UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Comparative Study of End-Mill Performance between Straight and Spiral Flute

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) with Honours.

by

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APPROVAL

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ABSTRACT

Nowadays, there are many studies done on the effects of the cutting tool and other parameters to the surface finish of the product. There are also studies done to study the effect of the machining parameters on the cutting tool itself. Those studies were conducted to find the suitable parameters in order to optimize the metalworking process. In metalworking industries, good surface finish is one of the criteria that the product should have. Therefore, the study on chatter stability has carried out widely by studying the effect of end mill used in the metalworking process such as helical ball end end-mill, and straight end-mill on the product being machined. There is some studies that are also study the effect of the straight flute end mill and spiral flute end mill in chatter stability to the product that been machined. Since there is no performance comparison made to both straight and spiral flute end mill, this study focused on performance different for both end-mills at the end of the study. The comparison will be analyzed by referring the trend line showed by the plotted graph after the data produced through the experimental data collected. The result evaluated based on the experimental data in this study shown that the spiral flute end-mill have the best performances compared to straight flute end-mill and end-mill with a helix angle of 15° is more stable than end-mill with a helix angle of 30° in-terms of cutting forces, surface roughness and tool wear performances.

ABSTRAK

Dewasa ini, terdapat banyak kajian yang dilakukan berkaitan mata alat pemotong dan pelbagai parameter lain yang mungkin memberi kesan terhadap permukaan produk yang dihasilkan. Terdapat juga kajian yang dilakukan terhadap parameter-parameter yang mungkin memberi kesan terhadap mata alat pemotong itu sendiri. Semua kajian ini dilakukan untuk mencari parameter yang optimum bagi tujuan pemesinan. Dalam industri pemesinan, hasil akhir pada permukaan produk adalah suatu kriteria yang perlu dicapai. Maka dengan itu, kajian tentang kesan kestabilan geligis terhadap produk yang dihasilkan banyak dilakukan terutama yang berkaitan mata alat pemotong. Terdapat juga kajian yang dilakukan terhadap kesan kestabilan geligis mata alat pemotong yang lurus serta yang berlengkuk kepada produk yang dimesin. Walaubagaimanapun, tiada perbandingan khusus yang dilakukan terhadap pencapaian atau prestasi memotong antara mata alat pemotong yang lurus dengan yang berlengkuk. Diakhir kajian ini, rumusan tentang prestasi mata alat pemotong yang terbaik antara keduanya akan dinyatakan setelah perbandingan dilakukan dengan merujuk graf yang dibentuk melalui data-data yang dikumpul melalui eksperimen yang telah dijalankan. Berdasarkan data yang diperolehi, mata alat pemotong berlengkuk atau berpilin menunjukkan prestasi yang lebih baik jika dibandingkan dengan prestasi mata alat pemotong yang berpilin. Berdasarkan kajian ini juga didapati bahawa mata alat pemotong berpilin 15° menunjukkan prestasi yang lebih stabil berbanding mata alat pemotong berpilin 30° dari segi daya pemotongan, permukaan pemotongan dan kehausan mata alat pemotong.

DEDICATION

For my supervisor, lecturers, family and friends

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LIST OF ABBREVIATIONS

3D	-	Three Dimensional
AISI	-	American Iron and Steel Institute
AMC	-	Advance Manufacturing Center
CMM	-	Coordinate Measuring Machine
CNC	-	Computer Numerical Control
Fc	-	Cutting Force
FEA	-	Finite Element Analysis
Fn	-	Normal Force
Fs	-	Shear force
Ft	-	Trust Force
HSS	-	High Speed Steel
N	-	Number of flute
PSM	-	Projek Sarjana Muda
R	-	Resultant Force
Ra	-	Arithmetic Average
Rq	-	Root Mean Square
SFPM	-	Surface Feed per Minute
UTeM	-	Universiti Teknikal Malaysia Melaka
V	-	Cutting Speed
WC	-	Tungsten Carbide

CHAPTER 1
INTRODUCTION

1.1 Project Background

End Milling is an important and common machining operation because of its versatility and capability to produce various profiles and curved surfaces. End-mill has either a straight shank or a tapered shank and is mounted into the spindle of the milling machine. End-mills may be made of high speed steels (HSS), carbide or with carbide inserts, similar to those for face milling. The cutter usually rotates on an axis perpendicular to the workpiece surface. End milling can produce a variety of surfaces at any depth, such as curved, stepped, and pocketed. The cutter can remove material on both its end and its cylindrical cutting edges.

End-mills have greatly improved since the days of carbon-steel cutting tools. High-speed steels (HSS) cutting tool are considered old today, yet still maintain a very importance place in the metal-cutting industry (Krar, et al. , 2005). In the industry today, cutting tool material must have properties that can provide efficient metal removal rates for the machining application. All of variables involved such as part shape, machine condition, workpiece material, relative wear resistance of the cutting tool, toughness, cutting forces and others influence the decision on the type of cutter that should be selected.

Therefore, many researches have been done to improve metal cutting performance and ease the selection of the parameters in metal cutting. One of the research areas done on end mill was on relieve cutter design, especially on helical flute end-mills. Helix angle of the end mill influence the instability of milling due to repetitive impact driven chatter (Zatarain, et al. 2006). There were several studies on the influence of spiral and straight flute in milling operation. They are the analytical prediction of chatter stability conditions for multidegree of freedom systems in milling that been conducted and the analysis of the influence of mill helix angle on chatter stability have been done by Zatarain, et al. (2006). Both studies investigate only on the influences of spiral flute end-mills and straight flute end-mills to the milling process on the chatter stability. However, those studies do not provide comparison of performance between spiral and straight flute in milling operation in terms of cutting force, surface roughness and tool wear. Thus, this study is carried out to gain those information which can be used to improve machining performance especially in end-mills machining operations.

1.2 Problem Statement

There are two main problems that lead to the study and investigation on the comparison of end-mill performance between straight and spiral flute. Firstly, based on published studies spiral flute end mill gives smoother cutting action and chatter stability in machining process which should contributes to the finer surface finish. However, there is no study been done to compare performance of straight and spiral flute end mill to validate the assumptions. This study, is trying to prove or disprove that assumption. Other than that, very little study has been done on the influences of spiral and straight flute end-mills in the metalworking operation. This study will provide some comparative data on the cutting force and tool wear of end mill during milling process between straight and spiral flutes end mills.

1.3 Objectives

The main purposes of this project are:

- To determine the performance differences in terms of surface roughness, cutting force and tool wear between end-mill with straight flute and that of with spiral flute.
- To compare and identify the best end-mill flute design, between straight flute and spiral flute, with respect to overall machining performance.

1.4 Project Scope

The experiment will be conducted using conventional milling and vertical type of milling machine. Both straight flute end-mill and spiral flute end-mill will be used to machine the mild steel as the workpiece material. In this experiment, both types of milling cutter are made from Tungsten Carbide materials which are four flutes type of end-mills. The feed rate and depth of cut will be kept constant for all the setting conditions. The feed rate value is 71 mm/min and the depth of cut value is 0.5 mm. Then, after the machining process on the milling machine, the Ziess Microscope Axioskop Two Mat will be used to examine the tool wear on the cutting tool.

1.5 Report Structure

Overall this report is divided into six chapters. The first chapter is mainly about the introduction of the project. This chapter highlights the background of the project, problem statements, objectives, scopes of study and the important of this study. Then, the next chapter is Chapter 2 which is the literature review of this project. This literature review consists of the brief explanation of four main topics which are the end-mills, tool wears, cutting force and the surface finish. After that, Chapter 3 will describe about the methodology that will be used to complete this project. In this chapter also, all the fundamental, equipment, and parameters that going to be used in experiment are briefly described. Then, Chapter 4 will display the results and its analysis, the discussion of the results of end-mills also been discuss in this chapter. Lastly, the conclusion is concluded in the Chapter 5 which determined the best type of end-mills' flute between both straight and spiral flute.

CHAPTER 2

LITERATURE REVIEW

2.1 Milling

Milling is a process in which a rotating cutter removes material while travelling along various axes with respect to the workpiece. Milling machines are machines tools used to produce one or more machined surfaces accurately on a piece of material, which is called workpiece. This process is done by one or more rotary milling cutters having single or multiple cutting edges. The workpiece is held securely on the work table of the machine or in a holding device clamped to the table. It is then brought into contact with a revolving cutter (Krar et al., 2005).

The vertical milling machine is one of the most common and versatile machine tools, uses end-milling-type cutters to machine horizontal, vertical, and angular surfaces, grooves, slots, and keyways plus a wide variety of other machining operations. The vertical milling machines are easy to be set up and operate, it is equipped with the proper accessories, it can machine circular forms and performing-boring operations.

2.2 End Mill

End mill is the cutter that is used in milling operations. It has either a straight shank (for small cutter sizes) or a tapered shank (for larger cutter sizes) and is mounted into the spindle of the milling machine. End mills may be made of high-speed steels or with carbide inserts. The cutter usually rotates on an axis perpendicular to the workpiece surface, and it also can be tilted to machine tapered or curved surfaces.

End mills are available with hemispherical ends (ball nose mills) for the production of sculptured surfaces, such as on dies and molds. Hollow end mills have internal cutting teeth and are used to machine the cylindrical surface of solid, round workpieces. End milling can produce a variety of surfaces at any depth, such as curved, stepped, and pocketed. The cutter can remove material on both its end and its cylindrical cutting edges. Vertical spindle and horizontal spindle machines, as well as machining centers, can be used for end milling workpieces of various sizes and shapes.

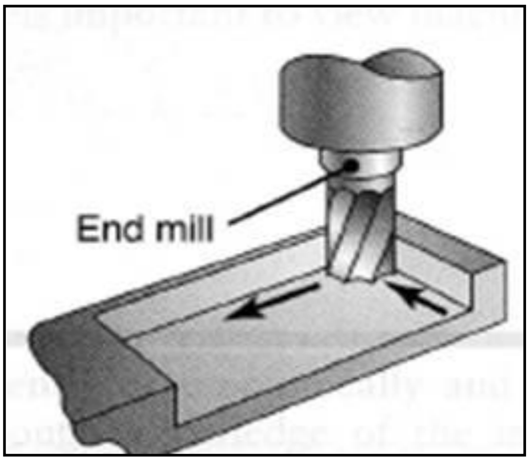

Figure 2.1: End milling operation (Kalpakjian & Schmid., 2006, p.608).

2.3 End Mill Form

End mills can be ground into required shapes but, the most common type of end mills is flat bottom end mill, end mill with a full radius (often called a ball nose end mill) and an end mill with a corner radius (often called a bull nose end mill).

Every type of end mill is used for a specific type of machining operation. Standard flat end mils are used for all operations requiring a flat bottom and sharp corner between the wall and the bottom. Meanwhile, a ball nose end mill is used for 3D machining on various surfaces, and a bull nose end mill is used for either 3D work, or flat surfaces that require a corner radius between the wall and the bottom (Krar et al 2005).

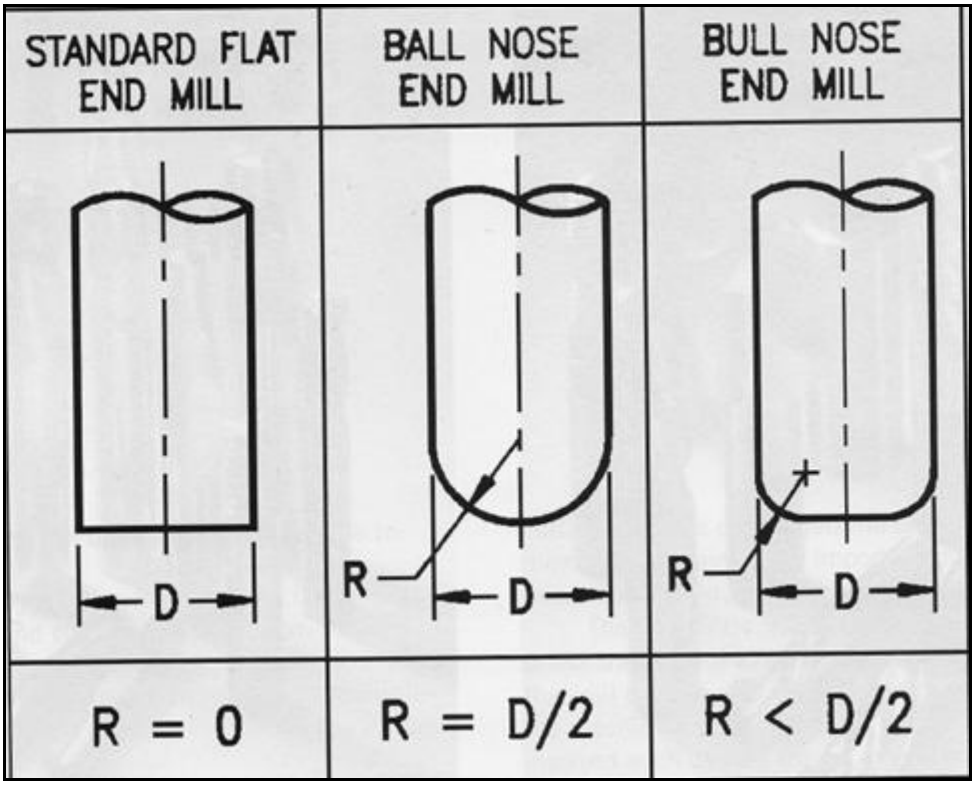

Figure 2.2: Three common shapes ground on end mills. (Niagara Cutter cited in Krar 2005, p.478)

2.4 End Mill Features

As far as metal cutting action is concerned, the pertinent angles on the tooth are those that define the configuration of the cutting edge, the orientation of the tooth face, and the relief to prevent rubbing on the land. The terms defined below and illustrated in Figures 2.3 are important and fundamental to milling cutter configuration.

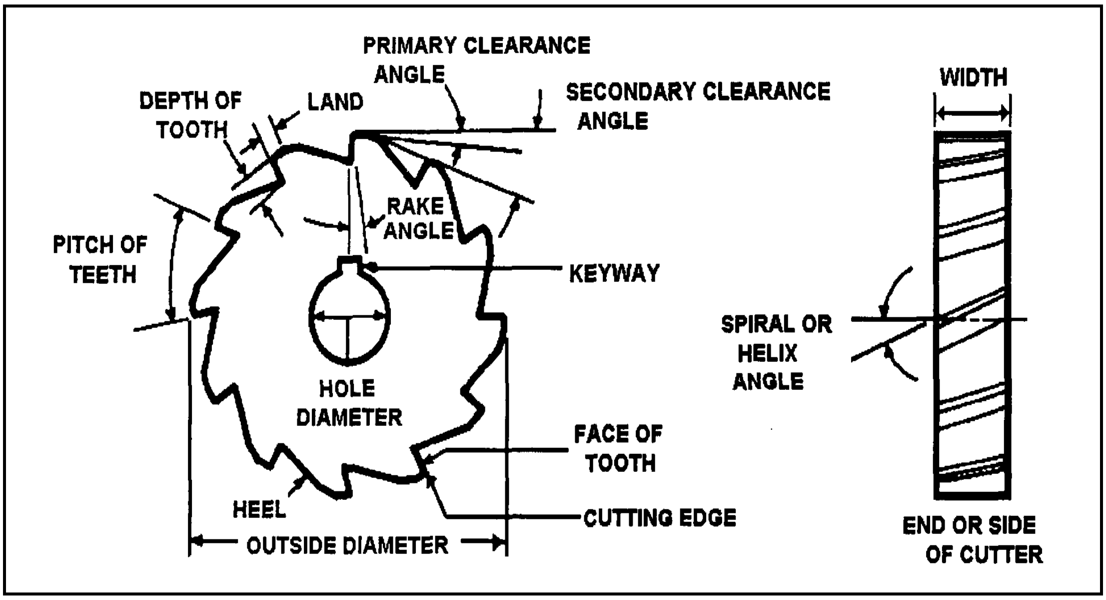

Figure 2.3: Milling cutter nomenclature (Milling Machine, Anon p.8-3)

Outside Diameter: The outside diameter of a milling cutter is the diameter of a circle passing through the peripheral cutting edges. It is the dimension used in conjunction with the spindle speed to find the cutting speed (SFPM).

Root Diameter: The root diameter is the diameter of the circle passing tangent to the bottom of the fillet.

Tooth: The tooth is the part of the cutter starting at the body and ending with the peripheral cutting edge. Replaceable teeth are also called inserts.

Tooth Face: The tooth face is the surface of the tooth between the fillet and the cutting edge, where the chip slides during its formation.

Land: The land is that part of the back of the tooth adjacent to the cutting edge which is relieved to avoid interference between itself and the surface being machined. A raised land permits numerous resharpenings before a secondary clearance has to be ground.

Flute: The flute is the space provided for chip flow between the teeth.

Gash Angle: The gash angle is measured between the tooth face and the back of the tooth immediately ahead.

Fillet: The fillet is the radius at the bottom of the flute, provided to allow chip flow and chip curling. The terms defined above apply primarily to milling cutters, particularly to plain milling cutters. In defining the configuration of the teeth on the cutter, the following terms are important.

Peripheral Cutting Edge: The cutting edge aligned principally in the direction of the cutter axis is called the peripheral cutting edge. In peripheral milling, it is this edge that removes the metal.

Face Cutting Edge: The face cutting edge is the metal removing edge aligned primarily in a radial direction. In side milling and face milling, this edge actually forms the new surface, although the peripheral cutting edge may still be removing most of the metal. It corresponds to the end cutting edge on single point tools.

Relief Angle: The peripheral relief angle is the angle between the surface formed by the land and a tangent to the cutter outside circle passing through the cutting edge in a diameter plane. It is to prevent the land from rubbing on the surface of the work being cut. Relief and clearance are measured in degrees or in radial fall in inches at a certain specified distance back of the cutting edge on the land. For this latter measurement, a dial indicator may be used to measure the radial fall in thousandths of an inch from the outside or cutting edge diameter back of the cutting edge.

Clearance Angle: The clearance angle is provided to make room form chips, thus forming the flute. Normally two clearance angles are provided to maintain the strength of the tooth and still provide sufficient chip space.

Radial Rake Angle: The radial rake angle of a milling cutter is the angle formed in a diameter plane between the face of the tooth and a radial line passing through the cutting edge. This may be positive, negative, or zero degree.

Axial Rake Angle: When a milling cutter has helical teeth, that is, when its cutting edge is formed along a helix about the cutter axis, the resulting rake is called helical rake. If the cutting edge is straight, its rake is axial rake. The axial rake or helical rake angle is the angle formed between the line of the peripheral cutting edge and the