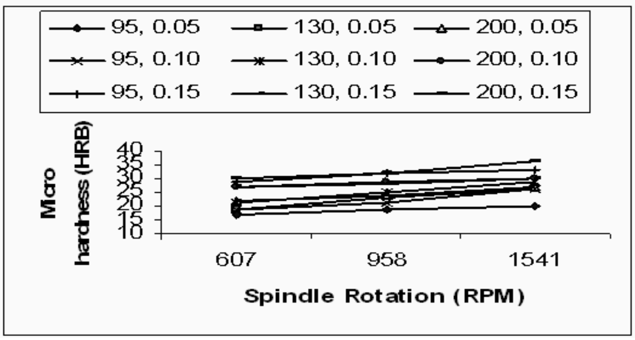

Fig. 8. Spindle Rotation Vs Micro Hardness for copper

3.2. Surface hardness

The increase in the burnishing force will increase the plastic deformation, as the penetration of the ball or roller is increased [15]. This will lead to an increase in the internal compressive residual stress, which in turn causes a considerable increase in the surface hardness. The surface hardness increases with increase in spindle speed, feed and depth of penetration. Here, also there is a limit beyond which it is not possible to increase the hardness due to work hardening effect. The Figure 6, 7 and 8 represents the micro hardness against spindle speed for aluminum, brass and copper respectively.

4. Conclusions

The following conclusions are drawn from the experiments on aluminum, brass and copper.

1. The experiments are useful in improving the quality of the burnished surface by selecting proper input parameters.
2. The surface roughness has increased as the spindle rotation, feed and depth of penetration increased for aluminum, brass and copper. If the over lapping of the roller is maintained, and then it is possible to achieve lower surface roughness value. This is only possible where there is no fixed feed rate in the machine.
3. The micro hardness also increased as the spindle speed, feed and depth of penetration increased for all the three non-ferrous metals. The work hardening effect has increased at higher operating parameters.
4. There is some limitation to increase the depth of penetration. If the depth of penetration is increased the roller will act as cutting tool with larger nose radius and material removal takes place.
5. The burnishing is good process to improve the surface roughness for metals where grinding is not possible due to wheel loading effect in material like aluminum etc.

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