



# Effect of Different Cutting Speed towards Machinability of Titanium (Ti6Al4V) Curved Thin Wall using Trochoidal Milling Path

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**Abstract:** Aircraft parts and components used a lot of titanium as the material for body parts and engines. The materials offer rigidity, strength and light in weight. This unique characteristic was the major advantages in improving the payload capacity and improving the fuel consumption of the jet engines. The problem raised during the machining process of the material. Titanium is a hard material, elastic and poor thermal conductor. As the material is hard, higher machining force is required to perform the machining. Elasticity added the difficulties as it will spring away from the cutting tool which cause the tool to rub instead of cutting that can increased the heat. Thus, machining titanium alloy is expensive and difficult. This preliminary study looks into several machinability aspects and machining parameters for curved thin wall machining profile in the research. Machining accuracy and cutting tool wears were observed during the experiments. There are two set of machining parameters for the machining trials. At the same time, this research able to recommend the suitable machining parameters analysed from the experiments.

**Index Terms:** trochoidal milling path, titanium, thin wall, tool wear, dimension accuracy.

## I. INTRODUCTION

The purpose of this study is to observe the machinability of trochoidal milling path on titanium curve thin wall profile.

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There are three elements that will be highlighted throughout this experiment. First, the Trochoidal machining path towards the machining accuracy of the curved thin wall. Second, this experiment will also obtain the suitable machining cutting parameters in order to achieve a good machining accuracy towards the machining process and material and last, the experiment will also study the cutting tool wear after the curved thinwall machining process. Curved thin wall profile is a design that widely used in manufacturing and aviation industries. In aviation, it is normally placed in the wall of fuselage as one of the main structure of an aircraft [1].

[2]. The advantages of the thin wall features is to ensure its strength and lightweight constraints to meet the design specification Based on the previous research, the common material that used thin wall features is aluminium and titanium alloy, both are lightweight and strong compared to other types of metals. In this study, titanium alloy Ti6Al4V has been chosen as the material for the curved thin wall machining because of widely used in aircraft parts and components. Titanium offers high strength material, low weight ratio and good corrosion resistance suits the aircraft application [3].

In addition, titanium alloy contains excellence mechanical properties and the best chosen material for weight reduction while maintaining the overall strength of the aircraft parts and components. Researchers have conducted lots of machining trials to produce the thin wall features. Part of the method is climb milling method, thin wall milling path and straight milling path [4]. Meanwhile, this research will be using trochoidal milling path to examine the curved thin wall machining path performance. The advantages of using trochoidal milling path are the method able to improving the cutting tool life, reduce the machining cycle time, and improves the material removal rates [5].

On the contrary, trochoidal milling path for the curved thin wall features also affected to the machining performance because of the vibrations occurs in between the workpiece and cutting tool. This disturbance will result of poor surface finish on the workpiece, reduce geometrical accuracy and spindle's life and increase the rate of tool wear [6].

II. EXPERIMENTAL

Method

Two set of machining parameters have been carried out and investigated in this experiment. Fig. 1 illustrates the curved thin wall machining profile designed in CAD software. The curved thin wall profile was 1mm in thickness with several duplicate fins are required to be machine depends on the cutting tool wears. Fig. 2 shows the actual completed machined part by 3 axis CNC milling machine.

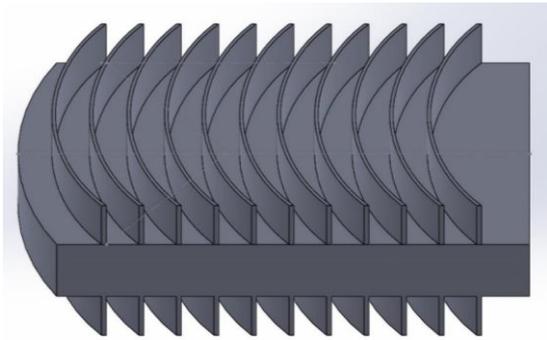


Fig. 1 Curved thin wall profile in CAD software



Fig. 2 Completed machined part by 3 axis CNC milling machine

The research works on determining the early findings in machining by using different cutting speed in machined the curved thinwall profile. Titanium alloy Ti6Al4V was used as the workpiece material as it is one of the common material used in aircraft parts and components. The chosen cooling method was by flood application with the emulsified coolant concentration was maintain at the range of 6-8 % [7].

In the experiment, there are two different cutting speed ( $v$ ) (m/min) was tested as the variables factor, feed per tooth (fpt) and the cutting tool stepover was fixed at 0.03 and 1.6. Trochoidal milling path was selected to remove the excess material in the curved thinwall machining. It is one of a high speed machining method used to form a slot wider than the cutting tool’s diameter. This method is done by circular cuts with a high speed force with preserving the low radial depth of cut (RDOC) and high axial depth of cut (ADOC). Both of this type depth of cut is related to each other where low RDOC allows higher of ADOC which means the whole length of the cutting edge can be utilized [7]. Trochoidal milling path also known as a chip thinning concept, it can minimize the load and wear of the cutting tool when the RDOC is low and unintentionally it produces less or optimum chip. By means, a cutting tool that able to produce optimal chip load can be considered as a good cutting tool because it has an ideal width and size. By these advantages, it helps to decreased cutting force, reduce heat, greater machining accuracy, improved tool life, faster cycle time and multiple slot sizes can be processed by using minimum quantity of cutting tool.

In Fig shows the actual cutting tool used for the experiment, solid carbide end mill was used to perform the trochoidal milling path. The cutting tool is Ø10mm with the cutting length is 25mm. The titanium specimen was machined to 150mm (length) x 70mm (width) x 50mm (thick) rectangular sizes by using conventional milling machine.

Experimental design

Design of Experiments was chosen to suit the experimental design to analyze the data from the machining parameters. Table 1 tabulated the detail of the machining parameters used for the machining trials.

Table. 1 Machining parameters

Parameters	Level	
	Minimum	Maximum
Cutting Speed	47	50
Feed per Tooth	0.03	0.03
Stepover	1.6	1.6

III. RESULT AND DISCUSSION

Flank and notch wear

After completed the machining trial for both machining parameters, the early discovery for the machining trials was obviously on the wear of the cutting tool for flank and notch wear area.

In Table 2, shows the result of flank wear and notch wear on solid end mill cutting tool after machining the first cutting parameter of curved thin wall on titanium alloy. The result shows that flank wear has the highest number of wear which is 0.317mm while the highest number of notch wear on the cutting tool is 0.258mm. Based on the result, the flank part of the cutting tool has high wear rate when using the 47m/min of cutting speed with 0.03 of feed per tooth and 1.6 of stepover.

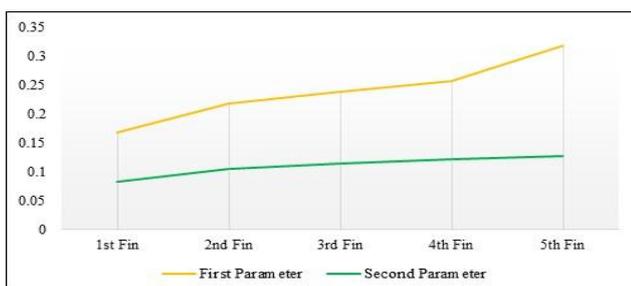
**Table. 2 The result of flank wear and notch wear of first cutting parameter**

Fins	Flank Wear (mm)	Notch Wear (mm)
1 <sup>st</sup>	0.168	0.071
2 <sup>nd</sup>	0.218	0.075
3 <sup>rd</sup>	0.238	0.212
4 <sup>th</sup>	0.257	0.234
5 <sup>th</sup>	0.317	0.258

Meanwhile, in Table 3 shows the result of flank wear and notch wear for the second cutting parameters on the cutting tool. The result of this second cutting parameter is shows the highest result of notch wear is 0.759mm but the flank wear from this machining parameter is 0.128mm. the second machining parameters indicates the notch wear is high wear rate compared to flank wear when using 50 m/min as the cutting speed, 0.03 as the feed per tooth and 1.6 as the stepover.

**Table. 3 The result of flank wear and notch wear of second cutting parameter**

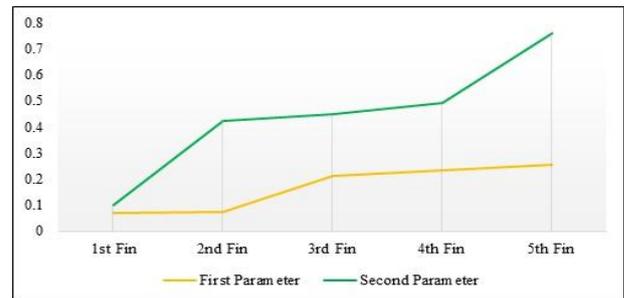
Fins	Flank Wear (Mm)	Notch Wear (Mm)
1 <sup>st</sup>	0.083	0.101
2 <sup>nd</sup>	0.106	0.424
3 <sup>rd</sup>	0.114	0.449
4 <sup>th</sup>	0.121	0.494
5 <sup>th</sup>	0.128	0.759



**Fig. 3 Flank wear comparison between first cutting parameter and second cutting parameter**

Based on the graph in Fig. 3, the result of flank wear of the first cutting parameter is apparently increased starting from the initial fin until the last fin meanwhile the graph of flank wear of the second cutting parameter is just gradually increased. The highest number of flank wear for the first cutting parameter is 0.317mm while 0.128mm for the second cutting parameter. In addition, the average flank wear for the first cutting parameter is 0.141mm but the average wear of the second parameter is literally smaller than the first parameter which is 0.0113mm only.

It showed that the flank wear of the first cutting parameter is larger than the second ones. Initial observation shows that higher cutting speed able to achieved low flank wear towards the cutting tool.

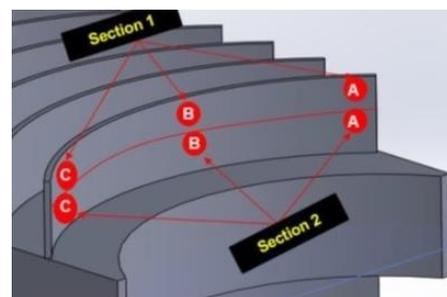


**Fig. 4 The comparison of notch wear between first cutting parameter and second cutting parameter**

As refer to the graph in Fig. 4, the result of notch wear of the second cutting parameter is higher than the notch wear of the first cutting parameter. This is because the final result for notch wear of the second cutting parameter is 0.759mm while the final result of notch wear for the first cutting parameter is 0.258mm. The results show such a big different between both of the cutting parameter. In fact, the total average of notch wear for the first cutting parameter is 0.047mm and 0.165mm for the second cutting parameter. It is proven that the notch wear of the second cutting parameter is greater than the first cutting parameter after machining one fin to another fin. Based on the result, it can be summarized that cutting speed has the relation with wear of the cutting tool. This is because low cutting speed with 47m/min is applied when machining the first cutting parameter where it caused bad result of notch wear on the first cutting tool. Meanwhile, high cutting speed with 50m/min is used during machining the second cutting parameter and caused the notch wear is less than the first cutting tool.

**Result on dimension accuracy of the curved thin wall**

The curved thin wall is measured separately in two different section which is upper section and lower section for each fin. Section 1 is representing the upper section while Section 2 is representing the bottom section. Moreover, every fin is measured by 3 points where Point A is the initial edge of the fin, Point B is the centre of the fin and Point C is the end point of the fin. Fig. 5 shows the section and location of the inspection area for the curved thinwall after machined.



**Fig. 5 Section and location of the inspection area**

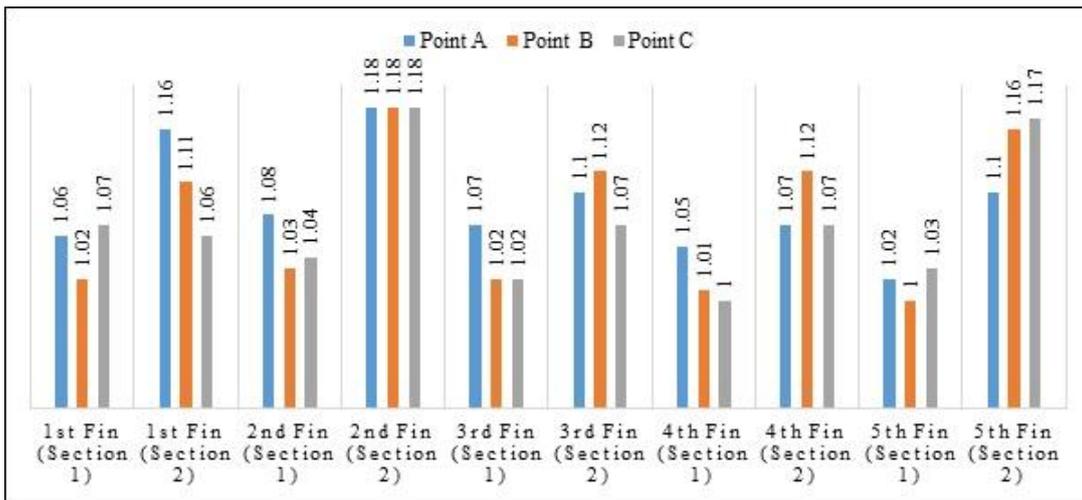


Fig. 6 Comparison of accuracy of curved thin wall for the first cutting parameter

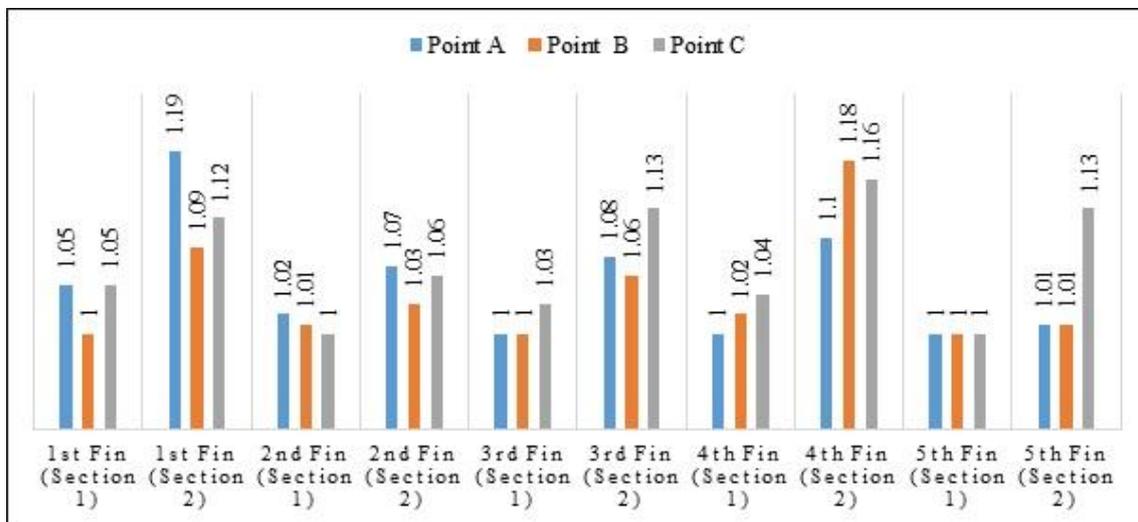


Fig. 7 Comparison of accuracy of curved thin wall for the second cutting parameter

Fig. 6 shows the overall result and accuracy of the curved thin wall for the first cutting parameter meanwhile Fig. 7 represents the result and accuracy of the curved thin wall for the second cutting parameter. The result from the first cutting parameter is seemed far from achieving the targeted dimension given. However, some of the result of the second cutting parameter able to achieved the desired accuracy. It can be seen through the third fin on Section 1 as well as the fifth fin of Section 1 and the result of other fins are almost near to 1.0mm.

Somehow, the result from Section 2 are obviously different. It is much difficult to achieve the desired accuracy. In early observation during machining, chatters was initially begin on 5mm depth of cut towards the final depth of 10mm [8]. Furthermore, the highest machining result of the second cutting parameter is 1.19 mm and it is slightly higher than the machining result of the first cutting parameter which is 1.17mm. There are several factor that caused to this chatter condition [9]. Chatter can also happen from vibration that arises from the motion between tool and workpiece. In addition, spring back in titanium further complement the effect of machining tolerance as the material flex during the

cutting edge touches the workpiece during machining process and causes the workpiece to move away from the cutting tool[10]. Vibration and noise emission was also generated from the instability of the cutting process. It has been observed that the vibrational chip thickness effected the cutting forces which in turn it increases the vibration and causes chatter. This vibration resulted in a poor surface finish, low accuracy, and high noise emission and also reduces the cutting tool life.

#### IV. CONCLUSION

The following conclusion from the preliminary experiment can be drawn:

- a) Higher cutting speed in machining the curved thin wall able to prolong the cutting tool life as the flank wear progression rate seem to have a slow progress compare to lower cutting speed. Parallel to the wear progression, notch wear was found rapidly increased due to the higher cutting speed.

b) By using higher cutting speed managed to achieve the dimension accuracy as the result was better compare to the lower cutting speed.

Further research can be done by adding the various machining factor. A suitable titanium curved thin wall machining parameters can be proposed to improve the productivity of manufacturer sector.

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