UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MACHINABILITY STUDY UTILIZING VORTEX MACHINING APPROACH - DELCAM SOFTWARE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering Technology (Product Design) with Honours

by

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DECLARATION

I hereby, declared this report entitled "Machinability Study Utilizing Vortex Machining Approach - Delcam Software" is the results of my own research except as cited in references.

Signature :………………………

Name : ………………………

Date : ………………………

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Product Design) with Honours. The member of the supervisory is as follow:

……………………………….

(Project Supervisor)

ABSTRACT

This project was done to validate the capability of Vortex Machining than can minimize the cycle time of machining because of the capability to machine a part with a shorter time and cut deeper depth in one cut compared to the conventional machining and Computer Numerical Control (CNC) machining. The Vortex Machining also had been validating three times tool diameter depth of cut. The project was conduct by using 3-axis CNC milling machine for both machining with variation of different materials. The result from this project that the machined part that undergo through Vortex Machining had been reduced the time to cut deeper depth in one cut compare to conventional machining. Other than that, the results obtained are to validate the Vortex Machining reduce cycle time compare to conventional machining. For aluminium materials, cycle time of machined part just need a shorter time to cut deeper depth in one cut compare with mild steel materials because aluminium is more frictionless surface than steel that have hard surface. The analysis from the results also considered the dimensional accuracy and surface roughness. From this project, the Vortex Machining was given a positive impact to the nowadays technology especially in industries field because the production time can be reduce and increase the productivity of the company and beneficial to community. Vortex Machining was the faster machining and can increased tool life that totally can cut tooling costs. Vortex develops offsets from the part profile to produce efficient on roughing process to produce efficient toolpaths regardless of part shape.

ABSTRAK

Projek ini adalah untuk mengesahkan keupayaan pemesinan Vortex yang boleh mengurangkan masa kitaran pemesinan kerana keupayaan untuk mesin dengan masa yang lebih pendek dan mengurangkan kedalaman lebih mendalam dalam satu potong berbanding dengan kawalan berangka komputer (CNC) pemesinan konvensional. Pemesinan Vortex juga telah mengesahkan tiga kali alat kedalaman garis pusat dipotong. Projek ini dijalankan dengan menggunakan 3-paksi mesin pengilangan CNC untuk kedua-dua pemesinan dengan perubahan bahan-bahan yang berbeza. Hasil daripada projek ini adalah bahagian dimesin yang menjalani melalui pemesinan Vortex telah mengurangkan masa untuk mengurangkan kedalaman lebih mendalam dalam satu potong berbanding dengan pemesinan konvensional. Selain daripada itu, keputusan yang diperolehi adalah untuk mengesahkan Vortex Machining mengurangkan masa kitaran berbanding dengan pemesinan konvensional. Untuk bahan-bahan aluminium, masa kitaran bahagian dimesin hanya memerlukan masa yang lebih pendek untuk mengurangkan kedalaman lebih mendalam dalam satu potong berbanding dengan bahan-bahan keluli lembut kerana aluminium menpunyai permukaan tanpa geseran lebih daripada keluli yang mempunyai permukaan yang keras. Analisis daripada keputusan juga mengambil kira ketepatan dimensi dan permukaan kekasaran. Daripada projek ini, pemesinan Vortex telah memberi kesan positif kepada teknologi pada masa kini terutamanya dalam bidang industri kerana masa pengeluaran boleh dikurangkan dan meningkatkan produktiviti syarikat dan memberi manfaat kepada masyarakat. Pemesinan Vortex adalah cara mesin yang lebih cepat dan boleh meningkatkan hayat alat yang benar-benar boleh mengurangkan kos peralatan. Vortex mewujudkan ofset dari profil bahagian untuk menghasilkan keberkesanan kepada proses kasar untuk menghasilkan laluan mata alat cekap tanpa mengira bentuk bahagian.

DEDICATIONS

This project I dedicated to my beloved parents, Md.Yunus Bin Ramlan and Zainab Binti Yusof, my siblings and also my friends.

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I would like to thanks to Allah Almighty Who enabled me to do this report these days. I revere the patronage and moral support extended with love, by my parents whose financial support and passionate encouragement made it possible for me to complete this report.

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LIST OF SYMBOLS AND ABBREVIATIONS

NC	=	Numerical Control
CNC	=	Computer Numerical Control
CAD/CAM	=	Computer-Aided Design/Computer-Aided Manufacturing
VMCs	=	Vertical Machining Centers
HMCs	=	Horizontal Machining Centers
HSS	=	High Speed Steel
CMM	=	Coordinate Measurement Machine

CHAPTER 1
INTRODUCTION

1.0 Background

Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) was utilizing computer as method to assist in manufacturing computer-aided manufacturing (CAM). There are various types of CAM technology software in the industries such as Delcam, SolidCAM, MasterCAM, PowerMILL and HyperMILL. Delcam technology was one of the advanced CAD/CAM solutions especially for the manufacturing industry that lead the complex-shaped products from the concept ideation to make it to reality and Delcam conducts the Vortex Machining that are focusing on the roughing process.

This project was focused on utilizing Vortex Machining approach with variation of different materials which was been cut to validate the capability. The Vortex Machining which was claimed as being able to cut deeper depth in one cut. The machined part has been analysed. Vortex was a Delcam's current technology and latest patent continuing high speed roughing technology before the invention of Vortex Machining, industries used conventional machining to machine a part. However, with the aid of Delcam software tools, this special feature of Vortex Machining becomes more popular and gets the high achievement. This was because of the capability to machine a part with a shorter time and deeper depth of cut.

CAD/CAM was the computer software that used for design and manufacture products specially for Computer Numerical Control (CNC) machining. Machining was the process of cutting metal to form or finish a part, by using methods like drilling, milling, and grinding. CAD/CAM was very important to the design and machining process because it was related from the first stage of drawing until the workpiece part is machined. All the problem or an error had been detected in the

CAD/CAM software when run the simulation exactly like the machine and this can reduce the mistakes and error while machining in CNC machine.

To test the capability of this Vortex Machining as compared to conventional machining, CNC machine was been used to cut off the workpiece. CNC machine was the machine that read the coded programs that control the movement of the workpiece or tool, the materials such as depth of cut and spindle speed and for this case study, CNC milling machine has been chosen. CNC machine can reduced human error because of the part had been run into the simulation software before the coded was been transfer to the machine and CNC was high precision in manufacturing.

1.1 Scope of Study

This project was focused on Vortex Machining than can minimize the cycle time compared to the CNC conventional machining. With the different types of the workiece material, the machine part had been analysed to validate the results. Scope of this project covers the software, materials and cutting tool that are:

(a) Delcam for SolidWorks software was used for programming.
(b) Aluminium and mild steel are the material had been cut.
(c) Solid carbide end mills are used as the cutting tool.

1.2 Problem Statement

Nowadays, industries problem was to increase their productivity especially in the machining process that affects the cycle time to produce a part. With the advance technology of Vortex Machining, the productivity may be increase because it can reduce the cycle time of machining.

The Vortex Machining concept can reduce the cycle time of machined part but CNC conventional machining takes a longer time to machine a part because depth of cut is often shallow. The problems occur can be seen in the aerospace industry because the aerospace pocketing part is more to cut out the materials rather than machined the design part only. The Vortex Machining results depend on the hard of the materials to be cut and the dimensional accuracy will be taken both conventional and Vortex Machining.

1.3 Objectives

The main objectives of this project are:

(a) To validate the capability of Vortex Machining against manufacturer claims.
(b) To analyse the machine part in terms of dimensional accuracy for aluminium and mild steel.
(c) To validate three times tool diameter depth of cut using Vortex Machining.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

This chapter will discuss mainly on the theory and current development in Delcam software, Vortex Machining, and other machining theories.

2.1 Machinability

Machinability was one of the factors influencing machining operations that related to tool life, surface finish and surface principle of the machined part, pressure and forces needed, and the difficulty in chip control. Ferrous metals machinability such as steel and stainless steel are challenging to machine but the non-ferrous metals machinability such as aluminium normally not difficult to machine. Material of workpiece used in this case study is an aluminium and mild steel. The cycle time for machining depends on the type of material with their properties of hardness and the thickness of the workpiece.

2.1.1 Aluminium

Figure 2.1: Aluminium machining

(Source: <http:// www.sandvik.coromant.com/aluminium-machining >3/5/2015)

The aluminium material was the most common metals with good machinability and aluminium had a specific generally low cutting force of about a third of steel and a have a higher of melting point which is the temperature in the cutting zone had been not increase above this level inconsiderate of cutting speed. The characteristic of aluminium was softer than steel and the method to improve its machinability commonly build on making it more brittle but some of the aluminium had a good machinability such as alloys 2007, 2011 and 6020.

On the other hand, the requirements for sufficient machine power, chief to a disadvantageous ratio of material removed per power unit are the common problem in machining aluminium for high speeds machining. For tool aspect, unrelated cutting forces have great control on power requirements. Reducing the power needed for material removed had a positive effect on aluminium milling, usually through higher productivity. When determining the ease of cut, the rake angle also affects unrelated cutting force and by increasing this angle it can make a more positive insert and also aligning it with the rest of the geometry. From this situation, resultant cutting force can be minimized.

2.1.2 Mild Steel

Mild steel is the most common steel because of the low price in market and it was provides material properties that are suitable for many applications. The reason that mild steel was malleable and ductile because of the low-carbon steel approximately contains 0.05-0.15% of carbon. Mild steel also easy to form means that surface hardness can be increased through heat treatment process that applied for low-carbon workpiece.

2.2 Vortex Machining

In this project, the workpiece had been undergoing CNC machining that involves two different types of machining that are conventional machining and Vortex Machining. Conventional machining in CNC programs means that the normal machining in the CNC machine with the setting in the programs software had been set to spiral with normal condition of cutting while the Vortex Machining in CNC programs means that the setting in the programs software had been set to Vortex before the machining run in the CNC machine.

The CNC conventional machining take a longer time to machine a part depends on the type of material and the depth of cutting is step by step and cannot undergo deeper depth in one cut. The CNC Vortex Machining take a shorter time compare to CNC conventional machining because the Vortex setting can undergo deeper depth in one cut. The conventional path had tools dive down to a surface or ramp into the material.

One basic or common problem with conventional area-clearance method was that the optimum cutting conditions only occur during a straight-line cut. Any internal corners within the model excessively increase the engagement angle of the cutter. To maintain and protect the cutter, this increase needs to be balanced and aligned by setting a lower feed rate. The user then has the exceptional of using this lower rate over the whole toolpath, which increase the machining time, or changing the feeds and speeds as the cutter moves around the model and increasing wear on the cutter.

Unlike other high-speed roughing techniques that intent to maintain a constant theoretical metal-removal rate, the Vortex strategy generates toolpaths with a controlled engagement angle for the complete operation. This maintains the optimum cutting conditions for the entire toolpath that would normally be possible only for the straight-line moves. As a consequence, the cutting time will be shorter, while cutting had been attempted at a more uniform volume-removal rate and feed rate, so at the same time protecting the machine.

Vortex toolpaths had a controlled engagements angle and the tools should never be overburden and that had affected the maximum tool life. Modification in the contact angle had caused the shock loading and had avoided chipping of the flutes. Moreover, the balancing and determination of the cutting conditions gives more steady edge temperature and then increase the life of the tool coating and remove heat damage to the surface of the machine part. The ability to use stepdowns of up to two, the tool diameter extends the tool wear evenly over the cutting surface of the tool had attributed to longer tool life.

This project also had been done to verify that Vortex Machining was the fastest way to cut deeper depth in one cut compare to conventional machining that takes a longer time to machine a part. A study on Delcam as one of the world's leading suppliers of advanced CAD/CAM solutions for the manufacturing industry. Delcam's range of design, manufacturing and inspection software provides complete, automated CAD/CAM solutions, to take complex-shaped products from concept to reality as viewed in the website at <www.delcam.com/>. Vortex known as an excellent strategy for high speed machining that can increase the productivity of the company.

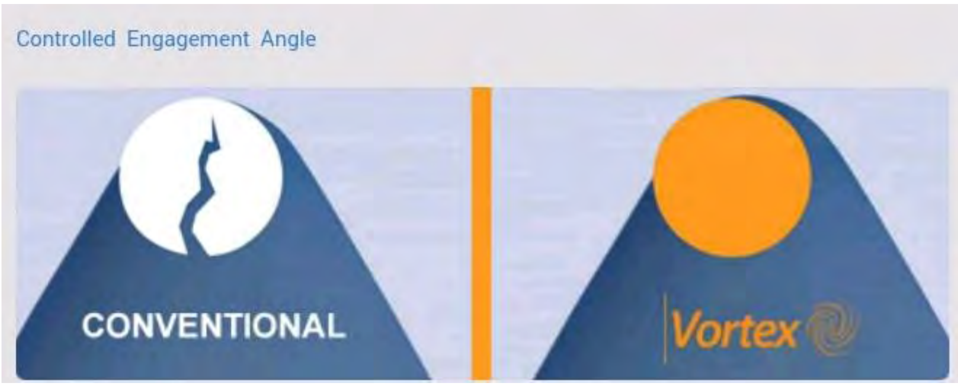

Figure 2.2: Controlled Engagement Angle

(Source: <http://www.vortexmachining.com/features/ >17/4/2015)

Vortex Machining gives the fastest safe metal removal from solid carbide tooling, in particular designs that give deeper cuts by using the full flute length as the cutting surface. Vortex produces toolpaths with a controlled engagement angle as shown in Figure 2.2 and so maintains the optimum cutting conditions for the complete toolpath that would normally be possible only for straight-line moves. As a result, higher feed rates are possible, making the cutting time shorter, while cutting was undertaken at a more consistent volume-removal rate and at a near constant federate, so protecting the cutter and the machine as viewed in the website at <http://www.delcam.com/news/press_article.asp?releaseId=1778>.

Vortex Machining give more beneficial to the technology because more effective than conventional machining. From this project, it had been machine a part with different materials with deeper depth in one cut that can reduce the time to machine a part. This Vortex can protect against damage to the surface of the part and it was make the process easier to analyse the machined part. Conventional machining produce the sound of unstable pitch that refer to the tool overload while Vortex roughing produce constant pitch because of the tool was operating under consistent conditions.

Previous case study into Vortex Machining by Jeffrey *et al*. (2013) was focused on investigation of tooling effects, slurry composition and workpiece material. These achievement resulted improved repeatability had been obtained in the Vortex Machining process through improvement in position, slurry height and other controls.

Other previous case study into Vortex Machining by Howard *et al.* (2013) was focused on the development of an experimental testing platform. These efforts resulted in a three-axis platform with sub-micrometer feedback with other controls implemented to control slurry depth and probe dynamics. The past case study just shows that the effects of Vortex Machining on surface, tools and parameters but for this new case study was validate the Vortex Machining capability on different materials.

2.3 CAD/CAM Technology

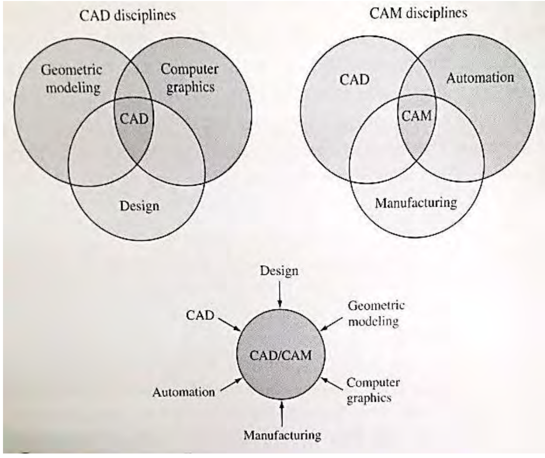

Figure 2.3: CAD and CAM disciplines (Ibrahim Zeid, 2005)

Nowadays, many toolpaths are too difficult and expensive to program manually and from that we need an aid from the computer and software to write an NC part program. The advantage using CAD/CAM was the system can be used to check the program in off-line mode that resulting toolpaths appear on the computer screen and user can view the toolpaths at various orientations. The system also can predict and generate the cycle time to machine a part and can detect the part or tools problems for the machining process. At the same time, the system can determine the optimum tooling, speeds, and feeds for the material selected for roughing and finishing process.

CAD/CAM had been used in engineering practice in many fields including design, simulation, analysis and manufacturing. If NC programming was used in an integrated CAD/CAM environment, the toolpath generation, verification, and post-processing are performed by the NC package which was part of the overall software (Ibrahim Zeid, 2005).

2.3.1 CAD Software

CAD uses a computer to create, modify, and refine a design (James V. Valentino, 2008). CAD system was to draw the geometry of a workpiece on the computer or draw 3-Dimensional (3D) drawing. There a lot of CAD software available in the market such as SolidWorks, AutoCAD, CADAM, and Pro-Engineer. By using CAD software, the modelling techniques can be representing the part with the lines, arcs, circles, and points in 3D modelling. Advances in CAD software and hardware enable to draw and create the part as a solid.

2.3.2 CAM Software

CAM system software was specially designed to generate a complete word address program for machining a part on a CNC machine. CAM software can be directed to draw and create a 3D toolpath over the surface element and the CAM system was used to generate an NC toolpath refers to the CAD geometry. There are multiple types of CAM technology software in the industries such as Delcam, MasterCAM, and PowerMILL.

Delcam have a various type of roughing, but Vortex toolpaths are computed to give more efficient machining by following the shape of the part and by keeping air moves to a minimum. This is distinctly important for rest machining operations. The machine part run by Delcam on different machine tools has shown that a time savings being found is 71% and other examples included a reduction of 67% when cutting a number of pockets in a stainless steel part, a 63% time saving on a titanium part and 58% saving when cutting an aluminium part.

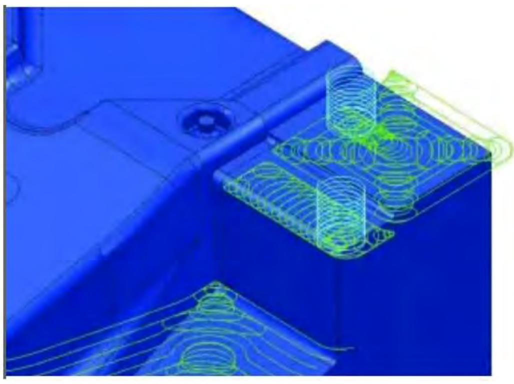

Figure 2.4: The conventional toolpaths for roughing out a pocket

(Source: http://www.autofieldguide.com/articles/cam-getting-better- >9/5/2015)