UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE ERROR COMPENSATION STRATEGY USING STEP APPROACH FOR MACHINING THIN-WALL LOW RIGIDITY COMPONENT

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

by

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TAJUK: **The Error Compensation Strategy Using Step Approach for Machining Thin-wall Low Rigidity Component**

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I hereby, declared this report entitled "The Error Compensation Strategy Using Step Approach for Machining Thin-Wall Low Rigidity Component" is the results of my own research except as cited in references.

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APPROVAL

This report is 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). The member of the supervisory committee is as follow:

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ABSTRAK

Ketepatan komponen yang dimesin adalah salah satu perkara yang paling penting untuk dipertimbangkan bagi mana-mana pengilang. Salah satu bidang yang yang agak sukar dan mencabar bagi pengeluar adalah pengeluaran komponen monolitik yang biasanya dikaitkan dengan industri aeroangkasa. Komponen monolitik ini terdiri daripada beberapa rasuk berdinding nipis dan bahagian bebibir yang perlu dimesin. Oleh kerana komponen monolitik mempunyai kawasan yang besar dan ketegaran rendah, komponen berdinding nipis sentiasa dimesin dalam kawalan berangka (NC) proses akhir pengilangan. Walaubagaimanapun, oleh kerana pelbagai sebab dalam proses pemesinan, ciri-ciri bagi komponen berdinding nipis sangat mudah untuk berubah bentuk di bawah kuasa pemotongan yang akan mempengaruhi ketepatan dan kualiti.

Laporan ini adalah untuk menyiasat prestasi pemesinan menggunakan langkah strategi untuk pemesinan komponen berdinding nipis dengan ketegaran yang rendah. Empat langkah strategi berbeza iaitu langkah garis air, langkah bertindih, tiga langkah bijak dan kaedah 4-to-1 yang akan disiasat dengan menilai prestasi pemesinan pada pemesinan komponen berdinding nipis yang diperbuat daripada aloi aluminium.

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ABSTRACT

Accuracy of machined components is one of the most critical considerations for any manufacturer. One of the challenging difficult areas for manufacturer is the production of monolithic component that is usually associated with aerospace industries. This monolithic component consists of several thin-wall rib and flange sections that need to be machined. Due to the large area and low rigidity of monolithic component, the thin-walled are always machined using numerical control (NC) end milling process. However, owing to various reasons in the machining process, the thin-walled features are very easy to deform under the cutting force which will influence the accuracy and quality.

This report investigates the machining performance using the step strategy for machining thin-wall low rigidity component. Four different step strategies namely waterline-step, overlapping-step, three wise-steps and 4-to-1 rule method are investigated by evaluating their machining performance on machining the thin-wall component made of aluminum alloy.

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DEDICATION

This study is dedicated to my beloved family, Aishah Binti Salleh and Noor Hidayah Binti Ahmad.

To my supervisor, lecturers and fellow friends for all their helps and supports.

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TABLE OF CONTENT

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LIST OF TABLES

© Universiti Teknikal Malaysia Melaka

LIST OF FIGURES

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

%	-	Percentage
°	-	Degree
°C	-	Degree Celsius
°F	-	Degree Fahrenheit
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
CMM	-	Coordinate Measuring Machine
CNC	-	Computer Numerical Control
Co	-	Cobalt
Cr	-	Chromium
g/cm^3	-	Gram per centimeter cube
HEM	-	High Efficiency Machining
HSM	-	High-Speed Machining
HSS	-	High-Speed Steel
NC	-	Numerical Control
R_a	-	Average Roughness
V	-	Vanadium
W	-	Tungsten

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CHAPTER 1
INTRODUCTION

1.1 Background

Many components used in the aerospace industry are usually thin-walled structures. Due to the gradual reduced thickness during cutting, the end milling of thin-walled plate is a very complicated process. The tight dimensional tolerance of aerospace component poses a great challenge for the manufacturer especially for machining a component that contains a thin-wall feature (Tang and Liu, 2007).

Traditionally, aircrafts were fabricated from thin sheets of aluminum which were bent or folded for strength and then riveted to form light weight, rigid and strong air frame components. Several bent and riveted components were then riveted and bolded together into larger and more complex assembles. These were in turn riveted on to the aircraft frame.

In today’s highly competitive commercial aircraft market, this manual method has many disadvantages such as slow processes, expensive, labor intensive, highly error prone and highly non uniform which is depend on the operator. Each assembly is just slightly different from the next which adversely affects how each assembly is mounted on to the aircraft frame.

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This manual production method has been replaced by an automated, highly uniform and very accurate method called monolithic machining. The monolithic components are commonly used as structural parts in the aeronautical industry due to the homogeneity and excellent strength to weight ratio. The components are milled starting from a raw block of material and removing up to 95% of the weight of the initial block (Campa et al, 2007).

In end milling process, the thickness of the plates is reduced gradually, which makes it even more difficult to control the accuracy of machining. The end milling of such component is complicated, where periodically varying milling forces excite the flexible plate structures both statically and dynamically and leading to significant deformations (Ratchev et al., 2005).

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1.2 Problem Statement

The tight dimensional tolerance of aerospace component poses a great challenge to manufacturer especially for machining a component that contains a thin-wall feature. Because of the poor stiffness of thin-wall feature, deformation is more likely to occur in the machining of thin-wall part which resulting a dimensional surface errors. Figure 1.1 shows the dimensional surface errors produced in machining thin-wall feature. Material in the shaded areas *MNOP* as depicted in Figure 1.1 (b) is to be removed ideally. However, due to the milling force the wall is deflected which make point *M* moves to point *M'* as well as point *N* to point *N'*. As a result of the wall deflection, only material *MN'OP* is removed resulting a dimensional surface errors in *NON'* areas.

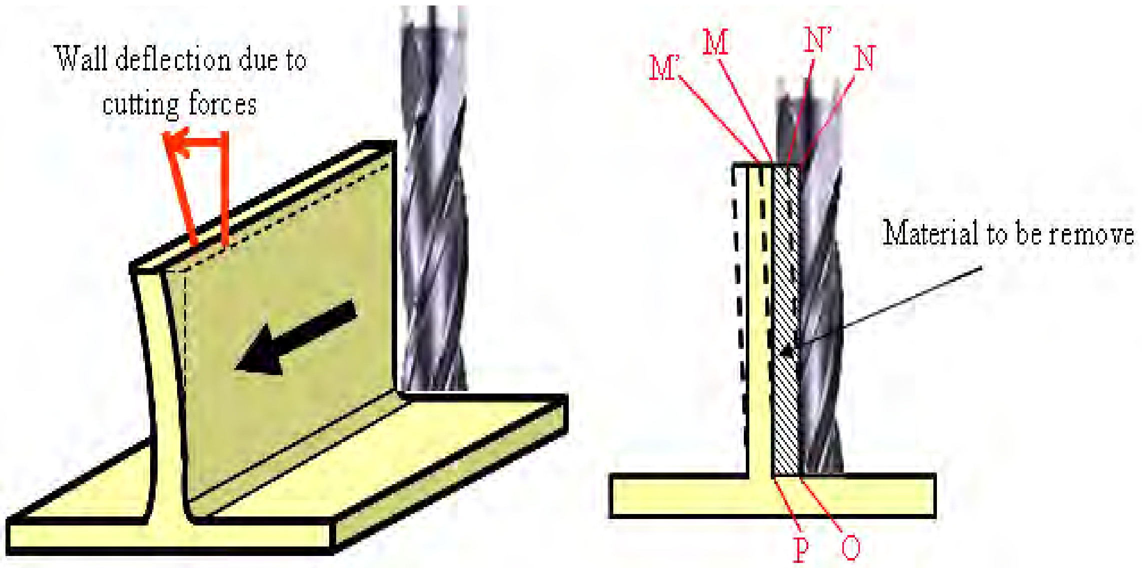

Figure 1.1: Dimensional surface errors produce in machining thin-wall feature. (a) Deflection of wall resulting from cutting force. (b) Machining sketch of thin-wall component.

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In current industry practice, the strategies for machining the thin-wall component are using one or more of the following techniques:

(i) Using a repetitive feeding and final 'float' cut to bring the machined surface within tolerance.
(ii) Manual calibration to determine 'tolerable' machining conditions.
(iii) A lengthy and expensive trial and error numerical control validation process.
(iv) Using a step machining approach, this alternately is milling each side of the wall.

The last technique of using a step machining approach is favorable in industry practice. This project investigated the machining performance using step machining approach or strategy for machining thin-wall low rigidity component.

1.3 Objective

The objectives of the project are:

i. To study the step machining strategies namely 4-to-1 rule, waterline-step, overlapping-step and tree wise-step for machining the thin-wall component.
ii. To evaluate the machining performance of each strategy for machining the thin-wall component.

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1.4 Project Scope

This project focuses on the effects of different step machining strategies on the machining performances for milling thin-wall workpiece. Four different step machining strategies namely 4-to-1 rule, waterline-step, overlapping-step and tree wise-step are generated. A 12 mm carbide endmill cutter is used for machining of aluminum workpiece. The machining performance includes dimensional accuracy, machining time, cutting forces and surface finish were measured for results evaluation.

1.5 Report Outline

This report writing consists of three chapters for Final Year Project (FYP) 1. The Chapter 1 is explaining about the introduction; which is includes the project background, problem statement, objectives of the project, scope of the project and the significant of this project. Then the Chapter 2 was stressed on the literature review of the related issues in this project. Meanwhile, Chapter 3 is more about the project methodology which is includes the process planning for this project, flowchart, data gathering method and data analytical techniques in this project.

Then the second phase report writing of Final Year Project, which is FYP 2, was covered with two more chapters. It continues with the Chapter 4 that is all about the result and discussion of experimental that have been done. Lastly in Chapter 5, it had state the conclusion and recommendation to improve the experimental or analysis of this project for the next time.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review will discuss in detail on the issue that is related with the step approach for machining thin-wall low rigidity component. This chapter is included explanation about the related study based on this project and the machining process that need to be considered in the cutting process. The other related topic is about the cutting tool and material of the workpiece and cutting tool that will used for machining process in this project.

2.2 Milling

Milling is a process of generating machined surfaces by progressively removing a predetermined amount of material or stock from the workpiece at a relatively slow rate of movement or feed by a milling cutter rotating at a comparatively high speed. The characteristic feature of the milling process is that each milling cutter tooth removes its share of the stock in the form of small individual chips.

Milling tends to be an expensive manufacturing process because the bits and cutters operate at high temperatures and burn coolant that is sprayed on them in the process to keep them from overheating. The cutting bits themselves are also very expensive as they must be hardened to a degree where they can repeatedly cut into metals such as aluminum and stainless steel (Hawk, 2012).

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2.2.1 Peripheral Milling

Peripheral milling of very flexible components is a common manufacturing process in the aerospace industry. Very flexible components are considered to have a wall thickness thinner than 5 mm and an axial depth of cut larger than 30 mm. The wall thickness of the component is reduced further by peripheral milling operation using a long and helical slender end mill (Budak, Altintas et al., 1995).

In peripheral milling (also called slab milling), the axis of cutter rotation is parallel to the workpiece surface, as shown in Figure 2.1. The cutter body which is generally is made of high-speed steel (HSS). It has a number of teeth along its circumstances and each tooth acts like a single-point cutting tool. When the cutter is longer than the width of the cut, the process is called slab milling (Kalpakjian, 2006).

Cutters for peripheral milling may have straight or helical teeth which are resulting in orthogonal or oblique cutting action. Helical teeth generally are preferred over straight teeth because the tooth is partially engaged with the workpiece as it rotates. Consequently, the cutting force and the torque on the cutter are lower which is resulting in a smoother operation and reduced chatter (Kalpakjian, 2006).

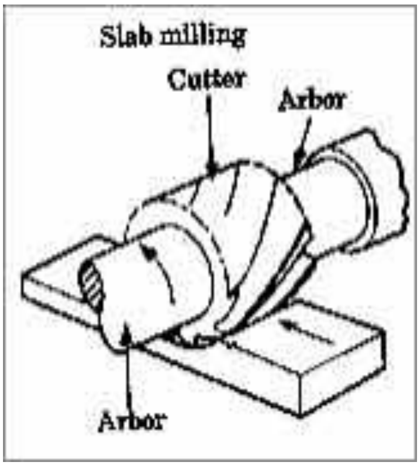

Figure 2.1: Peripheral milling (Source: Kalpakjian. S, 2006)

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2.3 Cutting Tool

In machining, a cutting tool (or cutter) is a tool that is used to remove material from the workpiece by means of shear deformation. Cutting tools must be made of a material harder than the material which is to be cut. The cutting tool also must be able to withstand the heat generated in the metal-cutting process.

2.3.1 End Mill

An end mill is a tool used on a milling machine. A milling machine is a machine found in a metal working shop that is used to remove material from a metal block to make it into a finished part. An end mill is one of the tools used on the milling machine to make a particular type of cut (Sunshine, 2012).

End mills come in single ended and double ended varieties. A single ended end mill has only one useful working end and the other end is just a smooth shank for holding the end mill in the tooling holder on the milling machine. A double ended end mill has two useful working ends. When one end becomes dull and no longer useful, the end mill can be installed such that the opposite end can be used (Sunshine, 2012).

End mills are made of carbide steels with the cutting surfaces sometimes made entirely of carbides. It is also common for end mills to be coated with a very thin layer of titanium nitrate. Titanium nitrate is a gold coloured coating that prevents the metal chips being removed from the part from sticking to the end mill, reducing its life and the quality of the cut. End mills come in a wide variety of shapes and sizes (Sunshine, 2012).

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End mill is an important and common machining operation because of its versatility and capability to produce various profiles and curve surfaces. The cutter called an end mill has either a straight shank (for small 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 which are similar to those for face milling. The cutter usually rotates on an axis perpendicular to the workpiece surface (Kalpakjian, 2006).

The end mill is an important tool in the milling process. A typical example for the end mill is the milling of a pocket and slot in which a lot of material is removed from the workpiece. Therefore the proper selection of cutting parameters for end milling is one of the important factors affecting the cutting cost (Tsai and Liao, 1999).

2.3.1.1 Two-Flute

The flutes of the milling bit are the deep helical grooves running up the cutter while the sharp blade along the edge of the flute is known as the tooth. The tooth cuts the material and chips of this material are pulled up the flute by the rotation of the cutter. There is almost always one tooth per flute but some cutters have two teeth per flute.

The words flute and tooth are used interchangeably. Milling cutters may have from one to many teeth with 2, 3 and 4 being most common. Typically, the more teeth a cutter has, the more rapidly it can remove material. So, a 4-tooth cutter can remove material at twice the rate of a 2-tooth cutter.

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