EXPERIMENTAL STUDY ON THE ALUMINUM ALLOY 7075 DURING TURNING UNDER DRY AND MINIMAL QUANTITY LUBRICATION CONDITIONS

BY

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ABSTRACT

Aluminum alloys Al7075-T651 is non-ferrous metal with great properties of light in weight and high strength which offers wide opportunity to wide range of applications. Currently, Al7075-T651 is used to manufacture components, gear and shaft in various industries such as automotive, aerospace and military. The rise of cutting temperature during machining in the manufacturing of the components contribute to the deterioration in the surface integrity of aluminum alloys. Ductility is one of the characteristics of the material that contributes to built-up-edge (BUE) and built-up-layer (BUL) on the cutting tool. The continuous formation of BUE in cutting operation alters the geometry of the cutting tool and consequently accelerates the tool wear progression. Chips produced during machining are simultaneously affecting the machining performance. Intensity of the BUE in dry machining not only contributed to different types of wear on the cutting tool but also lead to poor surface finish of the machined components. Minimum quantity lubrication (MQL) machining of aluminum alloys is predicted to be able to suppress the poor machining output effect during machining aluminum alloys. This study investigates the performance of uncoated carbide cutting tool in dry and MQL machining of Al7075-T651. The study aims to analyze the effect of tool performance on surface roughness and chip morphology in dry and MQL machining of Al7075-T651. 18 experimental tests were conducted in turning operation at various cutting speeds (450 – 650 m/min) and feed rate (0.05 – 0.15 mm/rev) under dry and MQL machining with uncoated carbide cutting tool. The average flank wear of cutting tool used in MQL reduced by 8.3%. The type of tool wear detected on the cutting tool were flank wear and crater wear, meanwhile adhesion, abrasion, (BUE) and (BUL) were among the wear mechanisms that can be observed on the tools. The surface roughness of the Al7075-T651 produced in MQL machining improved by 25% compared to in dry machining. Types of chips observed from various cutting parameter was continuous and discontinuous chips. In MQL machining, the chip thickness reduced by 6% - 11% at first cut of machining with new uncoated carbide cutting tool. At 50 minutes of machining time, the chip thickness in MQL machining reduced by 0.5% - 7.5%. The application of MQL was observed to be effective at cutting speed 450 m/min in reducing the coefficient of friction, with 6% - 11% reduction compared to dry machining. Meanwhile, at higher cutting speed, the coefficient of friction (CoF) was found to be 6% - 15% higher in MQL machining compared to dry. As the cutting progress, MQL application was found to be less effective by showing no specific trend in the resulting CoF. Thus, this study shows that the application of MQL in machining Al7075-T651 is beneficial to reduce the tool wear and improve the quality of surface finish but less favorable in reducing the CoF.

خلاصة البحث

سبائك الألومنيوم Al7075-T651 عبارة عن معدن غير حديدي يتمتع بخصائص رائعة من حيث الوزن الخفيف والقوة العالية مما يوفر فرصة واسعة لمجموعة واسعة من التطبيقات. حاليًا ، يتم استخدام Al7075-T651 لتصنيع المكونات والتروس والمحاور في العديد من الصناعات مثل السيارات والفضاء والصناعات العسكرية. يساهم ارتفاع درجة حرارة القطع أثناء المعالجة الآلية في تصنيع المكونات في تدهور سلامة سطح سبائك الألومنيوم. الليونة هي إحدى خصائص المادة التي تساهم في بناء الحافة (BUE) على أداة القطع. يؤدي التكوين المستمر لـ BUE في عملية القطع إلى تغيير هندسة أداة القطع وبالتالي تسريع تآكل الأداة. تؤثر الرقائق التي يتم إنتاجها أثناء القطع في نفس الوقت على أداء القطع. تؤثر الرقائق التي يتم إنتاجها أثناء المعالجة في نفس الوقت على أداء المعالجة. لم تساهم كثافة BUE في المعالجة الآلية الجافة في أنواع مختلفة من التآكل على أداة القطع فحسب ، بل أدت أيضًا إلى تشطيب سطح سيئ للمكونات الآلية. من المتوقع أن تكون معالجة سبائك الألمنيوم MQL قادرة على قمع تأثير الخرج السيئ أثناء تصنيع سبائك الألومنيوم. تبحث هذه الدراسة في أداء أداة القطع بالكربيد غير المطلية في المعالجة الجافة و MQL لـ Al7075-T651. تهدف الدراسة إلى تحليل تأثير أداء الأداة على خشونة السطح ومورفولوجيا الرقاقة في المعالجة الجافة و MQL لـ Al7075-T651. تم إجراء 18 اختبارًا تجريبيًا في عملية التقليب بسرعات قطع مختلفة (450 – 650 م / دقيقة) ومعدل تغذية (0.05 – 0.15 مم / لفة) تحت المعالجة الجافة و MQL باستخدام أداة قطع كربيد غير مطلية. انخفض متوسط تآكل الجناح لأداة القطع المستخدمة في MQL بنسبة 8.3٪. كان نوع تآكل الأداة الذي تم اكتشافه على أداة القطع هو تآكل الجناح ، وتآكل الحفرة ، وفي الوقت نفسه كان الالتصاق ، والتآكل ، و BUE والطبقة المبنية (BUL) من بين آليات التآكل التي يمكن ملاحظتها على الأدوات. تحسنت خشونة السطح لـ Al7075-T651 المنتجة في معالجة MQL بنسبة 25٪ مقارنة بالمعالجة الجافة. كانت أنواع الرقائق التي لوحظت من معاملات القطع المختلفة رقائق مستمرة وغير مستمرة. في معالجة MQL ، تم تقليل سماكة الرقاقة بنسبة 6٪ – 11٪ في أول عملية قطع للقطع باستخدام أداة قطع كربيد جديدة غير مطلية. بعد 50 دقيقة من وقت المعالجة ، انخفض سمك الرقاقة في معالجة MQL بنسبة 0.5٪ – 7.5٪. لوحظ أن تطبيق MQL كان فعالًا عند سرعة القطع 450 م / دقيقة في تقليل CoF ، مع تقليل بنسبة 6٪ – 11٪ مقارنة بالتشغيل الآلي الجاف. وفي الوقت نفسه ، عند سرعة القطع الأعلى ، وجد أن CoF أعلى بنسبة 6٪ – 15٪ في معالجة MQL مقارنة بالجفاف. مع تقدم القطع ، وجد أن تطبيق MQL أقل فعالية من خلال عدم إظهار أي اتجاه محدد في CoF الناتج. وهكذا تظهر هذه الدراسة أن تطبيق MQL في تصنيع Al7075-T651 لم يكن مفيدًا في تقليل معامل الاحتكاك. ومع ذلك ، فانه مفيد لتقليل تآكل الأداة وتحسين جودة تشطيب السطح.

APPROVAL PAGE

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DECLARATION

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LIST OF SYMBOLS

DOC	Depth of cut (mm)
f	Feed rate (mm/rev)
R_a	Surface roughness (µm)
RPM	Revolution per min (RPM)
t_c	Chip thickness (mm)
t_0	Uncut chip thickness (mm)
µ	Coefficient of friction
V_{bave}	Average flank wear (mm)
V	Flow rate (ml/h)
V_c	Cutting speed (m/min)

LIST OF ABBREVIATIONS

Al	Aluminum
BUE	Built up edge
BUL	Built up layer
CoF	Coefficient of friction
Doc	Depth of cut
EDS	Energy-dispersive X-ray
FVM	Focus-variable microscopy
HSS	High speed steel
ISO	International Standard Organization
MQL	Minimum quantity lubrication
SEM	scanning electron microscope
SOM	Stereoscopic Optical Microscope
TiN	Titanium nitride
WC	Tungsten carbide

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Aluminum alloy is a non-ferrous metal with various alloying elements. It is widely used in various industries such as aerospace, automotive and military equipment due to its mechanical characteristic of high strength-to-weight ratio, easy processing, low cost and similar to superior properties of ferrous metal. Different alloying elements in the composition of aluminum determine its characteristics and properties. Among the aluminum alloys, Al7075 is marked as the highest strength of aluminum alloy with 570MPa tensile strength in which Zinc (Zn) is the most dominant alloy with the weight percentage of wt0.6%-5.6% (Ozer and Karaaslan, 2017).

Precise components such as gear and shaft undergo various metal cutting processes which is to transform the raw material into components or products through milling, turning, grinding and drilling processes. The metal cutting process is to remove excess material in order to achieve the designated shape. In case of round bar materials, it will be processed through turning operation to transform the raw material into fitting components, gears and shafts (Santos, Machado, Sales, Barrozo, and Ezugwu, 2016). Turning operation can be done through conventional machine or Computer Numerical Control (CNC) machine. The working principle of turning process is done on lathe machine where a round bar or shaft rotates at controlled speed calculated in revolution per minute (RPM). A single point cutting tool is moving forward perpendicular to the rotational axis. While the cutting tool perform cutting, it will continuously travel in the direction parallel to the rotational axis. Through cutting action, output produced from the processes are new surface of desired shape, dimension or diameter and also metal chips known as waste.

Along this while, cutting fluid used in turning process acts as a coolant to remove heat, as well as to supressed poor tribology behaviour such as high cutting force, rapid tool wear and poor surface finish. Flooded machining were implemented to supply the cutting fluid to the machining area and mentioned that 85% of the cutting fluid in the industries around the globe is petroleum-based (Shokoohi, Khosrojerdi, and Rassolian Shiadhi, 2015). Therefore, Minimum Quantity Lubrication (MQL) has been implemented in today's machining process to improve their efficiency and productivity as well as to improve the quality of the machined components. The use of MQL with different medium such as water, oil or veggie oils became a great subject of interest for manufacturer to observe the significance of MQL used on various ferrous and non-ferrous materials during machining processes (Zainol and Yazid, 2018). A part from that, MQL setup such as flow rate and medium of supply are still a great subject to be discovered by researcher. MQL has a lot of benefits to offer in machining; reduce cutting temperature, improve surface quality and cleaner machining environment (Boswell, Islam, Davies, Ginting, and Ong, 2017).

In this study, the MQL technique were implemented in the CNC turning operation of Al7075-T651. The effect of MQL on tribology behaviour such as quality of surface finish, tool wear and coefficient of friction were studied and analyzed. The comparison in term of tool performance, surface roughness and chip morphology between dry and MQL techniques was compared and were presented in this research works.

1.2 PROBLEM STATEMENTS

Aluminum Alloy 7075 is the highest strength material in the aluminium alloy group which makes it favourable material used in different fields of applications. Unfortunately, the characteristic of the material limits it machinability of aluminum alloys (Zagórski and Warda, 2018). One of the mechanical properties of Al7075 is low meting point (477 – 635ºC). The consequence is that it will contribute to deterioration in the surface integrity during turning operation at 40 – 1500 m/min of cutting speed. Moreover, the material characteristics such as ductility of the material promotes built-up-edge (BUE) and built-up-layer (BUL) on the cutting tools as the continuous cutting take place during the turning operation (Santos, Machado, and Barrozo, 2018). BUE and BUL not only contributed to different types of wear on cutting tool but also lead to poor surface finish of Al7075-T651 (Zakaria, Afiq, Hafiz, Jamalludin, Rosli, Rosli, Rahim, Ishak, Khor, and Nawi, 2018).

Furthermore, the selection of appropriate cutting parameters to be applied during machining Al7075 seems to be unclear. Unlikely machining ferrous metal at low feed rate, it may result better surface finish in turning operation. However, this will cause the increment in machining time during production. However, long continuous chips produced in machining non-ferrous metal such as Al7075 at low feed rate could lead the chip to tangle around the workpiece and on the cutting tool then may result poor surface finish. In addition, dry machining of Al7075 at high speed increased the friction at tool-material and tool-chip which then can decrease the tool life and the quality of the product (Kouam, Songmene, Balazinski, and Hendrick, 2015). One of the solutions taken to solve the issues discussed above, is the application of conventional cooling method or wet machining to achieve better quality of surface finish and machining efficiency.

The rise of cutting temperature during turning could also a possible cause to tool wear. High cutting temperature is an indicator that high friction between tool-chips and tool-material during cutting operation. Therefore, lubricant is been used to reduce the friction by lowering the cutting temperature. However lubricant used in flooded machining became adverse on productivity in today's machining operation because it contribute to environmental issues especially during the disposal of the lubricant (Omair, Sarkar, and Barrón, 2017).

The tool wear is part of an important element in the turning operation. Machining high strength material such as Al7075 could cause unmanageable wear progression. The unrecognizable tool wear during machining ductile material such as Al7075-T651 occurred at vast range of cutting parameter. The tool wear occurred during machining Al7075 with uncoated carbide cutting tool at wide range of cutting parameter are still remained a great subject to be measured in different studies. The tool wear shown to have a great reduction in MQL cooling condition in machining other materials than Al7075. The MQL also showed great effectiveness in reducing tool wear in milling, grinding and drilling.

Rapid tool wear in machining could lead to poor surface finish produced from the machining operation. Components with poor surface finish may require to undergo secondary processes which may lead to increase of manufacturing cost. Furthermore, components with poor surface finish may not perform at its optimal condition. This condition could lead to mechanical failure of the component. Proper selection of cutting parameters and cooling condition in turning Al7075-T651 could improve the quality of the components.

Therefore, this research aims to employ an alternative of machining condition to improve the tribological issues such as tool wear, surface roughness and friction in