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Study of Cutting Force When Milling SKD61 Steel Using Minimal Lubrication of Sesame Oil

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Abstract— *This study focuses on evaluating the influence of SKD61 steel milling process parameters using CBN tools on the cutting force components when milling. The milling process used minimum quantity lubrication (MQL) emulsion, sesame oil and dry machining for control evaluation. Components of cutting force when milling are measured by a 3-component shear force measuring device of Kisler, Switzerland. Experiments are carried out with the plain milling process, the workpiece is mounted on the ETO. The cutting process was surveyed for more than 50 minutes. Initial results show that the cutting force increases slowly when the cutting process is done up to 30 minutes (increasing about 100N). After this period, with all cooling lubrication methods, the force increases sharply. However, the cutting force when using cooling lubrication is lower than in dry machining; The process of using sesame oil MQL results in the lowest, slowest, and most stable cutting force. This shows the positive effects of the cooling lubrication process, especially the sesame oil MQL process, on the cutting force components during milling.*

Keywords— *Sesame oil MQL, lubrication methods, cutting force.*

I. INTRODUCTION

Machining of hard materials is applicable to machining materials with a hardness of 45HRC or more. In 1988, Nakayama and colleagues at Yokohama University, Japan, (1) published their research results, demonstrating the difference between traditional machining technology and high hardness material processing technology. Scienfically, this work has made a significant contribution to further studies of hard material processing technology in general and hardened steel milling technology in particular. Milling is widely used to machine parts such as bearing rings, nozzles and parts of hydraulic systems. In the past, these details, after heat treatment, often had to go through grinding or sharpening, often making it inflexible and time consuming. Moreover, the low cutting productivity coupled with the cost of coolant makes grinding operations expensive. Also, the grinding waste is becoming an environmetal problem. Milling can reduce the depth of the hardening layer more than grinding (2), create residual compressive stress on the surface layer after machining to increase the fatigue strength of the machine parts (3). For these reasons, milling is becoming an alternative to grinding.

However, determining the cutting force in the hard milling process is one of the important factors to evaluate the related effects: thereby assessing the amount of wear of the cutting tools, assessing the microscopic undulation of the surface. Therefore, it is essential to determine the cutting force components in the milling process, assess the influencing parameters and provide solutions to reduce the cutting force.

Using cooling lubrication methods is one of the effective solutions to reduce the cutting force when machining. In the past, cooling lubrication solutions made from petroleum were popular. However, due to its adverse effects on the environment(4), now using cooling lubrication solution with vegetable oil and ester in cutting processing is increasingly prevailing. The use of vegetable oils in cutting can reduce harmful effects on workers' health (5, 6). The results show that vegetable oils using cooling lubrication have the same or even more positive effects than industrial oils on the quality of processed products and limit environmental pollution (7).

Minimum Quantity Lubrication (MQL) is a method that uses the cooling lubrication mechanism by injecting a high-pressure compressed coolant solution into the machined area. The different properties of dissolution mechanism of the lubricating fluid in this condition have created a different mechanism of penetration into the machined area from the traditional cooling lubrication methods. As a result, MQL technology has shown many advantages in both lubricating and cooling when processing of high hardness materials.

These advantages include reducing the cutting force and cutting heat, reducing tool wear, reducing tool stumbling thereby increasing productivity, improving the surface roughness of the workpiece, increasing the durability of cutting tools, increasing machining accuracy. Last but not least, it is not harmful to the environment and human health.

For the reasons mentioned above, I conducted an experiments to evaluate the effects of MQL parameters on the cutting process. Within the scope of this topic, the evaluation mainly focuses on the influence of MQL using sesame oil on cutting force when milling hardened steel SKD61.

II. EXPERIMENTAL SETUP

A. Used Devices

The experiments were carried out on a Japanese milling machine DMG-MORI DMU-50. Workpieces were made of SKD61 Steel. The size of the workpiece have a length of L = 150 mm, a width of 10 mm, a height of 30 mm. The billet has a hardness of 46 ÷ 50 HRC. End milling cutter, cutting piece made of CBN material SEKN1203AFFN (KYOCERA brand), made in JAPAN. The blade has the following angles: coner radius 0.8mm, lead angle=45°, relief angle=7°,

The mist-smooth liquid-forming system included equipment for compressing and mixing the solution. Compressed air was supplied to the compressor through Taiwanese STARY air compressor (Maximum compressed air

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pressure 16kg/cm2). The pressure measuring device used was the measuring sensor NA 321- Novaka, made in UK. Before sprayed into the cutting area, the solution was mixed evenly through the NOGA spray mixing equipment, made in Germany. Spray flow was determined through a flow divider with a clock.

MQL solution of sesame oil is produced in Vietnam. Sesame oil, is composed of unsaturated fatty acids accounts (33%), linolic (C18:2)13 (63%). MQL Emulsion solution is a mixture of Emulsion mixed with 10% distilled water. Emulsion solution is a type of cooling lubrication solution made in China

The experimental model was performed as shown in Figure 1. The workpieces were mounted on the ETO. After that, the they were checked and rough machined in order to limit the influence of changes in cutting depth when the experiments were conducted.

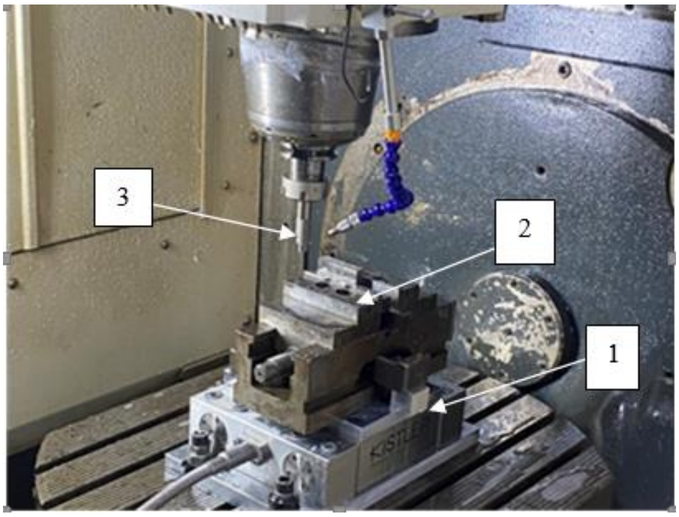

Figure 1. 1. Force measuring device(9257B), 2. Workpiece, 3. Nozzle MQL, 4. Cutting tools.

The respective experiments were performed with dry machining, MQL using Sesame Oil and emulsion mixed with 10 % distilled water (DI Water) having parameters listed in Table 1 below.

TABLE 1. The characteristic parameters of MQL used in the experimental process

Quantity	Specifications
Compression	5at
Solution forming temperature	25oC
Spray flow	5ml/Min

The cutting force was measured by a dynamometer (9257B) of Kisler, made in Switzerland. The dynamometer uses a 3-component sensor type 9602, a type of piezoelectric sensor. During the experiment, the cutting force measurement data is automatically collected and saved to the computer using DasyLab10.0 software.

III. Results and Discussions

The results of measuring the components of cutting force over machining time using different cooling lubrication methods are presented in Figures 2, 3 and 4. The cutting force Fy during dry machining increased rapidly in the first 30 minutes, while these force in MQL using emulsion and MQL using sesame oil increased more slowly.

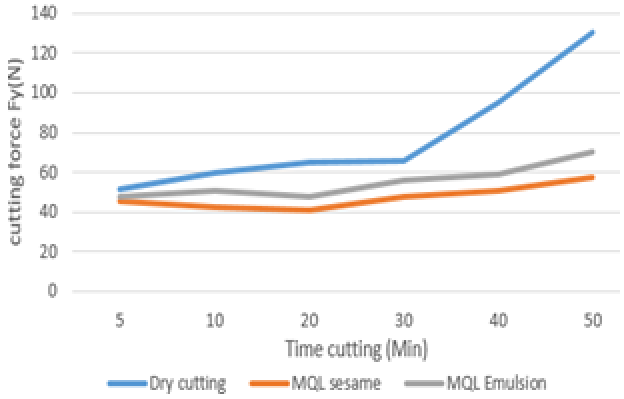

Figure 2. Relationship between Fy and τ when dry cutting and changing MQL solution

Similarly, the Fx component in dry machining increases rapidly, while Fx component in the machining methods using cooling lubrication increases slowly (Figure 3). However, the difference was only evident in the cutting time after the first 30 min.

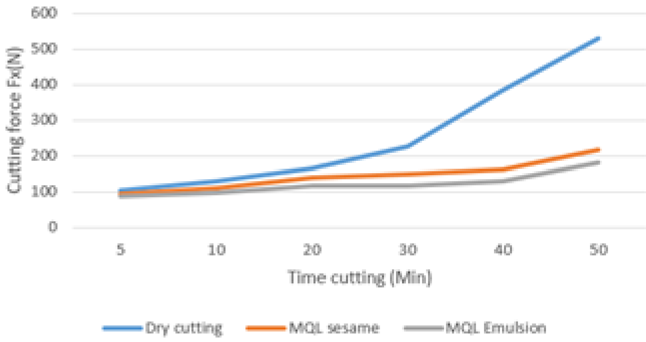

Figure 3. Relationship between Fx and t when dry cutting and changing the MQL solution

The results show a significant difference in cutting force Fx, when using different cooling lubrication methods, as demonstrated in Figure 4. As can be seen, the MQL method using sesame oil is more efficient than the other two machining methods.

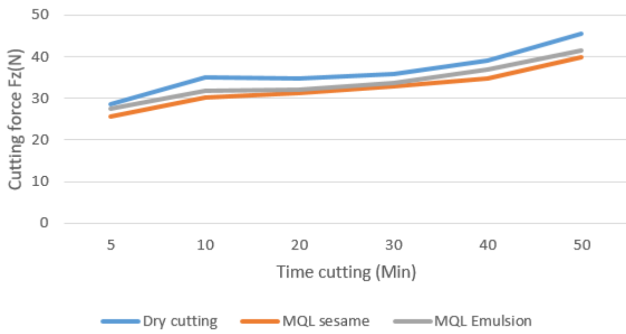

Figure 4. Relationship between Fz and τ when dry cutting and changing the MQL solution

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The influence of MQL methods on reducing tool wear and surface roughness during machining has been proved in many studies (5, 7, 8). In the machining process, the amount of tool wear greatly affects the increase in cutting force, increase in machining heat, causing machining errors and adversely affecting the surface quality of machine parts. As can be seen in Figures 2, 3 and 4, the results confirm those of the previous research. Indeed, when cutting tools wear out, their geometric parameters change, the sharp angle of the tool reduces, the contact surface between the cutting tool and the work piece increases. These obviously increases the cutting force.

The results of determining the cutting force components Fz, Fy, and Fx all show that cooling lubrication decrease cutting force. What is noteworthy is that the MQL method using sesame oil is the most effective method to reduce the cutting force. This shows the role of sesame oil in lubricating and cooling when machining.

When using the MQL method, the solution is compressed and mixed under high pressure before being sprayed into the cutting area. With this method, thanks to the solution applied to the chip-tool, tool-workpiece, their contact surfaces are improved. It is a condition to reduce the friction between the front of the tool and the back of the chip as well as the back of the tool with the machined workpiece surface, increase the ability of chip escape, reduce the chip shrinkage, and reduce the relative slip coefficients. These positive effects will be a direct condition for reducing the heat generated in the cutting area. Reducing heat is a factor to ensure stable machining accuracy, increase tool life, reduce hardening layer depth and surface residual stress.

The outstanding advantage of sesame oil can be explained through its ability to mix and save air bubbles inside them. The gas-liquid combination reduces the viscosity of the lubricating fluid and thus increases the ability to penetrate very small gaps in the cutting area that cannot be achieved by the traditional cooling lubrication method. This is evaluated and explained through the study of the machining process using MQL by Liao and Lin(9) and other basic studies.

In this study, the MQL method using sesame oil showed positive effects as it markedly help reduce cutting forces, which proves their lubricating and cooling capabilities. Other related effects need to be studied further.

IV. CONCLUSION

When conducting the milling process using sesame oil MQL, some features of the milling process show:

The components of the cutting force in milling are distributed according to the rules and are influenced by different cooling lubrication methods.

The cutting force when using cooling lubrication is lower than that of dry machining; especially the process using sesame oil MQL results in the lowest, slowest and most stable cutting force. This confirms the lubricating and cooling ability of sesame oil during processing. Using sesame oil MQL has the effect of reducing the cutting force components when milling clearly and stably.

The study proposes that Vietnam could focus on researching available vegetable oils for use in order to improve quality and lower product costs, then apply them to mass machining processes nationwide and introduce them to customers regionally and worldwide. Successful research will be the scientific foundation and motivation for businesses to use Vietnam's vegetable oil to save foreign currency and consume farmers' products, contributing to environmental protection and sustainable development.

REFERENCES

[1] Nakayama K., Arai M.,Kanda T., Machining Characteristics of Hard Materials, CIRP Annals - Manufacturing Technology, pp. 89-92,1988.
[2] J. Paulo Davim, Machining of Hard Materials, Springer London Dordrecht Heidelberg New York, pp. 90-100, 2010.
[3] Guo Y. B., Sahni J., A comparative study of hard turned and cylindrically ground white layers, International Journal of Machine Tools and Manufacture, pp. 135-145, 2004.
[4] Atkins T, The Science and Engineering of Cutting, Amsterdam: Butterworth-Heine-mann, pp. 130-140, 2009
[5] Schwach D. W., Guo Y. B., A fundamental study on the impact of surface integrity by hard turning on rolling contact fatigue, International Journal of Fatigue, vol. 28, pp. 38-44, 2006.
[6] Rahim E. A., Sasahara H., *A study of the effect of palm oil as MQL lubricant on high speed drilling of titanium alloys*, Tribology International, vol. 44, pp. 309-317, 2011.
[7] Lorincz J., *The Right Solutions for Coolant*, Manufacturing Engineering, vol. 39, pp. 89-96, 2007.
[8] Liao Y. S., Lin H. M., *Mechanism of minimum quantity lubrication in high-speed milling of hardened steel*, International Journal of Machine Tools and Manufacture, vol. 47, pp. 60-66, 2007.
[9] Davies MA, Burns TJ, Evans CJ, On the dynamics of chip formation in machining hard metals. CIRP Annals – Manufacturing Technology, vol. 46, pp. 25–30, 1997.