TAGUCHI METHOD APPROACH ON EFFECT OF LUBRICATION CONDITION ON SURFACE ROUGHNESS IN MILLING OPERATION

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ABSTRACT

This thesis presents an investigation into the MQL (minimum Quantity Lubrication) and wet machining in milling processes of AISI 1060 Aluminum work material with the main objective is to determine the effect of lubrication conditions on the surface roughness. Two types of insert had been used in this research, which is different in geometry selection is radius 0.8mm and 1.2mm. Three other parameters were also considered in this study; feed rate, depth of cut and cutting speed. The levels each parameter had been selected is four levels. The ranges of feed rate 0.05mm/min, 0.15mm/min,0.20mm/min and 0.25mm/min depth of cut used were 0.2mm, 0.4mm, 0.6mm and 0.8mm whereby the cutting speed values were 600mm/min, 800mm/min, 1000mm/min and 1200mm/min. The surface roughness was evaluated using surface roughness tester Mitutoyo. Taguchi method was used to predict the surface roughness. Finally, the experimental results showed good agreement with the estimated results. It was found that, MQL produced better surface finish as compared to wet machining. The result can significantly reduce cost and environmental pollution.

ABSTRAK

Thesis ini membentangkan sesuatu kajian mengenai (Pelinciran Kuantiti minimum) MQL dan pemesinan basah dalam proses pemotongan AISI 1060 sebagai kerja bahan ialah Aluminium dengan objektif utama ialah untuk menentukan kesan keadaan pelinciran pada permukaan. Dua jenis insert telah digunakan dalam kajian ini, yang berbeza dalam pemilihan geometri iaitu radius 0.8mm dan 1.2mm. Tiga parameter lain juga diambil kira dalam kajian ini; kelajuan kadar suapan, kedalaman pemotongan dan kelajuan pemotongan. Peringkat setiap parameter telah dipilih adalah empat peringkat. Julat kadar suapan 0.05mm/min, 0.15mm/min, 0.20mm/min dan 0.25mm/min kedalaman pemotongan yang digunakan adalah 0.2mm, 0.4mm, 0.6mm dan 0.8mm di mana nilai kelajuan pemotongan 600mm/min, 800mm/min, 1000mm/min dan 1200mm/min.Kekasaran permukaan diambil kira menggunakan alat pengukur permukaan ,Mitutoyo. Kaedah Taguchi digunakan untuk meramalkan kekasaran permukaan. Akhirnya, hasil eksperimen menunjukkan keputusan yang dianggarkan memuaskan. Ia telah mendapati bahawa, MQL menghasilkan permukaan halus yang lebih baik berbanding dengan pemesinan basah. Hasilnya boleh mengurangkan kos dan pencemaran alam sekitar.

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CS	Cutting Speed
DOC	Conclusion
FR	Feed Rate
µm	Micrometer
Ra	Surface Roughness
CBN	Cubic Boron Nitride
TiAlN	Titanium Aluminium Nitride
ε	Error
SST	Sum of Square Deviation

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Milling is a widely employed material removal process for different materials. Milling process leads to high friction between tool and workpiece, and can result high temperatures, impairing the dimensional accuracy and surface quality of product. The cutting fluid are used in machining process to reduce friction at tool chip and tool-workpiece interfaces, cool both chip and tool, and remove chip.(Reddy and Rao,2005).

Surface roughness is a commonly encountered problem in machined surfaces. It is defined as the finer irregularities of surface texture, which results from the inherent action of the production process. Consequently, surface roughness has a great influence on product quality. Furthermore a good-quality machined surface significantly improves fatigue strength, corrosion resistance, and creep life (Dhar *et al*., 2005).

The quality of the surface plays a very important role in the performance of milling as a good quality milled surface significantly improves fatigue strength, corrosion resistance, or creep life. Surface roughness also affect several functional attributes of parts, such as contact causing surface friction, wearing ,light reflection, heat transmission, ability of distributing and holding a lubricant, coating, or resistance fatigue.(Lou *et al*.,1998).

1.2 PROJECT BACKGROUND

Currently, all researcher make a same mission to investigate the effected of cutting fluid to environment. Industries are looking for ways to reduce the amount of lubricants in metal removing operations due to the ecological, economical and most importantly human health. Therefore, it is important to find a way to manufacture products using the sustainable methods and processes that minimize the use of cutting fluids in machining operations. In addition, it is essential to determine the optimal cutting conditions and parameters, while maintaining long tool life, acceptable surface finish and good part accuracy to achieve ecological and coolant less objective.

In this project, the purpose of research is to know the effected of surface roughness using different of condition of cutting fluid. The tool have been using is Taguchi method and Minitab Software to analyze the data. The equipments will be use vertical Milling machine. The variable parameters to be consider is cutting speed, depth of cut, feed rate and cutting tools. The type material will fixed is Aluminum.

1.3 PROBLEM STATEMENT

In manufacturing sector, manufacturers focused on the quality and productivity of the product. Surface roughness is one of the most important parameters to determine the quality of product. Actually the cost related to cutting fluid represent a large amount of total machining cost. Using cutting fluid is the most common strategy to control the cutting temperature, but it also brings in the environmental and cost concerns and even accelerates the tool wear. (Li *et al*., 2006).

The problem during machining is the workers does not control the parameter of machine properly based on the condition of lubricant. It can be affected to the cost saving and quality of products. Some of the machine operator using ‘trial and error’ method to set-up milling machine cutting conditions (Zhang *et al*., 2006).

1.4 PROJECT OBJECTIVE

The objective of this project is to known the relationship between cutting fluid with surface roughness. The several objectives have been targeted is:

(i) Analyze the effect of using minimum quantity lubricant (MQL) on performance of surface roughness.
(ii) Analyze the effect of using wet machining lubricant on performance of surface roughness.
(iii) Analyze the effect of geometry insert to surface roughness.

1.5 SCOPE PROJECT

The scope of project for this experiment is:

(i) Two different lubrication conditions are considered; wet machining and minimum quantity lubricant (MQL).
(ii) Machining variables considered are lubrication condition, cutting speed, depth of cut, feed rate.
(iii) Two same types insert has been used, but the different selected is geometry insert (Nose Radius).
(iv) Type of material is set as constant throughout the entire experiments. It is 1060 Aluminum Alloy.
(v) Cutting operation is performed using conventional Milling machine.
(vi) Surface roughness of material is analyzed by using surface roughness tester Mitutoyo Brand.
(vii) Taguchi Method has been used to predict the experimental.
(viii) Minitab15 software is used to analyze the data.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is discusses on some literature studies related to the effect of cutting fluid condition on surface roughness in Milling operation.

2.2 CUTTING FLUID

The main functions of cutting fluids are, cooling at relatively high cutting speeds and lubrication at relatively low cutting speed. Cutting fluids is a liquid added to reduce the friction coefficient between the grain and workpiece by way of cooling and lubrication the cutting site of tools by flooding or spraying (Rao, 2007). They have a strong effect on shearing mechanism and, consequently, on machined surface quality and tool wear (Diniz and Micaroni, 2002).For companies, the cost related to cutting fluids represent a large amount of total machining cost. Research has found that those related to cutting tools. Moreover, cooling lubricant has been found to cause health and social problems for workers, related to lubricant use ad correct disposal (Diniz and Micaroni, 2002).

Therefore, many researchers have focused on environment friendly machining technology. Environment friendly machining technologies can be classified into dry and semi-dry machining technologies according to consumption of cutting fluids (Lee and Lee, 2001).

2.3 MACHINING CONDITION

2.3.1 Minimum Quantity Lubricant (MQL)

(MQL) refers to the use of cutting fluids of only a minute amount—typically of a flow rate of 50–500 ml/h which is about three to four orders of magnitude lower than the amount commonly used in flood cooling condition. (MQL) in machining is an alternative to completely dry or flood lubricating system, which has been considered as one of the solutions for reducing the amount of lubricant to address the environmental, economical and mechanical process performance concerns. (Thakur *et al*., 2009). Then (Yalçın *et al*., 2009) researched the effect of dry, wet, and air cooling cutting conditions on the surface roughness during annealed AISI 1050 steel milling. It was found that the surface roughness values under air cooling condition were lower than those under dry condition, while higher than those under fluid cooling condition

2.3.2 Wet Machining

Wet machining refers use a large quantities of lubricants. The wet machining can reduce the heat between the material surface and tools surface (Byers, 2006). In wet machining, both the tool and the workpiece are cooled using large quantities of lubricants. The coolant is subsequently cleansed and used again (Dhar *et al*., 2005). In wet machining, the role of cutting fluids is transports the chips away from the cutting zone, at the same time cooling the chips and keeping dust and small particulates in liquids rather than in the air (Byers, 2006). Hot chips have collecting around the machine base and the cutter or the part, thus it need the wet machining to cools the chips and also washes them away from the machine tool into the filtering system for separation from the fluids. In wet machining, less heat is generated. It will generally follow that if less heat is generated, the tools will last longer and the surface integrity of the workpiece will be protected (Byers, 2006).

2.4 MACHINING PARAMETERS

2.4.1 Cutting Speed

Cutting Speed (CS) of a material is the ideal number of Feet-per-Minute that the tool-bit should pass over the work-piece. This "Ideal" cutting speed assumes sharp tools and flood coolant. Adjustments need to be made for less than ideal cutting conditions. Different materials (High-Carbon/Low-Carbon Steels, Aluminums, Different kinds of Plastics) have different Cutting Speeds and can be worked/cut at different rates. In addition, some tools or processes (like threading, knurling, or cutting-off) will need to be worked at slower speeds than the Cutting Speed would indicate.

The cutting speeds have been considered based on the types of material and cutting tools. Figure 2.1 show the hardness of the work material has a great deal to do with the recommended cutting speed. The harder increase the work material, the slower the cutting speed. The softer the work material the faster the recommended cutting speed.

Figure 2.1: Work Material versus Cutting Speed

The hardness of the cutting tool material has a great deal to with the recommended cutting speed. The harder the cutting tool material, the faster the cutting speed figure 2.2 shows the softer the cutting tool material the slower the recommended cutting speed.

Figure 2.2: Tool Material versus Cutting Speed

2.4.2 Spindle speed calculation

In general, speed (V) was the primary cutting motion, which relates the velocity of the rotating workpiece with respect to the stationary cutting tool. The cutting speed refers to the edge speed of the rotating workpiece. It is generally given in unit of surface feet per minute (sfpm) or inches per minute (in. /min), or meters per minute (m/min). For a given material there will be an optimum cutting speed for a certain set of machining conditions, and from this speed the spindle speed (RPM) can be calculated (Kalpakjian, 2006). Factors affecting the calculation of cutting speed are:

(i) The material being machined (steel, brass, tool steel, and plastic, wood).

(ii) The material the cutter is made from (Carbon steel, High speed steel (HSS), Carbide, ceramics)

(iii) The economical life of the cutter (the cost to regrind or purchase new, compared to the quantity of parts produced).

$$V = \pi DN \tag{2.1}$$

Where:

V = Cutting Speed

D = Diameter Cutting Tools

N = Spindle Speed

2.4.3 Feed Rate

Feed Rate (Milling Machine) refers to how fast a milling-tool moves through the material being cut. This is calculated using the Feed Per Tooth (FPT) to come up with the Inches Per Minute that a milling bit can move through a particular type of material. Thus, a Four-Flute End-Mill will cut through material at twice the speed of a Two-Flute End Mill. Feed Rates will decrease with dull tools, a lack of coolant, or deep cuts. Table 1 show the prefer table for feed rate based on material.

Table 2.1: Feed Rate Recommendation

	Rough Cut		**Finish Cut**	
	inches	**millimeters**	**inches**	**millimeters**
Machine steel	0.10-0.020	0.25-0.50	0.003-0.010	0.07-0.025
Tool steel	0.10-0.020	0.25-0.50	0.003-0.010	0.07-0.025
Cast iron	0.015-0.025	0.40-0.65	0.005-0.012	0.13-0.30
Bronze	0.015-0.025	0.40-0.65	0.003-0.010	0.07-0.25
Aluminum	0.015-0.030	0.40-0.75	0.005-0.010	0.13-0.25

2.5 MATERIAL

The material has been used in this experiments is 1060 Aluminum Alloy. This standard structural alloy, one of the most versatile of the heat ratable alloys, is popular foe medium to high strength requirements and has good toughness characteristic. Application to recreation products and consume.

Table 2.2: Material Properties

PROPERTIES	**MATERIAL**
	1060 Aluminum Alloy
Hardness (HB)	23
Tensile Strength (Mpa)	83
Density (x 1000 kg/m^3)	2.7
Elastic Modulus (Gpa)	70-80

2.6 CUTTING TOOLS

Cutting tools have been variety types. The general properties of tools material must have hot hardness, toughness, impact strength, thermal shock resistance, wear resistance and chemical stability. The variety of types of material used in cutting tools such as, High-speed steels, uncoated carbides ,coated carbides, ceramics, polycrystalline cubic boron nitride(CBN) and diamond. Each types of material used in cutting there have different general characteristic, model of tool wear or failure and limitations.

The experiments will conducted with two types of cutting tools. The cutting tools has been used on this experiments is end mill with insert. The insert coated carbide type will be conducted in this experiment. The type of coating has been used is Titanium Aluminiun Nitride (TiAlN). The advantages of this coated is have low friction coefficients, high hardness, resistances to high temperature, and good adhesion to the substrate.

The difference between insert is the radius insert. The WRX Wave repeater end mill system features AXMT style inserts vertically mounted and positioned to provide a long continuous cutting edge suitable for deep shoulder milling. The insert first cutting radius is 1.0mm see the second last number from that code. The insert two have cutting radius 1.2 mm. So the radius also will affect to the surface of roughness.

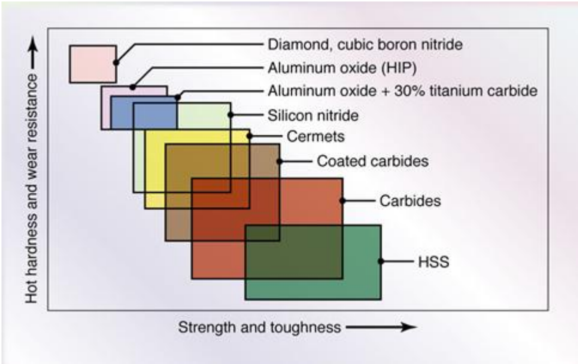

Figure 2.3: Ranges of mechanical properties for various groups of tool materials

2.7 SURFACE ROUGHNESS

The quality of the surface plays a very important role in the performance of milling as a good quality milled surface significantly improves fatigue strength, corrosion resistance, or creep life. Surface roughness also affects several functional attributes of parts, such as contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, coating, or resisting fatigue. (Lou *et al*., 1998).

Dr. Mike S. Lou in his journal cited that the terms surface finish and surface roughness are used very widely in industry and are generally used to quantify the smoothness of a surface finish. The surface roughness value depends mainly on feed rate and nose radius of the tool. The experimental and theoretical values of surface roughness are calculated and the deviation is within the acceptable range (Tamizharasan *et al*., 1999).

The characterization of surface roughness can be done in two principal planes (Thomass, 1999).Using a sinusoidal curves as a simplified model of the surface profile, roughness can be measured at right angles to the surface in terms of the wave amplitude, and parallel to the surface in terms of the surface wavelength. The latter one is also recognized as texture. The technique used to measure roughness in any of these two planes will inevitably have certain limitations.

The smallest amplitude and wavelength that the instrument can detect correspond to its vertical and horizontal resolution, respectively. Similarly, the largest amplitude and wavelength that can be measured by the instrument are the vertical and horizontal range. The first amplitude parameter used for roughness measurement was the vertical distance between the highest peak and the lowest valley of the unfiltered profile, Pt (Thomas, 1999).

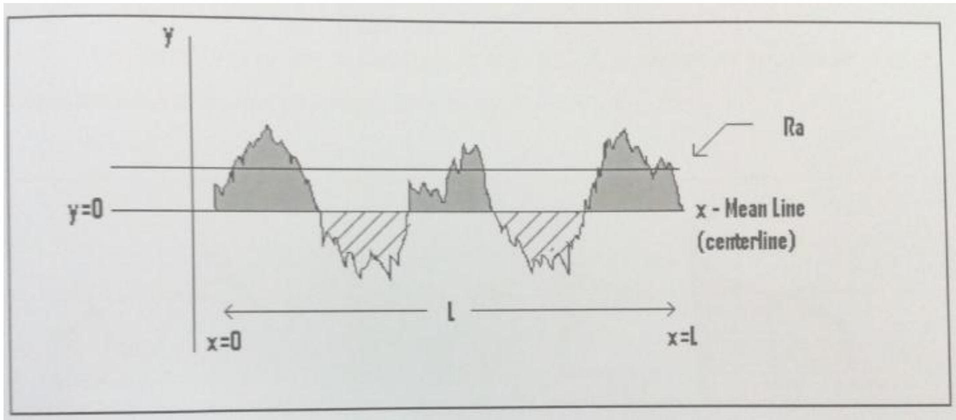

Figure 2.4: Graphical Description of Ra (Thomas, 1999)

2.7.1 Surface Roughness Parameters

Surface finish could be specified in many different parameters. Due to the need for different parameters in a wide variety of machining operations, a large number of newly developed surface roughness parameters were developed. Some of the popular parameters of surface finish specification are described as follows:

(i) Roughness average (Ra): This parameter is also known as the arithmetic mean roughness value, AA (arithmetic average) or CLA (center line average). Ra is universally recognized and the most used international parameter of roughness. Therefore,

$$Ra = \frac{1}{L}\int_0^L |Y(x)|\, dx \tag{2.2}$$

Where:

Ra = the arithmetic average deviation from the mean line

L = the sampling length

Y = the ordinate of the profile curve

It is the arithmetic mean of the departure of the roughness profile from the mean line. An example of the surface profile is shown in figure 2.4.

(ii) Root-mean-squsre (rms) roughness (Rq): This is the root-mean-square parameter corresponding to Ra:

$$Rq = \sqrt{\left[\frac{1}{L}\int_0^L (Y(x))^2\, dx\right]} \tag{2.3}$$

(iii) Maximum peak-to-valley roughness height (Ry or Rmax): This is the distance between two limes parallel to the mean lime that contacts the extreme upper and lower points on the profile within the roughness sampling length.

Since Ra and Rq are the most widely used surface parameters in industry, Ra was selected to express the surface roughness in this study.

2.8 TAGUCHI METHOD

Taguchi Method was proposed by Genichi Taguchi, a Japanese quality management consultant. The method explores the concept of quadratic quality loss function and uses a statistical measure of performance called signal-to-noise (S/N) ratio, Antony, 2001). It is the ratio of the mean (Signal) to the standard deviation (Noise). The ratio depends on the quality characteristics of the product/process to be optimized (Peace, 1993). The optimal setting is the parameter combination, which has the highest S/N ratio. Based on the signal-to-noise (S/N) analysis, the signal-to-noise (S/N) ratio for each level of process parameters are computed. Larger S/N ratio corresponds to better performance characteristics, regardless of their category of performance. It means that the level of process parameters with the highest S/N ratio corresponds to the optimum level of process parameters. Finally, a confirmatory experiment is conducted to verify the optimal processing parameters obtained from the parameter design.

2.9 SURFACE ROUGHNES TESTER

Surface roughness tester is equipment used for measuring the surface roughness of the workpiece. It is high-precision measurement in different positions and easy to position the material by using the V-blocks. It also has high level of scope of supply and service. That equipment does not complicate in handling and operating. It results is high level quality and in the nanometer range. The featured of the tester is given as below:

(i) Roughness and waviness measurements according to current standards (DIN EN ISO 3274, e.g. band-pass filter).

(ii) A large high-resolution graphics display to indicate results and profiles.

(iii) Easy operation based on the automatic teller principle and large operating elements.

(iv) Quick documentation via the integrated high-resolution thermal printer.

(v) Storage facility on PCMCIA memory card for measuring programs, results and profiles.

(vi) Extensive, easily applicable software functions, such as:

  a. Automatic function for setting standardized filters and traversing lengths.
  b. Monitoring of calibration and maintenance intervals.
  c. Variable selection of filters and traversing lengths.
  d. Tolerance monitoring with audible and visual signals.