PROCEEDINGS

STSS 2008

BROADENING HORIZONS THROUGH RESEARCH

3 - 4 June 2008

M.S. Garden Hotel
Kuantan, Pahang

SCIENCE & TECHNOLOGY

PROCEEDINGS OF
THE NATIONAL SEMINAR ON
SCIENCE, TECHNOLOGY AND SOCIAL SCIENCES
2008

Science and Technology : Volume 1

© Proceedings of the National Seminar on Science, Technology and Social Sciences 2008 (ISBN : 978-983-2607-17-5) is published by the Universiti Teknologi, MARA, Pahang.

Cover Design by:
NurMazwan Ramli
Unit Perkhidmatan & Teknologi Maklumat (UPTM)
Universiti Teknologi MARA

Effect of Cutting Fluid Pressure on Machining of AISI 304 Performances

Zainal Arifin Selamat
Mohd Razali Muhamad

ABSTRACT

This thesis presents the effect of cutting fluid pressure on the cutting performance. The cutting fluid is being used in metal cutting to optimize the process of machining operation. It has a significant role on shop floor productivity, tool life and quality of work. The objective of the study is to investigate the effect of cutting fluid pressure and machine parameter on the tool wear, tool life, chip formation and surface roughness on the process of metal cutting. The stainless steel AISI 304 and Al_2O_3 coated cemented carbide insert were used as a work piece material and cutting tool respectively. The experiment was being carried out on CNC turning machine with 2 axes movements using the different nozzle sizes. The cutting variables including the surface roughness, tool wears and tool failure modes were considered in this research. The effect of the cutting parameters including the cutting time, cutting speed, and depth of cut were investigated.

Keywords: *Al_2O_3 coated cemented carbide, cutting fluid, different nozzle size, stainless steel, tool life*

Introduction

In general, cutting fluid is used for cooling and lubricating the cutting zone, to flush away chip, and to inhibit corrosion during machining (de chieffre & Belluco, 2000; Seah et al. 1995).The cutting fluid system consists of a coolant tank, high pressure pump, piping system to transport the fluid and a various nozzle size at the tool holder. The high pressure pump is connected to the coolant tank which has five basic components: an internal pump, sump/reservoir, a 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 different size nozzle.

The cutting fluid is first pumped from the machine reservoir via a high pressure pump. The motor which drives the pump will pressurize the coolant and increases the flow rate. The piping system carries the coolant to the tool holder and through the different nozzle size which eventually delivers the cutting fluid to the cutting area.

In this paper, the pressure generation mechanism is experimentally verified for the different size nozzle coolant during turning operation. This research aims to investigate the performance with respect to tool life, failure modes, surface roughness and chip morphology of Al_2O_3- coated cemented carbide tools in the turning of AISI 304 Stainless Steel under various cutting conditions.

Experimental Procedure

Methods and Material

The machining operation was set up on PUMA 230 CNC lathe machine. In this research, some variables have been investigated including the cutting speed. The effects of cutting speed on the performance of insert coated cemented carbide with different inner pressure of the nozzle were observed. Machining parameters including the tool wear development, tool life; chip deformation and surface roughness were recorded.

Workpiece Material

The material used throughout the research was stainless steel, AISI 304. The corrosion resistance is higher after annealing and passivation. The work piece has a hardness of about 25 to 39 HRC in the form of round bar, 60 mm in diameter and 260 mm in length. The mechanical properties and chemical composition of the stainless steel, AISI 304 material are shown in Tables 1.

Table 1: Properties of the Stainless Steel AISI 304

Properties and Unit	Value
Tensile Strength (MPa)	515
Yield Strength (MPa)	205
Hardness (BHN)	25 to 39
Density (Kg/m3)	8000

Tool Material

In this experiment cemented carbide coated with Al_2O_3 was used as tool instruct The type inserts are used due to its durability, high performance and are commonly used in industries. The insert is mounted onto the tool holder which allows the cutting fluid to travel through its body at a pressure. Prior to experiment, the insert with tool holder was examined under microscope to detect any defect that would be misleading the experimental result.

Cutting Conditions

The experimental work was carried out based on the nozzle inner diameter of 1.0 mm, 1.5 mm, and 2.5 mm, The flow rate and inlet temperature of the cutting fluid soluble oil are used 10 litter/min and 27°C respectively.

Tool Wear Measurement

Tool wear was measured using a Tool Maker's Microscope with the magnification of 10X incorporated with a micrometer. All measurements were taken without removing the inserts from the tool holder to minimize the variation of reading which might occur during the measuring process. The flank wear was measured parallel to the surface of the wear land and perpendicular to the original cutting edge. The width of the flank wear was measured from the position of the original cutting edge which listed in measurement of flank wear at different cutting speed. The tool wear measurements were taken at 2 minute interval of cutting process until the tool fail. The instrument was calibrated before and after each set of experiment to ensure the accuracy. Within the experiment process turning used by the chuck and tailstock to reduce vibration (Axinte et al., 2001; Henry, 2002).

Tool Life Criteria.

The result of experiment will be used to formulate the general Taylor's tool life formula ($VT^n = C$) for the given workpiece material and tools. Tool life criteria were based on ISO 3685-1977(E) and ANSI/ASME B94.55M-1985. The selection tool life criteria have gave direct impact on the product controlled features and geometry.

Tool life is often measured in seconds or minutes and it is based on several wear criteria follows:

1. The geometry accuracy of product in the controlled value.
2. The surface finish of product in controlled value.
3. The product did not damage by catastrophic failure of tool.

The international standard of organization (ISO) has made standardization for measuring the tool life criteria (Simoneau et al., 2007) as follows:

1. Average VB = 0.2mm (Major flank) or
2. VB_{Max} = 0.4mm, when non-uniform wear occurs or
3. Average VC = 0.2mm (Minor flank) or
4. $VC_{Max.}$ = 0.4mm, when non-uniform wear occurs or
5. Notching/grooving = 1.00mm.

The tool life was measured and all data obtained were recorded for evaluation and listed in at different cutting speed. The tool life measurements were taken at 2 minute interval of cutting process until the tool at critical point.

Analysis of the Worn Inserts

The standard method was used to prepare the tool sample for analysis under SEM, which is cleaning by worn insert with a brush in dilute hydrochloric acid (HCL) and ultrasonically cleaned in acetone bath to remove all chips (Simoneau et al., 2006). Conductive glue was used to attach the cleaned specimens on the aluminum stubs before mounting them on the SEM for examination. Micrograph was taken at different angles under various magnifications. Energy dispersive X-ray spectroscopy which was attached to SEM used to detect any atomic elements, which might be present on the worn faces of the insert.

Chip Shape

Chip shape was collected at the beginning (new tools) and end (worn tools) of each test. Chip shapes and formations were analyzed referring to the British Standard on chip formations.

Measurement of Surface Roughness

"R_a" or arithmetical mean surface roughness is the recognized standard to evaluate the surface texture. 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, this equipment need to be calibrated using the standard block before and after the experiments

Results and Discussion

Tool Life

Tool life at various cutting speed with different nozzle pressure were recorded during machining. Figures 1-3 show the effect of the wear rate versus machining time in minutes with nozzle pressure of 1.8, 1.5 and 1.35 bar with constant depth of cut 1.0mm, feed rate 0.2m/min and cutting speed of 90 m/min, 100 m/min and 110 m/min respectively. The figures show that the flanks wear is minima for the high pressure coolant system. Figure.3.1 shows for the lower cutting speed 90 m/min with the nozzle coolant pressure 1.8 bar and nozzle orifice size of 1.0 mm. It can be seen that the time taken for the tool to wear is higher than the nozzle coolant pressure 1.5 bar and 1.35 bar, however, the value of flank wears is fairly close to each other. It also shows that the similar fashion of results for the nozzle coolant pressure 1.5 and 1.35 bar in Figures 3.2 and 3.3 respectively.

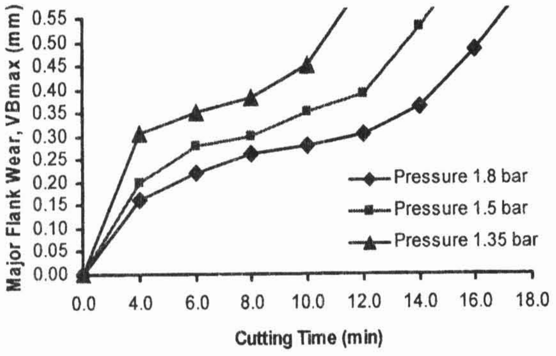


Figure 1: Progressive Tool Life using Cutting Speed of 90m/min

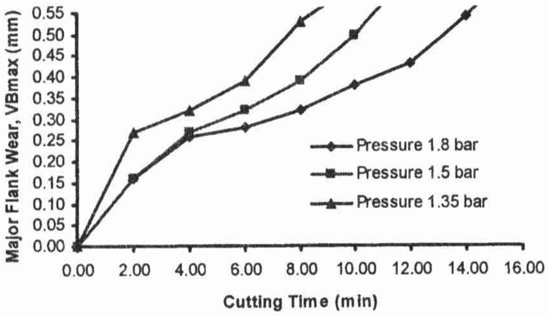


Figure 2: Progressive Tool Life using Cutting Speed of 100m/min

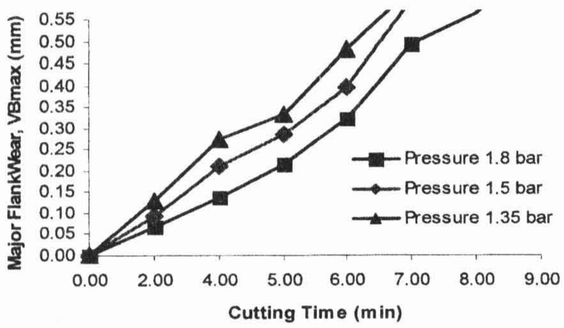


Figure 3: Progressive Tool Life using Cutting Speed of 110 m/min

Effect of Cutting Speed on Tool Life

Under most cutting condition, the tool life is affected by the change in cutting speed, as the rise in cutting speed raise the temperature generated at the interface of tool and materials. For the machining of stainless steel using different coolant of 1.35, 1.5 and 1.8 bar, the tool life of coated cemented carbide increase with decrease of cutting speed for all different pressure. It is observed that the cutting speed cutting speed 90 m/min, the tool life is increase tremendously. As mentioned in Figure 4 that the growth of flank wear is increases at cutting speed 110 and tend to slowdown at cutting speed 90 m/min. It can be suggested that 90 m/min is the best cutting speed for stainless steel when using 1.8 bar internal coolant pressure.

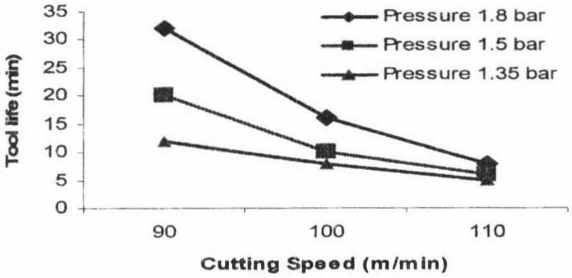


Figure 4: Graf from Summary of Tool Llife from Conducted Experiments

Flank Face Wear

Figures 5-7 show the flank wear rate at a cutting speed of 90, 100 and 110 m/min by using various pressures. The experimental results show that the flank wear dominantly control the tool life when machining the work piece with various pressure by using cemented carbide insert. Flank wear rate was rapidly increased at higher cutting speed and by using lowers pressure due to high temperature generated at the cutting edge closer to the nose radius. The flank wear progression at cutting speed of 90 m/min is the slowest with pressure 1.8 bar with nozzle size of 1.0 mm. This phenomenon is due to the high temperature generated at the cutting area whereby efficient cooling system is required to cool down the carbide insert and also the work piece. The nozzle orifice size of 1.0 mm could generate higher coolant pressure and more flow rate than 1.5 mm and 2.0 mm nozzle orifice. From this result, using nozzle pressure 1.8 bar at cutting speed of 90 m/min is recommended to achieve the optimum machining capability.

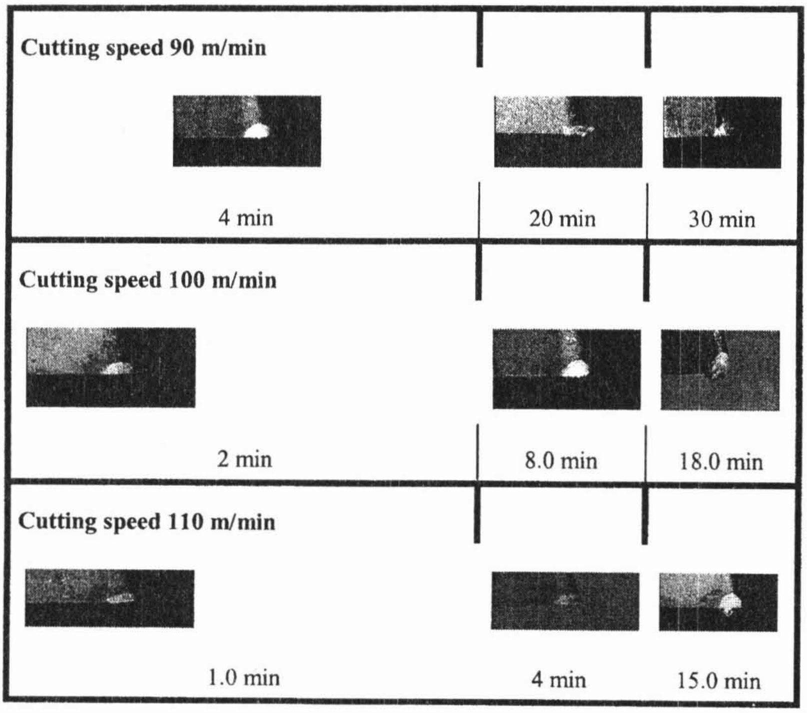


Figure 5: Flank Wear at Various Cutting Speed using Nozzle Size of 1.0mm

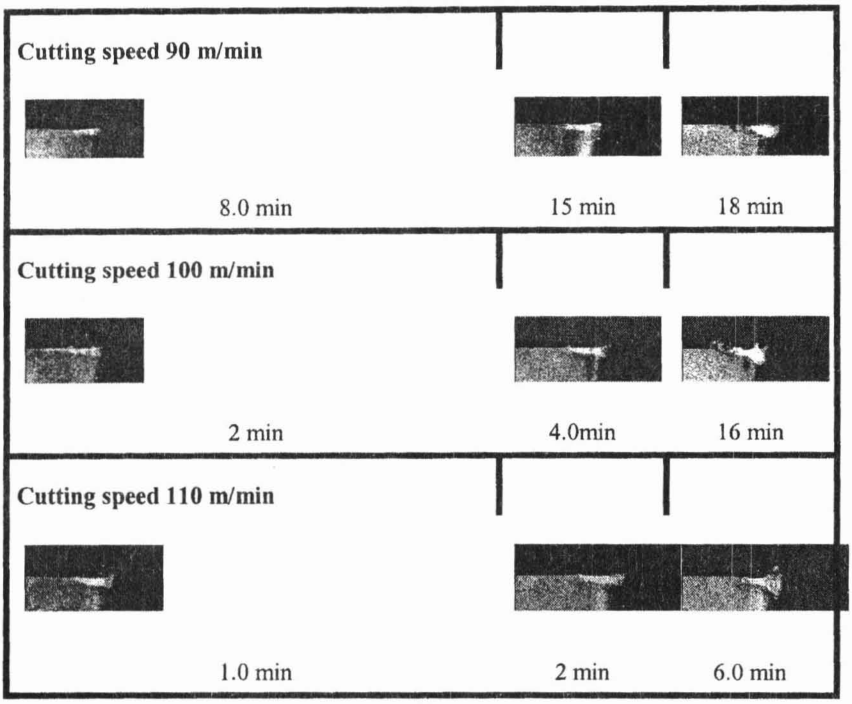


Figure 6: Flank Wear at Various Cutting Speed using Nozzle Size of 1.5mm

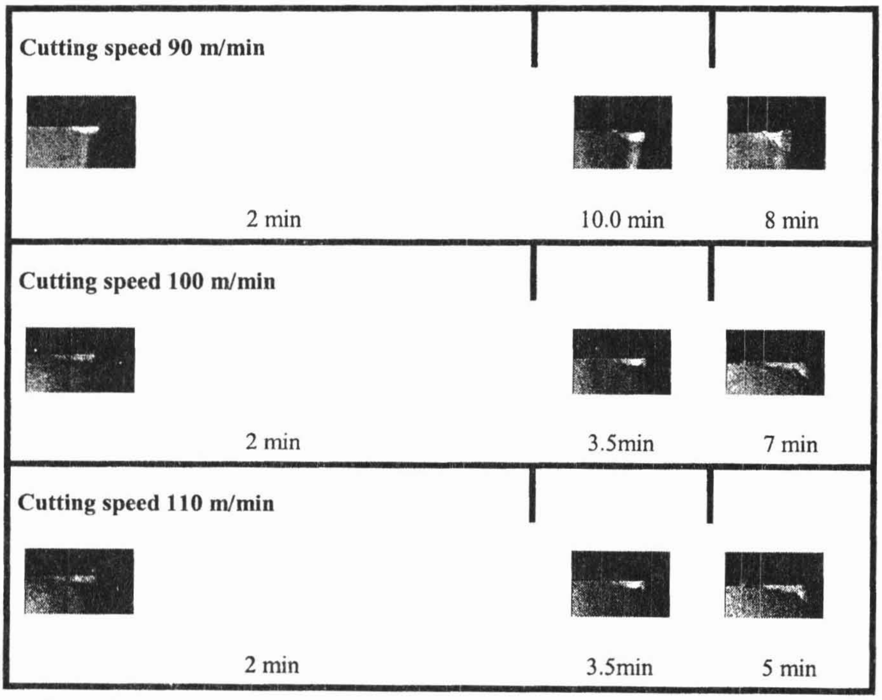


Figure 7: Flank Wear at Various Cutting Speed using Nozzle Size of 2.0mm

Effect of Cutting Speed on Surface Roughness

The surface roughness value on the machined work piece is one of the essential parameter in investigating the cutting tool performance. The values were recorded after each machining process as shown in Figures 8-10. From the tabulated data, it is observed that as the cutting speed increases, surface roughness increases too and at an interval of every 2 minutes, the average surface roughness slightly decreases and increases again. This phenomenon patterns are quite similar with all nozzle orifice sizes.

In the experiments using of high pressure coolant system, all the result show only a minor effect on the surface roughness for Ra. It can be seen that from the Figures 8-10, there were only small differences between each value of surface roughness for a difference coolant pressure for all cutting conditions. The surface roughness produced by 1.8 bar coolant pressure is the best result, followed by 1.5 bar and 1.35 bar. Generally an increase of the cutting speed leads to a deterioration of surface finish. But with an increase of the cutting speed and increase of coolant pressure, the value of Ra is drastically reduced. This indicates an improvement in 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 can be improved significantly but the surface roughness value were not very difference for all coolant pressure condition. It can be also seen the surface roughness formation contours in the Figures 4 with nozzle inner pressure respectively.

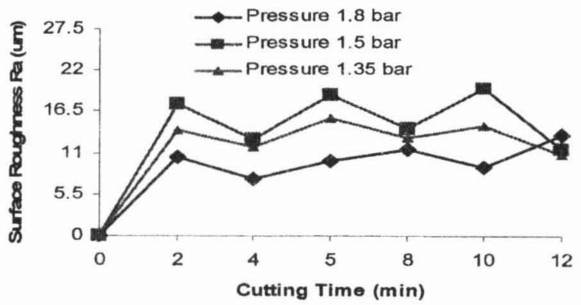


Figure 8: Effect of Machining Time on Surface Roughness, with Cutting Speed 90m/min

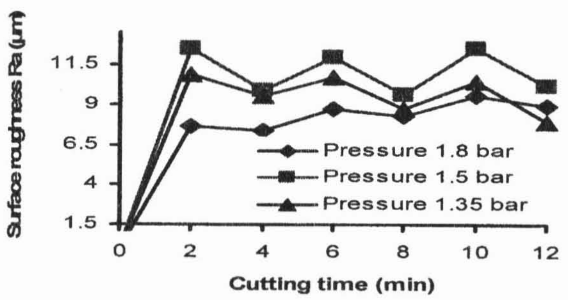


Figure 9: Effect of Machining Time on Surface Roughness with Cutting Speed 100 m/min

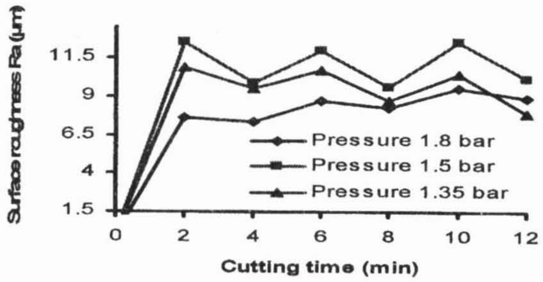
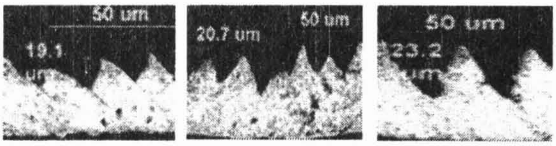


Figure 10: Effect of Machining Time on Surface Roughness with Cutting Speed 110 m/min

Chip Morphology

Understanding on chip morphology is important especially on its relationship with the cutting speed. These investigations will only concentrate on the physical appearance of the chip formation. Simoneau et al., 2007 stated that the role play by the cutting speeds and the allotropic transformation of the low temperature alpha phase to the high temperature beta phase in the change from discontinuous morphology at low cutting speeds (low temperature) to a segmented but continuous morphology at high cutting speed (high temperature).

It was observed that at cutting speed of 90 m/min, the frequency of the saw-tooth chip formation is less compared to cutting speed of 100 m/min and 110 m/min. The average amplitude recorded also show that the highest value is at lower cutting speed 90 m/min. as shown in Figure 11. It could be suggested that morphology of the chip for coolant nozzle orifice of 1.0 mm is similar with coolant nozzle orifice of 2.0 mm. As a conclusion by visualizing the chip physical appearance, shop floor operator can predict the surface finish conditions for nozzle orifice of 1.0 mm, 1.5 mm, 2.0 mm.



(a) 90 m/min (b) 100 m/min (c) 110 m/min

Figure 11: Chip Roots Thickness at Different Cutting Speeds

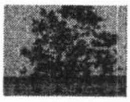
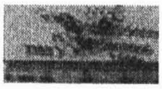
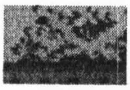
Various of pressure	Cutting Speed (mm)		
	90 m/min	100 m/min	110 m/min
1.8 bar			
1.5 bar			
1.35 bar			

Figure 12: Samples of Chip Formation on Stainless Steel Material

From the sample results in Figure 12, the chip size and chip length are different under different cutting conditions. By using nozzle size of 2.0 mm, the chip's curl size is relatively bigger and the chip length is long, as compare to the chip produced by nozzle size of 1.0 mm and 1.5 mm. The chip colour is yellowish at the low cutting speed and at the higher cutting speed the colour is rather dark blue. The yellowish colour of the chip produced by nozzle orifice of 2.0 mm indicated the chip was burnt. For all cutting condition by using nozzle orifice of 1.0 mm, the chips produced have a bright surface indicating that they are not burnt. Machining of stainless steel with nozzle orifice of 1.0 mm produces small fragment of segmented or serrated chip compare to the chip produce by 1.5 mm and 2.0 mm nozzle orifice.

increases, surface roughness increases too and at an interval of every 2 minutes, the average surface roughness slightly decreases and increases again. This phenomenon patterns are quite similar with all nozzle orifice sizes.

In the experiments using of high pressure coolant system, all the result show only a minor effect on the surface roughness for Ra. It can be seen that from the Figures 8-10, there were only small differences between each value of surface roughness for a difference coolant pressure for all cutting conditions. The surface roughness produced by 1.8 bar coolant pressure is the best result, followed by 1.5 bar and 1.35 bar. Generally an increase of the cutting speed leads to a deterioration of surface finish. But with an increase of the cutting speed and increase of coolant pressure, the value of Ra is drastically reduced. This indicates an improvement in 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 can be improved significantly but the surface roughness value were not very difference for all coolant pressure condition. It can be also seen the surface roughness formation contours in the Figures 4 with nozzle inner pressure respectively.

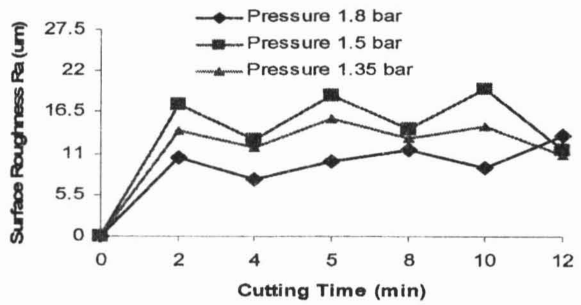


Figure 8: Effect of Machining Time on Surface Roughness, with Cutting Speed 90m/min

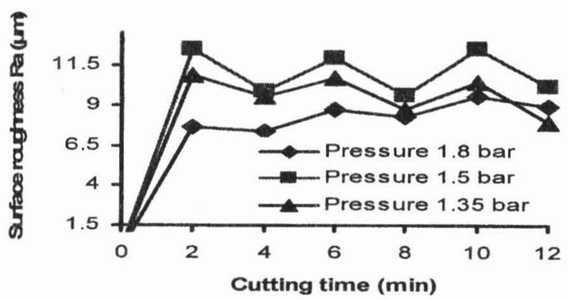


Figure 9: Effect of Machining Time on Surface Roughness with Cutting Speed 100 m/min

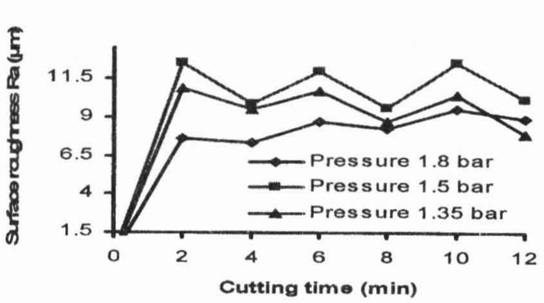
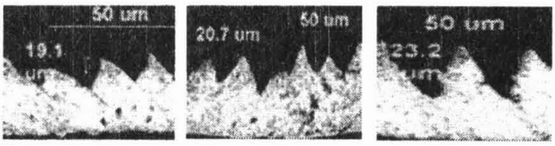


Figure 10: Effect of Machining Time on Surface Roughness with Cutting Speed 110 m/min

Chip Morphology

Understanding on chip morphology is important especially on its relationship with the cutting speed. These investigations will only concentrate on the physical appearance of the chip formation. Simoneau et al., 2007 stated that the role play by the cutting speeds and the allotropic transformation of the low temperature alpha phase to the high temperature beta phase in the change from discontinuous morphology at low cutting speeds (low temperature) to a segmented but continuous morphology at high cutting speed (high temperature).

It was observed that at cutting speed of 90 m/min, the frequency of the saw-tooth chip formation is less compared to cutting speed of 100 m/min and 110 m/min. The average amplitude recorded also show that the highest value is at lower cutting speed 90 m/min. as shown in Figure 11. It could be suggested that morphology of the chip for coolant nozzle orifice of 1.0 mm is similar with coolant nozzle orifice of 2.0 mm. As a conclusion by visualizing the chip physical appearance, shop floor operator can predict the surface finish conditions for nozzle orifice of 1.0 mm, 1.5 mm, 2.0 mm.



(a) 90 m/min (b) 100 m/min (c) 110 m/min

Figure 11: Chip Roots Thickness at Different Cutting Speeds

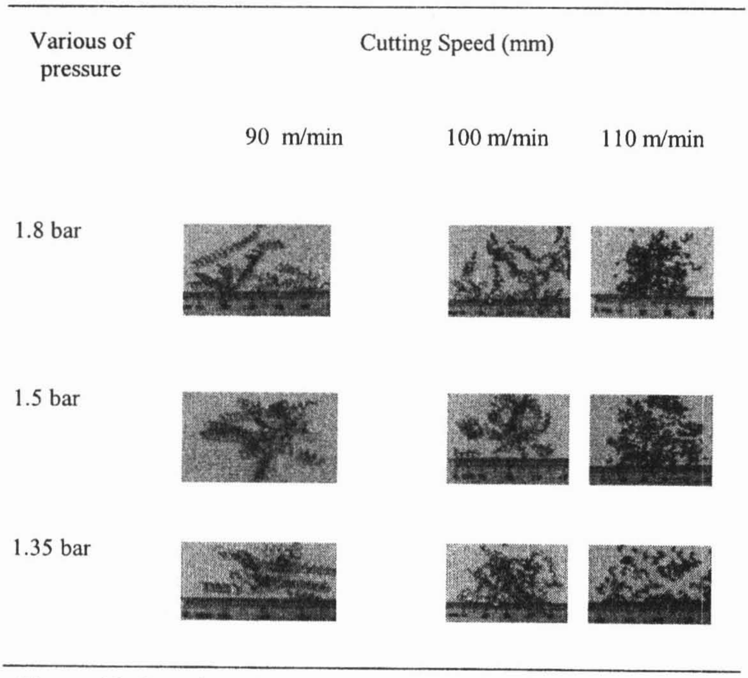


Figure 12: Samples of Chip Formation on Stainless Steel Material

From the sample results in Figure 12, the chip size and chip length are different under different cutting conditions. By using nozzle size of 2.0 mm, the chip's curl size is relatively bigger and the chip length is long, as compare to the chip produced by nozzle size of 1.0 mm and 1.5 mm. The chip colour is yellowish at the low cutting speed and at the higher cutting speed the colour is rather dark blue. The yellowish colour of the chip produced by nozzle orifice of 2.0 mm indicated the chip was burnt. For all cutting condition by using nozzle orifice of 1.0 mm, the chips produced have a bright surface indicating that they are not burnt. Machining of stainless steel with nozzle orifice of 1.0 mm produces small fragment of segmented or serrated chip compare to the chip produce by 1.5 mm and 2.0 mm nozzle orifice.

Conclusion

The following conclusions are drawn based on the results throughout the study on turning stainless steel AISI 304 with Al_2O_3 coated cemented carbide insert by using different nozzle orifice size of 1.0 mm (1.8 bar), 1.5 mm (1.5 bar), and 2.0 mm(1.35 bar). Nozzle orifice size of 1.0 mm with cutting speed of 90 m/min gives the optimum results in term of tool life, flank wear, and surface roughness. The smaller size nozzle orifice coolant pressure that emerged from the nozzle gives more advantages during the machining processes. It is due to the more coolant point pressure that has reduced the high temperature tremendously at the cutting region. By reducing this temperature, it prolongs the tool life and minimizes the chip from being welded onto the carbide insert which eventually reduces the build-up edge and chipping. The cutting speed also a significantly influenced on the surface roughness. As the cutting speed increases, it generated higher temperature which resulted in an increase of the surface roughness and reduces the tool life. 1.0 mm nozzle orifice sizes give the best chip formation with short curl chips. This chip will not get entangle within the cutting area but being removed by the flow of the coolant eventually increases the surface roughness. Feed rate is another criterion which could be affect the surface roughness of the work piece, however, it is not taken into consideration in this study. A constant feed rate is used throughout this research. It can be concluded from the presented results, the nozzle orifice size of 1.0 mm with 1.8 bar pressure and 90 m/min cutting speed gives the optimum cutting performance result.

Acknowledgement

The author would like to thanks TATI University College (TATiUC) for sponsoring this work, and UTem for providing the supervision.

References

Axinte, D., Belluco, W. & De Chiffre, L. (2001). Reliable tool life measurements in turning. An application to cutting fluid efficiency evaluation. *Int. J. Mach. Tools Manufacturing, 41,* 1003-1014.

De Chiffre, L. & Belluco, W. (2000-01). *Comparison of methods for cutting fluid performance testing. Ann. CIRP, 49/1 (2000) 57-60.* Centre for Geometrical Metrology Annual Report Page 25.

Henry, S.W. (2002). *Instrumentation for tool wear evaluation.* Journal, Page 14.

Seah, K.H, et al. (1995). The effect of applying coolant on tool wear in metal machining. *Matter Processing, Tech. 48,* 495-501.

Simoneau, A., Ng, E. & Elbestawi, M.A. (2006). Chip formation during microscope cutting of medium carbon steel. *Int. J. Mach. Tools Manufacturing, 46,* 467-481.

Simoneau, A., Ng, E. & Elbestawi, M.A. (2007). Modeling the effects of microstructure in metal cutting. *Int. J. Mach. Tools Manufacturing, 47,* 368-375.

ZAINAL ARIFIN SELAMAT, Faculty of Manufacturing Engineering, TATI University College (TATiUC), Jalan Panchor, Teluk Kalong 24000,Kemaman Terengganu, Malaysia. zainal @tati.uc.edu.my

MOHD RAZALI MUHAMAD, Faculty of Manufacturing Engineering, University Teknikal Kebangsaan Malaysia, Karung Berkunci 1200, Ayer Keroh, 75450 Melaka, Malaysia.
mohdrazali@Utem.edu.my