The effect of surface roughness on ultrasonic assisted milling of Inconel 718

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ABSTRACT – Ultrasonic assisted machining is a combination of precision machining with a small-amplitude vibration tool to improve machining capabilities. Recently, ultrasonic assisted machining has been the main focus of research particularly on ultrasonic vibration effects on machining processes. However, the characteristic of ultrasonic vibration has a potential to influence workpiece surface roughness. Therefore, the main objective of this study was to evaluate the performance of the ultrasonic assisted machining on the surface machined roughness in comparison with the conventional way. The result showed that the ultrasonic vibration improved the surface roughness up to 27% on flooded machining condition.

1. INTRODUCTION

Inconel 718 is widely used in aerospace industries due to its superior mechanical properties; high fatigue strength, higher creep resistance, good corrosion and outstanding high-temperature performance especially in the aero engines compartment such as engine mounts, casing, discs and etc. [1]. Although these properties are attractive for the design requirements, they create bigger challenges that lead to heavy tool damage and high cutting force in the conventional milling process, thus, affecting the workpiece surface roughness during the machining performance [2-4]. Ultrasonic vibration machining is the high-frequency tool displacement with addition of small amplitude to the cutting motion during an engagement between the cutting tool and workpiece [5]. Surveys conducted by Klocke and his co-worker [6] found that kinematical consideration of the vibration assisted process influences the machining performance on the surface condition and tool life/tool wear. The aim of this study was to evaluate the performance of the ultrasonic vibration presence on the surface roughness in comparison with the conventional way.

2. METHODOLOGY

Experiment was conducted to compare the ultrasonic vibration and conventional technique effectiveness on a milling process. Inconel 718 grade AMS 5663 material was used in this experiment. The block had a dimension of 154 mm x 52 mm x 105 mm (l x w x h). During the experiment, the block did not undergo any heat treatment process. The constant properties of the Inconel 718 are as shown in Table 1. The Inconel 718 was executed using CNC Milling Machine HAAS CNC Milling 3 Axis machine and the ultrasonic vibration was attached as shown in Figure 1. The value of the machined surface roughness was measured using Mitutoyo SJ-301 model. The averages Ra were produced after 20 times measurement which was adhering to the ISO 3274: 1997 standard. In addition, an optical microscope was used to observe the machining surface texture.

Table 1 Inconel 718 constant properties

Properties	**Constant**
Density	8.44 g/cm^3
Melting point	1290-1350 ^{o}C
Specific heat capacity	410 J/(kg.K)
Thermal expansion coefficient	12.8 (µm/m.K)
Electric resistivity	1290 µohm.mm
Thermal conductivity	9.8 (W/m.K)

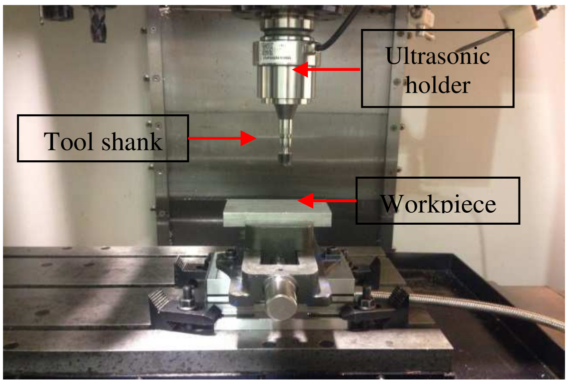

Figure 1 The setup of the ultrasonic vibration on the CNC Milling

3. RESULTS AND DISCUSSION

Figures 2 and 3 show a microscopic image of the milling processes. Figure 2 indicated the Ra value of 0.52 µm without the ultrasonic vibration presence during the machining whilst Figure 3 indicated the lower Ra value of 0.38 µm with the presence of 27 kHz ultrasonic vibration frequency. Figure 3 also showed that the machined surface was smoother and less of ploughing effect rather than the surface with no ultrasonic assisted. Hence, an implementation of the ultrasonic vibration on the milling process would improve the surface roughness up to 27%. This result was supported by few studies that found the effects of ultrasonic are significant on improving a workpiece surface roughness [7-8]. Similarly, recent studies of Sofuoğlu et al. [9] and Ramli et al. [10] ascertained that the method of utilizing a low amplitude vibration within the high frequency is possible to improve the surface roughness up to 89.50%. At this point, the profile surface results were subject to tool wear performance itself. The vibration mechanism which was the amplitude displacement helped the machining process to maximize the interrupted cutting condition rather than continuous cutting. Hence, ultrasonic vibration can break the "closed area" in the conventional milling process where the cutting edge contacts with the workpiece material all the time in its cutting cycle, which is helpful to the cutting fluid and chip flowing. Thus, the effect of tool wear would be minimized simultaneously, as a worn cutting tool performed during the machining might affect the machined surface roughness.

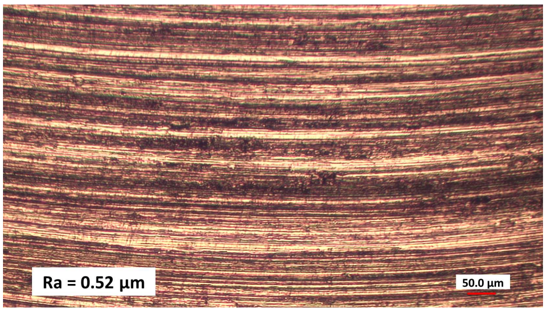

Figure 2 Optical microscopic image of milled surface roughness at 0 kHz

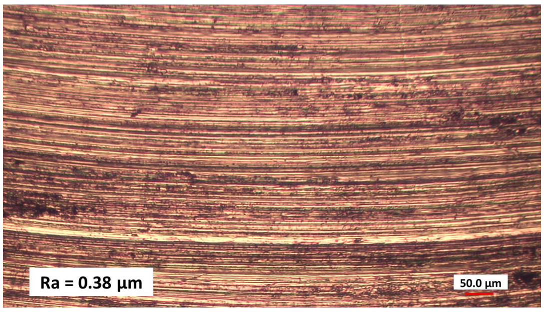

Figure 3 Optical microscopic image of milled surface roughness at 27 kHz

4. CONCLUSION

This paper represents the implementation of ultrasonic vibration on the milling machining process. Advanced machining technique such as ultrasonic assisted machining is an effective way to improve quality of product. Variance of analysis shows that the ultrasonic vibration can improve the surface roughness of the machined workpiece up to 27% at 100 m/min of cutting speed and 0.2 mm/tooth of feed rate during the machining performance. Although proper mechanics of the machining process support the improvements in machining, the development and other factors for the improvement in processes are yet to be studied in depth.

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