UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FEEDRATES OPTIMIZATION AND IN BALL END MILLING OF MILD STEEL

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

By

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APPROVAL

This report submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Process) with Honours. The member of the supervisory committee is as follow:

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ABSTRACT

Nowadays, milling is the most effective, productive and flexible-manufacturing method for machining complicated surfaces. Ball End Mill is the one of the millings tool. It also can used in machining the geometrical shapes of product or manufacture of free form surfaces such as dies and moulds, and various parts, such as aerospace components. The ball end milling is, however, less efficiency than the flat end milling. It is important to optimize the feedrate that gives the maximum material removal rate constrained by an allowable surface roughness. The purpose of this project are to study the optimization of the feedrate in Ball End Mill in order to consider the generated-scallop effect by the ball-end cutter, to optimum quality and efficiency in order to improve scallop height of machining in ball end milling and to obtain the scallop height after done sweeping process in ball end milling process. Hence, to find out the solution, this project done based on the study of the method of several journals. This study also is to discover the suitable feedrates to produce the best surface roughness of mild steel. The others method use in the study are modelling of the process using CATIA, basic machining of CNC Milling Machine, and measurement for the surface roughness which using ‘surface roughness tester’. Above all, this study uses the Design of Experiment (DOE) method in analyzing the result. Finally, the proposed methods are applied on workpiece (mild steel) and results are presented. The result is shown that the lowest step over, feed and angles is the lowest of scallop height (lowest Ry value).

ABSTRAK

Di zaman teknologi masa kini, pengisaran adalah yang paling efektif, produktif dan kaedah pembuatan fleksibel untuk permukaan mesin yang rumit. Ball End Mill adalah satu alat pengisaran. Hal ini juga boleh digunakan dalam enjin bentuk geometri produk atau pembuatan bentuk permukaan bebas seperti die dan mold, dan di pelbagai bahagian, seperti komponen kapal terbang. Ball End Mill walaubagaimanapun, kurang kecekapan daripada rata penggilingan akhir. Penting untuk mengoptimumkan kadar suapan yang memberikan kadar pembuangan bahan maksimum dihadkan oleh kekasaran permukaan yang dibenarkan. Objektif dari projek ini adalah untuk mengkaji pengoptimuman daripada kadar suapan di Ball End Mill dalam rangka untuk mempertimbangkan kesan yang dihasilkan oleh pemotongan permukaaan, untuk optimum yang tinggi dan kecekapan dalam rangka untuk meningkatkan ketinggian 'scallop' dalam Ball End Milling dan untuk memperoleh ketinggian 'scallop' selepas dilakukan proses 'sweeping' dalam Ball End Mill. Oleh kerana itu, untuk mengetahui penyelesaiannya, projek ini dilaksanakan berdasarkan kajian kaedah daripada beberapa jurnal. Kajian ini juga menemukan kadar suapan yang berpadanan untuk menghasilkan yang permukaan yang terbaik terhadap 'Mild steel'. Kaedah yang lain digunakan dalam kajian adalah muat pemodelan menggunakan CATIA, asas-asas mesin pengisaran dan pengukuran untuk kekasaran permukaan yang menggunakan 'surface roughness tester', kajian ini juga menggunakan Design of Experiment (DOE) kaedah dalam menganalisis hasil dapatannya. Akhirnya, kaedah yang dicadangkan dilaksanakan pada benda dan hasil dapat ditunjukkan. Hasilnya menunjukkan bahawa nilai terendah step over, feed dan angles menghasilkan nilai scallop height yang rendah (nilai terendah Ry).

DEDICATION

Special dedicated to my beloved mother, family, and friends who provide a loving, caring, encouraging and supportive atmosphere. These are characteristic that contribute to the environment that is always needed to achieve the goals ahead.

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LIST OF ABBREVIATIONS

C	-	Cross Feed Vector
CAD	-	Computer Aided Dimension
CATIA	-	Computer Aided Three-dimensional Interactive Application
CNC	-	Computer Numerical control
CMOS	-	Complementary Metal-Oxide Semiconductor
DOE	-	Design of experiment
F	-	Feed Vector
HSS	-	High Speed Steel
NC	-	Numerical Control
PH	-	Parker-Hannifin Corporation (NYSE)
PCD	-	Polycrystalline diamond
Ra	-	Arithmetical Roughness
Ry	-	Maximum Height
Rz	-	Roughness
Sm	-	Spacing of Profile Irregularities
SPC	-	Statistical Process Control
tp	-	Ratio
3D	-	Three Dimension

CHAPTER 1

INTRODUCTION

The content of this chapter is introduction to Ball End Mill. Here, the definition is explained as the movement of ball end milling and the result of scallop-height after machining. The problem statement, objectives of the project, scope of study and finally the contents of dissertation conclude this chapter.

1.1 Introduction to Ball End Mill

Nowadays, milling is the most effective, productive and flexible-manufacturing method for machining complicated surfaces. The end mill, which is used in surface contouring has a hemispherical end and is called ball-end mill. The ball-end mill is fed back and forth across the workpiece along a curvilinear path at close intervals to produce complex three-dimensional surfaces. Similar to profile milling, surface contouring require relatively simple cutting tool but advanced, usually computer-controlled feed control system. It also can used in machining the geometrical shapes of product or manufacture of free form surfaces such as dies and moulds, and various parts, such as aerospace components. Ball End Mill cutter (figure 1.1) also capable of manufacturing a workpiece appropriated to mass production with small size and a very high accuracy. Ball end mills also for shallow slotting contour milling and copying and pocketing operations. The ball end design allows these end mills to be used for radius milling of slots, filets or special contours.

A ball end mill is suitable to milling many types of materials, from plastics to steel alloys and titanium. The toughness and durability of the cutting edge is very high in Ball End Mills because of the rounded edge design. This fact is actually just a by product of the rounded cutting edge. It was rounded for a specialized purpose, often for milling grooves with a semi-circular cross-section. This type of groove is an important part of the metal bearings used in many machines.

Figure 1.1: Ball-end milling cutter (Jin, et al ,2007)

Tool path generation is the main issue in the finishing stage of NC machining. In order to satisfy surface finish quality, tool paths are generated so that the scallop height formed by two adjacent tool paths is controlled within a predefined machining tolerance. In order to fill this requirement, the path interval should be small enough, and consequently, the machining efficiency is limited. To achieve a significant improvement in machining efficiency, the scallop height is kept at a constant which is equal to the predefined machining tolerance. (Yoon, 2005)

The advantage of ball end mill is, it can handle very high feed rates, meaning it can mill the material very quickly and at the same time it can gives a high productivity. The smooth geometry of the cutting tip also translates into lower cutting forces, giving the cutter added strength under pressure. Since it is less to break under normal forces, the applications to which suited also will cost-effectively to the ball end mill.

Ball end mills are usually made from tungsten carbide and a high-strength metallic compound containing tungsten and carbon. The powder of tungsten carbide is pressed into rods, which are then ground and sharpened to various specifications. Usually, a typical ball end mill is manufactured with a protective coating which the coatings are comprise titanium mixed with other elements such as carbon and aluminium.

Finding optimum machining parameters in 3D sculptured surface machining is quite a widely researched problem. The cutting force generated during machining process is an important parameter, which reflects the machining conditions. The other important factors for the optimum machining are cutting time, cutting tool cost, quality of surface achieved, and machining errors visualized as shape deviation from the ideal. The above mentioned issues should really be considered simultaneously, which would render the optimization problem quite intricate. With an on-line monitoring system, the machining process and above mentioned factors can be monitored easily.

The determination of efficient cutting parameters has been a problem confronting manufacturing industries for nearly a century, and is still the subject of many studies. To ensure the quality of machining products, and to reduce the machining costs and increase the machining effectiveness, it is very important to select the optimal machining parameters. Optimal machining parameters are of great concern in manufacturing environments, where economy of machining operation plays a key role in the competitive market.

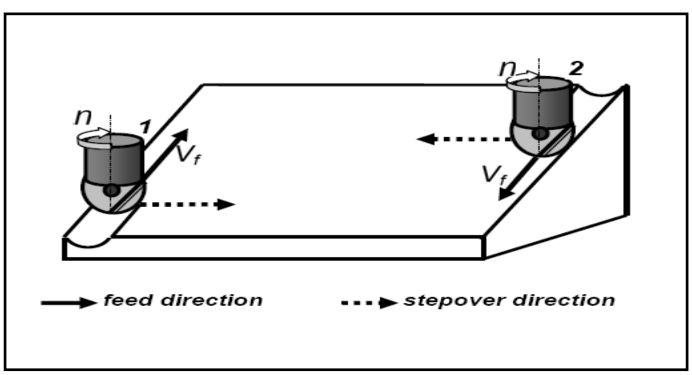

Figure 1.2: Vertical path Strategy (Jin, et al ,2007)

The cutter path orientation is crucial in achieving desired machined surface and without considering the impact of cutting edge with undeformed chip in different path strategy with adequate consideration of the chip area variation, cutting forces, temperature and vibration analysis, the result can lead to cutter failure and therefore lead to unnecessary waste of time, cost and poor surface quality In this report the vertical path strategy, in climb-milling (feed and cutting speeds are in the same sense, tool-left in CNC program) is evaluated using 3D-CAD geometric method and according to the feed direction the milling can be divided to vertical upward and vertical downward(Fig.1.2): (Cosma, 2005)

This project investigated the feedrate optimization and efficiency enhancement in Ball End Milling on Mild Steel process because the previous works show that it is the one of factor that affects the feed-interval scallop due to the dynamical and the periodical change of the cutting edge orientation. In addition, this project also investigate the calculation of ‘f=p’ by Chen, (2005) that refer to the path and pick interval scallop produced after machining. Also, in other parameters in ball end milling that will be considered in this project is depth of cut, lubrication, material and tool material.

1.2 Problems statement

In this project, the scallop heights generate by ball end milling machining are depends on the design desired. But, the way to enhance the efficiency in the Ball End Milling machining, variable feedrates optimization instead of constant feedrate becomes very important under constraints of surface roughness and the generated scallop height. In addition, the study of optimization of the feedrate will be consider the generated-scallop effect by the ball-end cutter.

In the other hand, the quality and efficiency in ball end milling machining are effect by generated scallop height which also includes the parameters that use in machining. For instant, in ball end milling process there is several methods that can be use in machining.

In this project, the sweeping process will be use to see the result or the surface generated.

1.3 Objective

a) The objective of this project is to study the optimization of the feedrate in Ball End Mill in order to consider the generated-scallop effect by the ball-end cutter.

b) To optimum quality and efficiency in order to improve scallop height of machining in ball end milling.

c) To obtain the scallop height after done isoparametric process in ball end milling process by using 3-axis CNC milling machine.

1.4 Scope

This study is mainly about the experimental test of the Ball end milling process to study the effects of the feedrate of Ball End Milling process on the mild steel. The focus of this project is study on the several journals to identify the method to calculate the feed interval scallop. By this, the generated-scallop will be measure using the calculation to compare the better surface roughness due to the variable feedrate optimization using measuring scope. Different feedrates of the Ball end milling machine will result different surface roughness.

Hence, this study is to discover the suitable feedrates to produce the best surface roughness of mild steel. The others method use in the study are modelling of the process using CATIA, basic machining of 3-axis Milling Machine, and measurement for the surface roughness which using measuring scope Above all, this study uses the Design of Experiment (DOE) method in analyzing the result.

CHAPTER 2

LITERATURE REVIEW

This chapter consists of literature reviews of subjects that are going to be investigated throughout this project. Theories, related studies, testing involve and previous researches of the feedrate optimization in ball end mill and matters involved will be reviewed. The concept of sculptured surface including feedrate especially with calculation that related to the process also step over distance, tilt and lead angles, cutting speed, spindle speed and depth of cut. Previous research from journals and papers are also being reviewed. This is to ensure that the project will be guided and avoid mistakes once the experiment takes place.

2.1 Introduction

Productivity and the quality in machining operations are determined by the process simulation. However, process simulation requires powerful geometrical and mechanics models. In literature, significant amount of work is available in milling geometry modeling 3-axis ball-end milling of sculptured surface geometries are modeled using various methods these studies consider a truly 3-axis process including the effects of tool orientation. In addition, this literature is also available in optimization and machining strategy selection. Also, the machining strategies are evaluated with respect to either process mechanics or workpiece geometry.

2.2 Basic Concept of Feedrate Optimization

To make the machining safe and efficience, the most important factor is feedrate. Feedrate is the rate at which the material is advanced into the work material. Depending on the rate of feed, a chip on a given thickness will be removed since each tooth of a multitooth milling cutter is cutting (Chen, et al., 2005). To give the longest tool life between resharpenings, they must be highest practical feed per tooth. From the machining of the ball end millng, the first thing that important to understanding is differential between pick-interval and feed-interval scallops.

In ball end milling operations, the cutting tool must step over and make several adjacent cuts to complete machining a feature. As a result, a small cusp of material, called a scallop, will remain between these cuts on any surrounding walls or on the machined surface if a ball end mill is used. The size of the step-over distance and the tool diameter will determine the scallop height between each step. Decreasing the step-over distance will minimize the scallop height, but will require more steps, and therefore more time, to machine the feature.

2.2.1 Comparison between Pick-interval and Feed-interval Scallops

The 3D and plane-projection views of a ball-end cutter are shown in Figure 2.1(Chen, et al., 2005) coordinate system is assigned to represent the tool geometry. For the ball-end milling, the machining process consists of successive parallel cutting paths separated by an offset distance. As shown in Figure 2.1, due to the spherical geometry, a path-interval scallop can be observed between successive paths. The path-interval scallop is simply formed by the stationary geometry of the ball-end cutter. Note that the path-interval scallop formation is assumed that the ball-end cutter is in pure translation to the workpiece.

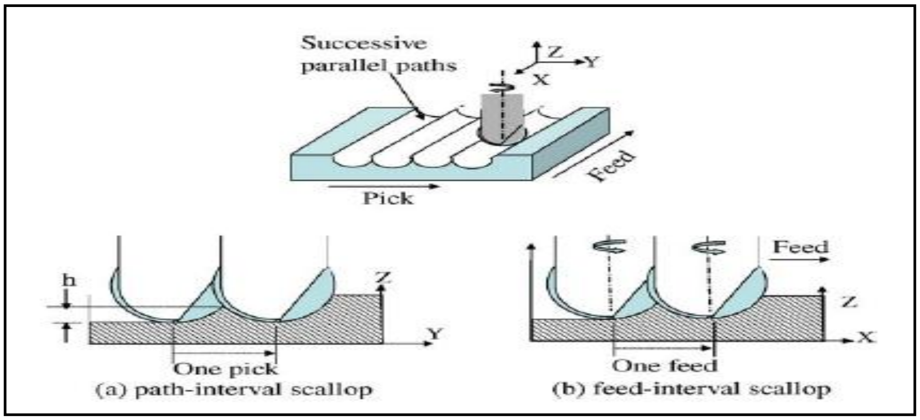

Figure 2.1: Path Interval Scallop and Feed interval Scallop (Chen, et al., 2005)

When the ball-end milling proceeds along a cutting path, the orientation of the cutting edge is dynamically and periodically changed during the spindle rotation. Due to the spherical shape of the ball-end cutter, another kind of feed-interval scallop is generated between successive tooth feeds. At the first look, the shape and generating mechanism of the feed interval scallop looks exactly same as the path-interval scallop.

The distance between two adjacent tool paths is commonly referred as side step or tool path interval. Generally the scallop-height requirement is employed to control the side steps of CNC tool paths (Yang, 2008).

2.3 Tool Orientation

Tool orientation is defined by lead and tilt angles which are measured between the tool axis and the surface normal. Lead angle is the rotation of the tool about the cross feed vector (C), where tilt angle is about the feed vector (F) with respect to machined surface normal. Lead and tilt angles are shown in Figure 2.2. The lead and tilt angles are defined in FCN.

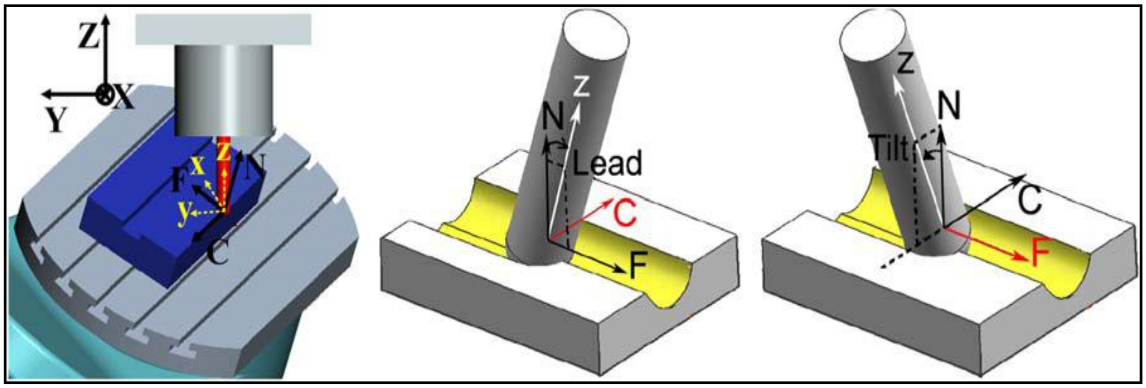

Figure 2.2: Coordinate systems and lead–tilt angles (Ozturk, E , et al., 2009)

The tool tilt angle is defined as the angle of rotation between the centerline of the tool and the normal plane to the workpiece. Contact angle is defined as the total angle of contact of the tool flute that is in contact with the workpiece and is a function of depth of cut. Since ball-ended mills are used in this research, the contact angle will always be the angle from workpiece normal to the workpiece surface.

2.3.1 Effects of lead and tilt angles on the process

Lead and tilt angles have effects on different factors such as tool tip contact with the workpiece, scallop height, cutting forces, torque, form errors and stability. In 5-axis milling, the additional motions of the cutter are the two rotary axes. (Ozturk, et al. ,2009)

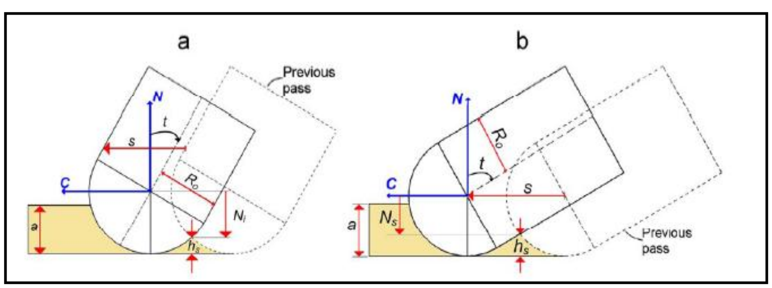

Figure 2.3: Scallop Height : (a) $s \leq 2Ro \cos t$ and (b) $s \geq 2Ro \cos t$ (Ozturk, E , et al., 2009)