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Investigation on Effect of Cutting Fluid Pressure Toward Machinability Using Stainless Steel 304 With Coated Cemented

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ABSTRACT

This paper presents the effects of cutting fluid pressure on various orifice nozzle sizes on the cutting performances. Cutting fluid is generally being used in metal cutting to optimize the machining operation process. The objectives of this study are to investigate the effects of various cutting fluid pressures on the stainless steel AISI 304 and the effect of the cutting performance on machining parameters such as tool wear, tool life and surface roughness. Stainless steel AISI 304 and coated cemented carbide, Al_2O_3 insert were used as work piece material and cutting tool respectively. The experiments were carried out on CNC Lathe machine by using various orifice nozzle sizes with synthetic soluble oils as a coolant. The results showed that Al_2O_3 insert gives good overall performance in terms of tool life and better surface roughness when the smallest orifice size is used.

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INTRODUCTION

The development of accurate and reliable machining processes has received considerable attention from both academic researchers and industry practitioners in recent years (Seah, K.H. *et al*. 1995). Machining process is an important element in manufacturing industry. In general, cutting fluid is used for cooling and lubricating the cutting zone, to flush away chip and to inhibit corrosion during machining (Chen, Z. *et al*. 2001). The high pressure pump is connected to the coolant tank which generally has four basic components: an internal pump, sump/reservoir, filtration system and pressure gauge. The flow of the cutting fluid is then connected from the pump to the tool holder via a piping system and through various nozzle sizes. In this paper, the pressure generation mechanism is experimentally verified for various size nozzle coolants during turning operation.

2. Methodology:

Designing Of Various Orifice Nozzles

The first stage was the orifice nozzle designing process using MASTERCAM software. The coding of the NC program was developed using the MASTERCAM and incorporated to the CNC Lathe machine. It was machined to achieve the required contour by using a brass material. The orifice hole diameter of 0.5 mm was drilled by the CNC lathe before finishing it using wire-cut machine to achieve an accurate dimensional size. The hole diameter of 1.0 mm, 1.5 mm and 2.0 mm were measured by using a pin gauge, are shown in Fig. 2.1

Fig. 2.1: Schematic Design of Nozzles Sizes

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Machine Tool and Equipments:

All experiments were carried out using PUMA 230 CNC lathe machine. This machine was equipped with a pressure pump system, whereby the flow rate from this pump is kept constant throughout the experiment. In this study, some variables were investigated, such as the various orifice nozzle sizes cutting speed and feed rate. The effects of cutting speed on the insert coated cemented carbide performance with different inner pressures of the nozzle were observed. Machining parameters such as tool wear development, tool life and surface roughness were recorded

Workpiece Material:

The material used in this study was stainless steel, AISI 304. The work piece has a hardness of about 25 to 39 HRC and was used the form of round bar, 65 mm in diameter and 260 mm in length. Such mechanical properties and chemical composition of stainless steel, AISI 304 material are shown in Tables 2.1 (Yue, Y. *et al*, 1996; Gunter, K.L *et al*. 1999).

Table 2.1: Mechanical properties of the stainless steel AISI 304; (Chan. R.W.*et al*. 1996).

Properties and Unit	Value
Tensile Strength (MPa)	515
Yield Strength (MPa)	205
Hardness (BHN)	25 to 39
Density (Kg/m3)	8,000

Cutting Tool Material:

The insert Al_2O_3 coated cemented carbide was used as tool material in this experiment. An alumina coating with a thin layer of high temperature and hard constituent was diffused into the surface of ordinary cemented carbide. This type of inserts is used due to its durability and high performance, besides they are commonly used in industries (Ko. T.J.*et al*. 2003; Lee, M. Koch, E.F. and Hale, T.E. 1996). The insert was mounted onto the tool holder which allowed the cutting fluid to travel by pressure, through its body.

Cutting Fluid Conditions.

The experimental work was carried out based on the nozzle inner with diameter of 1.0 mm, 1.5 mm and 2.5 mm. The flow rate and inlet temperature of the cutting fluid soluble oil used are 10 litter/min and 27˚C respectively (Machodo,A.R., *et al*. 1997).

Tool Life Criteria:

Tool life is often measured in minutes and is based on several wear criteria listed below:

i) Time taken for catastrophic failure
ii) Time taken for specified amount of wear in tool.

The international standard of organization (ISO) ([International Organization for Standardization 1977) has made standardization for measuring tool life according to these criteria:

i) The average flank wears reach 0.4 mm or the maximum flank wear reach 0.7 mm

Measurement of Tool Wear:

Tool wear was measured using a Tool Maker's Microscope with a magnification of 10X and incorporated with a micrometer. The width of the flank wear was measured from the position of the original cutting edge and the measurements are taken after each cutting process.(Yue, Y. *et al*. 1996; Viktor P. Astakhov, 2003; Steven W. 2002).

Measurement of Surface Roughness:

"R_a" or arithmetical mean surface roughness is the recognized standard to evaluate the surface texture (International Organization for Standardization, 19778). An average surface roughness value on the machined surface was measured perpendicular to the feed marks at a minimum of three location points around the work material circumference. Surface roughness tester was used to measure the roughness of the work piece and to achieve the maximum accuracy and consistency.

RESULT AND DISCUSSION

Effect of Cutting Speed on Tool life:

Under most cutting condition, tool life is affected by changes in cutting speed. A rise in cutting speed raises the temperature generated at the interface of the tool and materials. For the machining process of stainless steel using different coolants such as 1.35, 1.5 and 1.8 bar, and the tool life of coated cemented carbide increases with decreasing cutting speed. This is applicable for all different pressures. It is observed when the cutting speed is 90 m/min, the tool life increases tremendously. As mentioned in Fig.3.1, the growth of flank wear increases when cutting speed is 110 m/min, whereby it tends to slowdown at cutting speed 90 m/min. Therefore, it is suggested that 90 m/min is the best cutting speed for stainless steel, when using 1.8 bar internal coolant pressure.

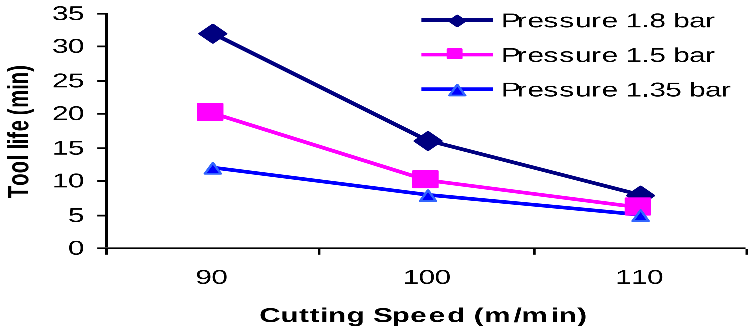

Fig. 3.1: Graf from Summary of tool life from conducted experiments

Effects Of Flank Wear At Various Cutting Speed:

Fig. 3.2 shows the flank wear rate at cutting speeds of 90, 100 and 110 m/min using various pressures. The experimental results show that the flank wear dominantly control the tool life during the machining process of the work piece at various pressures, using cemented carbide insert. The flank wear rate increased rapidly during high cutting speed and when lower pressures were used, because of high temperature generated at the cutting edge closer to the nose radius. The flank wears progression when cutting speed 90 m/min is the slowest, with pressure 1.8 bars and nozzle size of 1.0 mm. This phenomenon happens due to high temperature generated at the cutting area, where efficient cooling system is required to cool down the carbide insert and the work piece. The 1.0 mm nozzle orifice could generate higher coolant pressure and more flow rate than 1.5 mm and 2.0 mm orifice. Based on this result, using nozzle pressure 1.8 bar at cutting speed of 90 m/min is highly recommended to achieve optimum machining capability.

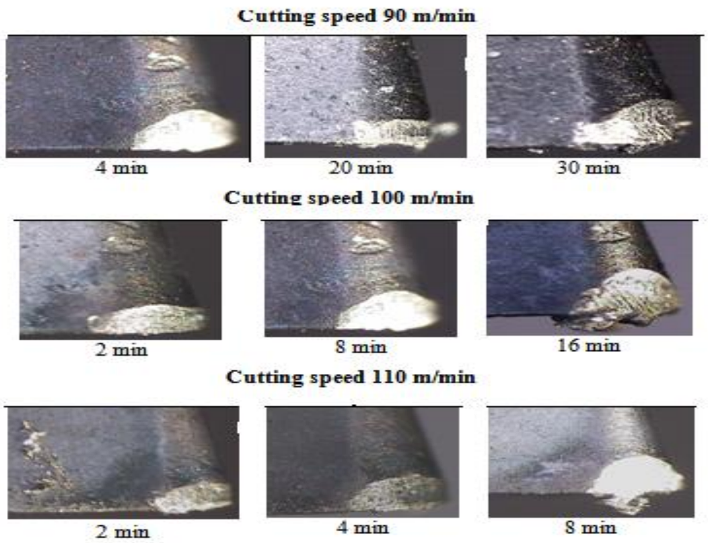

Fig. 3.2: Flank wear at various cutting speed using nozzle size of 1.0 mm

Effect of Cutting Speed on Surface Roughness:

Surface roughness value for machined work piece is one of the essential parameter to investigate cutting tool performance. Values were recorded after each machining process as shown in Fig. 3.3 to 3.5. From the tabulated data, it is observed that as cutting speed increases, surface roughness increases at 2 minutes interval and the average surface roughness slightly decreases and increases again. These phenomenon patterns are quite similar for all nozzle orifice sizes. In the experiments using various nozzle pressure coolant systems, the results show small effect on the surface roughness for Ra. It is shown that in Fig. 3.3 to 3.5, there were only small differences between each surface roughness value for different coolant pressures, in all cutting conditions. The surface roughness produced by 1.8 bar coolant pressure showed the best result, followed by 1.5 bar and 1.35 bar. Generally, an increase in cutting speed leads to deterioration of the surface finish. However, an increase in cutting speed and coolant pressure will reduce the Ra value drastically. Thus, it indicates an improvement in the surface finish. This shows that by using nozzle orifice of 1.0 mm with 1.8 bar cutting speed of 90 m/min, the surface finish could be improved significantly, although the surface roughness value were less different for all coolant pressure conditions. Fig.3.3 shows surface roughness formation contours with nozzle inner pressure 1.8 respectively.

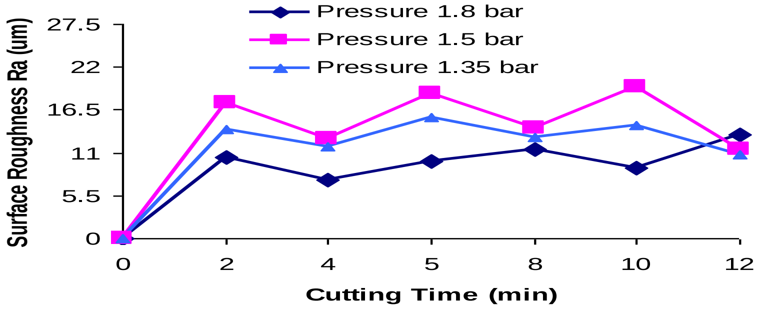

Fig. 3.3: Typical surface roughness of effect cutting time on surface roughness, with cutting speed 90m/min

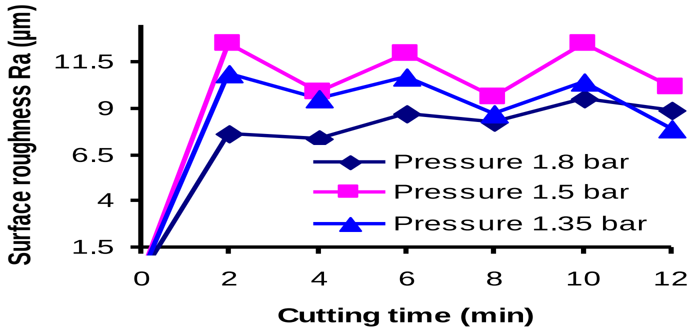

Fig. 3.4: Typical surface roughness of effect cutting time on surface roughness, with cutting speed 100 m/min

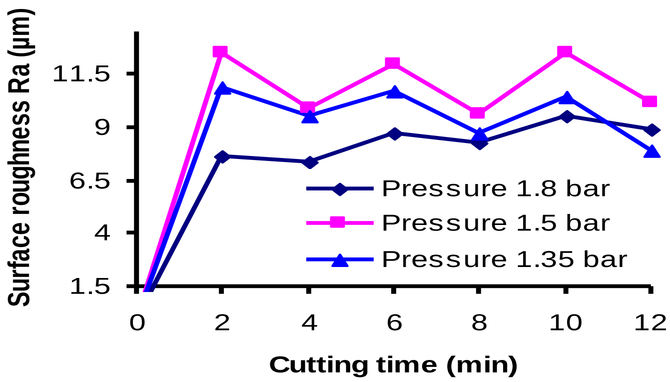

Fig. 3.5: Typical surface roughness of effect cutting time on surface roughness, with cutting speed 110 m/min

Conclusion:

1. The result showed that at low cutting speed, when the cutting fluid pressure at 1.8 bar and orifice nozzle size of 1.0 mm used, the flank wear was reduced which prolongs the tool life.
2. It was found that an orifice nozzle size 1.0 mm at cutting speed of 90m/min gives the best chip formation with short curl and smaller size chips. These chips do not obtain entangles within the cutting area and removed by the flow of the coolant.
3. The smaller size of orifice nozzle with high pressure that emerge from the nozzle, it generates lower friction and abrasion which resulted better surface roughness and increase the tool life.

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