I admit that I have read this report and in my opinion this report is sufficient from the perspective of the scope and quality for awarding purposes Bachelor of Mechanical Engineering (Thermal Fluid)

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EFFECT OF TOOL GEOMETRY, MATERIAL HARDNESS AND CUTTING PARAMETERS ON THE CUTTING FORCE FOR TURNING PROCESS

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DECLARATION

" I hereby, declare that the work in this report entitled "EFFECT OF TOOL GEOMETRY, MATERIAL HARDNESS AND CUTTING PARAMETERS ON THE CUTTING FORCE FOR TURNING PROCESS" is my own except for quotations and summaries which have been duly acknowledged "

Signature :..............................
Author : MOHAMAD SAIFUL AZHAR BIN HARUN
Date : 14 DIS 2005

DEDICATION

Dedicated to my beloved parents and my sisters……
For understanding and moral support
throughout the years…….

ACKNOWLEDGMENTS

Firstly, I would like to take this opportunity to express my deepest gratitude to my project supervisor, Mr. Mohd Nizam Bin Sudin from the Faculty of Mechanical Engineering, Kolej Universiti Teknikal Kebangsaan Malaysia (KUTKM), for his support, confidence, and guidance towards completing this project.

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ABSTRACT

In this experiment, effect of tool geometries, material hardness, feed rate, and cutting speed on cutting forces were experimentally investigated. High speed steel (HSS) tool blank with three type of geometries was prepared and mild steel CF1018 and DF2 steel bars were used as workpiece. Effect of tool geometries material hardness and cutting parameters on cutting forces statistical analysis of variance was performance. During the experiments two component of tool of tool force and tool life of cutting tool were measured. This experiment shows that the effect of tool wear was influenced to increase the cutting force. Different of tool geometries were showed the variance was performance on cutting force. Where sharp edge show lower tangential force on CF1018. The contact between 1mm radius (nose radius) and workpiece had been small impact on cutting force. But honed radius always high tangential force on CF1018 remarkably influence to material hardness also cutting force. However material hardness is a one of the factors of increased cutting force and tool life. Therefore, the resulted obtained from the analysis technique indicated that the longer the cutting tools were in contact with the workpiece, the higher the rate of wear. The Taylor's equation derived from the experiment is $VT^{0.15} = 4.78$

ABSTRAK

Didalam projek akhir ini, kesan terhadap rekabentuk mata alat dan kekerasan bahan kerja, kadar masukan dan kelajaun pemotongan didalam proses pemotongan secara ujikaji diselidik. Dengan menggunakan mata alat yang belum diasah (tool blank) jenis keluli berkelajuan tinggi (HSS) dengan tiga jenis rekabentuk mata alat disediakan dan dua jenis bahan kerja yang berlainan kekerasanya iaitu keluli lembut (mild steel) CF1018 dan DF2. Kesan rekabentuk mata alat dan kekerasan bahan kerja terhadap daya pemotongan secara statik dianalysis. Semasa ujikaji dijalankan dua komponan daya pemotongan, janka hayat mata alat serta kehausan mata alat diukur. Ujikaji ini menunjukan kesan kahuasan mata alat telah mempengaruhi peningkatan kepada daya pemotongan. Rekabentuk mata alat yang berbeza telah menunjukan kepelbagaian daya didalam daya pemotongan. Dimana tepi mata alat tajam menunjukan daya pemotongan menegak adalah rendah terhadap CF1018. Hubungan diantara 1mm jejari hujung mata alat (nose radius) dan bahan kerja menghasilkan kesan yang kecil terhadap daya pemotongan. Tetapi hujung mata alat bulat sentiasa menunjukan nilai yang tinggi didalam daya pemotongan menegak CF1018 yang dikatakan mempengaruhi kepada kekersan bahan kerja serta daya pemotongan. Namun begitu kekerasan bahan kerja adalah salah satu faktor peningkatan daya pemotongan dan janka hayat mata alat. Oleh kerana itu keputusan yang diperolehi menunjukan semakin panjang tempoh penggunaan mata alat terhadap bahan kerja, semakin tinggi kadar kehausan mata alat. Persamaan Taylor yang diperolehi didalam ujikaji ini ialah $VT^{0.15} = 4.78$.

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NOMENCLATURE

F	Frictional force at tool-chip interface
F_c	Cutting force
F_t	Thrust force
F_n	Normal force
F_s	Shear force
N	Normal force at tool-chip interface
R	Resultant cutting force
T	Time
C	Constant
V	Cutting Spindle
b	Thickness
t	Feed
t_{ch}	Chip thickness
t_o	Depth of cut
v	Cutting speed
α	Rake angle
β	Friction angle
μ	Coefficient of friction
Φ	Shear Angle

CHAPTER 1

INTRODUCTION

1.1 Background

Most of turning operation use single point cutting tool. The cutting tool is blank or tool insert. Tool geometry is very important in machining operation. Rake angle is one of the factors that influence in machining problem. In machining process, cutting tool removes material from the surface of the workpiece. Therefore, the selection of cutting tool material and workpiece is important to ensure the quality of product to fulfill the standard on metal cutting. In this project turning process parameter, tool geometry, material hardness, and cutting force were concentrating.

Another tool geometry of cutting tool is rake angles. The angles also influence to control chip formation and strength of the cutting tool. Nevertheless, positive and negative rake angle are usually used in cutting process. These two rakes will effect to the cutting forces and chip formation.

In metal cutting, cutting force are importance criteria to be measured. Many researchers concentrate on two dimensional problems instead of three dimensional cutting processes. Therefore, cutting force, F_c (horizontal) and trust forces, F_t (vertical) are determined in two dimensional cutting processes. Using 2-axis mechanical dynamometer, cutting force can be measured at X and Y direction. The magnitudes of cutting force are dependent on the cutting speed, feed rate, and the depth-of-cut.

Material hardness is another factor to be considered in cutting process. This factor contributes to surface roughness and tool life. Material hardness for mild steel 1018 CF and mild steel DF2, are usually between 42- 45 HRC. It is expected that tool wear and cutting forces will increase if the material is too high.

Effects of cutting tool wear and material hardness on cutting forces are major problem in metal cutting process. In this project high speed steel (HSS) cutting tool blank, mild steel 1018 CF and mild steel DF2 is used for experimental. Meanwhile cutting force was measured using 2-axis mechanical dynamometer. The parameters of this experiment are feed rate, depth of cut and cutting speed. The plotted graph were shown the polar of result for variable parameters.

1.2 Research Objective.

The main objective on this project is:-

The main objectives are:

i. To measure cutting forces for different tool geometry at constant feed rate.
ii. To measure cutting forces for similar tool geometry at varying feed rate.
iii. To measure cutting force at constant kinematics parameters for different material hardness.

1.3 Structure of the Project.

Chapter 1 of the project describe briefly about the introduction of them. It follows with chapter 2, that include literature review one metal cutting process. The explanation in tool wear, material hardness, and cutting force are also included. Chapter 3, describe in structure and methodology of the cutting process. Also include the explanation about cutting parameters that use directly cutting operation. Even, procedure and technique using external equipment also explained.

Result and discussion are described in chapter 4. The plotted graph between each cutting parameters are showed. However, discussion for every graph and also comparisons are made. Illustration also include to explanation. Chapter 5, conclude the project compulsory the result of effect tool wear and material hardness on cutting forces. As a result, recommendation for the future improvement are identified and explained.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In turning material is removed from workpiece while the workpiece rotating. There are several parameters, which have, significant impact into cutting process. However, tool wear and material hardness have a relationship between these parameters. These two parameters will influence the amount of generated cutting forces. A brief description of cutting force and review of specific of tool wear will describe.

Cutting force (Fc), act between the cutting tool and cutting speed. The force generated, when the spindle rotate and the cutting tool touch the workpiece. There are three cutting force acting on the cutting tool, which are Tangential force (Fc), Feed force (Ft) and Radial force (Fr). Forces will be measured by using the dynamometer.

The tangential force or cutting force (Fc) is generated due to the rotating workpiece and the resistance to rotation between cutting tool and workpiece. The direction of the cutting forces is perpendicular to the cutting tool. In a normal operation, a tangential force is the highest of the three forces and account for 98% of the power required by the operation George Schnelder (2001).

Thrust force (Ft) acting when the tool move in x direction while cutting process. However, when the tool at high positive rake angles, the thrust forces is negative and the tool is pulled into the workpiece. Thrust forces in metal cutting are importance because of the tool holder, work holding, and machine tool. The tool need to sufficiently stiff to the workpiece, to make sure the thrust force not too high and can be effect to other parameters.

There are several problems to overcome during the cutting process. One of the problems was tool wear, where the tool will be significant influence to workpiece. The rate of tool wear depends on tool and workpiece material, tool shape, cutting fluids, process parameters, and machine-tool characteristics. There are two basic type of wear, these two regions is flank wear and crater wear. A brief description of tool wear is described.

Tugrul Ozel et al. (2003) studied the effect of cutting edge geometry, workpiece hardness, feed rate, and cutting speed on surface roughness and forces in finish turning of hardened AISI H13 steel. They observed the effect of workpiece hardness, cutting edge geometry, feed rate, and cutting speed on surface roughness are statistically significant. Therefore, the lower workpiece surface hardness and honed edge geometry resulted in lower tangential and radial forces.

However, cutting parameters are important to the metal cutting. M.Liang et al. (2001) investigated the integration of cutting parameter selection and tool adjustment decision for multipass turning. They are measured with various parameters simultaneously in turning operations. From the experiments they are conclude that the effect of machining parameters and tool adjustment are significant importance in turning operations.

2.2 Material Removal.

The material removal rate (MRR) is the volume material removes from the workpiece per unit time (mm^3/min). For each revolution of workpiece, cutting tool remove a layer of material. Process removal referring to the rotation of spindle; where tool travel in one revolution feed and the depth of cut. The major parameters of interest for the material removal process can be classified for two. Binu Paul John (2003), the parameters that describe the material and parameters that describe the cutting process.

$$MRR = b \times t \times v \qquad \textbf{(2.1)}$$

From the equation above, material removal can be calculated to determine the volume material removes. Chip thicknesses represent for *b*, *t* is feed, and *v* is cutting speed.

2.3 Cutting Forces.

Forces turning can provide three forces acting on cutting tool. These forces are important in design of machine tools, as well as in the deflection of tools and workpiece for precision machining operations. However, the relationship of the cutting variables to the cutting forces such as tool angle, feed rate, and cutting speed. These are significantly influence to the tool and workpiece. Nevertheless, using the merchant's circle theory, forces also can be calculated. A brief description on the merchant's circle also included.

While the tool is forced to cut the workpiece, a chip produced from the shearing zone and moves on along the rake face of the tool until it curves off or brakes up. Cutting force and normal force acting together to perform the cutting operation. The parameters of forces and geometry with the primary deformation zone are shear force (F_s), normal force (F_n) and the shear angle. The secondary parameters deformation zone is friction force (F), normal force (N) and the rake angle (α). The cutting force (F_c) and thrust force (F_t) that can be measurable with the cutting process using the Merchant's analytical model for two-dimensional orthogonal cutting mechanics. Figure 2.1 shows Merchant's force circle of the forces involved in orthogonal cutting.

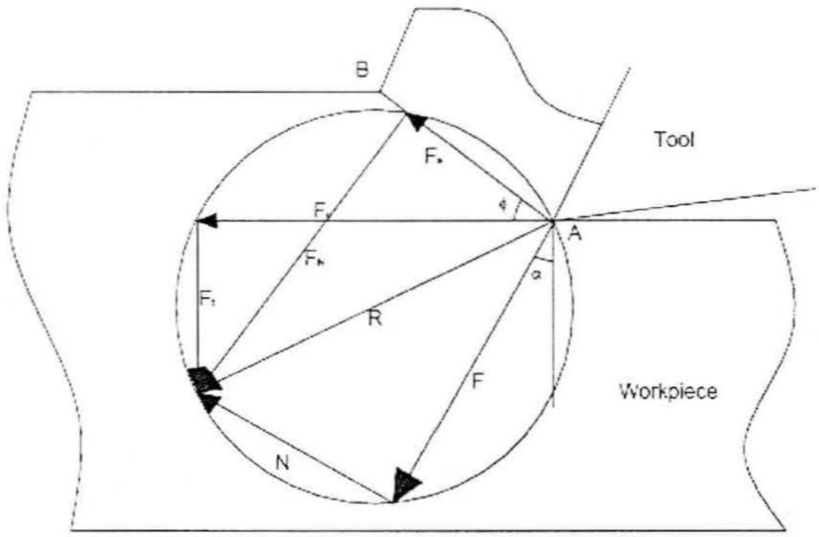

Figure 2.1: Merchant's composite force circle in orthogonal cutting [Binu Paul John (2003)]

Figure 2.1 above, shown the shear plane AB is inclined to the cutting direction with an angle Φ (shear angle). The resultant force, R, is resolved into the shear force F_s along the shear plane and normal force F_s perpendicular to the shear plane. At the rake face, the resultant force R is resolved into friction force F along the rake face and normal force N normal to the rake face. R is again resolved into cutting force F_c along the cutting direction and thrust force F_t normal to the cutting direction. F_c and F_t can be measured using a dynamometer and can be used to calculate the other force parameters using the equations given below:

$$F = Fc \sin\alpha + Ft \cos\alpha \qquad \textbf{(2.2)}$$

$$N = Fc \cos\alpha - Ft \sin\alpha \qquad \textbf{(2.3)}$$

$$Fs = Fc\cos\phi - Ft\sin\phi \tag{2.4}$$

$$Fn = Fc\sin\phi + Ft\cos\phi \tag{2.5}$$

2.4 Single Point Cutting Tool.

In metal cutting have a several factors are influencing on cutting process, one of the factors is cutting tool (tool angles and tool wear). Therefore, the shape and position of the tool are relative to the workpiece. Another fact is location of the cutting edge and the direction of cut.

The shape and position of the tool with relative to the workpiece have been effect to the metal cutting. The geometries of shape are nose, hone and sharp edge. Rake angle on cutting tool is importance to controlling both the direction of chip flow and strength of tool. Tool wear will be effect to the tool life, the quality of the machined surface, and consequently, the economics of cutting operations. Figure 2, shows the cutting tool terminology used in right hand cutting operation.

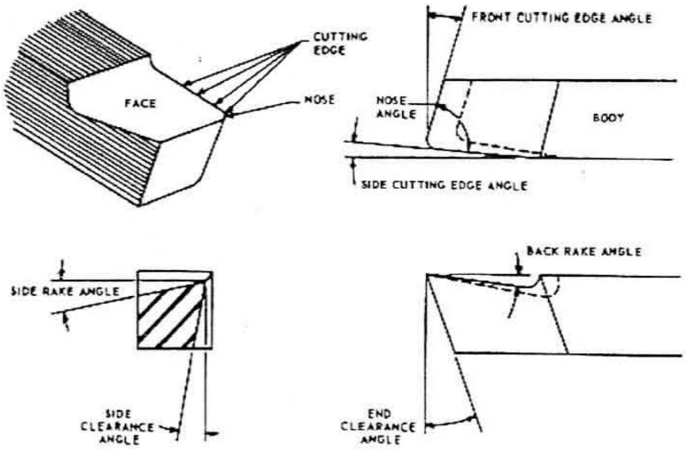

Figure 2.2: Cutting tools terminology [www-me.mit.edu/machine tools]

HSS tool with four type edge are use to investigated in this project. These edge preparations include chamfer, hones, radius flat and parting edge. Sandvik

(C45) is a model of this tool and size of tools; 8mm x 10mm x 160mm long. Table 2.1 shows the general recommendations for turning angles.

Table 2.1: General Recommendations HSS Cutting Tool Angles [Manufacturing Engineering and Technology]

Material	Back rake	Side rake	End relief	Side relief
Aluminum	20	15	12	10
Cooper alloys	5	10	8	8
Steel	10	12	5	5
Stainless steels	5	8-10	5	5

2.4.1 Rake Angle.

The slope of the face on cutting tool is determined by the back- rake and side rake angles. The side- rake angles is measured perpendicular to the side-cutting edge and the back-rake angles is measured parallel to the side cutting edge. Positive rake angle are generally preferred because less cutting force is required in order to take a given size cut as compared to a tool with negative side-rake angles.

There are two rake angles back rake and side-rake. For the turning and boring process, the side rakes the most influential. These cause by which two major effects during the metal cutting process. The effects are influence on tool strength and cutting pressure.