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A Study On Chip Formation Using Minimum Quantity Lubrication (MQL) Technique

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Abstract: Metal removal process is a process of removing amount of material from a work piece to get the desired shape. For metal removal process, there are some machines that commonly can be in fabrication workshops such as milling machine, drilling machine, and lathe machine. Turning machine is a machine that used to perform removal process to create cylindrical-shape products. The problem situations which related in this study is about the chip formation characteristics using MQL technique. Minimum Quantity Lubrication (MQL) technique in turning process is a workflow methodology designed to increase efficiency of the cutting process by applying coolant at the surface of the tool and work piece in order to prevent fracture of the tools as recommended in good cutting process. This technique is used to study the chip formation characteristics after the cutting process with the MQL coolant. Machining parameters included in this chapter are the main indicators which decide the process, the procedure of the experiment and also the effect after the experiment. The parameters used for the study are cutting speed, feed rate and depth of cut. Comparison between flood cutting and MQL cutting will be explained with data obtained from the previous researcher based on the parameter such as cutting speed, feed rate and depth of cut. The parameters will give effect to the work piece and cutting tool. This thesis written reviewed study because the method used in order to study the chip formation characteristic using MQL technique is reviewing journal. A study on chip formation with various machining patterns and also tool wear conditions will be explained in this study.

Keywords: Turning Process, Chip Formation Characteristics, MQL, Flood, Parameter, Cutting Speed, Feed Rate, Depth Of Cut

1. Introduction

Basically, turning machine is a machine that used to perform removal process to create cylindrical-shape products. The common method used when performing a turning process is by orthogonal cutting. Orthogonal cutting defined as the position of the cutting tool is perpendicular to the direction of the work piece. This cutting process will allow the procedure to deal with stresses and strains that act in a plane. There are some terms related with the orthogonal cutting as stated which are rake angle, the shear

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angle, tool-chip contact length, chip thickness and chip formation. By definition, Rake angle, γ is defined as the angle between the cutting face of the tool and the line perpendicular to the work piece [1]. For shear angle, shear angle is the accepted plane along which shearing takes put and the angle of inclination between the shear plane and the cutting velocity vector. Tool-chip contact length is the distance over which a continuous chip flows over the tool rake face while maintaining contact tool [2] and chip thickness is the layer removed at wheel speed during turning process.

For this study, the turning process is applied to cut the cylindrical shape product used which is AISI 1045 in order to study the chip formation characteristics after cutting. Chip formation occurs during the orthogonal cutting between the tool and the work piece. The product from the cutting which are the leftover from the cutting is called chip. Several types of chip can be obtained due to different machining parameters occurred during the cutting process. Examples of types of chips formed are continuous chip, discontinuous chip and continuous chips with built up edge (BUE). In addition, cooling technique Minimum Quantity Lubrication (MQL) is applied during the cutting process. MQL is a cooling technique which uses cutting lubricant mixed with compressed air with some certain speed and sprayed to the cutting area during the machining process. Another example of cooling technique is flood cutting. Flood cutting is the conventional method of chilling the cutting zone is using cooling agents, delivered at the cutting zone in an excess amount [3]. Two different cooling techniques which are MQL and flood cutting is compared in this case of study in terms of chip formation and also the parameters used by previous researcher when carrying out the experiment which are cutting speed, feed rate and depth of cut.

1.1 Background of study

For this thesis, the method that being used is turning machining process. There are some criterions that have to be focused on when carry out the turning machining process are the cutting technique, the parameters during the turning process and most importantly the cooling technique that been used in order to study the chip formation characteristics. Hence, the aim of this study is to identify the characteristics of chip formation produced using minimum quantity lubrication (MQL). Cooling technique is very important in whatever types of machining process because of their benefits itself for example, in order to reduce friction between cutting tools and work piece and also reducing heat on the tool to prevent microstructure deforming. MQL is a cooling technique which uses cutting lubricant mixed with compressed air with some certain speed and sprayed to the cutting area during the machining process. MQL is a simple technique and also considerably lowest cost technique. The lubrication used in MQL can be from bio-based oils or some renewable sources.

The chip formation produced during the cutting process are the best indicator to identify either this technique is the most efficient way to being used in the cutting process or not because different chip formation produced shows different characteristics of the chip formation and also we can identify the characteristics of the method itself. During the cutting process, contact between the tool and the work piece create some sort of heat energy through the friction itself. The heat flow during the cutting is dependent on this contact length with larger contact lengths causing more heat dissipated into the tools. There are some factors which causing the problem during the cutting process which are, the tool material, tool geometry, work piece material, machine tool stability, cutting operation type and cutting parameters [4]. Chip thickness is affected by the frictional conditions existing at the chip-tool interface. The existence of lubricating medium between the tool and work piece is very important because when the cutting process is carrying on, the friction at the shear zone will causing excessive heat, so, the purpose of having this lubricating medium is to minimize the heat occurred between the tool and work piece. There are also some parameters which may affect the chip formation characteristics which are cutting speed, feed rate and also depth of cut. The aim of identifying the problem statement for this study is because the effect of different parameters can give a different result in order to identify the chip

formation pattern or even the chip formation characteristics. Therefore, the objectives of this study are: -

1) To identify the relation between machining pattern and chip pattern in MQL technique
2) To compare between flood cutting and MQL technique in terms of chip formation characteristics.

2. Methodology

A systematic review in methodology method or we called it Scopus method is a systematic review of the evidence on a clearly formulated question that uses systematic and explicit methods to observe, identify and appraise the relevant primary research. This method used to extract and analyze data from the previous study which included in the review. Some information from previous research about the project is collected and from the information, the problem statement is defined. The sources of the findings for the research is carried out by using the medium and facilities including the internet and also the research found from the previous researcher. One of the example of where the source is found out is by using Google Scholar and also Science Direct. In order to find the required and related to the topic study, some keywords are used in the website listed. The review overall procedure can be performed by using the flowchart method. The method which allows the study to a systematically process where it use to create mathematical models of the samples being processed [5]. Figure below shows the flow chart of methodology in this study.

3. Results and Discussion

The study is based on the previous researcher regarding the related topic which are the study of the chip formation characteristics using MQL technique. Work piece material used by the previous researcher in their experiment are the same which are AISI 1045. Table below shows the previous study cases according to the related topics, included in the table are the title of the study, the author and the year published, the parameters used in the experiments and also the results obtained by each researcher.

Table 1: Previous study of chip formation using MQL technique

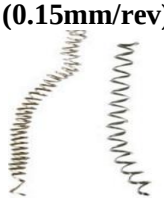
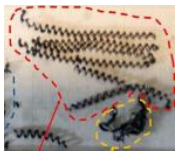
Title	Author	Parameters	Chip Formation (MQL)
[6]	(Mithu,2008)	V_c=(72,94,139,164)m/min f_r=(0.10,0.013,0.160.20)mm/rev D =1.5mm	 **Figure 1: Ribbon shape chip**
[7]	(Sumaiya,2017)	V_c=(700,420,300)m/min f_r =0.15mm/rev D =(1.0,1.5)mm	 **Figure 2: Chip formed (MQL)**
[8]	(Kaynak,2017)	V_c=(20,60,120,210)m/min D =0.1mm	 **Figure 3: Chips formed (120m/min)**

[9]	(Kaynak,2018)	V_c=(30,90,120,150,210)m/min f_r =0.15mm/rev D =1.2mm	 **Figure 4: Chips formed (120m/min)**
[10]	(Nizamuddin,2018)	V_c=(100,125,150,175,200)m/min f_r=(0.1,0.15,0.20,0.25,0.30)mm/rev D =(0.5,0.75,1,1.25,1.5)mm	 **Figure 5: Chips formed (0.15mm/rev)**
[11]	(Khanna,2020)	V_c=130m/min f_r =0.222mm/rev D =1mm	 **Figure 6: Chip formed (MQL)**
[12]	(Rika,2020)	f_r =0.108mm/rev D = 1.5mm	 **Figure 7: Continuous and snarling chips**

As the review is carried out, the results from the researched experiments have been obtained and compared between two different cooling technique which are flood cutting and MQL cutting by different experiment from previous study which have the same purpose in common which is to study the chip formation using flood cutting and MQL technique. Table below shows the comparison deducted from using the flood cutting and MQL technique in terms of chip formation characteristics by researchers.

Table 2: Chip formation comparison between flood cutting and MQL technique

Title	Author	Chip formation (Flood)	Chip Formation (MQL)
[6]	(Mithu,2008)	 **Figure 8: Spiral shape chip**	 **Figure 9: Ribbon shape chip**
[7]	(Sumaiya,2017)	 **Figure 10: Chip formed (flood)**	 **Figure 11: Chip formed (MQL)**

[8]	(Kaynak,2017)	 **Figure 12: Chips formed (120m/min)**	 **Figure 13: Chips formed (120m/min)**
[9]	(Kaynak,2018)	 **Figure 14: Chip formed (120m/min)**	 **Figure 15: Chips formed (120m/min)**
[10]	(Nizamuddin,2018)	 **Figure 16: Chip formed (0.15mm/rev)**	 **Figure 17: Chips formed (0.15mm/rev)**
[11]	(Khanna,2020)	 **Figure 18: Chip formed (flood)**	 **Figure 19: Chip formed (MQL)**
[12]	(Rika,2020)	 **Figure 20: Chip formed (flood)**	 **Figure 21: Continuous and snarling chips**

4. Conclusion

In conclusion, two different cutting techniques is compared in order to identify the chip pattern and the chip formation characteristics after cutting process. The flood cutting mechanism is by allowing the cutting fluid to come out of a nozzle in the form of liquid jet to immerse the entire cutting zone. The main functions of cutting fluid in machining operations are reduction of tool and work piece temperature and reduction of heat generation by decreasing the friction coefficient between tool and chips, which minimizes cutting forces as well as tool and piece heating [13]. For MQL, it is the process of applying minute amounts of high-quality lubricant directly to the cutting tool and work piece interface. MQL lubricants are mostly consumed in the cutting process. The situation occurred during the cutting process is the friction and heat in the interface vaporizes the small amount of lubricant and leaves cutting tools, parts, equipment and floors dry and clean. Temperature reduction at the cutting zone is achieved by its evaporation and vaporization, which differs from flood cutting application [14].

Based on the researched [12], a study of chip formation on turning with Minimum Quantity Lubrication (MQL) have been made. The machining parameters that been used in order to carry out the experiment are spindle speed (585 rpm), feed rate (0.108 mm/rev) and depth of cut (1.6,1.8,2 mm). The results for the chip formation are shown in the figure below.

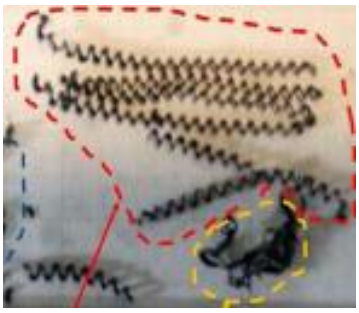


Figure 23: Chip formation using flood cutting [12]

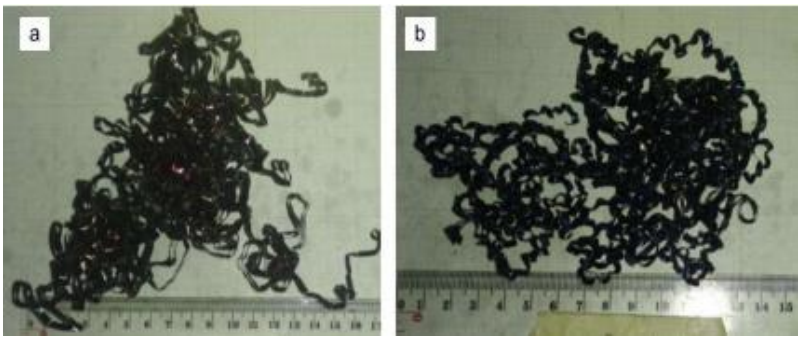


Figure 24: Chip formation using MQL technique [12]

The results for the chip formation shown above are from the flood cutting and MQL cutting technique. For the flood cutting technique, it is clearly seen that the chip formation produced are long chips and continuous chips while for the MQL cutting technique is clearly seen that the chip formation produced for the MQL technique are long, snarling and continuous chips. Flood cooling seems to be much better in terms of chip breakability at higher speed and the most desired chips are obtained by using flood cutting technique compared to MQL [9]. MQL cutting seems to be the least effect to the chips formation because the usage of MQL coolant is the most efficient in term of fluid lubrication consumption [12]. From the result obtained, some comparisons have been made which conclude the experiment from the previous study. Comparisons are as followed: -

a) The chip formation produced are long chips and continuous chips [9].
b) The smooth wear pattern was observed on the flank face for MQL condition while the crack propagation was observed for the flood machining [11].
c) The chip formation produced are long, snarling and continuous chips for MQL technique [12].
d) The presence of MQL designed with the objective to provide and optimal lubrication [15].
e) MQL machining technique was found to be more superior than flood condition [16].
f) By visual, tool wear under flood condition shows more aggressive (rough surface) when compared to MQL [17].

The objectives of the study have been achieved which are to identify the relation between machining pattern and chip pattern in MQL technique and to compare between flood cutting and MQL technique in terms of chip formation characteristics. As recommendation for the future researcher, in order to enhance the identification of chip formation after cutting process, use MQL lubricants which have refined bio-based (plant) oils and are completely for skin contact as well as having the extra benefit of coming from renewable, environmentally-friendly material. It is important for the cutting tool parts work piece as it will be not requiring any cleaning before secondary operations take place. It is because, when the lubrications are consumed, there is no disposal required and no extra equipment is necessary for fluid reclamation. The chips from the cutting process with the MQL are virtually dry and can be

recycled without cleaning and for greater profit. MQL technique contribute a lot in machining process by giving the best surface integrity compared to dry or flood cutting mechanism.

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