NATIONAL TECHNICAL UNIVERSITY COLLEGE OF MALAYSIA

Investigation of Conventional Milling Machining to the Surface Roughness Condition

Thesis submitted in accordance with the requirements of the National Technical University College of Malaysia for the Degree of Bachelor of Engineering (Honours) Manufacturing (Process)

By

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KOLEJ UNIVERSITI TEKNIKAL KEBANGSAAN MALAYSIA

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ABSTRACT

Milling is a process of generating machined surfaces by progressively removing a predetermined amount of material or stock from the workpiece which is advanced at a relatively slow rate of movement or feed to a milling cutter rotating at a comparatively high speed. The feature of the milling process is that each cutter tooth removes its share of the stock in the form of small individual chips. It is believed that milling operation is capable of producing a smooth surface finish based on their characteristic feature like the multi-tooth type of cutting tool that produces a number of chips in one revolution. The cutting parameters like feed rate and cutting speed have a significant affect on the surface roughness condition. This project is to investigate whether this claim is true based on manipulation of basic cutting parameters such as feed rate and cutting speed. These parameters will give some range of variables that will be useful for comparative analysis. The aim of this project is to determine the parameter that capable to produce a good surface finish with the use of conventional milling machine available at the machine shop in the Faculty of Manufacturing Engineering. Hopefully the result analysis can be helpful for reference during operating the conventional milling machine in the machine shop.

DEDICATION

A huge dedication goes to myself. For all happiness and sadness you face in 23 years of age, may it become a brilliant experience for you to improve in the future. God bless you.

I would like to dedicate my thesis report to my beloved mum, dad and three little sisters. You know you all will always have my love and my pray.

Special dedication goes to someone I love as a lover. May god bless and fulfill your dreams.

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First of all I would like to give my full gratitude to the Al-Mighty for His kindness and mercy that enable me to breath and to face through everyday life with all blessing and good fortune.

I would like to thank everyone who directly involves in my thesis preparation especially my supervisor, Mr. Abdul Rahim Samsudin who had giving his support and guidance not only with expertise but also with love. The next in line will be Mr. Hairul, the young technician who in charge for milling machine at machine shop, thank you for letting me uses the milling machine. I must not forget Mr. Jaafar, a senior technician for metrology laboratory where the surface roughness tester equipment is located. Thank you for your understanding in my task.

Last but not least for all my friends who may involve indirectly in the preparation of this report. I respect to those who willing to tolerate and share the limitation of working and finally I like to thank for all support received from whoever you are.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

PSM	-	Projek Sarjana Muda
KUTKM	-	Kolej Universiti Teknikal Kebangsaan Malaysia
rpm	-	revolution per minute
mm	-	millimeter
mm/m	-	millimeter per minute
Ra	-	Roughness average
rms	-	Root-mean-square
Rq	-	Root-mean-square roughness
Ry	-	Maximum peak-to-valley roughness height

CHAPTER 1
INTRODUCTION

1.1 Overview

This project paper is to discuss the effect of conventional milling machining parameter in production of the surface roughness of the cutting material. Milling operation has been classified as the material removal processes or in other terms the machining process. The machining process consists of three processes that is cutting, abrasive and advanced machining process. Cutting process, which generally involves single-point or multipoint cutting, has features milling, turning, broaching, sawing and filing as the type of cutting processes. Abrasive machining features the grinding operation while advanced machining process utilize electrical, chemical, thermal methods in machining process. For this project, milling machining has been selected as the topic of research.

Cutting process aims to generate the shape of the workpiece from a solid body, or to improve the tolerances and surface finish of a previously formed workpiece by removing excess material in the form of chips. The basic cutting parameters are spindle speed, feed rate and depth of cut. Another factor concerned with this project is type of material used for the cutting operation.

These cutting parameters are important especially the feed rate in determining the surface roughness of the cutting surface of the material. Surface roughness is used to determine and evaluate the quality of a product, is one of the major quality attributes of milling product. In order to obtain better surface finish, the proper setting of cutting parameters is crucial before the process takes places. This project will investigate the relationship of the cutting parameter with the surface roughness of milling cutting operation.

1.2 Problem Statement

Milling machine is believed capable in producing a smooth surface finish. This investigation is to prove this claim. In other word this project is to find out whether our conventional milling machine available in KUTKM's machines shop can comply with this statement.

1.3 What is milling machining?

Milling machining is the process of cutting away material by feeding a workpiece past a rotating multiple tooth cutters. The cutting action of the many teeth around the milling cutter provides a fast method of machining. The machined surface may be flat, angular, or curved. The surface may also be milled to any combination of shapes. The machine for holding the workpiece, rotating the cutter, and feeding it is known as the milling machine.

Milling is versatile for a basic machining process, but because the milling setup has so many degrees of freedom, milling is usually less accurate than turning or grinding unless especially rigid fixturing is implemented. In concept, milling is very straightforward. A cutter is held in a chuck, which rotates at a controlled speed. The cutter is suspended over a work surface whose location can be precisely controlled. The part to be machined is securely fastened to the work surface, and the work surface is moved underneath the cutter. Appropriate choices of cutter type, depth of cut and speed determine the final shape.

Milling includes a number of machining operations, including: slotting, drilling, reaming, facing, and pocket removal. A cutting tool that revolves around its central axis carries out these operations. A workpiece or stock is clamped on a bed, and the cutting tool moves into it, removing material as it goes. Either the tool itself is moved, usually it moves along the axis of the tool, or the bed the stock is attached to moves, bringing the workpiece into contact with the tool.

1.4 Scope of Project

The purpose of this project is to investigate the available technique and system of cutting process by a conventional milling machine in KUTKM's manufacturing machine shop. From the machining process, observation will be made on the variety of cutting parameter and the material surface roughness.

This project will concentrate on the conventional milling operation where the research will mainly around the fundamental of milling process. The parameter of milling operation like cutting speed and feed rate will be investigated to determine the pattern that will be evaluated in order to select the most suitable cutting parameter to be used in conjunctions with purpose of gaining a good surface finish.

A conventional turret machine that available in faculty machine shop will be used for this project. Face-milling operation will be done to machine a small block of workpiece. As this project is to determine the surface roughness, only little cutting cavity is required. Although the most popular milling process is end milling, the face-milling operations is also important and capable to give required variables for data analysis in order to relate the variables with the result that being search for, which is the surface roughness condition.

The material can be various depend on project capability. This mean only few type of material required based on usage of student in KUTKM's machine shop. The common material available in the workshop is mild steel and aluminum. However, variability of material is required to enhance the project analysis.

1.5 Objectives

The main purpose to run this project is to fulfill the requirement of Final Year Project (Projek Sarjana Muda) of Kolej Universiti Teknikal Kebangsaan Malaysia (KUTKM).

As state in the title, this project will investigate and evaluate current approaches when machining with conventional milling machine. From here the variables of the cutting parameters that has significant affect on surface roughness like cutting speed and feed rate in face milling operation will be determined and evaluated.

The product that underwent the face milling process then will be observed for its surface roughness condition. The surface roughness measurement will use the surface roughness tester model SJ-301 Surface Roughness Tester.

Various variables will be chosen for the cutting parameters and types of material use in order to get a good result data. The data then will be analyzed to determine the relationship between the variables and the surface condition of a machined product.

1.6 Project Outcome

At the end, this project is expected to deliver the analysis of the experiment that will show the relationship of cutting parameter with the surface roughness measurement. The result will be used to determine the most affective cutting parameter that will produce a good surface roughness condition.

From the project analysis, a reference data table will be build. The table will show the recommended cutting parameter for face-milling operation on the conventional milling machine. The table can be used by KUTKM's student as a reference while doing job with the conventional milling machine.

CHAPTER 2
LITERATURE REVIEW

2.1 Types of Milling Operations

Depending on the geometry of the cutter and the motion between the cutter and the workpiece, we distinguish the following milling categories: slab milling, face milling, end milling, straddle milling, and form milling. (S. Kalpakjian, 1997). The scope of this project is to use face milling operation.

2.1.1 Face Milling

In face milling the cutter is mounted on a spindle having an axis of rotation perpendicular to the workpiece surface and removes material in the manner shown in the figures below.

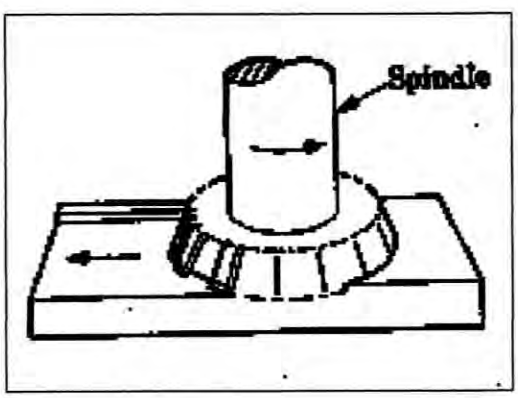

Figure 2.1.1a: Face Mill Operation

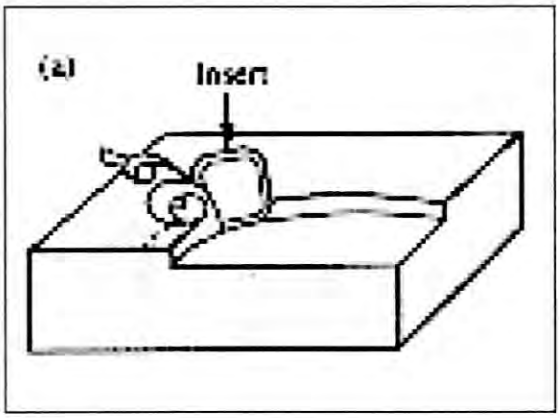

Figure 2.1.1b: Face-Milling Operation Showing Action of an Insert in Face Milling

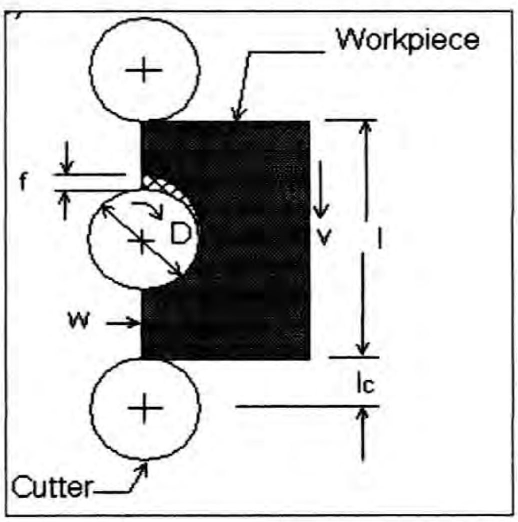

Figure 2.1.1c: Face Milling Operation Shows Action of Climb Milling

The cutter rotates at a rotational speed and the workpiece moves along a straight path at a linear speed. When the cutter rotates such that its linear velocity is in the same direction as that of the workpiece, the operation is climb milling; when it rotates in the opposite direction, the operation is conventional milling.

The cutting tools are usually carbide or high-speed-steel inserts and are mounted on the cutter body. Because of the relative motion between the cutting teeth and the workpiece, a face milling cutter leaves feed marks on the machined surface, much as in turning operations. Surface roughness depends on insert corner geometry and feed per tooth. (S. Kalpakjian, 1997).

2.2 Machine Features

Most of the milling machines are constructed of column and knee structure and they are classified into two main types namely Horizontal Milling Machine and Vertical Milling Machine. The name Horizontal or Vertical is given to the machine by virtue of its spindle axis. Horizontal machines can be further classified into Plain Horizontal and Universal Milling Machine. The main difference between the two is that the table of a Universal Milling Machine can be set at an angle for helical milling while the table of a Plain Horizontal Milling Machine is not.

The basic components of milling machines are:

i. *Worktable*, on which the work piece is clamped, using the T-slots. The table moves longitudinally with respect to the saddle.
ii. *Saddle*, which support the table and can move transversely.
iii. *Knee,* which support the saddle and gives the table vertical movement for adjusting the depth of cut.
iv. *Overarm,* in horizontal machines, which is adjustable to accommodate different arbor lengths.
v. *Head,* which contains the spindle and cutter holders. In vertical machines the head may be fixed or vertically adjustable and can be swiveled in a vertical plane on the column for milling tapered surfaces.

(S. Kalpakjian, 1997).

Figure 2.2a illustrates a typical column-and-knee type manual mill. Such manual mills are common in job shops that specialize in parts that are low volume and quickly fabricated. Such job shops are often termed "model shops" because of the prototyping nature of the work.

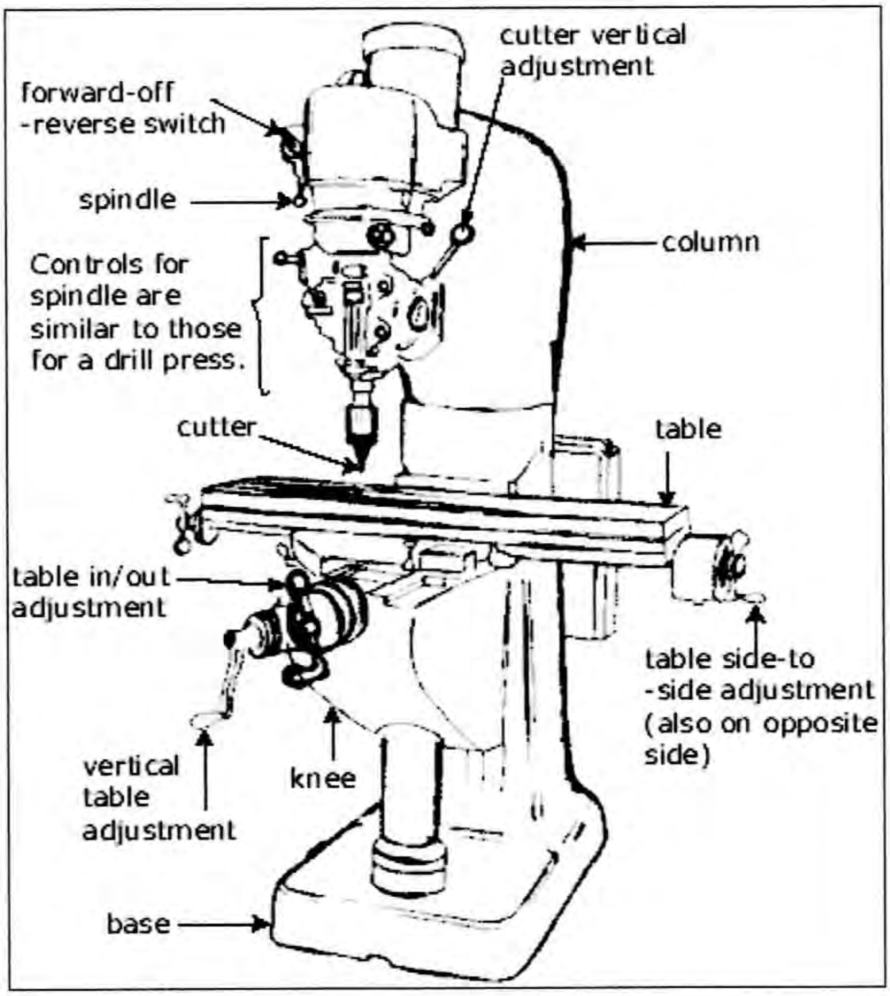

Figure 2.2a: Basic Knee-type Milling Machine Features

The parts of the manual mill when separated are shown in Figure 2.3b below. The knee moves up and down the column on guide ways in the column. The table can move in x and y on the knee, and the milling head can move up and down.

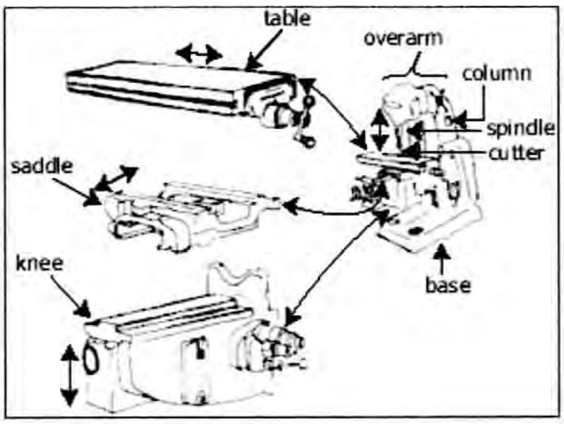

Figure 2.2b: Important Features of Knee-type Milling Machine

2.3 Milling Cutter and Inserts

Inserts are individual cutting tools with a number of cutting edges. A square inserts for example, has eight cutting points and a triangular inserts has six. Inserts are usually clamped on the tool shanks with various locking mechanism. Inserts may be brazed to the tool shank. However, because of the differences in thermal expansion between the inserts and the tool shank material, brazing must be done carefully to avoid cracking and warping.

Clamping is preferred method because each insert has a number of cutting edges, and after one edge is worn, it is indexed (rotated in its holder) to present another cutting edge. In addition to these examples, a wide variety of other tool holders are available for specific applications, including those with quick insertion and removal features.

Carbide inserts are available in a variety of shapes, such as square, triangle, diamond, and round. The strength of the cutting edge is depends on its shape. The smaller the angle, the lower the strength of the edge. In order to improve edge strength and prevent chipping, all inserts edges are usually honed, chamfered, or produced with a negative land. Most inserts are honed to a radius of about 0.025 mm. (S. Kalpakjian, 1997).

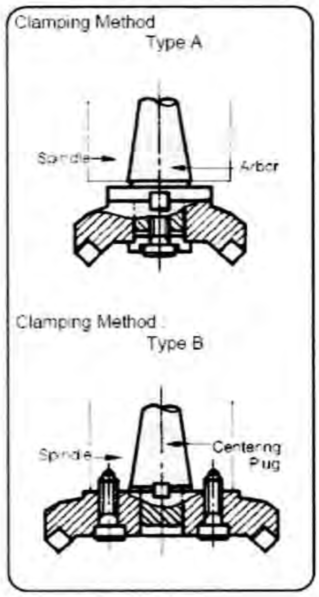

Figure 2.3: Clamping Method of Tool Shanks with Inserts

2.4 Cutting Parameters

In order to understand the fundamental of cutting, a two-dimensional model is presented as below (S. Kalpakjian, S. R. Schimd, 2001). In this model, a cutting tool moves to the left along the workpiece at a constant velocity. a chip is produced ahead of the tool by deforming and shearing the material continuously along the shear plane.

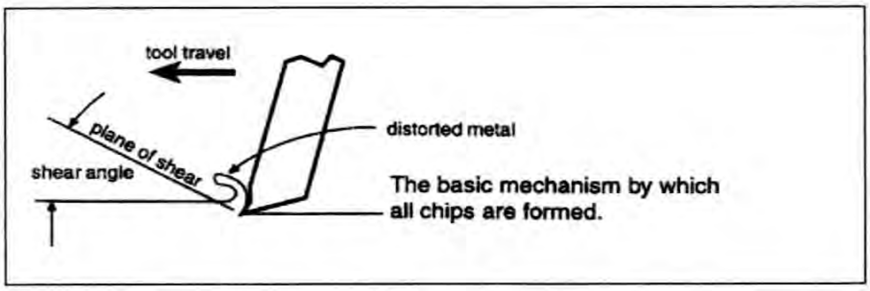

Figure 2.4: Model Fundamental of Cutting

Table 2.4: Factors influencing Cutting Process. (S. Kalpakjian, S. R. Schimd, 2001).

	Parameter	Influence and interrelationship
1	Cutting speed, depth of cut, feed, cutting fluids.	Forces, power, temperature rise, tool life, type of chip, surface finish.
2	Tool angles.	As above, influence of chip flow direction, resistance to tool chipping.
3	Continuous chip.	Good surface finish, steady cutting force, undesirable in automated industry.
4	Built up edge chip.	Poor surface finish, thin stable edge can protect tool surface.
5	Discontinuous chip.	Desirable for ease chip disposal, fluctuating cutting forces, can affect surface finish and cause vibration and chatter.
6	Temperature rise.	Influence tool life, particularly crater wear, and dimensional accuracy of workpiece; may cause thermal damage to workpiece surface.
7	Tools wear.	Influences surface finish, dimensional accuracy, temperature rise, forces and power.
8	Machinability.	Related to tool life, surface finish, forces and power.

2.5 Surface Finish

Surface finish influences not only the dimensional accuracy of machined parts, but also their properties. Whereas surface finish describes the geometric features of surfaces, surface integrity pertains to properties such as fatigue life and corrosion resistance, which are influenced strongly by the type of surface produced. Factors influencing surface integrity are temperatures generated during processing, residual stresses, metallurgical (phase) transformations, and surface plastic deformation, tearing and cracking.

The built-up edge, with its significant effect on tool profile, has the greatest influence on surface roughness. Ceramic and diamond tools generally produced better surface finish than other tools, because of their much lower tendency to form built-up edge type of chips. A tool that is not sharp has a large radius along its edges, just as dull as pencil or knife does. At small depth of cut the rake angle can effectively become negative, and the tool may be simply ride over the workpiece surface and not remove chips. (S. Kalpakjian, 1997).

2.6 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. (Dr. Mike S. Lou, Dr. Joseph C. Chen & Dr. Caleb M. Li, 1998):

In face milling processes, the surface quality of the material of the machined part depends on many factors, including feed, cutting tool geometry and tool error. (P.Franco, M. Estrems, F Faura, 2004).

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. A few concepts are discussed as follows (Dr. Mike S. Lou, Dr. Joseph C. Chen & Dr. Caleb M. Li, 1998):

a) Surface texture;
    - Surface texture is the pattern of the surface, which deviates from a nominal surface. The deviations may be repetitive or random and may result from roughness, waviness, lay and flaws.
b) Real surface;
    - The real surface of an object is the peripheral skin, which separates it from the surrounding medium. This surface invariably assimilates structural deviations, which are classified as form errors, waviness, and surface roughness.
c) Roughness;
    - Roughness consists of the finer irregularities of the surface texture, usually including those irregularities that result from the inherent action of the production process. Profiles of roughness and waviness a
d) Roughness width;
    - Roughness width is the distance parallel to the nominal surface between successive peaks or ridges, which constitute the predominant pattern of the roughness.
e) Roughness width cutoff;
    - Roughness width cutoff is included in the measurement of average roughness height, which denotes the greatest spacing of repetitive surface irregularities. It is rated in thousandths of an inch. Standard tables list roughness width cutoff values of 0.003, 0.10, 0.030, 0.100, 0.300 and 1.000 inches. If no value is specified, a rating of 0.030" is assumed.
f) Waviness;
    - Waviness should include all irregularities whose spacing is greater than the roughness sampling length and less than the waviness sampling length.