CUTTER PATH STRATEGY FOR MACHINING CRANIOFACIAL MEDICAL IMPLANT PEEK COMPOSITE

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This report submitted in accordance with the requirement of the UniversitiTeknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) (Hons.)

by

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I hereby, declared this report entitled “Cutter Path Startegiy For Machining Craniofacial Medical Implant PEEK Composite” is the results of my own research except as cited in the references.

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Date	:	3 June 2013

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The member of the supervisory is as follows:

.....

Dr Raja Izamshah Bin Raja Abdullah

Project Supervisor

ABSTRACT

Polyetheretherketones (PEEK) have been increasingly employed as biomaterials for trauma, orthopedic, and spinal implants. Composites such as polyetheretherketone (PEEK) used in orthopedic structural components, are generally manufactured by extrusion, and for this fact, these recent materials need additional machining operations. One of the major concerns in machining is to reach a good surface roughness and dimensional precision. However, the experience acquired without considering the peculiar material response to machining especially to the cutting tool. Hith tool waer and the need for tight tolerance and good surface finish are some of the major concerns in machining this material which are directly relate with the machining cutter path. No significant study has beed carried out so far on the effects of cutter path on machining PEEK composite. This, this research aims to investigate the effects of different cutter path strategy on maching performance. Three cutter path strategies will be investigate namely lead and tilt, normal to dirve surface and optimized lead on the machining performances namely surface roughness, dimensional accuracy and machining time. Portions of human craniofacial complex geometry shape are used as the case study.

ABSTRAK

Polyetheretherketones (PEEK) semakin meningkat kegunaannya sebagai biobahan untuk trauma, ortopedik, dan implan tulang belakang. komposit seperti polyetheretherketone (PEEK) yang digunakan dalam komponen struktur ortopedik, biasanya dibuat oleh penyemperitan, dan untuk fakta ini, bahan-bahan ini memerlukan operasi pemesinan tambahan. Salah satu daripada permasalahan utama sewaktu pemesinan adalah untuk mencapai kekasaran permukaan yang baik dan ketepatan dimensi. Kehausan mata alat yang tinggi dan keperluan untuk toleransi yang ketat dan kemasan permukaan yang baik adalah sebahagian daripada permasalahan utama dalam pemesinan bahan ini yang secara langsung berkaitan dengan laluan pemotong pemesinan. Tiada kajian yang ketara yang telah dijalankan setakat ini mengenai kesan-kesan laluan pemotong permesinan pada komposit PEEK. Penyelidikan ini bertujuan untuk menyiasat prestasi permesinan bagi kesan pemotongan pada laluan pemotongan permesinan yang berbeza. Tiga strategi laluan pemotong yang di kaji iaitu “Lead And Tilt”, “Normal to Drive Surface”, dan “Optimized Lead” berdasarkan prestasi permesinan yang telah ditentukan iaitu kekasaran permukaan. Ketepatan dimensi dan masa permesinan. Tiga strategi jalan pemotong akan menyiasat iaitu memimpin dan miring, biasa untuk dirve permukaan dan dioptimumkan membawa kepada prestasi pemesinan iaitu kekasaran permukaan, ketepatan dimensi dan masa pemesinan. Sebahagian daripada kraniofasial manusian berbentuk geometri yang komplek digunakan sebagai kajian kes.

DEDICATION

To my beloved parent and family.

ACKNOWLEDGEMENT

Alhamdulillah, Thanks to the entire Almighty from Allah for giving me all the strength and good health to complete this report without problems and barriers. This report is finally completed with much assistance of many people.

I would like to express the deepest appreciation to Universiti Teknikal Melaysia Melaka for providing such a brilliant facility such as equipment and machine for me to fulfil PSM requirement that's need to use while the project is carry on .

Besides that, I am heartily thankful to my supervisor, Dr. Raja Izamshah Bin Raja Abdullah, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the research. I am truly grateful for his the time spent proofreading and correcting my many mistakes, his tolerance of my mistakes, and his commitment to my future career.

In addition, I would like to thank all manufacturing engineering department lab staff for giving me an opportunity to work in a good and productive environment. Their continuous support and guidance whenever problems occurred while I was performing new task is really an encouragement in making me to perform at my very best. This has partly contributed to the success of my research and the completion of this 'Projek Sarjana Muda'.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS & NOMENCLATURE

CNC	-	Computer Numerical Control
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
%	-	Percentages

CHAPTER 1
INTRODUCTION

1.1 Background of study

To meet the demands of the growing orthopaedic market and changing demographics of patients, implant design solutions are becoming increasingly sophisticated. Today, device manufactures are leveraging implantable plastics that process highperformance and customized properties, as they allow for greater design freedom and ultimately lead to improved applications. Polyetheretherketones (PEEK) is the most widely used long-tern implatable plastics in medical application. The increasing use of high performance plastics, composite materials and compounds can be seen in the development of a wide range of orthopedic application, including spinal fusion cages and plates, artificial discs, acetabular cups, femoral stems and arthroscopic bone anchors and interference screws. In addition to meeting these general implant requirements. For this reason, only limited number of suitable biomaterials are available for the development of implantable orthopedic devices, and the emergence of new biomaterials is rare. Because of their biocompability and high performance, implatable-grade plastics have emerged as a leading biomaterial in the developmentof orthopedic applications. These biomaterials are attractive for both their machenical properties and their associated processing technologies, which enable device manufacturers to tailor their characteristics to meet certain needs. The ability to tailor the characteristics of certain implantable-grade plastics means that device designers can consider factors other than the structural

substitution of the natural tissue. Physical characteristics such as the elastic modulus can be modified to recreate bone modulus. Mechanical properties such as the strength, wear resistance and impact performance of polymers and composites can be comparable to metals and offer additional benefits. Since implantable-grade plastics are not metallic, they do not release metal ions into the body, which can trigger allergic ractions in certain patients. In addition to reducing or eliminating allergic reactions, these materials also eliminate artifacs during post operative examination by traditional techniques such as X-ray, CT and MRI technology. Non-metallic materials also resist corrosion, leading to a longer implant life span. Polymers are also less dense than metals, have lower thermal conductivity and, in areas close to the translucent skin surface, provide better color aesthetics. In addition, oplymers present the ability to be surface modified with such coatings as hydroxyapatite or titanium, to aid secondary fixation or with chemical species as with bone morphogenic proteins (BMPs). Processing for some plastics can be easily scaled up to meet the increasing demand for product parts. Incorporating plastic technologies (for example, injection molding) means that the economics of production are viable on a larger scale, while complex shapes can be formed as required to aid device fabrication. However, often for prototype designs or shor production runs, it is not economically viable to manufacture an injection molding tool. Under such circumstances, it is common to employ a machining process on the PEEK polymer materials to form the components.

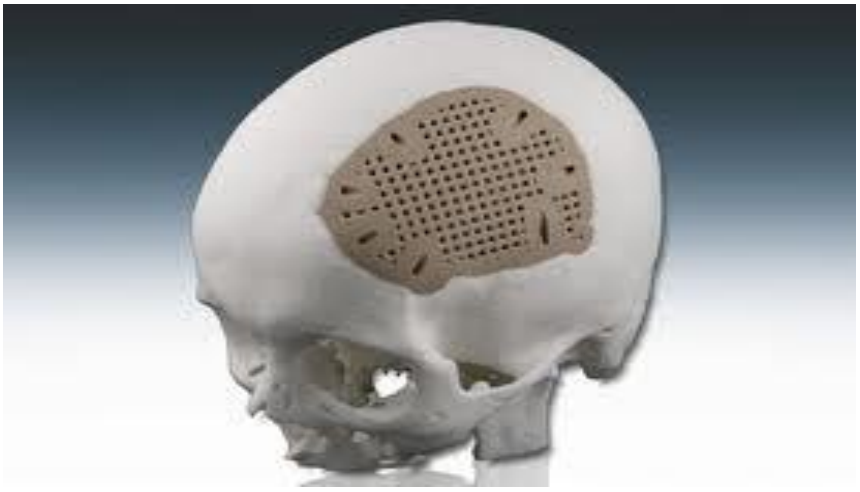

Figure 1.1 Example of a PEEK implant fabricated using milling process

1.2 Problem Statement

Often for prototype designs or short production runs, it is not economically viable to manufacture an injection molding tool. Under such circumstances, it is common to machine the PEEK polymer materials to form components. However, because of the excellent physical properties and wear characteristics of these material can poses a challenging machining process.

- Machining and finishing operation on polymeric materials are prone to propagating molded-in or residual stresses. Futher stress may be built up within the material by localized heating at the cutting point during machining process.
- The best way to avoid adverse affects on the material's biocompability is to machine dry. However, in many cases coolant is necessary to remove cutting heat that builds in the workpiece (PEEK doesn't disspite heat the way metals do). Pure water serves as the best coolant because it is likely to affect material biocompability.
- As with all medical components, precautions must be taken to prevent surface contaminant of PEEK workpieces. One precautionary measure is to dedicate the machine tool, fixturing and tools to machining only that material. Some shops also insist their employees use gloves when handling PEEK to keep oils off the part surface.
- Most of the machining processes for machining PEEK using a same cutting tool as machining metal. As the use of PEEK for medical implant devices is rising, success or failure in machining such an abrasive material depends largerly on the cutting tools.
- Due to the customers' high quality requirements and the huge price of the materials, particular care and precision are required during machining.
- Traditional manufacturing methods associated with metallic implants are generally not satisfactory for polymeric materials. Polymers are raltively soft when compared to implant alloys and this can create manufacturing problems related to machining, deburring, and cleaning operations.

1.3 Objective

Both the difficulties and conventional cutting strategies for machining the PEEK materials cause to initiate this research. The objectives of this research are :

1. To investigate the effects of cutter path strategy (Lead and tilt, Noraml to drive surface and Optimized lead) on machining performance of PEEK material.
2. To propose the optimal cutter path strategy base on machining performance for effectively machining orthopedic component.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Innovation is the driver of industrial growth and doctors, consultants and surgeons, who are always seeking better treatment for their patients, are driving the orthopaedic implants market. Alternative material such as biocompatible polyetheretherketone has been increasingly employed as orthopaedic structural material such as stand-alone anterior lumbar fusion cage. The benefits of this implant offer include reduced operating time, better bone fusion, less shrinkage and loss of height, and improved spinal alignment. The implant can be inserted between vertebrae where it serves as a substitute for degenerative spinal discs. In first time spinal operations, it can simply be inserted into place and the grip-like tread on its surface and screws hold it in place.

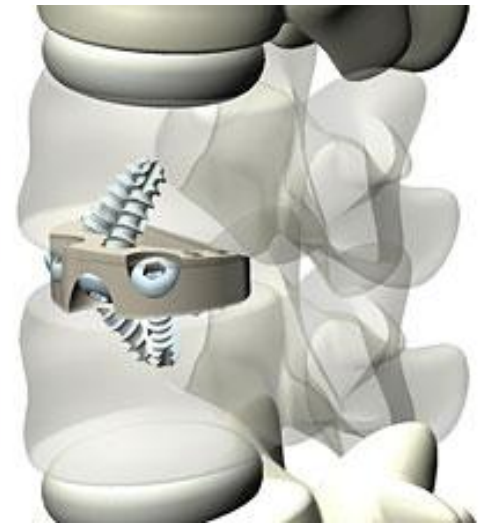

Figure 2.1 Example of stand-alone anterior lumbar fusion cage

The Young's Modulus of PEEK is similar to that of cortical bone, therefore, it offers more elasticity that metal. It can absorb energy, handle the normal weight of the body and minimise stress on adjacent levels. The material is also radiolucent (transparent to X-rays) and thereby allows an improved view of the fusion mass that is taking place. However, to be able to offer X-ray (computer tomography or magnetic resonance) imaging for optimal positioning and postoperative assessments, titanium trace wires are press fitted into the implant. Recovery for the patient is faster in many cases. Some patients need to be operated on from the back. However, the implant can be inserted through the patient's stomach where reconstructing the spine is much less invasive that through the back. Some only need a small incision from the fron or side, and in these cases recovery can be rapid, requiring only a four or five day hospital stay followed by a period of recuperation to allow the fusion to knit.

2.2 Orthopaedics machining

Fabrication of orthopaedic implants required a combination of multidiscipline fields especially machining. In the case of machining, the ability to interact with the concept for new or modified implants is essential.

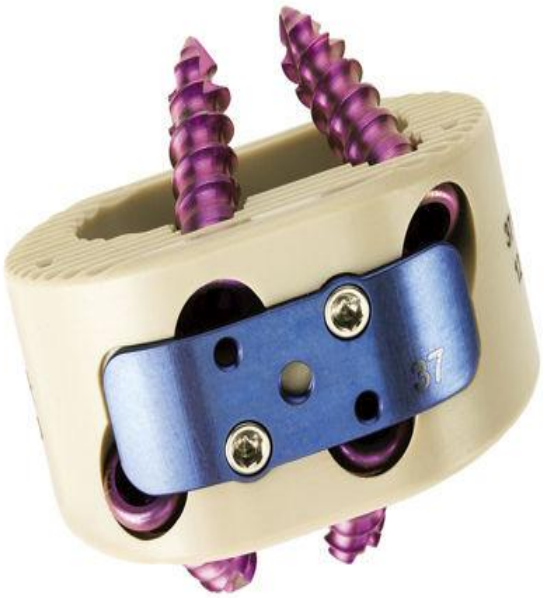

Figure 2.2 Example lumbar interbody fusion cage anterior

Once the design has been given final approval, the fabrication or machining section must then be able to produce variable bacthes of complex, high tolerance medical implants from “exotic” materials. As well as PEEK, these include carbon composite, manganese alloys and ceramics. A material’s characteristics change during machining because the process introduces internal stresses into its molecular lattice. If these stresses are not removed, there is a risk that the implant will fail during its period of implantation. Post-operation stress relieving (annealing) involves drying the components for a minimum of 3 hours at 150 deg C. The components are then

heated up at 10 deg C per hour until an equilibrium temperature of 250 deg C is reached. Then the components are allowed to cool at 10 deg C per hour until reaching below 140 deg C, and subsequently allowed to cool down to room temperature. In addition, the tight quality control and short lead time's order of medical component make it more challenging. The production equipment used in the manufacturing process of orthopaedic implants involves computer numerical controlled (CNC) multi-axis machine tools that are able to produce high quality complex components in a consistent way from raw plastic and titanium material billets. Novel work holding techniques have been developed for two axis and three axis CNC machine tools to address the following issues:

- The need to keep wastage of high cost materials to an absolute minimum
- The complexity of the shapes being machined
- The ability to handle components with unsual material characteristics
- The need to maintain high accuracy at all times
- Specialist applications that required standard machine tool technology to be adapted

To produce the spinal implants, a CNC vertical machining centre with a fully integrated fourth-axis capability is required. The main operations are drilling, tapping and surface contouring components manufactured from titanium and plastic. In addition, an inclined fixed fifth-axis configuration is required. Combining this with the CNC machine tool will enable the machining cycle time to be kept to a minimum. Using CNC programs that contain high levels of parameters programming capability, it is possible to machine components 8-10 times faster than using manual machine tool technology. Coordinate measuring (CMM) with bespoke probing systems and statical process control help ensure accurate and consistent manufacture of quality products.