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Experimental investigation of surface roughness using ultrasonic assisted machining of hardened steel

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ABSTRACT – Machining of hardened mould and die material is a very challenging process due to the high strength of the materials. Rough machined surface and premature tool wear are some of the issues that are related when machining with this material. On the other hand, ultrasonic assisted machining (UAM) technique has proven to improve the machined surface and tool life especially for brittle materials such as glass and quartz. Based on the capabilities of UAM technique and to overcome the problem owned by a conventional milling method, this paper evaluate the UAM technique for machining hardened AISI D2 material with the aim to improve the machined surface. Experiments of ultrasonic assisted milling were conducted to investigate the surface roughness of machines surface during slot milling cutting operation. From the conducted investigation, surface roughness values was improved from 0.60 μm (non ultrasonic) to 0.26 μm (ultrasonic) at 37 m/min (cutting speed), 65 mm/min (feed rate) and 0.4 mm (depth of cut). The results from the macroscopic observation shows that the machine surface of slot milling cutting by UAM appeared to be very smooth with consistent scaly and structured.

1. INTRODUCTION

Work piece surface roughness are the most important criteria for machining hardened steed, D2 to get a mirror surface sculptured profile and good finishing surface of products. Surface roughness is surface texture or surface topography and it's a nature of surfaces.

Modern manufacturing industry currently requires produces a finished products with high product accuracy and good surface quality. The machining hardened steel, ceramics and composites material involve high cost and difficult to machine. To overcome this problem, non-traditional machining with new process and new method is required to replace a traditional machining because traditional machining is more to the metal removal process using the tool that is harder than the work piece.

Ultrasonic machining (USM) is machining operation using vibration tool oscillating at ultrasonic frequencies (18-20 kHz) and aided by abrasive slurry that flows freely between the tool and the work piece to remove material from the work piece. The vibration tool oscillating with amplitude 10 to 40 μm imposes a static pressure on the abrasive grains, hammered into the work piece surface, causing chipping of fine particles and formed the required tool shape. According to [1], ultrasonic machining is non-conventional machining with low material removal rates and operates at ultrasonic frequency range between 20-40 kHz. Investigation by [2] revealed that material removal rate (MRR) and surface roughness (Ra) will increase when amplitude of vibration increase, static load increase and size of abrasive increase when using K-type magnetic ferrite as work piece with using ultrasonic machining. Also, it shown that material removal rate depends on the amount of energy exerted to the materials. Ultrasonic assisted machining also applied in industry for manufacturing process of ceramics components [3]. Experiment by [4] used Rotary Ultrasonic Machining (RUM) based on abrasive removing mechanism and using ultrasonic vibrating diamond particles, which are bonded on the active part of a rotating tool for machining Poly-crystalline cubic boron nitride (PCBN). The result of this experiment shown that Rotary Ultrasonic Machining (RUM) can machining PBCN with a low surface roughness value which Ra 0.24 μm, Rz 2.834 μm and it can be concluded that Rotary Ultrasonic Machining (RUM) is suitable for finishing of hard and brittle material's surface.

In mould and die industry, fine machined surface qualities are necessary and usually are achieved through several processes i.e. roughing, semi roughing and manual polishing which are very costly. To solve this problem, ultrasonic assisted machining is proposed to eliminate the manual polishing process. Thus, this paper attempt to investigate the effectiveness of ultrasonic assisted machining for machining hardened mould and die material. The investigation will taking into accounts on the effect of machining parameters namely cutting speed, feed rate, depth of cut and ultrasonic amplitude on surface roughness magnitudes.

2. METHODOLOGY

A methodology was carried out to obtain the effects of machining parameters on surface roughness of hardened steel material for slot milling operation as shown in Figure 1. The experiment was conducted to compare the surface roughness magnitudes obtained through the present of ultrasonic vibration and without ultrasonic.

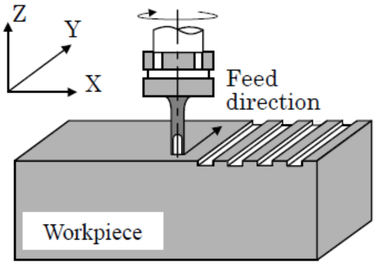

Figure 1 Slot cutting test.

The study was carried out on CNC Milling Machine, Hass VF 1 model (3axis). Figures 2 and 3 show the cnc machine and ultrasonic tool holder assisted milling setup in this experiment.

Figure 2 Three axis CNC machine used in the experiments.

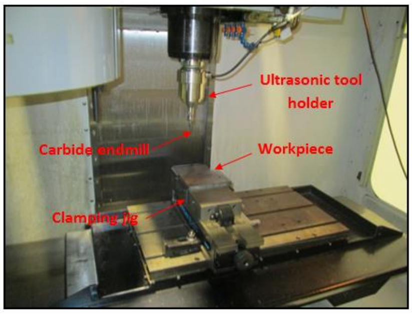

Figure 3 Ultrasonic assisted milling setup.

The work piece material employed in a study is hardened steel AISI D2 with dimension of 100mm × 100mm × 20mm (W×H×L) in rectangular shape. The cutting tool was used for this experiment (slot milling machining) is solid carbide ball nose mill-K20 micro grain, diameter 5 mm, 2 flutes, 35 degree of helix angle and 50 mm length. The machining parameters are summarized in Table 1.

3. RESULTS AND DISCUSSION

The result of the effect of machining parameters on surface roughness during slot milling cutting of hardened steel, AISI D2 using ultrasonic tool holder assisted milling with solid carbide ball nose mill (2 flutes) are shown at the Table 2.

The maximum value of surface roughness, Ra is 0.60 μm and was obtained at 37 m/min (cutting speed), 65 mm/min (feed rate) and 0.4 mm (depth of cut) at run 1(without ultrasonic tool holder assisted). While, the minimum value and a good of surface roughness, Ra is 0.25 μm at 46 m/min (cutting speed), 145 mm/min (feed rate) and 0.2 mm (depth of cut) at run 4 (ultrasonic tool holder vibration).

The results shown that, the average surface roughness, Ra is decreases when the cutting speed increase, feed rate increase, depth of cut decrease and applying an ultrasonic tool holder assisted milling.

Table 1 Machining parameters.

Cutting speed(m/min)	**Feed rate (mm/min)**	**Depth of cut (mm)**	**Frequency (kHz)**
37	65	0.4	-
46	145	0.2	-
37	65	0.4	23.14
46	145	0.2	23.14

Table 2 The surface roughness of hardened steel using ultrasonic tool assisted milling.

Cutting speed (m/min)	**Feed rate (mm/min)**	**Depth of cut (mm)**	**Surface roughness, Ra(μm)**
37	65	0.4	0.60 (non ultrasonic)
46	145	0.2	0.41 (non ultrasonic)
37	65	0.4	0.26 (ultrasonic)
46	145	0.2	0.25 (ultrasonic)

4. CONCLUSION

Surface roughness of machines surface hardened steel was improved from 0.60 μm (non ultrasonic) to 0.26 μm when apply the ultrasonic tool holder assisted milling. The result shows that the machine surface of slot milling cutting from using ultrasonic tool holder assisted much better compare to non ultrasonic tool holder machine surface. Also, it shows that surface area of slot cutting using ultrasonic very smooth compare to non ultrasonic slot cutting. Machine surface with ultrasonic tool holder assisted milling become consistent scaly, structured and very smooth compare to conventional cutting.

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