



**Faculty of Manufacturing Engineering**

**DEVELOPMENT OF SIMULTANEOUS TWIN CUTTER FOR  
MACHINING THIN-WALL COMPONENT**

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**Master of Science in Manufacturing Engineering**

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**DEVELOPMENT OF SIMULTANEOUS TWIN CUTTER FOR MACHINING  
THIN-WALL COMPONENT**

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**A thesis submitted in fulfillment of the requirements for the degree of Master of  
Science in Manufacturing Engineering**

**Faculty of Manufacturing Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2019**

## DECLARATION

I declare that this thesis entitled “Development of Simultaneous Twin Cutter for Machining Thin-Wall Component” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

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Date : .....

## APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature : .....

Supervisor Name : ASSOCIATE PROF. DR. RAJA IZAMSHAH BIN  
RAJA ABDULLAH

Date : .....

## **DEDICATION**

To my beloved mother, late father and family who taught me that even the hardest task can be accomplished if it is done one step at a time.

## ABSTRACT

Peripheral milling of very flexible components with a large span ratio of heights to thickness such as monolithic component is a common manufacturing process in the aerospace industries. In such cases, the wall thickness of the part is further reduced, leading to dimensional surface error that causes the finished part to be out of specification. The surface errors are mainly induced by the acts of cutting force, which deflect the wall on the opposite direction. To solve the problem, this research proposes a simultaneous twin cutter machining technique aim to control the wall deflection. A twin cutter adaptor consists a set of gear arrangement design for transmitting the rotation of the machine spindle has been developed. A set of experimental work performs to validate the effectiveness of the propose technique. The research focuses on machining thin-wall part made of Aluminium Alloy 7075-T6 as materials. Totals 6 runs of constant speed of 1500 rpm consisting of 50, 80 and 200 mm/min feed rate for both single and twin cutter respectively were used. The experimental results indicated that, the deflection of the thin-wall part can be neglected and hence minimize the surface errors since the same cutting force appears on both sides of the wall surface. The proposed technique can increase the component accuracy and reduce the machining time up to 50 percent as only one pass is required to mill the wall structure compare with the single cutter machining technique.

## **ABSTRAK**

*Mesin kisar periferai untuk komponen yang sangat fleksibel dengan nisbah ketinggian kepada ketebalan yang tinggi seperti komponen monolitik adalah proses pembuatan yang biasa di dalam industri aeroangkasa. Dalam beberapa kes, untuk mengurangkan lagi ketebalan dinding, ia boleh menyebabkan ralat ukuran pada produk yang dimesin dan tidak memenuhi spesifikasi. Ralat ukuran disebabkan oleh tindakan daya pemotongan yang memesonkan dinding pada arah bertentangan. Untuk menyelesaikan masalah ini, kajian ini mencadangkan teknik pemesinan berkembar serentak bertujuan untuk mengawal pesongan dinding. Pemotong berkembar yang telah dicipta, terdiri daripada satu set reka bentuk perkakas gear untuk menghantar putaran kepada spindal mesin. Satu eksperimen dijalankan untuk mengesahkan keberkesanan teknik yang dicadangkan ini. Tumpuan penyelidikan ini adalah untuk memotong dinding nipis yang diperbuat daripada bahan Aluminium Alloy 7075-T6. Enam ujian telah dijalankan dengan kelajuan yang sama iaitu 1500 ppm dengan kadar suapan 50, 80 dan 200 mm/min pada kedua-dua pemotong tunggal dan berkembar. Keputusan eksperimen menunjukkan, pesongan bahagian dinding nipis boleh diabaikan dan dengan itu meminimumkan ralat ukuran kerana daya pemotongan yang sama muncul di kedua-dua belah permukaan dinding. Teknik yang dicadangkan ini dapat meningkatkan ketepatan komponen dan mengurangkan masa pemesinan sehingga 50 peratus kerana hanya satu hala yang diperlukan untuk kisar struktur dinding dibandingkan dengan teknik mesin pemotong tunggal.*

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## TABLE OF CONTENTS

	PAGE
<b>DECLARATION</b>	
<b>APPROVAL</b>	
<b>DEDICATION</b>	
<b>ABSTRACT</b>	<b>i</b>
<b>ABSTRAK</b>	<b>ii</b>
<b>ACKNOWLEDGEMENTS</b>	<b>iii</b>
<b>TABLE OF CONTENTS</b>	<b>iv</b>
<b>LIST OF TABLES</b>	<b>vii</b>
<b>LIST OF FIGURES</b>	<b>ix</b>
<b>LIST OF APPENDICES</b>	<b>xiii</b>
<b>LIST OF ABBREVIATIONS/SYMBOLS</b>	<b>xiv</b>
<b>LIST OF PUBLICATIONS</b>	<b>xvi</b>
<b>CHAPTER</b>	
<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Research Background	1
1.2 Problem Statement	3
1.3 Objectives	5
1.4 Scope of Work	5
1.5 Significance of Study	6
1.6 Summary	7
1.7 Thesis Organization	7
<b>2. LITERATURE REVIEW</b>	<b>9</b>
2.1 Introduction	9
2.2 Thin-Wall Unitised Monolithic Component	9
2.3 Challenges in Machining Thin-Wall Monolithic Component	13
2.4 Reviews on Technique for Machining Thin-Wall Component	15
2.4.1 Finite Element Method	15
2.4.2 Step Machining Approach	17
2.4.3 High Speed Machining	20
2.4.4 Trochoidal Machining	21
2.4.5 Fixture Design Approach	22
2.4.6 Summary of Reviews on Technique for Machining Thin-Wall Component	23
2.5 Machining	25
2.5.1 Principle of Material Removal Process	26
2.5.2 Milling	28
2.6 Simultaneous Machining	31
2.6.1 Multi Spindle Simultaneous Cutting (MSSC)	34
2.6.2 Issues and Challenges for Simultaneous Machining	36

2.7	Cutting Tool	37
2.7.1	End Mill Geometrical Feature	37
2.7.2	Cutting Tool Material	42
2.8	Aluminium Alloy in Aerospace Industries	43
2.9	Machining Parameters	45
2.9.1	Cutting Speed	46
2.9.2	Feed Rate	47
2.9.3	Depth of Cut	47
2.10	Machining Performance	47
2.10.1	Dimensional Surface Error	48
2.10.2	Surface Roughness	49
2.10.3	Machining Force	52
2.11	Summary	53
<b>3.</b>	<b>RESEARCH METHODOLOGY</b>	<b>55</b>
3.1	Introduction	55
3.2	Research Flow Chart	55
3.3	Design and Development of Twin Cutter Milling Adapter	57
3.3.1	Working Principles of Twin Cutter Milling Adapter	58
3.3.2	Design Considerations	60
3.3.3	Parts and Assembly	62
3.3.4	Technical Drawings of Twin Cutter Milling Adapter	69
3.3.5	Fabrication of Twin Cutter Milling Adapter	71
3.3.6	Spindle Rotation Verification	73
3.4	Fabrication of Carbide End Mill Tool	75
3.5	Fabrication of Thin-Wall Aluminium Workpiece	80
3.6	Experimental Setup for Validation	83
3.6.1	Setting Machine Axis Datum	85
3.6.2	Machining Parameter	86
3.7	Experimental Observation	90
3.7.1	Dimensional Surface Error	90
3.7.2	Cutting Force	91
3.7.3	Surface Roughness	92
3.8	Summary	93
<b>4.</b>	<b>RESULT AND DISCUSSION</b>	<b>95</b>
4.1	Introduction	95
4.2	Measurement of Surface Error	95
4.3	Measurement of Surface Roughness	107
4.4	Measurement of Cutting Force	113
4.5	Machined Surface Analysis	114

<b>5. CONCLUSION AND RECOMMENDATION</b>	<b>119</b>
5.1 Research Contribution	119
5.2 Recommendations for Future Work	120
<b>REFERENCES</b>	<b>122</b>
<b>APPENDICES</b>	<b>136</b>

## LIST OF TABLES

<b>TABLE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Comparison between monolithic and conventional aircraft component	10
2.2	Limitation of technique for machining thin-wall component	23
2.3	List of United State patent	31
2.4	Explanation of terminology of end mill	38
2.5	Chemical composition of Al 7075-T6	44
3.1	Parts and descriptions	64
3.2	Bill of materials for twin cutter milling adapter	68
3.3	Spindle speed measurement	74
3.4	Specification of Carbide End Mill	76
3.5	End mill tool geometry	77
3.6	Machining parameters for grinding end mill	80
3.7	Material and geometry of the thin-wall component	81
3.8	Machining parameters for thin-wall fabrication	81
3.9	Machining parameter for experiment	86
3.10	Machines and equipment used for the experiment	87
4.1	Surface error of side A (right, up milling)	97
4.2	Surface error of side B (left, down milling)	98
4.3	Surface roughness of side A (right, up milling)	108

4.4	Surface roughness of side B (left, down milling)	109
4.5	Machining surface finish	115

## LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Aerospace monolithic component	1
1.2	Dimensional surface errors produce in machining thin-wall feature	
	(a) Deflection of the wall resulting from cutting force	
	(b) Machining sketch of thin-wall component	4
2.1	Examples of aluminum wing rib monolithic frame part for aircraft	11
2.2	Examples of titanium bulkhead monolithic frame part for aircraft	11
2.3	Examples of landing gear monolithic frame part for aircraft	11
2.4	Machining sketch of thin-wall part deflection	14
2.5	Non-overlapping passes	17
2.6	Waterline milling	18
2.7	Step-support milling	19
2.8	Tree Wise Steps	20
2.9	Trochoidal milling diagram	21
2.10	Schematic illustration of a typical flexible structural component and its fixture setup	22
2.11	Terminology of orthogonal cutting	26
2.12	Chip formation and shear in cutting zone	27
2.13	The peripheral milling of thin-wall workpiece	29

2.14	Up milling	30
2.15	Down milling	30
2.16	Different multi spindle device	32
2.17	Geometry of multi spindle simultaneous cutting	
	(a) multiple workpiece with two table motion	
	(b) single workpiece with two spindle motion	35
2.18	End mill Nomenclature	38
2.19	Recommended Cutting Speed for Different Materials	46
2.20	Surface roughness profile	51
2.21	Terminology of cutting force	52
3.1	Process plan flowchart	56
3.2	Surface error produced from the conventional single cutter machining	
	Technique (a) cutting condition model (b) error model	58
3.3	Act of cutting force in twin cutter machining technique	59
3.4	Arrangement of main elements of twin cutter milling adapter	60
3.5	Design concept for the twin cutter milling adapter	61
3.6	The joint	62
3.7	Quill clamp	63
3.8	Driver	63
3.9	Exploded view of twin cutter milling adapter	70
3.10	Detail view of twin cutter milling adapter (a) front view (b) front view	
	(c) top view (d) isometric view	71
3.11	Twin cutter milling adapter	72
3.12	Assembly of twin cutter to CNC milling machine (side view)	72
3.13	Assembly of twin cutter to CNC milling machine (front view)	73

3.14	Spindle speed measurement of 500 rpm	74
3.15	Spindle speed measurement of 1000 rpm	74
3.16	Spindle speed measurement of 1500 rpm	75
3.17	End mill specification for twin cutter milling adapter	76
3.18	The machine coordinate system	78
3.19	Grinding wheels for end mill manufacturing	78
3.20	Fabricated end mill	80
3.21	Illustration of thin wall component	81
3.22	Waterline steps	82
3.23	Thin-wall workpiece fabrication	82
3.24	Thin-wall workpiece	83
3.25	Experimental setup for the twin cutter milling adapter machining technique	84
3.26	Experimental setup for single cutter machining technique	84
3.27	Illustration for twin cutter setting	85
3.28	Dimensional surface error measurement	91
3.29	Location for surface measurement	91
3.30	Experimental setup for cutting force measurement	92
3.31	Surface roughness measurement	93
4.1	Surface error at start ( $x = 0$ ) for 50 mm/min of feed rate	100
4.2	Surface error at middle ( $x = 55$ ) for 50 mm/min of feed rate	101
4.3	Surface error at end ( $x = 110$ ) for 50 mm/min of feed rate	101
4.4	Surface error at start ( $x = 0$ ) for 80 mm/min of feed rate	102
4.5	Surface error at middle ( $x = 55$ ) for 80 mm/min of feed rate	102
4.6	Surface error at end ( $x = 110$ ) for 80 mm/min of feed rate	103



4.7	Surface error at start ( $x = 0$ ) for 200 mm/min of feed rate	103
4.8	Surface error at middle ( $x = 55$ ) for 200 mm/min of feed rate	104
4.9	Surface error at end ( $x = 110$ ) for 200 mm/min of feed rate	104
4.10	Wall thickness after machining with 50 mm/min of feed rate (a) single cutter technique (b) twin cutter technique	106
4.11	Wall thickness after machining with 80 mm/min of feed rate (a) single cutter technique (b) twin cutter technique	106
4.12	Wall thickness after machining with 200 mm/min of feed rate (a) single cutter technique (b) twin cutter technique	107
4.13	Surface roughness of side A (right, up milling)	111
4.14	Surface roughness of side B (left, down milling)	112
4.15	Cutting force $F_x$ direction	113
4.16	Machining surface comparison (a) single cutter technique (b) twin cutter technique	117

## LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Cutting Force for Single Cutter Down Milling of Feed Rate 50 mm/min	136
B	Cutting Force for Single Cutter Up Milling of Feed Rate 50 mm/min	137
C	Cutting Force for Single Cutter Down Milling of Feed Rate 80 mm/min	138
D	Cutting Force for Single Cutter Up Milling of Feed Rate 80 mm/min	139
E	Cutting Force for Single Cutter Down Milling of Feed Rate 200 mm/min	140
F	Cutting Force for Single Cutter Up Milling of Feed Rate 200 mm/min	141
G	Cutting Force for Twin Cutter of Feed Rate 80 mm/min	142
H	Cutting Force for Twin Cutter of Feed Rate 200 mm/min	143
I	Copyright	144
J	ITEX 2017 Certificate	145

## LIST OF ABBREVIATIONS/SYMBOLS

°	-	Degree
μ	-	Micron
BOM	-	Bill of Materials
CAD	-	Computer Aided Design
CMM	-	Coordinate Measuring Machine
CNC	-	Computer Numerical Control
EDM	-	Electric Discharge Machine
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
HSM	-	High Speed Machining
ISO	-	The International Organization for Standardization
MSSC	-	Multi Spindle Simultaneous Cutting
mm	-	Milimeter
min	-	Minute
m	-	Meter
NC	-	Numerical Control
N	-	Newton
PCD	-	Polycrystalline Diamond
RMT	-	Reconfigurable Machine Tool
RPM	-	Revolutions per Minute

Ra	-	Roughness Average
Rq or RMS	-	Root Mean Square Roughness
Ry or Rmax	-	Maximum Peak-Valley Roughness
WC	-	Carbide

## LIST OF PUBLICATIONS

### Journal

1. Izamshah, R., Affendi, H., Mo, J.P.T., Kasim, M.S., Ding, S., Mohamad, N., Liew, P.J., Ali, M.A., Sundi, S.A. and Sued, M.K., 2018. *Simultaneous Twin Cutter Technique for Machining Thin Wall Low Rigidity Part*. Journal of Advanced Manufacturing Technology (JAMT), 12(1 (4)).
2. Izamshah Raja, Affendi Helmi, Aziz Sanusi Abdul Mohd, Kasim Shahir Mohd, Bakar Hadzley Abu Mohd, Ali Amran Md Mohd, Sulaiman Amri Mohd and Teruaki Ito, 2015. *Modelling Effect of Cutter Geometrical Feature for Shoulder Milling Of Thin Deflecting Wall*. Proceedings of International Design and Concurrent Engineering Conference 2015 (iDECON2015), No.39, 1-9, Tokushima, Sep. 2015.

### Exhibition

1. Dr. Raja Izamshah Bin Raja Abdullah, Helmi Affendi Bin Mohamad Azmi, Dr. Mohd Shahir Bin Kasim, Syahrul Azwan Bin Sundi, Ir. Dr. Mohd Hadzley Bin Abu Bakar, Dr. Norfariza Binti Abd Wahab, Dr. Mohd Amran Bin Md Ali and Hassan Bin Atan, 2017. *Twin Spindle Milling Cutter Adapter for Machining Thin-Wall Aerospace Component*, 28<sup>th</sup> International Invention, Innovation & Technology Exhibiton 2017 (ITEX 2017), Kuala Lumpur, May 2017. (Silver Medal).

### Copyright

1. Dr. Raja Izamshah Bin Raja Abdullah, Dr. Mohd Shahir Bin Kasim, Dr. Mohd Amran Bin Md Ali, Dr. Mohd Hadzley Bin Abu Bakar and Helmi Affendi Bin Mohamad Azmi, 2016. *Twin Spindle Milling Cutter Adapter*, Perbadanan Harta Intelek Malaysia (MyIPO), LY2016001949.

## CHAPTER 1

### INTRODUCTION

#### 1.1 Research Background

The next generation aircraft must meet demands for high performance and cost effective, hence, providing motivation to aerospace industry to use new aircraft structural design and non-traditional materials. To replace the large number of assembled component, aircraft structures are designed with one piece unitised monolithic component. Sridhar & Babu (2013) concluded that monolithic thin-wall components are light in weight, provide high strength to weight ratio and can reduce the overall manufacturing costs compared with traditional structure. In general, the monolithic components are produced by machining from the solid block. Machining of monolithic component involves several thin-wall flange and rib sections as shown in Figure 1.1.

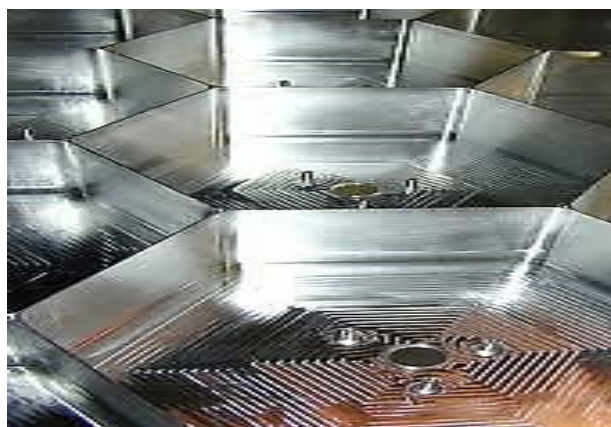


Figure 1.1: Aerospace monolithic component (St. Lawrence Machining)

Peripheral milling of very flexible components with a large span ratio of height to thickness such as monolithic component is a common manufacturing process in aerospace industry. In such cases, the wall thickness of the part is further reduced during the process leading to dimensional surface error, which makes the precision difficult to master. The surface error is induced mainly by the act of cutting forces, which deflect the wall on the opposite direction. As demonstrated by several studies (Arnaud et al., 2011; Tongyue et al., 2010; Herranz et al., 2005; Budak and Altintas, 1994), machining of the thin-wall parts can cause dimensional surface error as a result from poor stiffness of thin-wall feature. The dimensional surface error is caused generally by the part deflection which results in the tool radius immersion variation. To solve the problem with the current machining technique, this research proposed a simultaneous twin cutter milling technique, aiming to control the wall deflection.

By employing this technique, the milling forces can be controlled, hence minimizing the wall deflection which is the main factor for the errors. Once the wall deflection can be controlled, the part accuracy can be increased. As highlighted by Ratchev et al. (2006), most existing techniques are based on idealized geometries and do not take into account the static and dynamic compliance of the parts during machining. As a result, there is often a significant deviation between the planned and machined part profiles. The resulting errors are normally compensated through a lengthy and expensive trial and error NC program validation process using an ordinary milling machine i.e. single spindle milling head which tends to lower productivity and difficulty in ensuring the component accuracy. Apart from accuracy, a simultaneous twin cutter milling strategy is able to reduce the machining time up to 50 percent because only one pass is required to mill the wall structure compared with the normal machining technique.

## 1.2 Problem Statement

Aerospace component manufacturing poses great challenges especially on machining thin-wall monolithic component. One of the main challenges faced is to control the part accuracy or to minimize the dimensional surface errors caused by the part deflection. The generated radial machining force causes the thin-wall part to deflect and shift away from the cutting tool. The relationship between cutting forces and part deflection can be described as follows;

$$\delta = F H t - \delta_{tool}$$

Where,

$\delta$  is deflection of the thin wall part

$F$  is cutting forces

$H$  is height of the thin wall part

$t$  is thickness of the thin wall part

$\delta_{tool}$  is deflection of the cutting tool

Figure 1.2 (a) shows the dimensional surface errors produced in machining thin-wall feature. Materials in the shaded areas of ABCD as depicted in Figure 1.2 (b) are to be removed ideally. However, due to the milling force, the wall is deflected which moves point A to point A' as well as point B to point B'. As a result, only AB'CD material is removed which in turn, produces dimensional surface errors in BCB' areas (PalPandian et al., 2013).