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UNIVERSITI TEKNOLOGI MARA
University Publication Centre (UPENA)

Journal of Mechanical Engineering

An International Journal

Volume 6 No. 1 April 2009 ISSN 1823-5514

JOURNAL OF MECHANICAL ENGINEERING (JMechE)

Journal of Mechanical Engineering is jointly published by the Faculty of Mechanical Engineering and University Publication Centre (UPENA), Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

Journal of Mechanical Engineering

An International Journal

Volume 6 No. 1 **April 2009** **ISSN 1823-5514**

In-Process Investigation of Turning Process Applied with and without Cutting Fluid

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ABSTRACT

The aim of this research is to investigate the cutting conditions applied with and without cutting fluid in order to obtain the proper cutting condition for the plain carbon steel with the coated carbide tool based on the consideration of the surface roughness of the machined part, the life of the cutting tool, and the use of minimum quantity lubrication (MQL). The applications of cutting fluid are wet cutting and mist cutting. The dynamometer is installed on the turret of CNC turning machine to measure the in-process cutting force. The in-process cutting forces obtained are examined and analyzed for the machinability of steel under various cutting conditions. The experimentally obtained results showed that the relation between tool wear and surface roughness, the relation between tool wear and cutting force, and the relation between cutting force and surface roughness are correspondent with the same trend. The phenomena of surface roughness and the tool wear can be well explained by the in-process cutting forces obtained. Referring to the criteria, the proper cutting condition determined is the dry cutting at a cutting speed of 250 m/min, a feed rate of 0.15 mm/rev, and a depth of cut of 0.5 mm.

Keywords: *Turning, Cutting Force, Cutting Fluid, Tool Wear, Surface Roughness*

Introduction

The steel family such as S45C is most popularly used for the mechanical parts. Turning process is one of the important cutting processes, which is used to cut those materials in order to obtain the shape of the parts as required. However, the tool wear is still the main problem in turning process because it deteriorates not only the machined surface but also geometry and accuracy as well as causing the low productivity due to the change of the new cutting tools.

The cutting fluids have been used extensively in cutting operation to improve the cutting performance [1]. The cutting fluids are applied to cutting operations in various ways to remove the heat at shear zone and friction zone, reduce cutting forces and improve surface finish [2].

For economical and environmental reasons, there has been a continuing worldwide trend to minimize or eliminate the use of cutting fluids [3]. This trend leads to the practice of minimum quantity lubrication (MQL) with major benefits such as reducing the cost of machining operations and the disposal of cutting fluids [4-6]. Extensive research efforts have been devoted so far to investigate the effects of the cutting fluid and the application of MQL [7-11]. However, the effectiveness of the cutting fluid depends on a number of factors, such as the type of machining operations, the cutting tools, the workpiece materials, the cutting conditions, and the cutting fluids.

It is therefore desirable to know the effects of the different applications of cutting fluid under any cutting conditions to improve the stability of cutting [12-13]. Hence, the aim of this research is to investigate the cutting conditions applied with and without cutting fluid in order to obtain the proper cutting condition for the plain carbon steel in turning process. The applications of cutting fluid used in this research are wet cutting (W) and mist cutting (M) while dry cutting (D) is applied for without cutting fluid.

In-Process Monitoring of Turning Process and Proper Cutting Condition

The in-process monitoring of cutting process is utilized to examine and analyze the cutting conditions applied with and without cutting fluid. The in-process cutting forces and the particles of cutting fluid are monitored during the cutting.

The dynamometer is employed and installed on the turret of CNC turning machine in order to measure the in-process cutting force. The cutting forces obtained are analyzed and interpreted for the in-process cutting temperature, surface roughness, and tool wear under various cutting conditions applied with and without cutting fluid.The proper cutting condition is determined based on the criteria of the surface roughness of the machined part, the life of the cutting tool, the use of minimum quantity lubrication (MQL).

Relation of Tool Wear, Cutting Force and Surface Roughness

The applications of cutting fluid with the different cutting conditions may affect the tool wear rate. As the tool wear progresses, the cutting force is also increased mainly due to the increase in the force at the tool flank. Consequently, the surface quality is poor. Hence, the surface roughness is expected to be good when the tool wear is small and the cutting temperature is suitable. The cutting force is low while cutting the softened materials due to the suitably high cutting temperature.On the other hand, the poor surface roughness is expected to be happened when the tool wear is large and the cutting temperature is unsuitable. As a consequence, the high cutting force occurs.

Relation of Cutting Condition, Cutting Temperature, Surface Roughness, and Chip Formation

The different cutting conditions applied with and without cutting fluid affect the cutting temperature during the in-process cutting. In case of turning operation, the cutting speed is generally adopted as the major cutting condition to be monitored, as it is directly related to the tool wear and the cutting temperature. A selected cutting speed may cause the suitably in-process cutting temperature, and hence the work material becomes soft and easy to cut. Consequently the quality of surface roughness is good. It is expected that the tool wear rate is low and the small cutting force happens. The broken chip formation tends to be appeared due to the suitable cutting temperature, which results in the lower resistance of chip breaking [14].

It is well-known that the built-up edge formation depends on the cutting speed, which causes the poor surface roughness. In order to reduce built-up edge, the high cutting speed is recommended.

However, the high cutting speed may cause the highly in-process cutting temperature, and hence the rate of tool wear is high. The cutting force becomes large, as a result of the poor quality of surface roughness. It is expected that the increase in cutting speed causes the higher cutting temperature in the cut, as a result of the continuous chip formation due to softening of work material.

Experimental Equipment and Cutting Conditions

Series of cutting experiments were carried out with the dry cutting, the wet cutting, and the mist cutting in order to obtain the proper cutting condition. The cutting tests are conducted on a commercially available small CNC turning machine. The longitudinal turning of plain carbon steel (JIS:S45C) is adopted in the cutting experiments, and the cutting tool is coated carbide tools (DNMG150604FN). The limited flank wear (Vb) is chosen here to be 0.2 mm. The acceptable surface roughness (Rz) is less than 12.5 μm referring to JIS B0601 (1982).

The well-known cutting parameters which have the effect on the cutting performance are utilized here for the cutting experiments. The major cutting conditions are summarized in Table 1. The parameter values are selected from the recommended values in the cutting tool manual [18]. The cutting speeds are predetermined by selecting the normally and generally used cutting speeds of 150, 250 and 350 m/min, and feed rates of 0.15 and 0.18 mm/rev at depths of cut of 0.5 and 1.0 mm. The different levels of air pressure for mist cutting are performed at 0.3, 0.5 and 0.7 MPa.

A tool dynamometer has been installed onto the tool turret of the machine as shown in Figure 1. The cutting force signals detected by the tool dynamometer are amplified and low-pass filtered with the cut-off frequency of 500 Hz prior to digitization and calculation within PC.

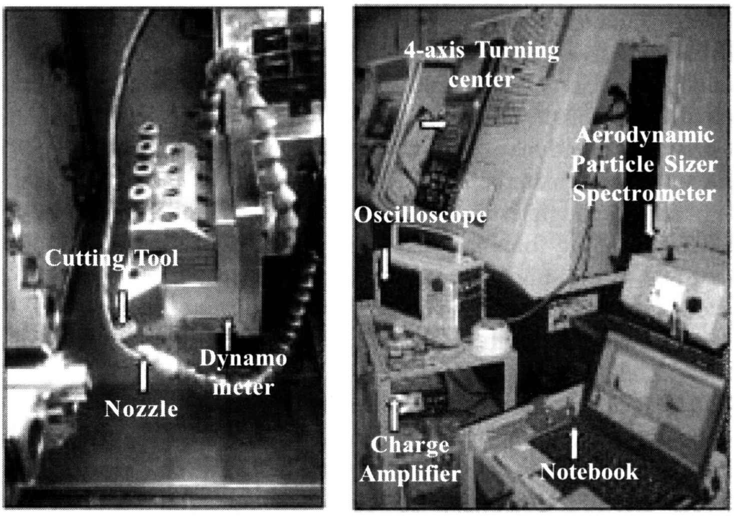


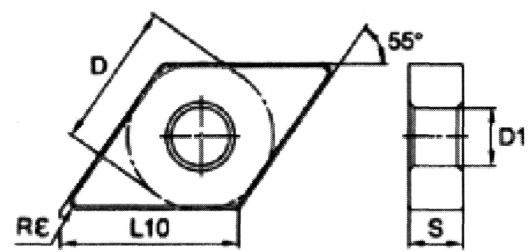
Figure 1: Illustration of Experimental Setup

Experimental Results and Discussions

Series of cutting tests are carried out with the applications of dry cutting, wet cutting, and mist cutting under the major cutting conditions. Some examples of experimentally obtained relation of surface roughness and cutting speed are shown in Figure 2. Figure 2 shows that the poor surface roughness is obtained at low cutting speed for dry, wet, and mist cutting because of built-up edge formation [22-23], especially at cutting speed of 150 m/min. It is understood that a good surface roughness is obtained when cutting speed is high enough for avoiding the built-up edge.

The figure shows that the better surface roughness (Rz) is obtained when the cutting speed is 250 m/min with dry cutting at depth of cut 0.5 mm. It is understood that the work material becomes soft and easy to cut because of the suitable cutting temperature. At greater speeds, the local thermal softening of chip material due to friction heating results in a degree of self-lubrication [19]. Hence, the quality of surface improves.

Table 1: Major Cutting Conditions

Cutting Condition		Dry Cutting (D)	Wet Cutting (W)	Mist Cutting (M)		
				0.3 MPa	0.5 MPa	0.7 MPa
Cutting Speed (m/min)		150 , 250 , 350	150 , 250 , 350	150 , 250 , 350	150 , 250 , 350	150 , 250 , 350
Feed Rate (mm/rev)		0.15 , 0.18	0.15 , 0.18	0.15 , 0.18	0.15 , 0.18	0.15 , 0.18
Depth of Cut (mm)		0.5 , 1.0	0.5 , 1.0	0.5 , 1.0	0.5 , 1.0	0.5 , 1.0
Volume of Chip (cm^3)		2000	2000	2000	2000	2000
Coated Carbide Tool	Tool geometry					
		D	L10	S	Rε	D1
		12.70 mm	15.50 mm	6.35 mm	0.40 mm	5.16 mm
	ANSI Number (ISO number)	DNMG441FN (DNMG150604FN)				

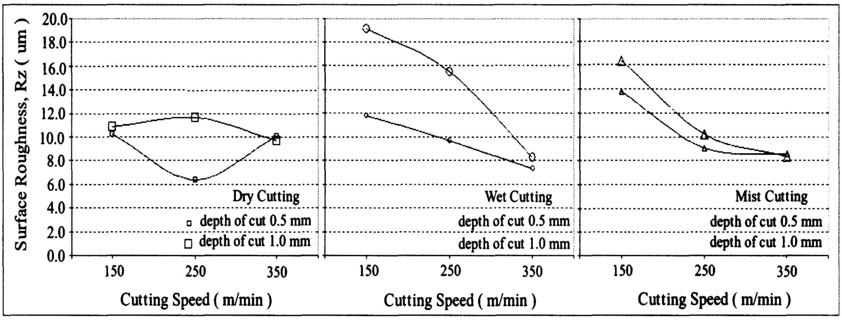


Figure 2: Examples of Experimentally Obtained Relation of Surface Roughness and Cutting Speed with Dry Cutting, Wet Cutting, and Mist Cutting at Air Pressure 0.7 MPa at Feed Rate 0.15 mm/rev, Volume of Chip 1500 cm^3

While the higher surface roughness obtained from wet cutting and mist cutting because of the effect of cutting fluid, which results in low cutting temperature and make work material difficult to cut. This reason leads to the case of using the cutting speed of 150 m/min with dry cutting at a depth of cut 0.5 mm However, the surface roughness becomes worse at cutting speed of 350 m/min with dry cutting and depth of cut 0.5 mm. The reason is the cutting temperature mentioned above. It can be interpreted that the unsuitably high cutting temperature causes the rapid progress of tool wear, as a result of high surface roughness obtained.

The other interesting observation is that chips produced in dry cutting have side curl radius. Side flow is the flow of material to the sides in the shear plane. The higher the temperature in the shear plane the less viscous is the material and the more side flow is seen [20]. The material that flows to the side makes the chips wider than depth of cut and generally sticks on the hills of feed marks and makes the surface finish worse.

The good quality of surface is also obtained at small depth of cut 0.5 mm for dry, wet, and mist cutting as shown in Figure 2. Since the surface roughness depends on the cutting force. Because the high cutting forces occurred affect the vibration of tool during the cutting which leads to the poor surface roughness. Generally, the cutting force increases with an increase in the depth of cut and the feed rate. Hence, the larger cutting force appears, the higher surface roughness occurs.

Figure 3 shows the examples of experimentally obtained relation of surface roughness and cutting speed, and also the relation of cutting forces and cutting speed. All three components of cutting forces (Fx: thrust force, Fy: feed force, Fz: main force) are measured for dry cutting, wet cutting, and mist cutting. The relation of surface roughness and cutting speed, and the relation of cutting forces and cutting speed show the same trend. Since the in-process cutting force tends to decrease while the cutting speed is higher due to the softening of work material. At the same time, the better surface roughness is obtained as the cutting force decreases. For dry cutting, the cutting force and the surface roughness are not shown here at cutting speed of 350 m/min because of the tool breakage.

However, the cutting force and the surface roughness become larger at 350 m/min with mist cutting. This can be due to the higher heat that may burn the mist of cutting fluid before the lubrication with higher speed (350 m/min) as compared to 250 m/min [20]. Moreover, the cutting speed is high, which makes the entrance of mist of cutting fluid close to the cutting area difficult and makes the work of mist of cutting fluid more insufficient.

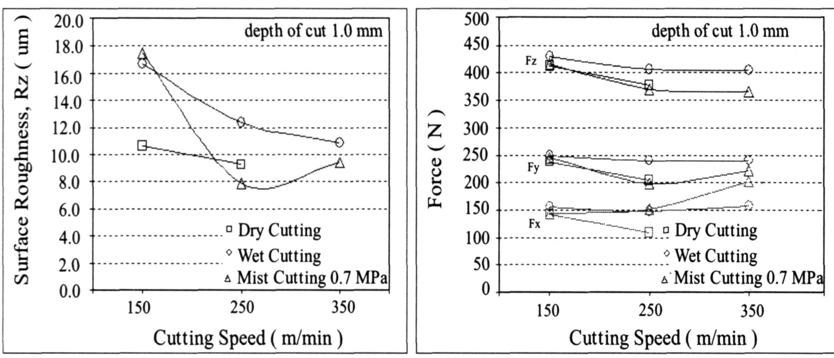


Figure 3: Examples of Experimentally Obtained Relation of Cutting Speed with the Surface Roughness, and Cutting Force with Dry Cutting, Wet Cutting, and Mist Cutting at Air Pressure 0.7 MPa at Feed Rate 0.15 mm/rev, Volume of Chip 2000 cm^3

According to the experimentally obtained results, it is understood that the in-process cutting forces obtained by employing the dynamometer can be used to predict the surface roughness during the in-process cutting. The estimation model of surface roughness is hence performed in the next research.

Figure 4 shows the examples of experimentally obtained relation of surface roughness and flank wear. The surface roughness increases when the tool wear increases. However, the surface roughness becomes lower, which is less than 12.5 µm, when the flank wear is about 0.2 mm. It is understood that the tool nose radius becomes larger when the cutting tool is worn, and consequently the theoretical surface roughness decreases as shown in Figure 5. The nose radius of worn tool (R2) is larger than the one of new tool (R1). The high contact length between tool edge and workpiece helps to dissipate heat, which makes dry cutting even more suitable [21].

However, the surface roughness will increase far above the theoretical value expected due to the effect of tool wear. Since the vibration of tool increases due to the larger contact length between cutting edge and workpiece caused by the larger nose radius, which damages the surface roughness.

Figure 4 shows that the experimentally obtained surface roughness at air pressure of 0.7 MPa is higher than that at air pressure of 0.3 MPa and 0.5 MPa. It means that the particles of cutting fluids are dispersed in working area and undelivered to the cutting area.

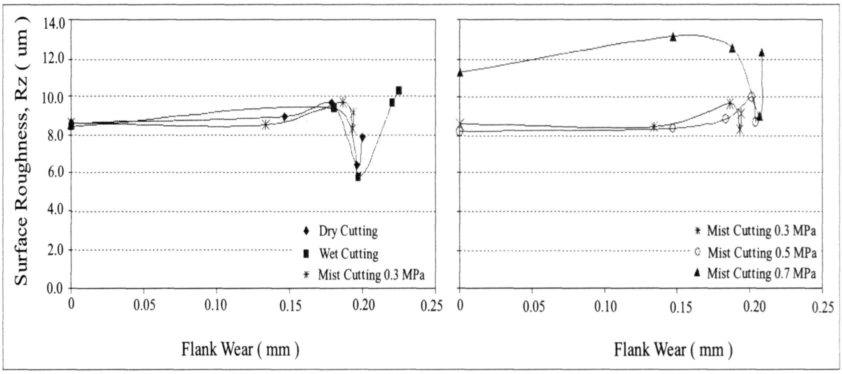


Figure 4: Examples of Experimentally Obtained Relation of Flank Wear and the Surface Roughness Applied with Dry Cutting, Wet Cutting, and Mist Cutting at Different Air Pressures, at Depth of Cut 0.5 mm, Feed Rate 0.15 mm/rev, Cutting Speed 250 m/min

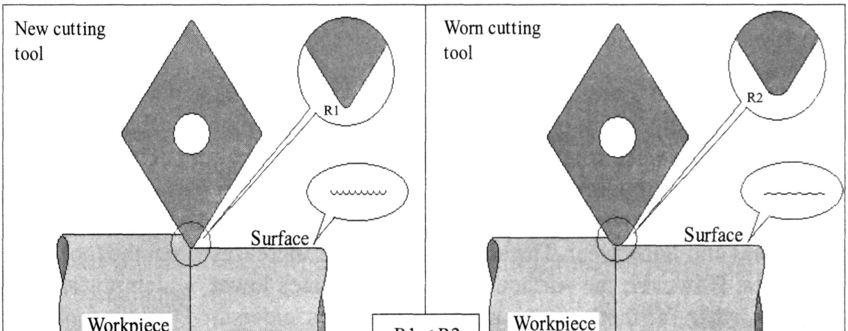
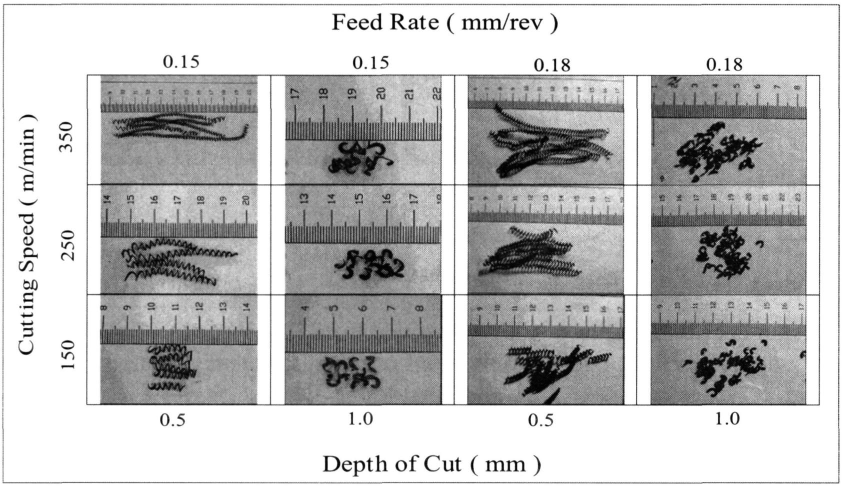
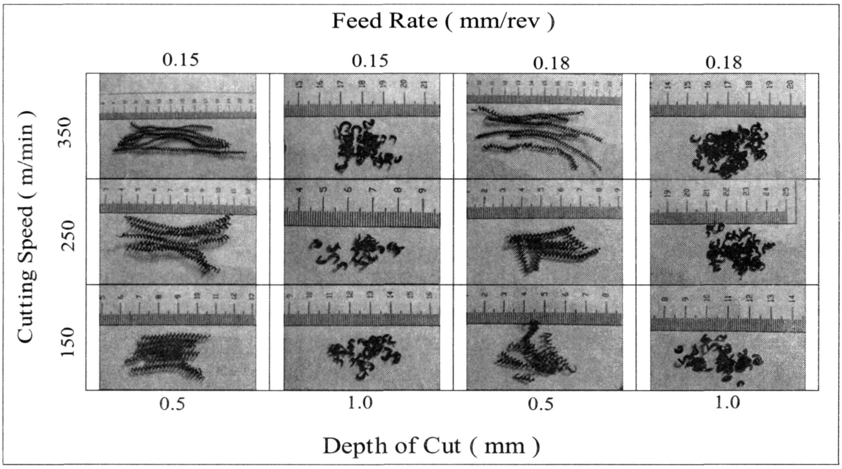


Figure 5: Illustration of Tool Nose Radius of New Tool R1, and Worn Tool R2

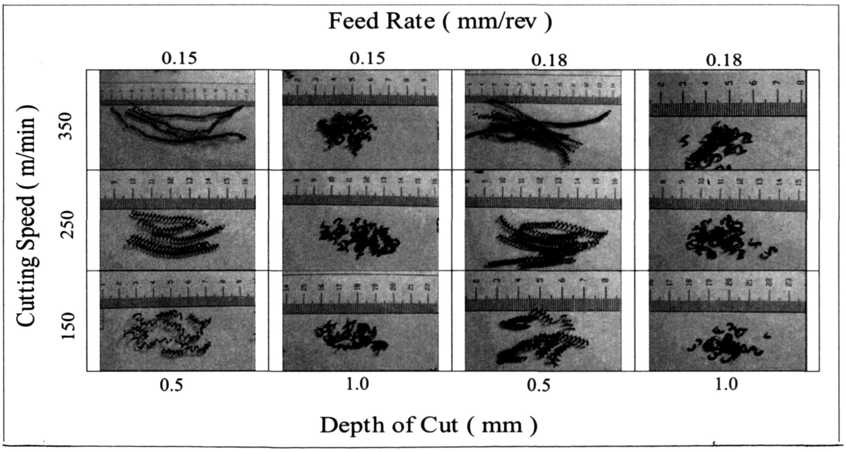
Figure 6 shows the examples of experimentally obtained photographs of the chips when the cutting tool is new with and without the different applications of cutting fluid under combinations of the cutting speeds, depths of cut and feed rates. The morphology of chip is classified into two types of continuous and broken. The broken chip disappears at higher cutting speeds of 250 and



(a) Dry Cutting



(b) Wet Cutting



(c) Mist Cutting

Figure 6: Photographs of Chips Obtained from Dry, Wet and Mist Cutting with New Tool Under Combinations of Cutting Speeds, Depths of Cut and Feed Rates

350 m/min, which means that the continuous chips are formed. It is understood that the increase in cutting speed causes the higher temperature in the cut, which results in the softening of work material, and as a consequence, the chip breaking is poor [15-17]. Thermal softening can ease flow at the chip-tool contact area at high cutting speeds.

Figure 7 shows the examples of experimentally obtained relation of chip thickness and cutting speed for dry, wet, and mist cutting. The chip thickness becomes thinner as the cutting speed increases, which causes the low cutting forces and reduces the built-up edge. Hence, the better surface is obtained.

On the other hand, the broken chip was found to happen at low cutting speed. It is understood that the shear angle becomes smaller at lower cutting speed, which results in thicker chip formation and leads to efficient chip breaking.

It is well-known that the chip breaking condition is improved as the feed rate and the depth of cut are increased as shown in Figure 6. When the feed rate is increased the thickness of chip increases, and the chip tends to curl which results in improved chip breaking regardless of the cutting speed and the depth of cut.

The depth of cut affects the chip width, and the initial chip flow angle, which leads to increase side-curl of chips or up-curl of chips. The chips produced in dry cutting are wider than the chips produced in wet cutting and mist cutting. The wider chip for dry cutting is a result of side flow in the shear plane that was also observed in the earlier work [20].

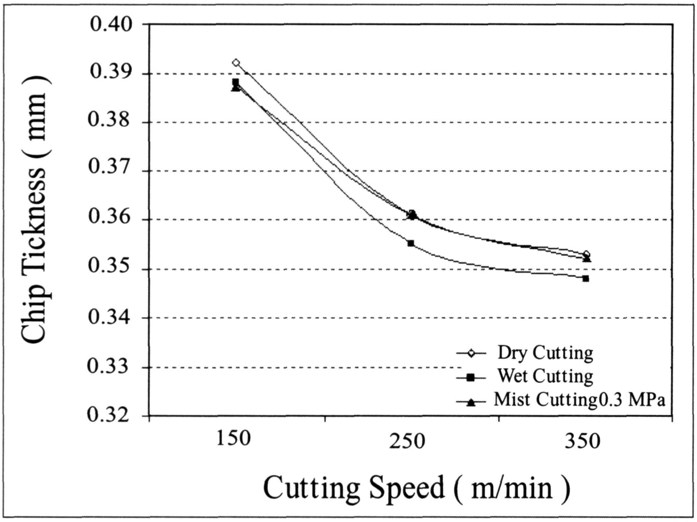


Figure 7: Examples of Experimentally Obtained Relation of Chip Thickness and Cutting Speed with Dry Cutting, Wet Cutting, and Mist Cutting at Air Pressure 0.3 MPa, at Depth of Cut 1 mm, Feed Rate 0.18 mm/rev, Volume of Chip 500 cm^3

The nominal chip thickness is also affected by the depth of cut compared to the tool nose radius [14-15]. It is understood that the nominal chip thickness becomes thicker at larger depths of cut, and the chips tend to curl which results in breaking.

Figure 8 shows the examples of experimentally obtained relation of surface roughness and cutting speed with mist cutting at different levels of air pressure 0.3, 0.5, and 0.7 MPa, at depth of cut 0.5 mm, feed rate 0.15 mm/rev, volume of chip 2000 cm^3. The surface roughness is deteriorated by excessive tool vibration and the built-up edge for all different air pressures at the low cutting speed. However, an increase in the cutting speed causes the low cutting forces and reduces the built-up edge, as a result of better surface roughness obtained. The reasons are the same as previous mention in Figure 2.

When the mist cuttings are performed at air pressure 0.3 MPa, the relation of surface roughness and cutting speed is similar to the wet cutting as shown in Figure 2. It is understood that the particle sizes of the cutting fluids are large while applying the mist cutting at air pressure 0.3 MPa. Hence the characteristic of mist cutting at low air pressure is consistent to the wet cutting.

The examples of two experimentally obtained relations of surface roughness and cutting speed with mist cutting at different air pressures of 0.5 and 0.7 MPa show the same trend. The figure shows that the surface

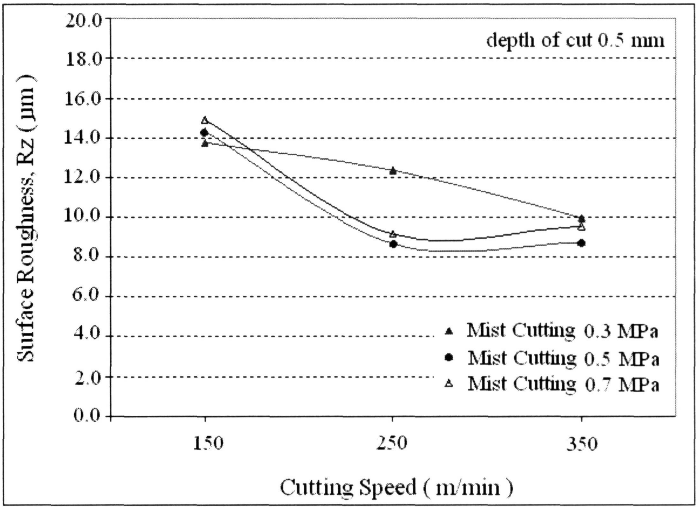


Figure 8: Examples of Experimentally Obtained Relation of Surface Roughness (Rz) and Cutting Speed with Mist Cutting at Different Levels of Air Pressure 0.3, 0.5, and 0.7 MPa at Depth of Cut 0.5 mm, Feed Rate 0.15 mm/rev, Volume of Chip 2000 cm^3

roughness (Rz) is low at cutting speed of 250 m/min with mist cutting and depth of cut 0.5 mm at air pressures of 0.5 MPa. The trend of surface roughness is similar to the dry cutting from the cutting speed 150 to 250 m/min as shown in Figure 2, because of the effect of the mist of cutting fluids. It is understood that the mist of the cutting fluids is delivered to the inaccessible cutting areas. Consequently, the cutting temperature is low, and hence the rate of tool wear is low which leads to the good quality of surface. The surface roughness becomes high at cutting speed of 350 m/min with mist cutting and depth of cut 0.5 mm at air pressures of 0.5 MPa. But the surface roughness obtained is less than the one obtained from dry cutting as shown in Figure 2. The reasons are the same as above.

However, the surface roughness obtained at air pressures of 0.7 MPa is higher than the one obtained at air pressures of 0.5 MPa as shown in Figure8. It is understood that the mist of cutting fluids is not delivered to the cutting areas but it is dispersed in working area by high air pressure of 0.7 MPa.

Figure 9 shows the progress rates of flank wear with dry cutting, wet cutting and mist cutting. The progress rate of flank wear is low obtained by using dry cutting. It is understood that the cutting temperature is suitable which causes the softening material and easy to cut. While the cutting temperatures of wet cutting and mist cutting are lower than the one of dry

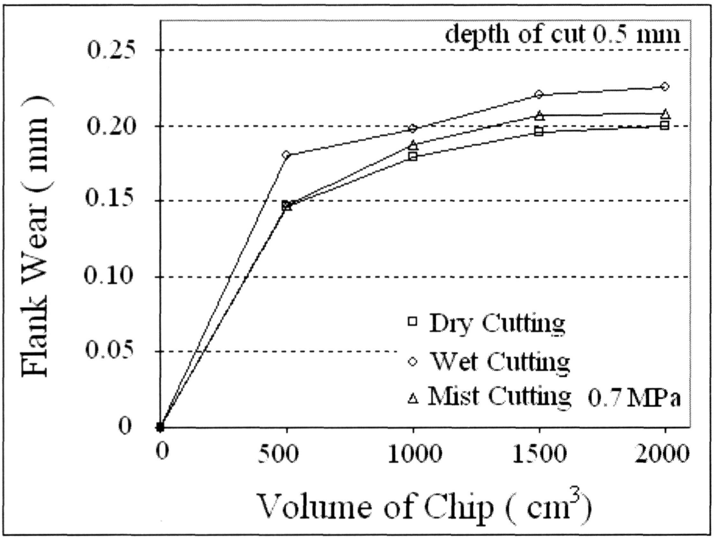


Figure 9: Examples of Experimentally Obtained Relation of Flank Wear and Volume of Chip with Dry Cutting, Wet Cutting, and Mist Cutting at Air Pressure 0.7 MPa at Cutting Speed 250 m/min, Depth of Cut 0.5 mm, Feed Rate 0.15 mm/rev

cutting due to the effect of cutting fluid. Hence, the rate of tool wear of dry cutting is lower than the ones of the wet cutting and mist cutting. According to Figure 9, the corresponding percentages of tool lives are presented in Figure 10.

Figure 10 shows the examples of experimentally obtained relation between tool life and volume of chip at cutting speed 250 m/min, depth of cut 0.5 mm, feed rate 0.15 mm/rev for dry cutting, wet cutting, and mist cutting at 0.7 MPa. The longest life of cutting tool is the dry cutting. The application of dry cutting can cut the work materials up to the 2000 cm^3 for one cutting edge.

While the life of cutting tools for wet cutting is 1000 cm^3, and 1250 cm^3 for mist cutting. It means that the tool cost of the dry cutting is less than the wet cutting about 50% and the mist cutting about 37.5%. The dry cutting leads to the practice of minimum quantity lubrication (MQL) with major benefits such as reducing the cost of cutting fluids, disposal of cutting fluids, and the cutting-fluid contamination in the working area.

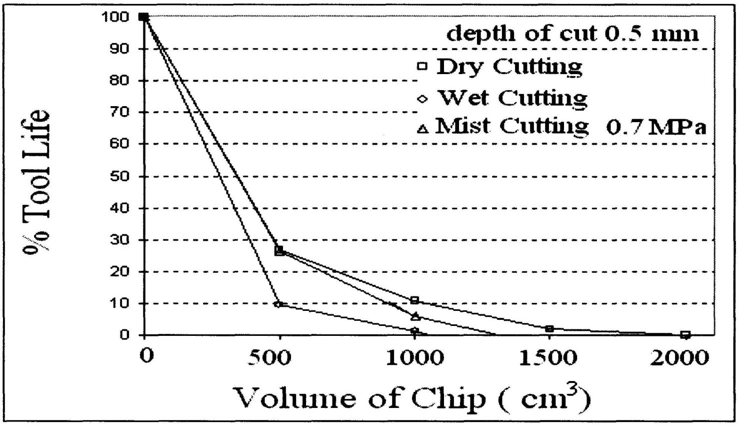


Figure 10: Examples of Experimentally Obtained Relation of Tool Life and Volume of Chip with Dry Cutting, Wet Cutting, and Mist Cutting at Air Pressure 0.7 MPa, Tool Life (Vb) 0.2 mm at Cutting Speed 250 m/min, Depth of Cut 0.5 mm, Feed Rate 0.15 mm/rev

Table 2 summarizes the comparison of experimentally obtained tool life under any cutting conditions for dry cutting, wet cutting, and mist cutting. Based on the consideration of tool cost, the tool life can be prolonged by using the dry cutting at cutting speed 150 and 250 m/min for all depths of cut and feed rates.

On the other hand, the wet cutting and the mist cutting have to be applied to prolong the tool life when using the cutting speed 350 m/min. But the particles of cutting fluids are also dispersed and contaminated in working area which causes the environmental hazards.

Referring to the criteria of the acceptable surface roughness, the longest tool life, and MQL, the proper cutting condition obtained is the dry cutting at the cutting speed 250 m/min, the feed rate 0.15 mm/rev, and the depth of cut 0.5 mm.

Conclusions

In order to obtain the proper cutting condition, the in-process monitoring of turning process is proposed and utilized to investigate the cutting conditions applied with and without cutting fluid. The proper cutting condition is determined based on the criteria of the surface roughness of the machined part, the life of the cutting tool, and the use of minimum quantity lubrication (MQL).

Table 2: Comparison of Experimentally Obtained Tool Life at Any Cutting Conditions

Condition		Cutting Speed (m/min) 150	250	350	
Feed Rate 0.15 mm/rev	Depth of cut 0.5 mm	W < M 0.3 = M 0.5 = M 0.7 < D	W < M 0.3 < M 0.5 < M 0.7 < D	D < M 0.7 < M 0.5 = M 0.3 < W	Tool Life
	Depth of cut 1.0 mm	W < M 0.3 = M 0.5 = M 0.7 < D	M 0.3 = M 0.5 = W < M 0.7 < D	D < M 0.7 < M 0.5 = M 0.3 < W	
Feed Rate 0.18 mm/rev	Depth of cut 0.5 mm	W < M 0.3 = M 0.5 = M 0.7 < D	W < M 0.3 < M 0.5 < M 0.7 < D	D < M 0.7 = M 0.5 < M 0.3 < W	
	Depth of cut 1.0 mm	W < M 0.3 = M 0.5 = M 0.7 < D	W < M 0.3 = M 0.5 = M 0.7 < D	D < M 0.7 = M 0.5 < W < M 0.3	

The in-process cutting force is utilized to monitor the cutting process. The dynamometer is employed and installed on the turret of CNC turning machine in order to measure the in-process cutting force. The cutting forces obtained are analyzed and interpreted for the in-process cutting temperature, the surface roughness, and the tool wear under various cutting conditions. The phenomena of the surface roughness and the tool wear can be explained very well by the in-process cutting forces obtained.

The experimentally obtained proper cutting condition is the dry cutting at the cutting speed 250 m/min, the feed rate 0.15 mm/rev, and the depth of cut 0.5 mm.

Acknowledgement

This work was supported by National Metal and Materials Technology Center, Thailand from September 2006 to August 2007. Within this period, experimental work for this study was carried out. The author is grateful to Professor Moriwaki Toshimichi and Associated Professor Shibasaka Toshiroh, Kobe University for their excellent help.

References

[1] Axinte, D. A., Belluco, W. and Chiffre, L. D. (2001). "Reliable tool life measurements in turning-an application to cutting fluid efficiency evaluation", International Journal of Machine Tools & Manufacture, Vol. 41, 1003-1014.

[2] Dhar, N. R., Kamruzzaman, M. and Mahiuddin Ahmed (2006). "Effect of minimum quantity lubricant (MQL) on tool wear and surface roughness in turning AISI-4340 steel", Journal of Materials Processing Technology, Vol. 172, 299-304.

[3] Diniz, A. E. and Micaroni, R. (2002). "Cutting conditions for finish turning process aiming: the use of dry cutting", International Journal of Machine Tools & Manufacture, Vol. 42, 899-904.

[4] Sutherland, J. W., Kulur, V. N. and King, N. C. (2000). "An experimental investigation of air quality in wet and dry turning", Annals of the CIRP, Vol. 49/1, 61-64.

[5] Ko, T. J., Park, S. H. and Kim, H. S. (2003). "Experimental verification of the mist generation mechanism in turning", International Journal of Machine Tools & Manufacture, Vol. 43, 115-120.

[6] Kishawy, H. A., Dumitrescu, N. E. G. and Elbestawi, M. A. (2005). "Effect of coolant strategy on tool performance, chip morphology and surface quality during high-speed machining of A356 aluminum alloy", International Journal of Machine Tools & Manufacture, Vol. 45, 219-227.

[7] Ii, M., Eda, H., Imai, T., Nishimura, M., Kawasaki, T., Shimizu, J., Yamamoto, T. and Zhou, L. (2000). "Development of water-content cutting fluids with a new concept fire prevention and environmental protection", Journal of the International Societies for Precision Engineering and Nanotechnology, Vol. 24, 231-236.

[8] Gunter, K. L. and Sutherland, J. W. (1999). "An experimental investigation into the effect of process conditions on the mass concentration of cutting fluid mist in turning", Journal of Cleaner Production, Vol. 7, 341-350.

[9] Cakir, O., Kiyak, M. and Altan, E. (2004). "Comparison of gases applications to wet and dry cutting in turning", Journal of Materials Processing Technology, Vol. 153, 35-41.

[10] Weinert, K., Inasaki, I., Sutherland, J. W. and Wakabayashi, T. (2004). "Machining and minimum quantity lubrication", Annals of the CIRP, Vol. 53/2, 511-537.

[11] Dhar, N. R., Islam, M. W. and Mithu, M. A. (2006). "The influence of minimum quantity lubricant (MQL) on cutting temperature, chip and dimensional accuracy in turning AISI-1040 steel", Journal of Materials Processing Technology, Vol. 171, 93-99.

[12] Rahman, M., Senthil Kumar, A. and Salam, M. U. (2002). "Experimental evaluation on the effect of minimal quantities of lubricant in milling", International Journal of Machine Tools & Manufacture, Vol. 2, 539-547.

[13] Varadarajan, A. S., Philip, P. K. and Ramamoorthy, B. (2002). "Investigations on hard turning with minimal cutting fluid application (HTMF) and its comparison with dry and wet turning", International Journal of Machine Tools & Manufacture, Vol. 42, 193-200.

[14] Moriwaki, T., Shibasaka, T. and Somkiat, T. (2003). "Chip control on CNC turning", Proceedings of The Japan Society for Precision Engineering, Kansai Branch Conference, 117-118.

[15] Moriwaki, T., Shibasaka, T. and Somkiat, T. (2004). "Development of in-process chip-breaking detection system in turning", Memoirs of graduate school of science and technology, Kobe University, 1-19.

[16] Teti, R., Jawahir, I. S., Jemielniak, K., Segreto, S., Chen, S. and Kossakowska, J. (2006). "Chip form monitoring through advanced processing of cutting force sensor signals", Annals of the CIRP, Vol. 55, No. 1, 75-80.

[17] Jawahir, I. S., and Luttervelt, C.A. (1993). 'Recent developments in chip control research and applications', Annals of the CIRP, Vol. 42, No.2, pp. 659-685.

[18] Kennametal GmbH & Co.KG. (2007). 'Lathe Tooling Catalog', pp. 54.

[19] Childs, T. H. C. (2006). "Friction modeling in metal cutting", Wear, Vol. 260, 310-318.

[20] Tasdelen, B., Thordenberg, H. and Olofsson, D. (2008). "An experimental investigateion on contact length during minimum quantity lubrication (MQL) machining", Journal of Materials Processing Technology, Vol. 203, 221-231.

[21] Anselmo, E. D., and Ricardo, M. (2002). "Cutting conditions for finish turning process aiming: the use of dry cutting", International Journal of Machine Tools & Manufacture, Vol. 42, 899-904.

[22] Thomas, M. and Beauchamp, Y. (2003). "Statistical investigation of modal parameters of cutting tools in dry cutting", International Journal of Machine Tools & Manufacture, Vol. 43, 1093-1106.

[23] Abdelmoneim, M. ES. and Scrutton, R. F. (ASME, 1974). Tool edge roundness and stable built-up formation in finish machining, pp. 1258-1267.

JOURNAL OF MECHANICAL ENGINEERING (JMechE)

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Footnotes should be kept to an absolute minimum and used only when essential.

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Formulae should be typewritten using MS Word compatible Equation Editor.

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Authors should appreciate the importance of good-quality illustrations. All graphs and diagrams should be referred to, for example, Figure 1 in the text. All figures must be numbered consecutively with Arabic numerals. A detailed caption should be provided below each figure according to the following format:

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Figures should be embedded within the text where appropriate. Glossy photographs when required should be scanned to a resolution suitable with the reproduction requirements (1200 dpi generally will be sufficient).

References

Use squared brackets to indicate reference citation such as [1], [3]-[5] in the main text. Include references at the end of the paper according to the citations order that appears in the paper using the following format.

[1] M. K. Ghosh and A. Nagraj, "Turbulence flow in bearings," Proceedings of the Institution of Mechanical Engineers 218 (1), 61 - 64 (2004).

[2] H. Coelho and L. M. Pereira, "Automated reasoning in geometry theorem proving with Prolog," J. Automated Reasoning 2 (3), 329-390 (1986).

[3] P. N. Rao, Manufacturing Technology Foundry, Forming and Welding, 2nd ed. (McGraw Hill, Singapore, 2000), pp. 53 – 68.

[4] Hutchinson, F. David and M. Ahmed, U.S. Patent No. 6,912,127 (28 June 2005).