MACHINABILITY STUDY ON DRILLING AUSTENITE STAINLESS STEEL 316L1 USING MINIMUM QUANTITY LUBRICATION (MQL) ON SURFACE ROUGHNESS

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ABSTRACT

This research was carried out to determine the optimum condition of cutting speed, feed rate and point of angle while drilling the austenite stainless steel in order to get the good surface finish by using Minimum Quantity Lubrication (MQL). This project focuses on the drilling small hole on the austenite stainless steel by using milling machine. The aim of this project is to find the optimum condition in producing the good surface finish in drilling process with MQL. The Taguchi OA from software Minitab 16 was used to formulate the experiment, to analyze the three factors and also to predict the optimal choices of the drilling parameters. The selected cutting speeds for the drilling process are 15m/min, 25m/min and 35m/min. For the feed rate, the parameters are 0.1mm/rev, 0.15mm/rev and 0.2mm/rev. The third parameter that will be considered in this project is point of angle, and the parameters that will be used are about 110°, 120° and 135°. The machining processes were performed on the CNC milling machine. The surface roughness will be test by using Surfcom 130A. Results shows that, the best surface roughness were obtained at the lower cutting speed, middle of feed rate and middle of point of angle. So, the optimum cutting speed, feed rate and point of angle are, 15m/min, 0.15mm/rev and 120°. The confirmation results show that, the predicted values and the measured values are quite close to each other.

ABSTRAK

Kajian ini dijalankan untuk menentukan keadaan optimum kelajuan memotong, kadar memotong dan titik sudut untuk proses penggerudian keluli tahan karat austenit untuk mendapatkan kemasan permukaan yang baik dengan menggunakan pelinciran kuantiti minimum (MQL). Projek ini memberi tumpuan kepada lubang pengerudian kecil pada keluli tahan karat austenite dengan mengunakan mesin pengilangan. Tujuan projek ini dijalankan adalah untuk mencari keadaan optimum dalam menghasilkan permukaan yang baik dalam proses penggerudian mengunakan MQL.Taguchi OA daripada perisian Minitab 16 telah digunakan untuk merangka dan menyusun atur setiap eksperimen, manganalisis tiga faktor yang digunakan dan juga untuk meramalkan pilihan optimum parameter penggerudian. Kelajuan memotong yang dipilih untuk proses penggerudian adalah 15m/min, 25m/min dan 35m/min manakala untuk kadar memotong, parameter yang digunakan adalah 0.1mm/rev, 24mm/rev dan 35mm/rev. Parameter yang ketiga pula adalah 110°, 120° dan 135°. Kekasaran permukaan akan diuji dengan mengunakan alat Surfom 130A. Keputusan menunjukkan bahawa, keputusan yang terbaik untuk kekasaran permukaan telah diperolehi pada kelajuan pemotongan yang lebih rendah, pertengahan kadar suapan dan pertengahan titik sudut. Jadi, nilai yang optimum untuk kelajuan pemotongan, kadar suapan dan titik sudut adalah 15m/min, 0.15mm/rev dan 120 °. Keputusan pengesahan menunjukkan bahawa nilai-nilai yang diramalkan dan nilai-nilai yang diukur agak dekat antara satu sama lain.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CNC	Computer Numerical Control
DOE	Design of Experiment
MQL	Minimum Quantity Lubricant
S/N	Signal Noise

CHAPTER 1

INTRODUCTION

1.1 PROJECT MOTIVATION

Coolants and lubricants for machining can improve the machinability of the workpiece, increase productivity and extend tool life by reducing tool wear. Besides that, it also will make the surface roughness become smooth. However, for environmental and economic reasons, recent research in industry and in academic field, try to find ways to reduce the use of machining fluids in machining process (A. Meena, 2010; M. El Mansori,2010). So, some researcher has promoted the new technique for applying lubricant during machining process which is called minimum quantity lubricant (MQL).

Minimum Quantity Lubrication is minimum lubricants that used together with the compressed air. This new technique is really environmental friendly because the usage of the coolant is in the small quantity (Khan, 2006; Dhar,2006). Government has promoted green technology to be use in all fields. So, the MQL can be used to replace the conventional cutting fluid and at the same time will reduce pollution to the environment. Besides that, this project also will find the good surface finish in drilling hole and the optimum condition of cutting speed, feed rate and point of angle that will be a guide to other people when they want to drill hole.

1.2 PROJECT BACKGROUND

Cutting fluids were used during machining of materials in milling, drilling, grinding or turning process. The function of cutting fluids is to improving the tool life, improving the surface finish and also to flush away the chips that are produced during the machining. Besides that, the cutting fluid also can remove the heat that is produced during the machining process whether at the tool or at the material that has been machined. The disadvantage of the cutting fluid is it could be harm to the environment. This is because some of the cutting fluid may contain the chemical that cannot be disposed by using the conventional method like throw them away in river or just plant them in the ground (Sutherland, 2009).

Nowadays, some of the machining processes were introduced to use new lubricant technique which is Minimum Quantity Lubrication (MQL) or can be called as Near Dry Machining (Klocke, 1997; Eisenblatter, 1997). When using this lubricant, we can save the cost of the lubricant than the flooding coolant that uses high amount of the coolant during the machining process. The MQL is used by applying the small amount of fluid in the high pressure together with the compressed air flow (Autret,2003 ; Liang, 2003). This lubricant is really environmental friendly and does not cause harm to the user and this lubricant can reduce the pollution. The usage of the lubricant is really minimal than the conventional cutting fluid (Braga, 2002). Usually, the vegetables oil or synthetic ester oil are use instead use the mineral oil (Boubekri, 2010).

1.3 PROJECT PROBLEM STATEMENT

Drilling process is a difficult process in order to make a hole with a good surface finish. The cutting fluid also plays important factors in order to achieve a good surface finish. To find the good surface finish, feed rate, cutting speed and point of angle will be manipulated and the effect on surface roughness while drilling the austenite stainless steel 316L1 with MQL will be observed. Researchers nowadays have focused on different approach of machining such as dry, cryogenic and chill jet air to prolong the tool life and achieve surface finish (Rahim, 2011; Sasahara, 2011). From this project, the minimum quantity lubrication will be used during the drilling process.

1.4 PROJECT OBJECTIVES

The objectives of this research are:

1) To design the experiment by using Design of Experiment (DOE) software for drilling process on surface finish.
2) To analysis the results obtained from the conducted experiment.
3) To find the optimum condition of cutting speed, feed rate and point of angle.

1.5 PROJECT SCOPE

The scopes of this project are:

1) The project only focuses on the surface finish when the three parameters which are cutting speed, feed rate and point of angle are variables.
2) The project only uses MQL as the lubricant and not uses the other lubricant.

1.6 PROJECT REPORT ORGANIZATION

This project report consists of 5 major chapters. The descriptions of each chapter are stated below:-

a) Chapter 2 presents the drilling process from background knowledge as well as literature review perspective.
b) Chapter 3 gives full details on ways how experiment was performed in this project. It shows how machining was conducted, equipments used and the design experiment was used in order to complete this project.
c) Chapter 4 is focused on results and discussions. The surface roughness measurement, the graph for each parameter and the SN ratio for each parameter.
d) Chapter 5 covers the project conclusion and the recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Drilling processes are widely used in aerospace, aircraft, and automotive industries. Although modern metal cutting methods have improved in the manufacturing industry, like electron beam machining, ultrasonic machining, electrolytic machining, and abrasive jet machining, conventional drilling is still the most common machining processes (Kurt, 2008; Bagci, 2008).

On the other hand, in drilling processes, cutting fluids are used to lubricate the process and reduce the effects of high temperature. In the last few years, environment problems had forced the development of cutting fluids of low environmental impact in order to minimize the usage of cutting fluid. The reason why this lubricant needs to be minimized the usage because it will be cause hazard and also will difficult to dispose the lubricant or coolant. Therefore, some researchers have been investigating the alternative methods like dry machining or minimum quantity lubricant (Kelly, 2002; Cotteral, 2002).

2.2 CUTTING FLUIDS

In high speed machining, conventional cutting fluid application fails to penetrate the chip tool interface and as a result cannot remove heat effectively (Paul, 2000). However, high pressure jet of soluble oil, when applied at the chip tool interface, could reduce cutting temperature and improve tool life (Alexander, 1998).

When waste of cutting fluids are not handle in appropriately manner, cutting fluids may damage soils and water resources, causing serious loss to the environment. Therefore, the handling and disposal of cutting fluids must obey rigid rules of environmental protection. On the shop floor, the operators may be affected by the bad effects of cutting fluids, such as by skin and breathing problems (Sokovic and Mijanovic, 2001).

Dry machining is now will be a great interest and actually, this method had met with success in the field of environmentally friendly manufacturing (Klocke and Eisenblatter, 1997b; Aronson, 1995). In reality, however, they are sometimes less effective when higher machining efficiency, better surface finish quality and minimum cutting are required. For these situations, semi dry operations utilizing very small amounts of cutting lubricants are expected to become a powerful tool and in fact, they already play a significant role in a number of practical applications (Sutherland, 2000). MQL refers to the use of cutting fluids of only a minute amount typically of a flow rate of 50 to 500 ml/h. the concept of MQL, sometimes referred to as near dry lubrication (Klocke and Eisenblatter, 1997b) or micro lubrication (MaClure et al., 2001), has been suggested since a decade ago as means of addressing the issues of environmental intrusiveness and occupational hazards associated with the airborne cutting fluid particles on factory shop floors. The minimization of cutting fluid also leads to economical benefits by way of saving lubricant costs and workpiece/tool/machine cleaning cycle time (Khan, 2006).

2.2.1 Cutting Fluids for Drilling

Table 2.1 show the cutting fluid for drilling that has been recommended by the metal cutting tool handbook;

Table 2.1: Cutting Fluid for Drilling

Material Drilled	Suggested Cutting Fluid	Remarks
Plain carbon and low alloy steels	1. Water soluble oils 2. Synthetics 3. Cutting oils - sulfurized and/or chlorinated	
Tool and die steels	1. Cutting oils - sulfurized and/or chlorinated 2. Water soluble oils 3. Synthetics	
Stainless steels	1. Cutting oils - sulfurized and /or chlorinated	
Stainless steels- free machining	1. Water soluble oils 2. Synthetics	
Super alloys (mostly nickel or cobalt base)	1. Cutting oils - sulfurized and/or chlorinated 2. Synthetics	

Material Drilled	Suggested Cutting Fluid	Remarks

Cast irons	1. Synthetics 2. Water soluble oils 3. Dry	1. For rust inhibition 2. Good for malleable and ductile only, not for plain gray cast iron-may cause rusting and chip caking
Aluminum and aluminum alloys	1. Synthetics 2. Water soluble oils	
Magnesium and magnesium alloys	1. Mineral oils 2. Dry	Do not use water soluble oils because of reactivity with magnesium
Copper and copper alloys (brasses and bronzes)	1. Water soluble oils 2. Synthetics 3. Mineral oils	Fluids containing sulfur may cause staining
Titanium and titanium alloys	1. Synthetics 2. Water soluble oils 3. Mineral oils	

Source: Metal Cutting Tool Handbook, 1989

2.3 MACHINABILITY

Machinability can be defined as the relative ease with which material can be removed from metal by machining process such as cutting or grinding. In the machining process, machinability may be seen in terms of tool wear, total power consumption, attainable surface finish or several other benchmarks. It also depends on the physical and mechanical properties of the workpiece such as hard, brittle metals being generally more difficult to machine than the soft and ductile workpieces. It also depend on type and geometry of tool used, the cutting operation, the machine tool, metallurgical structure of the tool and workpiece , the cutting or cooling fluid, and the machinist’s skill and experience (Thiele et al, 2009).

According to the journal Ekinovic et.al. (2005) the most important criteria to defining machinability are:

- Tool life
- Cutting forces
- Machined surface quality
- Cutting temperature
- Chip shape

Material removal process can be defined as the cutting tool removal of the unwanted material from the workpiece in order to produce a desired shape. The formula to determine the material removal rate (MRR) is:

$$\text{MRR} = \pi \frac{D^2}{4} \times f \times N$$

Where;

D is the drill diameter (mm)

f is the feed (mm/rev)

N is the rotational speed (rpm)

2.4 AUSTENITE STAINLESS STEEL 316L1

Austenite stainless steel 316L1 is the steel that have low carbon that can avoid corrosion that is caused by welding. The L indicates the carbon content is less than 0.03% (Korane, 2009). The advantage of the lower carbon is that it forms less chromium carbide during welding. This material is suitable to use in:

- Chemical
- Medical Field (pharmaceutical industry, Surgical and medical tools, and surgical implants).
- Paper industry digesters, evaporators & handling equipment.
- Petroleum refining equipment
- Textile industry equipment, textile tubing.
- Scrubbers for environmental control
- Duct works, feed-water tubes, sewage water filters
- Heat exchanger tubes, ozone generators

Austenite stainless steel have high ductility, low yield stress and have high ultimate tensile strength. This steel is widely use in medical and food industries because it is easily to clean and sanitized than the other material (Korane, 2009)

Table 2.2: Types of Stainless Steel and the Descriptions.

Sources Designer Handbook**,** Stainless Steel for Machining.

Types of Stainless Steel	Descriptions
Type 304	• Withstands ordinary rusting in architecture. • Strongly resistant in food processing environments (except possibly for high temperature conditions involving high acid and chloride contents). • Resists organic chemicals, dyestuff, and wide variety of inorganic chemicals. • Resists nitric acid well and sulfuric acids. • Applications - For storage of liquefied gases, equipment for use at cryogenic temperatures, appliances and other consumer products, kitchen equipment, hospital equipments transportation and waste-water treatment.
Type 316	• Contains slightly more nickel than Type 304 and 2-3 percent molybdenum. • Better resistance to corrosion than Type 304, especially in chloride environments that tend to cause pitting. • Develop for use in sulfide pulp mills because it resists sulfuric acid compounds. • Use has been broadened, however, to handling many chemicals in the process industries

Types of Stainless Steel	Description
Type 317	• Contains 3-4 percent molybdenum and more chromium than Type 316 for even better resistance to pitting.
Type 430	• Has lower alloy content than Type 304. • Used for highly polished trim applications in mild atmospheres. • It used in nitric acid and food processing.
Type 410	• Has lowest alloy content of the three general purposes stainless steel and is selected for highly stressed parts needing in the combination of strength and corrosion resistance, such as fastener. • This Type resists corrosion in mild atmosphere, steam, and many mild chemical environments.

2.5 SURFACE ROUGHNESS

Surface roughness of a machined product could affect several of the products functional attributes, such as contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, coating, and resisting fatigue (Lou et al., 1998). Surface finish has been an important factor of machining in predicting performance of any machining operation. Most surface roughness prediction models are empirical and are generally based on experiments in the laboratory, so it is very difficult in practice to keep all factors under control as required to obtain the reproducible results (Kilickap et al, 2010).

There are several ways to describe surface roughness. One of them is average roughness which is often quoted as R_a symbol. R_a is defined as the arithmetic value of the departure of the profile from the centerline along sampling length as Figure 2.1. It can be expressed by the following mathematical relationship (Yang JL, 2001; Chen JC, 2001).

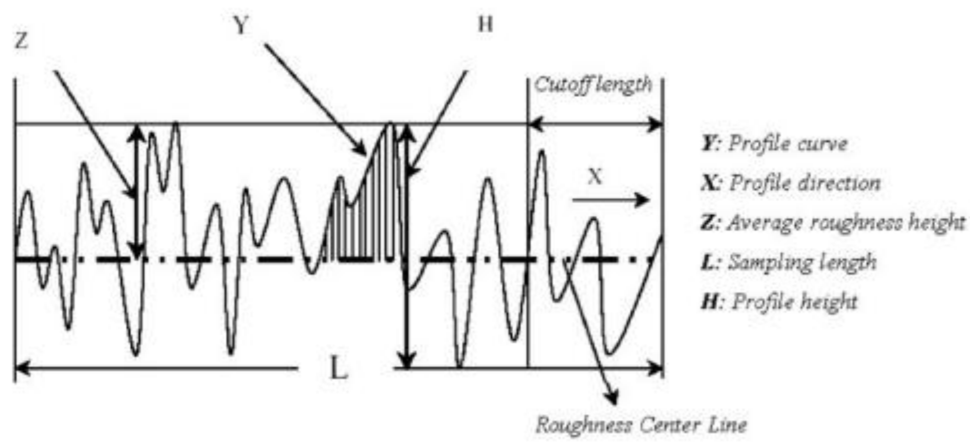

Figure 2.1: Surface Roughness Profile (Yang JL; Chen JC, 2001)

$$R_a = \frac{1}{L}\int_0^L |Y(x)|dx$$

Where; R_a = the arithmetic average deviation from the mean line, Y= the ordinate of the profile curve.

There are many methods of measuring surface roughness, such as using specimen blocks by eye or fingertip, microscopes, stylus type instruments, profile tracing instruments, etc (Bagci, 2005; Aykut, 2005).

According to the Braga et al (2005), the mean values of the hole surface roughness are much better for the MQL condition than for the flood with soluble oil, mainly for the diamond coated drill as can be seen in Figure 2.2 in the MQL condition the surfaces of the holes were smooth than the FSO condition where the diamond coated drill was used. The Ra values obtained when MQL and uncoated K10 tool was used are very impressive which is around 0.5mm with very small dispersion. These values are not easily obtained with the drilling process, even when low feed is used. This thing happen because the high rigidity of the carbide tool and the effectiveness of the lubrication generated by the MQL system, which made a smooth chip formation possible.

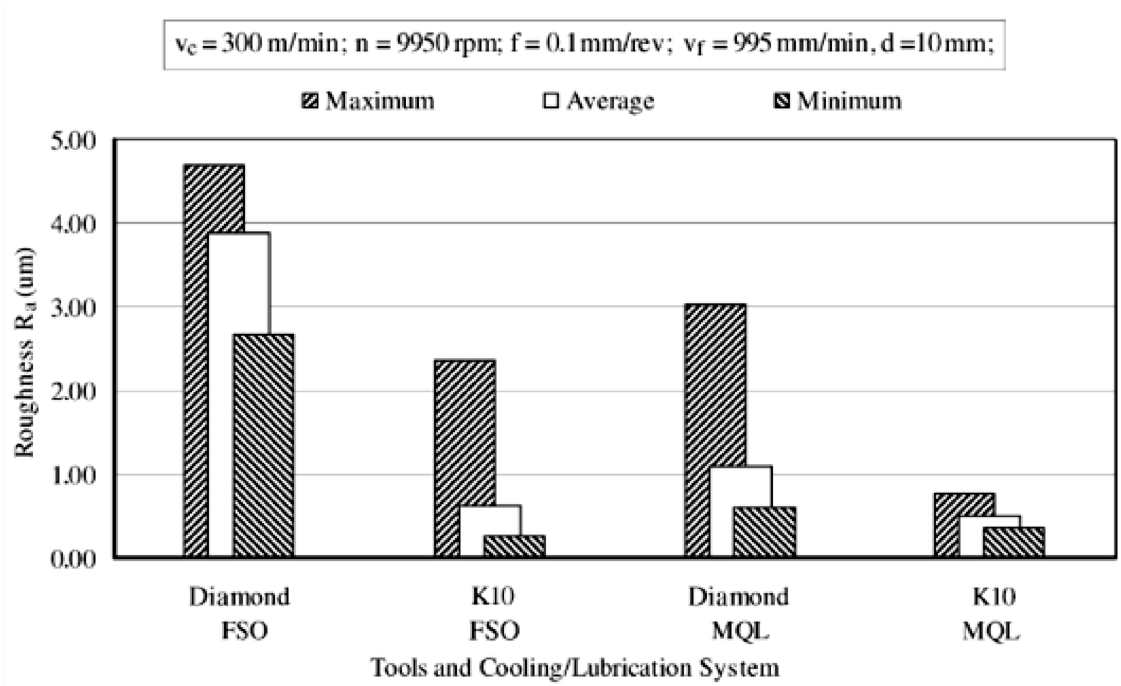

Figure 2.2: Average Roughness around the Central Part of the Holes and Its Dispersion for Both Cooling/Lubrication Systems and Tool Materials.

Surface roughness resulting from drilling operations has traditional received considerable research attention. It has an impact on mechanical properties like fatigue behavior, corrosion resistance, creep life and etc. It also affects other functional attribute of parts like friction. Wear, light reflection, heat transmission, lubrication, electrical conductivity etc (Sahoo et al. 2008).

2.6 OPTIMIZATION METHODS

2.6.1 Taguchi Method

The Taguchi method, a powerful tool to design optimization for quality, is used to find optimal cutting parameters. This tool was used by Yang and Chen (2001) to find the optimum surface roughness in end milling operations. They introduced a systematic approach to determine the optimal cutting parameters for minimum surface roughness. An application of Taguchi method to optimize cutting parameters in end milling is perform by Ghani et al. (2004). They investigate the influence of cutting speed, feed rate and depth of cut on the measured surface roughness. The study shows that the Taguchi method is suitable to solve the stated within minimum number of trials as compared with a full factorial design.

Taguchi methods (orthogonal array) has been widely utilized in engineering analysis and consists of a plan of experiments with the objective of acquiring data in a controlled way, in order to obtain information about the behavior of a given process. The greatest advantages of this method is to save the effort in conducting experiments, to save the experimental time, to reduce the cost and to find out significant factors fast.

Genichi Taguchi have considered three steps in a process and product development which are system design, parameter design and tolerance design. In system design, the engineer uses scientific and engineering principles to determine the fundamental configuration. In the parameter design step, the specific values for system parameters are determined. Tolerance design is used to determine the best tolerance for the parameters (Ross PJ, 1996).