UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Investigate the Influence of Cutting Fluids Direction to the Tool Life

Thesis submitted in accordance with the requirements of the
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Bachelor of Engineering (Honors) Manufacturing (Process)

By

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DECLARATION

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ABSTRACT

Heat has critical influences on machining (Tlusty, 2000). Tool life is a measurement of how long an individual edge can effectively hold up to the temperatures and pressures that are generated in the cutting zone. This study is basically focused on the effect of the direction of cutting fluid on tool life. By varying the position or direction of the cutting fluid (stream line) towards cutting tool, the influence of the direction will results many effect on cutting tool. The observation on the flank surface of cutting tool is the main findings on relating the direction of the cutting fluid with tool life.

Commonly, fluids are directed to the workpiece as the rotating movement of workpiece will drive the fluids along the cutting operation. But, better penetration into the tool-workpiece and tool-chip contact regions could be achieved if the two (2) suggested cooling conditions (nose radius face and flank face) are applied. These two cooling condition if applied, should provide a better cooling effect and decreasing tool wear through lubrication of the contact areas.

Typically, maximum flank wear, VB_{max} is the medium of ensuring the failure of the tool (carbide insert). By using an image analyzer, result of each direction applied may lead to the tool effectiveness. Apart from that, the measurement of crater wear also being observed as well as the volume of material removed from the turning operation of AISI 1045 steel bar. The discussion on crater wear, flank wear measurement and other wear pattern based on scanning electron microscope analysis are some of the factors involved on determining the wear mechanism of the cutting tool.

Keywords: Directions of Cutting Fluids, Maximum Flank Wear, Wear Pattern

ABSTRAK

Haba mempunyai pengaruh yang kritikal semasa memesin (Tlusty, 2000). Hayat alat ialah pengukuran betapa lama sesuatu sisi sempadan boleh bertahan secara efektif terhadap suhu dan tekanan terhasil dalam zon pemotongan. Kajian ini secara ringkasnya difokuskan pada kesan arah cecair pemotongan terhadap hayat alat. Dengan mempelbagai posisi atau arah cecair pemotongan (garis aliran) terhadap alat pemotongan, pegaruh arah akan memberi banyak kesan terhadap alat pemotongan. Pemerhatian pada sisi permukaan alat adalah penemuan utama dalam megaitkan arah cecair pemotongan dengan hayat alat.

Kebiasaannya, cecair diarahkan ke benda kerja dan pergerakan memutar benda kerja akan membawa cecair sepanjang operasi pemotongan. Tetapi, penembusan ke dalam alat-benda kerja dan kawasan bersentuhan alat-serpihan yang lebih baik akan tercapai jika dua (2) arah cadangan (nose radius face and flank face) di gunakan. Dua keadaan penyejukan ini jika digunakan, sepatutnya memberi kesan penyejukan yang lebih baik dan melambatkan kehausan alat melalui pelinciran pada kawasan bersentuhan.

Secara biasanya, haus sisi maksimum, VB_{max} adalah medium untuk memastikan kegagalan alat (carbide insert). Degan menggunakan penganalisa imej, keputusan bagi setiap arah penggunaan akan membawa kepada keefektifan alat. Selain itu, pengukuran haus kawah juga diperhatikan bersama dengan berapa banyak bahan dikeluarkan daripada operasi 'turning' pada benda kerja AISI 1045 steel. Perbincangan pada haus kawah, pengukuran haus sisi dan bentuk haus yang lain dianalisa melalui 'scanning electron microscope' adalah merupakan faktor-faktor terlibat dalam menentukan mekanisma haus bagi alat pemotongan.

Kata kunci: Arah Cecair Pemotongan, Haus Sisi Maksimum, Bentuk Haus

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

AISI	-	American Iron and Steel Institute
BUE	-	Built-up edge
HPC	-	High-pressure coolant
MRR	-	Material Removal Rate
SEM	-	Scanning Electron Microscope
VB	-	Average flank wear
VB_{max}	-	Maximum flank wear

CHAPTER 1

INTRODUCTION

1.0 Background of Project

Since the beginning of the 20th century, when F.W. Taylor used water for the first time to cool the machining process and concluded it increased tool life, a large variety of cutting fluids has been used with this and other purposes. Regarding to this idea, the planning of producing an investigation of directed cutting fluid on turning steel AISI is considerably a good improvement in order to increase tool life.

Machining is inherently characterized by generation of heat and high cutting temperature. At such elevated temperature the cutting tool if not enough hot hard may lose their form stability quickly or wear out rapidly resulting in increased cutting forces, dimensional inaccuracy of the product and shorter tool life. The magnitude of this cutting temperature increases, though in different degree, with the increase of cutting velocity, feed and depth of cut, as a result, high production machining is constrained by rise in temperature. This problem increases further with the increase in strength and hardness of the work material.

(Reed and Clark, 1983) reported that the hardness, plastic modulus and the fracture toughness of the tool decline with increase in cutting temperature, which accelerates tool wear rate. Moreover, thermal stresses in the tool increase with the temperature resulting in more cracks in the tool and premature failure of the tool. The high cutting temperature also causes mechanical and chemical damage of the finished surface.

The high specific energy required in machining under high cutting velocity and unfavourable condition of machining results in very high temperature which reduces the dimensional accuracy and tool life by plastic deformation and rapid wear of the cutting points (Chattopadhyay and Chattopadhyay 1982 and Singh et al. 1997). On the other hand such high temperature, if not controlled, impairs the surface integrity of the machined component by severe plastic flow of work material, oxidation and by inducing large tensile residual stresses, micro cracks and subsurface cracks. This problem is further intensified while machining for faster material removal in bulk and finishing very hard, strong and difficult-to-machine materials, which are gradually adventing with vast and rapid developments in the modern areas, like aerospace technology and nuclear science.

High cutting zone temperature is conventionally tried to be controlled by employing flood cooling by soluble oil. In high speed-feed machining conventionally applied cutting fluids fail to penetrate the chip-tool interface and thus cannot remove heat effectively (Shaw et al. 1951, Merchant 1958, Dhar 2003, Islam 2005). Addition of extreme pressure additives in the cutting fluids does not ensure penetration of coolant at the chip-tool interface to provide lubrication and cooling (Cassin and Boothroyed 1965). In 1997, in high speed machining of inconel and titanium alloys, cutting fluids failed to reduce cutting temperature and improve tool life effectively (Kitagawa et al. 1997). However high pressure jet of soluble oil, if applied at the chip-tool interface, could reduce cutting temperature and improve tool life to some extent (Mazurkiewicz et al. 1989). In machining ductile metals even with cutting fluid, the increase in cutting velocity reduces the ductility of the work material and causes production of long continuous chips, which raises the cutting temperature further (Nedess and Hintze 1989).

The main objective of this work is to understand how the tool wear mechanism are influenced by the direction of the fluid's flow in finish turning of AISI 1045 steel using coated carbide tools. The main finding was that when cutting fluid was applied to the tool rake face, the adhesion between chip and tool was very strong, causing the removal of tool particles and large crater wear when the adhered chip material was removed from the tool by chip flow. The variation of fluids direction is investigates in order to asses the tool life while turning the workpiece until it reaches the maximum flank wears.

1.2 Problem Statement

This investigation is to determine the wear occurs in each direction applied to the turning process. By varying the direction of the cutting fluid, the optimum tool life is probably obtained as the purpose of this study is to investigate the tool life of carbide cutting tool influenced by the direction of cutting fluid.

The temperature at the contact between the chip and the tool and, in general, in the tool tip is one of the most decisive factors for toll wear rate, and it plays an important role in the machinability of various workpiece materials (Tlusty, 2000). Apart from that, the consideration of selecting cutting tool also contributes to the effectiveness of the process. Also, the design of the nozzle gives better penetration on the cutting area, thus the lubricating action is applied to the tool-chip interface.

The application of cutting fluid is supposedly reducing the temperature generated on the interfaces area (cutting zone area) and thereby will extend the life of the tool (Anselmo and Ricardo, 2006). Since the use of cutting fluid is still provides longer tool lives than dry cutting, attempts should be made to know the effect of directing the fluid to specific contact region.

1.3 Project Objective

There are three (3) main objectives that have to be in consideration in this investigation:

1. To investigate the tool life of carbide cutting tool influenced by the direction of cutting fluid.
2. To measure time consumed while the tool reaches its failure by varied direction of cutting fluid.
3. Determining the most effective cooling condition (direction of application).

1.4 Scope of project

By directing the fluid to the selected area (flank face and nose radius), tool life is believed to increase with application of right pressure and flow rate. Therefore, the study of the direction of cutting fluid is important in order to elevate the working efficiency, enhance accuracy of product, protect the service life of cutting tools, curtail working hours, and lower cost that makes it an efficient instrument to enhance the competitiveness.

The experiments will be carried out on conventional lathe machine using carbide tool on 1045 steel AISI. The cutting fluid that will be used is soluble cutting oil. The direction of cutting fluid that will be used; flank face and nose radius. Flank wear is then will be determined by time interval of 5 minute using Image Analyzer. Subsequent step of investigating the wear pattern is by using Scanning Electron Microscope (SEM), and this step is also to ensure the flank wear measurement has reach its failure margin (300 μm). These two apparatus is used to make comparison between the selected areas of the fluid stream. By this, tool wear rate is calculated and discussed by consequences from the wear mechanism and its behavior.

CHAPTER 2

LITERATURE REVIEW

As everyone knows, flood coolant does not do much good if the coolant stream is not aimed adequately at the point where the cutting tool is removing metal. Therefore, the method of applying the cutting fluid by directing it on certain area of the cutting zone is considered will be effective as it increases tool life. The benefits of keeping cutting fluid on target make substantial contributions to productivity. It minimizes the risk of damaging heat build-up in the work piece or cutting tool, thus preserving tool life.

Cutting fluid or coolant is liquid used to cool and lubricate the cutting edges of machine tools and the pieces they are shaping. It is pumped over the cutting site of machines such as lathes, milling machines, shapers and saws. Metal cutting operations involve generation of heat due to friction between the tool and the pieces and due to energy lost deforming the material. Water is a great conductor of heat but is not stable at high temperatures, so stability is often achieved by making an emulsion of water with oil.

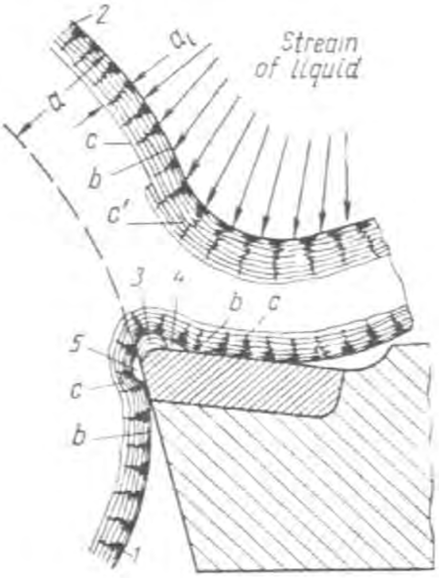

Figure 1: *Schematic diagrams illustrating the action of lubricating fluids in metal cutting. (V. Arshinov, G. Aleksheev, 1984)*

Cutting fluid affects not only the outer layers of the chip, but also the layer of metal contacting the cutting edge and the layer of the chip on tool side. In **Figure 1**, liquid reaches the tool surfaces and the zone of metal disintegration before the cutting edge through the voids *4* and *5* formed when built-up edge *3* breaks away and through vacuum micro-fissures originated as a result of the loosening and breaking of contact between the work and the tool (this being due to vibration).

Investigations (V. Arshinov, G. Aleksheev, 1984) show that each metal being machined and even each type of machining has its optimum cutting fluid, and that cutting fluids are most effective in machining tough, highly plastic metals subject to severe work-hardening. With an increase in uncut chip thickness and the cutting speed, the effect of cutting fluids is reduced insofar as the facilitation of chip formation is concerned.

2.0 Action of the cutting fluid

In order to increase tool life, consideration of cutting fluid is very crucial as mentioned by (William and Tyler, 1979) that cutting fluid must provide both a cooling and a lubricating action. These two criteria contributes to the wear of a cutting tool as well as the correlation of the influence of the directed of cutting fluid to the tool life. Several cutting condition and tool materials in rough and finish turning of AISI 1045 steel (Anselmo and Ricardo, 2006), it was found that turning with fluid results in longer tool life.

Cutting fluids not only promote reduction in heat evolution (by facilitating chip formation and reducing friction), but also absorb and carry away a part of the generated heat, thereby lowering the cutting temperature, **Figure 2**. The higher the specific heat and thermal conduction of the cutting fluid, the better the cooling effect will be.

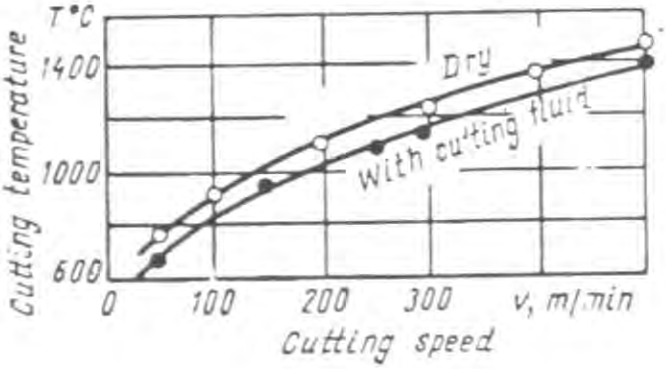

Figure 2: *Effect of the use of cutting fluid on the cutting temperature (steel 40; tool tip, grade T15K6; coolant – water, delivery-36 liters/min, water temperature--+10° C) (V. Arshinov, G. Aleksheev, 1984)*

The main functions of cutting fluids are:

- Lubrication at low cutting speeds;
- Cooling at high cutting speeds;

And less important:

- To help the chip removal of the cutting zone;
- To protect the machine tool and workpiece against corrosion.

At low cutting speeds, cooling is not very important, while lubrication is important to reduce friction and avoid the formation of built-up-edge. In this case, an oil based fluid must be used. At high cutting speeds, the conditions are not favorable to fluid penetration, to reach the interface and work as a lubricant. In these conditions cooling becomes more important and a water based fluid must be used.

As lubricant, the cutting fluid works to reduce the contact area between chip and tool and its efficiency depends on the ability of penetrating in the chip-tool interface and to create a thin layer in the short available time. This layer is created by either chemical reaction or physical adsorption and must have a shearing resistance lower than the resistance of the material in the interface. In this way it will also act indirectly as a coolant because it reduces heat generation and therefore cutting temperature.

It is neither completely clears how cutting fluid reaches this interface, nor how deep it can go. (Trent, 1967, 1991) says that the lubricant have no access to the seizure zone on the tool rake face. (Childs and Rowe, 1973) also affirms this theory and comments that further studies must be done in the chip-tool interface besides the difficulties encountered to access the seizure zone. (Postinikov, 1967) suggested that the lubricant penetrates against the metal flow, reaching the tool nose, through a capillary action, assuming that the contact in the interface is not total (sliding conditions). (Williams, 1977) supports this point of view. Some experiments with transparent sapphire tools (Horne, et al., 1978), demonstrated that the cutting fluid flow reaches the interface by the lateral parts of the contact, instead of moving against the chip flow. No matter the penetration method, cutting fluid, once in the interface, must form the lubricant layer with shearing resistance lower than the material resistance. It may also restrict the chip welding on the tool rake face, if suitable additives are used. The lubrication efficiency will depend on the fluid properties, such as: wet-ability characteristics, viscosity and layer resistance. These properties may be obtained with a suitable mixture of additives.

As coolers, cutting fluids decrease cutting temperature through the heat dissipation (cooling) When water based fluids are used cooling is more important than lubrication. It was experimentally proved (Shaw, et al., 1951) that the cutting fluid efficiency in reducing temperature decreases with the increase of cutting speed and depth of cut.

The cutting fluid ability of sweeping the chips away from the cutting zone depends on its viscosity and its volume flow, besides, of course, the kind of machining operation and chip type formed. In some machining operations such as drilling and sawing, this function is very important, because it may avoid chip obstruction and, consequently, tool breakage.

2.1 Applying the cutting fluid to the cutting process

(J. Kaminski and B. Alvelid, 2000) stated that conventional methods of fluid application are not very effective because the low-pressure jet hinders penetration in the interface, consequently increasing friction and temperature of the cutting zone. In the turning process, when directed fluid is applied with an increase in pressure makes it possible for the fluid to penetrate to the cutting-slide.

Investigations (W. M. Stocker, Jr. and T. Hicks, 1979) have shown that when turning with high speed steel tools, tool life can be doubled by applying cutting fluids at the tool flank rather than by conventional flooding, and carbide tool life could be