Faculty of Manufacturing Engineering

DEVELOPMENT OF SIMULTANEOUS TWIN CUTTER FOR MACHINING THIN-WALL COMPONENT

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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

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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	:	....
Name	:	HELMI AFFENDI BIN MOHAMAD AZMI
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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 periferal 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 memesongkan 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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LIST OF ABBREVIATIONS/SYMBOLS

º	-	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

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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;

$$\delta = FHt - \delta tool$$

Where,

δ 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).