STRATEGY FOR MILLING THIN-WALL LOW RIGIDITY CURVE SHAPE COMPONENT

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

by

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I hereby, declared this report entitled "Strategy for Milling Thin-Wall Low Rigidity Curve Shape Component" is the results of my own research except as cited in references.

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Date :

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) (Hons.). The member of the supervisory is as follow:

………………………………

(Project Supervisor)

ABSTRAK

Pada masa sekarang, terdapat pelbagai situasi dimana mata alat dari jenis lansing digunakan bagi tujuan pemotongan benda kerja dinding nipis yang berbentuk lengkung. Kegunaan ini biasanya terdapat pada teknologi pemesinan bahagian pada badan pesawat/kapal terbang. Dalam kes ini, banyak kecacatan telah berlaku iaitu pemesongan pada badan kerja. Projek ini menjalankan kajian tentang cara yang betul dan effektif dengan mengubah kedudukan dan pergerakan mata alat untuk mendapatkan produk yang dimensinya tepat. Untuk kajian ini, cara ‘compensation’ digunakan. Cara ini berdasarkan pada perubahan pada pergerakan mata pemotong pada magnitude permukaan yang salah yang telah diperolehi dari pemesinan awal. Ketepatan dan efektif proses ini dinilai berdasarkan kekasaran permukaan dan ketepatan dimensi produk.

ABSTRACT

There are many machining situations where slender tools are used to machine thin walled curve shape workpiece. Such instances are more common in machining of aircraft structural parts. In these cases, the workpiece deflections are quite common which result into surface error on machined components. This project presents a methodology for tool path compensation for effectively machining curve shape thin walled geometries by modifying the tool paths. The cutter compensation method is based on the adjustment of cutter path with respect to the magnitude of surface errors obtained from the preliminary machining with ideal cutter path. The effectiveness of the compensation strategy is then evaluated by measuring the component accuracy and surface roughness.

DEDICATION

To my beloved parents.

ACKNOWLEDGEMENT

Alhamdulillah, Thanks to the entire Almighty from Allah for giving me all the strength and good health to complete this report without problems and barriers. This report is finally completed with much assistance of many people.

I would like to express the deepest appreciation to Universiti Teknikal Melaysia Melaka for providing such a brilliant facility such as equipment and machine for me to fulfil PSM requirement that’s need to use while the project is carry on .

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Last but not least I would like to thank my friends especially those who help to contribute the idea and solution while the research is carry on. Thank you.

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LIST OF ABBREVIATION, SYMBOLS AND NOMENCLATURE

%	-	Percent
2D	-	2 Dimension
3D	-	3 Dimension
Al	-	Aluminium
ANN	-	Artificial Neural Network
CAM	-	Computer Aided Manufacturing
Catia	-	Computer Aided Three-Dimensional Interactive
CMM	-	Coordinate Measuring Machine
CNC	-	Computer Numerical Control
C^o	-	Degree Celsius
FEA	-	Finite Element Analysis
Gpa	-	Giga Pascal
HV	-	Hardness Vickel
kg	-	kilogram
m	-	meter
min	-	minute
mm	-	millimetre
Mpa	-	Mega Pascal
MYR	-	Malaysia Ringgit
NC	-	Numerical Control
PNN	-	Polynomial Neural Network
R_a	-	Arithmetic Average of Absolute Value
RPM	-	Revolution Per Minute
Ti	-	Titanium

CHAPTER 1
INTRODUCTION

This chapter reviews and describe the detail about the objective of the research for milling thin-wall low rigidity curve shape component. The objective clearly instructs what the researcher should do and what specific measure that must be follows in order to achieve the goal. The scope prevents the researcher from do the unneeded task that has no connection with the research topic.

1.1 Research Background

Milling of complex thin walled geometries is becoming increasingly important in aerospace industries due to its ability to produce complex parts as monolithic structures. The need for expensive multi-part manufacturing, large set up times on different machines and assembling of pieces together into finished product is eliminated here because the complete part is manufactured from a single piece by material removal processes. Many of the thin walled components produced in these industries are curve shape in nature. Closed nature of curve shape structures provides much needed stiffness to the components in resisting machining induced forces. In spite of this, a major problem associated with milling of thin walled curve shape components is cutting force induced static deflections of cutter and workpiece which manifest in form of surface error on finished parts. Highly non-linear and complex nature of surface error profiles during milling of such components not only deteriorates its dimensional accuracy but also geometric tolerances.

1.2 Problem Statement

It is challenging task for the process planner to obtain tight dimensional and geometric tolerances dictated by functional requirements of the product. One of the approaches is to use conservative cutting conditions and multi-pass machining to limit cutting forces. Such an approach reduces surface error but hampers productivity of machining operation significantly. Yet another approach is to use final “float” cut to bring machined surface within required tolerance. It is not advisable to take “float” cut in thin-walled machining as it may not be effective due to compliant nature of the workpiece. In such machining situations, single pass off-line tool path modification strategy can be considered as one of the efficient ways to produce thin walled quality parts without sacrificing productivity.

This report presents a methodology to predict and compensate surface errors in milling of thin walled curve shape structures. The effectiveness of the compensation strategy is evaluated by measuring the component accuracy and the surface roughness.

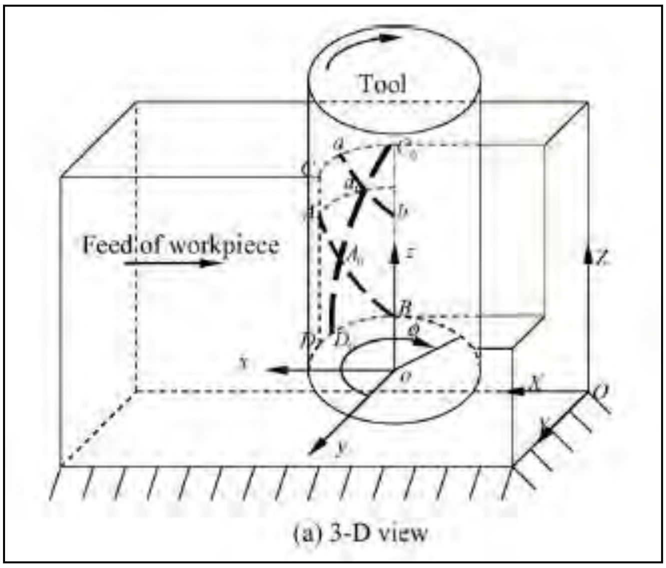

Figure 1.1: Isometric views of thin-wall cutting process. (Ratchev, 2004)

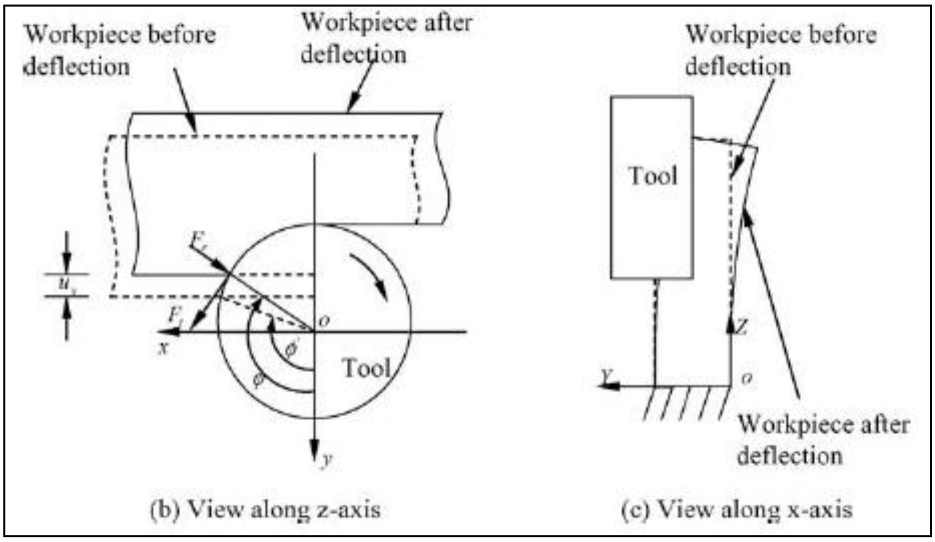

Figure 1.2: Deflection on the thin wall. (Ratchev, 2004)

1.3 Objective

The objective of this study as follow:

i. to develop a tool path compensation strategy for milling thin-wall low rigidity curve shape component
ii. to evaluate the effectiveness of the compensation strategy by measuring the dimensional accuracy and surface roughness

1.4 Project Scope

This project focuses on the tool path compensation strategy for milling thin-wall low rigidity curve shape component. The cutter compensation method is based on the adjustment of cutter path with respect to the magnitude of surface errors obtained from the preliminary machining with ideal cutter path. The obtained surface errors values will be used to generate a new surface profile for the generation of solid model. A new tool path is created using CATIA CAM software based on the new solid model of surface profile. The effectiveness of the compensation strategy is then evaluated by measuring the component accuracy and the surface roughness value using CMM and surface roughness tester respectively.

CHAPTER 2
LITERATURE REVIEW

Literature reviews, Chapter 3, are reviewing the relevant literatures about the method or approach that use to machining monolithic part which is aerospace part. This chapter also covered machining parameter that need to consider and the detail about the material type use to produce the part.

Section 2.1 Reviews the detail about the related works that has been done to produce the part base on the approach or the technique to fabricate the monolithic part. The related works are reviews such as, surface finish R_a, machining time and accuracy of dimensional that produce by the selected method.

Section 2.2 Reviews the detail compensation method and working principle

Section 2.3 Reviews the detail 8 to 1 rule Method and the working principle for workpiece preparation.

Section 2.4 Reviews on the aluminium material properties that related to the machining process. Reference from CES EduPack version 6.2.0 software and related journal about aluminium material is use for this section.

1.5 Related Works

Number of research attempts can be found in literature that deals with reduction of cutting force induced tool or workpiece deflection errors. But very few of these attempts are focused on reduction of combined tool and workpiece deflection errors. Research attempts focusing on reduction of deflection induced surface error can be broadly categorized into three groups:

i. Process design approach which controls cutting forces during machining by varying cutting parameters such as feed rate (Tarng and Cheng, 1993; Budak and Altintas, 1994) or cutting widths (Ryu and Chu, 2005) so that deflections do not exceed beyond specified limits,
ii. On line adaptive control approach proposes shifting of cutting tool in real time (Yang and Choi, 1998) necessitating use of measurement sensors and hardware,
iii. Off-line tool path modification approach consisting of correcting tool path on the basis of known surface error before performing actual milling operation.

Among all these approaches, off-line tool path modification is widely used in reduction of cutting force induced surface errors during milling operation. The methodology for off-line tool path compensation was originally proposed by Lo and Hsiao (1998) which was based on measured values of surface error. The methodology needs an additional set of machining and measurement test prior to machining of finished components. The first set of machining experiment is conducted with nominal tool path to obtain surface error variation which can be used further in determining modified tool path. The main drawback of this approach is that an additional experiment is required for each component to obtain compensated tool path. A similar methodology was also developed for compensation of surface error in ball end milling of sculptured surfaces (Yang and Menq, 1993). In one of the off-line tool path modification studies, it was observed that the reference coordinates for measurement are distorted due to movement of component from CNC machine to Coordinate Measuring Machine (CMM) and use of On-Machine Measurement

(OMM) system was emphasized for improvement in measurement accuracy and reduction of setup time (Cho et al., 2003).

It has been highlighted by many researchers that the predicted surface error can also be used to obtain compensated tool path so that an additional experimentation can be avoided. Based on this fact, an off-line tool path compensation methodology was proposed by Suh et al. (1996) for reduction of surface error during two-dimensional contour machining. The developed methodology computes modified tool path on the basis of tool deflection error predicted using process simulation models. Landon et al. (2003) applied compensation methodology for correction of tool path deformed due to action of cutting force on cutting tool, tool holder and spindle assembly. Depince and Hascoet (2006) carried out detailed investigations on surface error profile generated due to tool deflections and proposed a technique to obtain optimized tool path trajectory that achieves specified tolerances on finished components.

The application of tool path compensation strategy has also been extended in reduction of surface error during machining of pockets (Law and Geddam, 2003). It was highlighted that the non-uniform variation of surface error in machining of rectangular pockets can be effectively reduced using tool path compensation methodology. Some researchers recommended application of Artificial Neural Networks (ANN) to avoid computational complexities of predictive models while estimating surface error characteristics required for application of compensation algorithm. Cho and Seo (2002) used radial basis function based ANN to correlate cutting conditions like cutter type, workpiece material, spindle RPM, feed rate,radial and axial depth of cut with mean surface error. The compensation strategy has been applied with reference to mean surface error predicted using ANN model. Cho et al. (2006) used Polynomial Neural Network (PNN) in determination of mean surface error and then compensating the same using tool path modification techniques. Raksiri and Parnichkun (2004) proposed use of ANN in compensation of cutting force induced errors as well as geometric errors of machine tools. Recently, tool path compensation scheme was adopted by Rao and Rao (2006a) in peripheral milling of curved geometries where workpiece curvature changes continuously along the