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Laporan Akhir Projek Penyelidikan Jangka Pendek

Process Planning for Machining A16061-T6 Shield Components

by

Dr. Mohd Salman Bin Abu Mansor

2011

UNIVERSITI SAINS MALAYSIA

LAPORAN AKHIR PROJEK PENYELIDIKAN JANGKA *PENDEK*

FINAL REPORT OF SHORT TERM RESEARCH PROJECT

Sila kemukakan laporan akhir ini melalui Jawatankuasa Penyelidikan di Pusat Pengajian dan Dekan/Pengarah/Ketua Jabatan kepada Pejabat Pelantar Penyelidikan

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1. **Nama Ketua Penyelidik:** *Name of Research Leader* — Mohd Salman Bin Abu Mansor

   ☐ Profesor Madya/ *Assoc. Prof.*   ☑ Dr./ *Dr.*   ☐ Encik/Puan/Cik *Mr/Mrs/Ms*

2. **Pusat Tanggungjawab (PTJ):** *School/Department* — School of Mechanical Engineering

3. **Nama Penyelidik Bersama:** *Name of Co-Researcher* — -None-

4. **Tajuk Projek:** *Title of Project* — Process planning for machining Al6061-T6 shield components

5. **Ringkasan Penilaian**/*Summary of Assessment*:

	Tidak Mencukupi *Inadequate* 1	2	Boleh Diterima *Acceptable* 3	Sangat Baik *Very Good* 4	5
i) **Pencapaian objektif projek:** *Achievement of project objectives*	☐	☐	☐	☑	☐
ii) **Kualiti output:** *Quality of outputs*	☐	☐	☐	☑	☐
iii) **Kualiti impak:** *Quality of impacts*	☐	☐	☐	☑	☐
iv) **Pemindahan teknologi/potensi pengkomersialan:** *Technology transfer/commercialization potential*	☐	☐	☐	☑	☐
v) **Kualiti dan usahasama :** *Quality and intensity of collaboration*	☐	☐	☐	☑	☐
vi) **Penilaian kepentingan secara keseluruhan:** *Overall assessment of benefits*	☐	☐	☐	☑	☐

(b) **Faedah-faedah lain seperti perkembangan produk, pengkomersialan produk/pendaftaran paten atau impak kepada dasar dan masyarakat.**
State other benefits such as product development, product commercialisation/patent registration or impact on source and society.

A good process planning is required for the machining of Al6061-T6 to ensure that the product can be machined using CNC milling even if the part has difficulty to setup due to its thin wall. Hence, the research output will be used for further research and development in the area of CAD/CAM/CAPP.

* Sila berikan salinan/*Kindly provide copies*

(c) **Latihan Sumber Manusia**
Training in Human Resources

i) Pelajar Sarjana: *B. Eng. (Hons), MSc, PhD*
Graduates Students
(Perincikan nama, ijazah dan status)
(Provide names, degrees and status)

Lee Ling Ling, B. Eng. (Hons), Graduated in 2010.

Nur Hazwani Ab Rahman, MSc, Started in April 2011 - On going.

Zuliani Zulkoffli, PhD, Started in April 2011 - On going.

ii) Lain-lain: *Research Assistants: Azlan Shah Ibrahim, Faraizam Azuan Hafiz Bin Jaffar, Mohd Rafiq Rahimi Bin Muhamad Rabea, Ameer Mohamed Abdeel Aziz Mohamed Hanafee, Mohd Zhafran Anwar Bin Mohd Tahar, Nuramidah Hamidon, Zuliani Zulkoffli, Nur Hazwani Ab Rahman, Siti Aiesah Mohamad.*
Others

9. Peralatan yang Telah Dibeli:
Equipment that has been purchased

High end pc, laser colour printer and extension wire.

Tandatangan Penyelidik
Signature of Researcher

14 June 2011
Tarikh
Date

UNIVERSITI SAINS MALAYSIA

FINAL REPORT OF SHORT TERM RESEARCH PROJECT

Comprehensive Technical Report

Process planning for machining Al6061-T6 shield components

15 December 2009 - 14 June 2011

By

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Contents

3. Keywords

Process planning, CNC Machining, CAD/CAM/CAPP.

4. Objectives

The objectives for this research are as follows:

(i) To identify the suitable operation and cutting parameters for machining Al6061-T6 shield components.

(ii) To propose a process planning for machining Al6061-T6 shield components.

(iii)To produce the real components based on the process planning that have been proposed.

5. Methodology

The methodology of this research is divided into four phases i.e. (i) resources; (ii) design and modelling; (iii) operation planning; and (iv) verification.

Phase 1: Resources

This phase involve literature review, exploration of appropriate machining operation and CAD/CAM software. The literature review covers all the basic theory regarding process planning for machining the shield components. All the basic principles are identified to establish the fundamental before it can be used for further design and modelling works. The manufacturing operation and software are investigated to identify the suitable manufacturing process and cutting parameters.

Phase 2: Design and Modelling

Based on all the information from the literature and exploration, the design and modelling of shield components are created. Several models of shield components have been designed and modelled. SolidWorks is used to create CAD models of the shield components.

Phase 3: Operation Planning

Once the modelling is obtained, the operation for machining is determined. A step-by-step approach of decision making activities which is the traditional method of process planning is used to select the best process plan for producing the shield components. With this approach,

	(Research), Development of computer aided process planning for 5 axis machining. Started in April 2011 - On going.

6.2.2. Undergraduate Student

Undergraduate Student	Detail
1 BEng (Hons) Graduated (2010)	LEE LING LING, 2010, Process Planning For Aluminium 6061-T6 Shield Component.

6.2.3. Research Assistants

Research Assistants	Detail
3 RA (2011)	Siti Aiesah Mohamad (2 Months, 3/1/11-3/3/11)+(2 Months, 5/3/11-5/5/11)
	Nur Hazwani Ab Rahman (2 Months, 4/1/11-4/3/11)+(2 Months, 5/3/11-5/5/11)
	Zuliani Zulkoffli (3 months, 1/11/10-31/1/11)
5 RA (2010)	Nuramidah Hamidon (2 Months, 9/11/10-9/1/11)
	Mohd Zhafran Anwar Bin Mohd Tahar (1 Month, 12/7/10-12/8/10)
	Ameer Mohamed Abdeel Aziz Mohamed Hanafee (1 Month, 19/7/10-19/8/10)
	Mohd Rafiq Rahimi Bin Muhamad Rabea (2 Months, 12/5/10-11/7/10)
	Faraizam Azuan Hafiz Bin Jaffar (2 Months, 11/5/10-10/7/10)
1 RA (2009)	Azlan Shah Ibrahim (3 Months, 15/12/09-15/2/10)+(2 Months, 14/10/10-14/12/10)

Process Planning for Machining Al6061-T6 Shield Component

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Abstract.
Process planning is a sequence of activities that strings together to define in detail the manufacturing steps or processes that transforms the raw material into a complete part. Usually, there are more than one solution to manufacture a part under constraints such as part geometry, material, manufacturing resources and etc. In the paper, a step-by-step approach of decision making activities which is the traditional method of process planning is used to select the best process plan for a particular mechanical part is proposed. With this approach, all the information, function and processes can be integrated. The challenge is that the part to be produced has a thin wall plate of 1.5mm and of a complex shape which has a setup problem in the machines. Setups and the element of workholding devices with the combination of machining operations, sequences, tools, and other parameters will be studied to produce the part. The result would be the achievable geometrical dimensions and tolerances after the process plan is validated by real time machining.

Keywords: Process planning, step-by-step decision making, aluminum T6061 components, thin wall plate, workholding

1. Introduction

Process planning defines in detail of the manufacturing steps, activities or the process that transforms raw material into the completed part, utilizing all available resources. The part to be manufactured is defined by the product engineer, and is expressed in engineering drawings and geometric dimensioning and tolerances. Process planning involves multiple decision making validation of the process plan where the parts are actually machined using CNC 3-axis milling machine to see the achievable geometrical dimensions and tolerances.

2. Methodology

The process planning for this project will be done to produce the product is as illustrated in Figure 2.1 below. There will be different in many ways such as the sequences or the content of the activities due to the changes in technological limitations, data limitations or even knowledge limitations. The best sequence of activities for process planning is yet to be determined thus what has been done is only to follow the current available technology, data and knowledge.

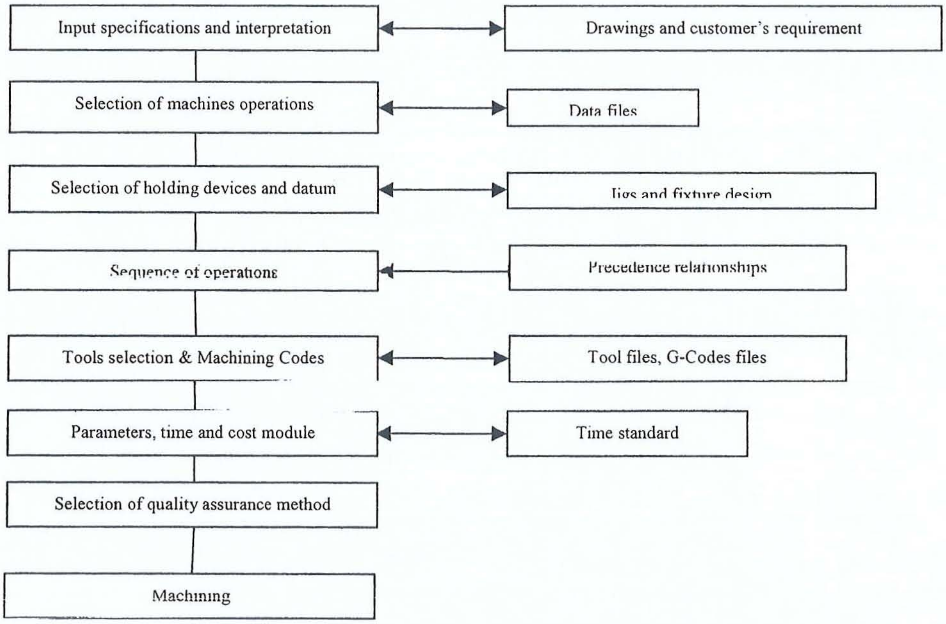

Figure 2.1 Process planning sequence of activities

2.1 Input Specifications and Interpretation

To start a process planning, primary input is very important. There is no specific method to generate the primary input. This primary input are generally facts known or given by customers such as part geometry, part raw material, part dimensional accuracy, part surface finish, part geometric tolerances, part heat treatment and quantity required. These inputs mentioned can be obtained through the technical drawings of the part.

Energy Source (Force, N)	Accumulated Energy (Force, N)	Applied Energy to Part (Force, N)
Screw		
Clamp	Moving Mass	Push
Fixed mass	Static mass	Hold

From the table, there are a few combinations. For each combination, there are a few conceptual designs as in figure 2.3 below:

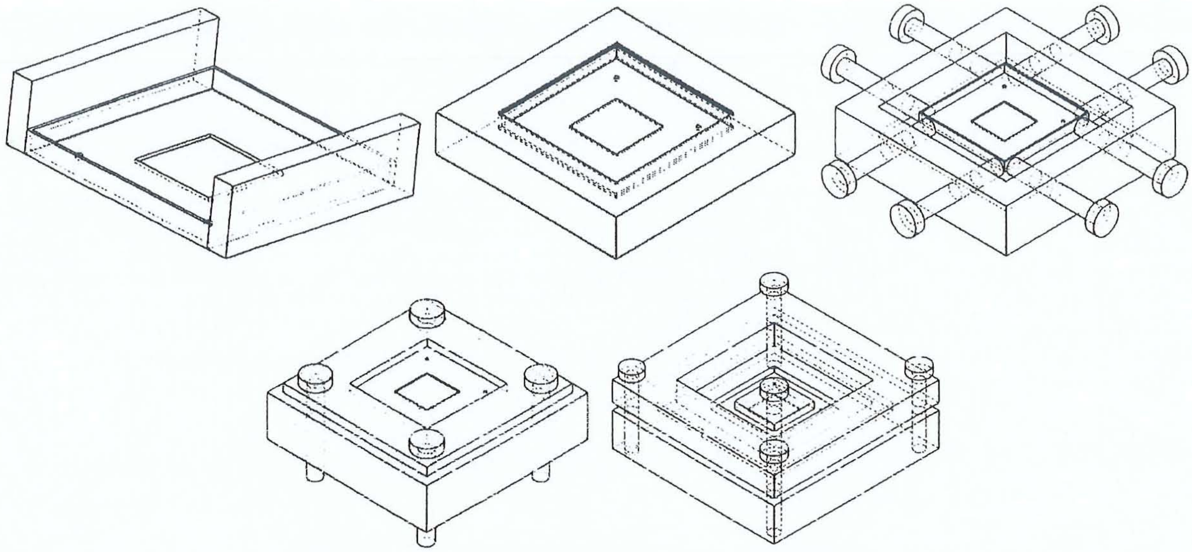

Figure 2.3 Few concepts fixtures generated

After the concepts are being generated, it is time to do the concept selection. For concept selection, there are two types of method, concept screening and scoring. Both also have the same six steps involved in the concept selection activities. Concept scoring is used because it has different selection criteria weight which is important.

2.4 Sequencing the Operations

There are no fix paths in operations sequences and alternative sequence of operations must also be taken into account. It can be rearranged over and over to fit the conditions as in the anteriority categories. For each design feature, there are three passes that is required go in order which are the roughing, then $\frac{1}{2}$finishing, and final finishing. Depending on the features, some of the passes can be skipped. Roughing usually uses big diameter tools and its

With MRR is the material removal rate, in mm^3 per min, w is width of cut in mm, d is depth of cut, mm, v is feed rate or linear speed of workpiece, mm per min. For machining time it can be obtained from the MasterCAM simulation result as prediction or estimation. The real machining time however, can only be obtained after the real part is being produced. As for the cost calculations, after simplification using two cases below,

Case 1: The longer the machining and setup time, the higher the cost where;

$$Total\ cost = working\ time\ \times number\ of\ worker\ \times RM\ per\ hour$$

and

$$Total\ cost = working\ time\ \times RM\ per\ hour\ usage\ of\ machining\ power$$

Case 2: The more the material used, the higher the cost and also cost of different materials;

$$Total\ cost = number\ of\ materials\ used\ \times price\ of\ each\ material$$

or

$$Total\ cost = size\ of\ material\ used\ \times price\ of\ each\ material \times total\ number\ of\ materials\ used$$

3. Result and Discussion

The primary input specifications and information obtained from the parts are as in the table 3.1 below:

Table 3.1 Part Information

Part geometry :	As in appendix A
Annual Volume:	Mass production
Part Volume:	100, 000 mm^3
Part Raw Material:	Aluminum T6061-T6
Part Requirement:	1.5mm thin wall as critical dimension

The material information obtained from machining handbooks is as in the table below:

Table 3.2 Material information at room temperature

Raw Material:	Aluminum T6061-T6
Melting Temperature, °C	660°C
Brinell Hardness Value (BHN)	95
Yield Strength	275 MPa

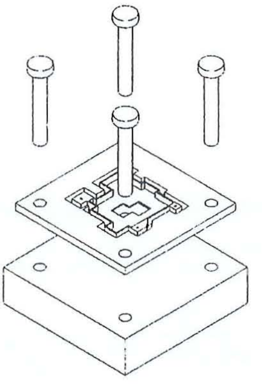

Figure 3.2 Exploded view of concept 4 for part B setup

Part B will have two setups but on the same fixture due to the complexity of shape and difficulty of machining for part B. These concepts are generated for the purpose of machining using CNC. From concept scoring, the highest rank was concept 4 and it is much recommended to be use to machine the part. However, it can be further improved to improve the scores of a few selection criteria such as, easy setup and less setup. Instead of using screws to hold the workpiece, it is recommended to replace the screws with machining clamps. For this setup, the clamp has to make sure that the workpiece will not slide in X-Y axis and also will not move in Z-axis. The advantage of this fixture is the part produced will have good dimensional accuracy for the perpendicularity and parallelism due to the machining operations of contouring. However, the disadvantage of this using this fixture is producing a material waste. But, the fixture can be further optimized to reduce its waste.

The operations sequences obtained are for CNC milling using the fixture above is,

Part B: B1/R – B2/R – B7/R – B5/ $\frac{1}{2}$F– B6/R – B4/R - B4/ $\frac{1}{2}$F – B6/ $\frac{1}{2}$F – B3/R

Below are the detailed operation's steps involved including fixture setups:

Step 1: Clamp part B raw material on the machine.

Step 2: Face milling on feature B1 getting a dimension of 180mm×180mm. (B1/R)

Step 3: Drilling a through hole of 5.5mm in diameter using tool 1. (B2/R)

Step 4: Hold part B using fixture and clamp it on to the machine.

Step 5: Pocket roughing with the depth of 8.5mm size using tool 6. (B7/R)

Step 6: Through hole drilling size 3mm in diameter using tool 5. (B5/ $\frac{1}{2}$F)

Step 7: Flip the raw material by 180°, attached to fixture and clamp it to the machine

Step 8: Pocket roughing with the depth of 8.5mm size using tool 6. (B6/R) selected after comparing all the different parameters and time obtained by changing the tool's diameter and tool path.

Table 3.3 Machining parameters and time of each step for part B.

Operations steps	Tools Diameter, *D* (mm)	Feed rate *v*, (mm/min)	Spindle speed *N*, (rpm)	MMR, mm³/min	Surface roughness *Ra* (μm)	Time Simulation (min, s)	Predicted time (min, s)
1	-	-	-	-	-	-	1min
2	-	-	-	-	-	-	50 min
3	5.5	68.7	1145	2863	-	4 min 16s	-
4	-	-	-	-	-	-	2 min
5	5	190.9	1909	2386.25	0.93	487 min 21s	-
6	3	114.54	1909	1432.35	-	3 min 25s	-
7	-	-	-	-	-	-	2 min
8	5	190.9	1909	2386.25	0.63	557min 52s	-
9	5	190.9	1909	2386.25	0.63	44min 2s	-
10	4	238.7	2387	1909.6	0.93	138min 41s	-
11	4	238.7	2387	1909.6	0.93	28min 24s	-
12	-	-	-	-		-	2 min
13	5	190.9	1909	2386.25	0.63	224min 6s	-
						1545min 7s	

The depth of cut for all the machining operations is 0.5mm each step. This is because the tool used is a high speed steel tool and does not have high strength as carbide tools. If using depth of cut that is more than 0.5mm will result in shorten tool life. Approximately, 25 to 26 hours to machine part B. The time obtained is only an estimated and prediction time from MasterCam software and is not 100 percent accurate. Actual machining time could be longer or shorter depending on the factors such as cleaning at a certain time interval to remove chips and using slower or faster feed rates.

Below are the estimated cost calculated for producing one part B:

Table 3.4 Estimated cost of part B

Cost of raw material - aluminum	RM200
Cost of fixtures – wood and screws	RM50
Cost of manpower(RM5 per hour)	RM125

5	5	200	2000	10000	400min
6	3	300	2250	16500	3 min
7	-	-	-	-	10min
8	5	200	2000	10000	500min
9	5	200	2000	10000	30min
10	4	200	2000	10000	15min
11	4	200	2000	10000	5min
12	-	-	-	-	2 min
13	5	200	2000	10000	180min
					1218 min

The CNC milling machine is only capable of machining the part up to ±0.1mm tolerances. The important design feature tolerance part B are the wall produced which is at the thickness of 1.5mm. These are the tolerances obtained as in the table 3.6 below.

Table 3.6 Tolerances of part B

Design feature	Readings			Average Reading
	1	2	3	
1	1.48	1.51	1.47	1.48
2	1.51	1.49	1.48	1.49
3	1.50	1.47	1.52	1.50
4	1.46	1.49	1.51	1.48
5	1.46	1.49	1.51	1.48
6	1.50	1.47	1.52	1.50

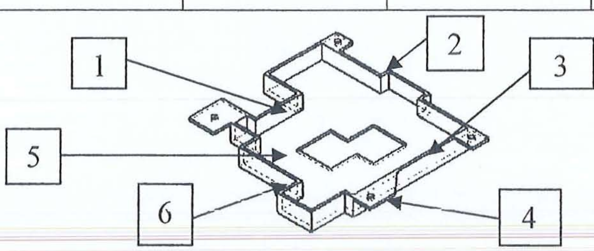

Figure 3.5 Important design features

As for part B, all the dimensions of the thin plate wall are within the acceptable range of tolerances. After the part finished its CNC machining operation, there are additional steps of deburring the part. It is done manually by polishing using sand paper.

[9] Tang Aijun, Liu Zhanqiang, Ma Hailong, "*Modeling and Simulation of Big Deformations of Thin walled Plate in End Milling Process*" Proceedings of the IEEE International Conference on Automation and Logistics August 18 - 21, 2007, Jinan, China.

[10]Zhang Yingjie, Zhao Liujie, "*Tool Path Optimization to Regulate the Cutting Forces in Pocket Machining*" Industrial Electronics and Applications, 2009. ICIEA 2009. 4th IEEE Conference on 25-27 May 2009.

[11]H. C. Kim., S. G. Lee and M.Y.Yang, "*An Optimized Contour Parallel Tool Path for 2D Milling with Flat End Mill,*" Journal of Advanced Manufacturing Technology, 31(5-6), pp. 567-573, 2006.