INVESTIGATION OF SURFACE INTEGRITY WHEN MACHINING FC300 GRAY CAST IRON WITH UNCOATED CARBIDE FLAT END MILL

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2015

B051110293 BACHELOR OF MANUFACTURING ENGINEERING (MANUFACTURING PROCESS) (HONS.) 2015 UTeM

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

by

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2015

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JUDUL: Surface Integrity of FC300 Gray Cast Iron When Machining with Uncoated Carbide Flat End Mill

SESI PENGAJIAN: 2014/2015

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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 (Process) (Hons.). The member of the supervisory is as follow:

………………………………

(Project Supervisor)

ABSTRAK

Kisaran berhad laju tinggi adalah merupakan salah satu proses penting dalam pembentukan acuan. Manakala, besi tempa kelabu FC300 adalah salah satu bahan yang digunakan dalam penghasilan acuan untuk proses penekanan. Walaubagaimanapun, bahan tersebut sukar untuk dipotong kerana sifat kekerasan, ketahanan dan kekuatannya yang tinggi. Oleh itu, kertas kerja ini akan membentangkan keputusan uji kaji eksperimen berkenaan kesan had laju gelendong dengan nilai kedalaman pemotongan dan kadar suapan yang malar dalam proses kisaran berhad laju tinggi FC300 dengan menggunakan mata pemotong “flat end mill” karbida yang tidak bersalut. Ujikaji proses kisaran tersebut akan dilaksanakan dalam persekitaran yang kering dan di bawah 5 had laju yang berbeza, iaitu 4000 rpm, 4500 rpm, 5000 rpm, 5500 rpm, dan 6000 rpm dengan kadar suapan 100 mm/min, dan kedalaman pemotongannya adalah 0.2 mm. Analisis keputusan menunjukkan bahawa kekasaran permukaan merosot secara beransur-ansur apabila kelajuan pemotongan meningkat, terutamanya pada kelajuan 4000 rpm hingga 5000 rpm, semantara mikrograf SEM bagi permukaan yang dimesin pula menunjukkan bagaimana pada kelajuan pemotongan tradisional permukaan yang dimesin itu boleh mengandungi keretakan, pembentukan “debris particles”, dan “smeared materials”. Selain itu, terdapat juga kemungkinan “plastic deformation” hadir di bawah rantau sub-permukaan yang dimesin pada kelajuan pemotongan 4000 rpm. Maklumat ini berguna untuk pemesin memilih keadaan pemotongan yang terbaik untuk proses pemesinan FC300

ABSTRACT

High Speed Milling is one of the most important processes especially in mold and die industry. Meanwhile, FC300 gray cast iron is one of the materials used in the manufacture of the stamping die. However, the material is difficult to be cut due to its high hardness, strength, and toughness. This paper presents the results of an experimental investigation on the effect of spindle speeds with constant depth of cut and feed rate in high speed milling of FC300 with uncoated carbide flat end mill cutting tools. Milling tests was carried out under dry condition at five different spindle speeds, 4000 rpm, 4500 rpm, 5000 rpm, 5500 rpm, and 6000 rpm with a feed rate of 100 mm/min, and depth of cut, 0.2 mm. The analysis of the results show that the surface roughness deteriorated gradually when the cutting speeds increased, especially for the speeds of 4000 rpm to 5000 rpm, whilst the SEM micrographs of the machined surfaces show how at the traditional cutting speeds the machined surfaces may contain cracking, formation of debris particles, and smeared materials. Additionally, there was also a possibility of plastic deformation present beneath the machined subsurface region at the cutting speed of 4000 rpm. This information is useful for the machinist to select the best cutting condition for the machining process of FC300.

DEDICATION

First and foremost, I would like to express my greatest appreciation to Universiti Teknikal Malaysia Melaka (UTeM) for giving me the opportunity to undergo my final year "Projek Sarjana Muda". A special gratitude also goes to my supervisor, Dr. Mohd Hadzley Bin Abu Bakar for his dedication and guidance during the period of undergoing my project and also to master student, Encik Muhammad Hafiz bin Samsudin for his guidance. Last but not least, I would like to give my deepest thanks to my beloved Father and Mother who always encourage and give all the support that I really need during accomplish this report.

Thank You!

ACKNOWLEDGEMENTS

I would like to express my greatest gratitude to Allah SWT for giving me chances to explore and gain new knowledge throughout the period of completing my Final Year Project. Further, it is a pleasure for me to acknowledge and express my deepest thanks to my supervisor, Mr. Hadzley bin Abu Bakar for his supervision, encouragement, suggestion and assistance through the research. Similar gratitude also goes to Mr. Safarizal bin Madon and Mr. Azhar Shah bin Abu Hassan, the assistant engineers who construct and guide through completing this research while conducting the processes of mounting, grinding, and polishing, besides the evaluation process by using Scanning Electron Microscope (SEM) as their kindness and willing really regards me with pleasure.

I wish to express huge gratitude to all staffs at Universiti Teknikal Malaysia Melaka (UTeM) for their cooperation, permission and ample opportunity to facilitate fruitful case study; and also my beloved parents, Mr. Zaidi bin Bai and Madam Ramilah binti Misran whose constant encouragement, faith and confidence besides continuously moral support. Last but not least, the greatest thanks should be goes to all individuals and colleagues who have contribute so much throughout my study. I could offer here only an inadequate gesture of my appreciation and all of your good deeds will always be in my mind.

Thank You.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AMZ	-	Altered Material Zone
BUE	-	Built-up Edge
CIRP	-	International Institution of Production Research
CNC	-	Computer Numerical Control
d	-	Diameter of Milling Cutter in mm
DOC	-	Depth of Cut
EDM	-	Electrical Discharge Machining
HSM	-	High Speed Machining
m	-	Meter
min	-	Minutes
mm	-	Milimeter
MMSB	-	Miyazu Malaysia Sdn. Bhd
n	-	Cutter Speed in Revolution per Minute
rpm	-	Revolutions per Minute
Ra	-	Roughness Average
SEM	-	Scanning Electron Microscope
SiC	-	Silicon Carbide
UTeM	-	Universiti Teknikal Malaysia Melaka
v	-	Cutting Speed (Linear) in meter per minute

WC	-	Tungsten Carbide
>	-	More than
<	-	Less than
3D	-	3 Dimensional
µm	-	Micrometer

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, machining of materials is getting more advance as there are many developments of new alloys and engineered material which eventually causes these materials to have high strength and toughness as well as other material properties. According to ThomasNet (2014), machining can be defined as a process of removing material from a workpiece using power-driven machine tools to shape it into an intended design. Meanwhile, traditional machining processes can be divided into several types including turning, drilling, boring, milling, broaching, sawing, shaping, planing, reaming, and tapping (Bikram and Harsimran, 2014). The machinability of a material is usually defined in terms of four factors which are surface finish and integrity of the machined part, tool life obtained, force and power requirements, and chip control (Kalpakjian and Schmid, 2001).

Milling is the most common form of machining. It is a material removal process which can create a variety of features on a part by cutting away the unwanted material. A milling machine, workpiece, fixture, and cutter are required during the milling process. The workpiece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to a platform inside the milling machine. The cutter is a cutting tool with sharp teeth that is also secured in the milling machine and rotates at high speeds. By feeding the workpiece into the rotating cutter, material is cut away from this workpiece in the form of small chips to create the desired shape. Milling plays a key role in machining dies and molds. Indeed, milling tools remove the most share of the material, shaping a workpiece to a die or mold part.

Cast iron, especially gray cast iron is considered as a die and mold material for manufacturing large-sized parts, plates, spacers, bushings and other components where wear is not expected. The term cast iron refers to a family of ferrous alloys composed of iron, carbon, and silicon. Carbon is ranging from 2.11 wt% to about 4.5 wt%, whilst silicon is up to about 3.5 wt% (Kalpakjian and Schmid, 2010). Cast iron tends to be brittle, except for malleable cast irons. Apart from that, cast iron has relatively low melting point, castability, excellent machinability, good fluidity, resistance to deformation and wear resistance. In this research, the grade of gray cast iron used is FC300 in the Japanese Industrial Standard (JIS G5501) code. Tupy (n.d.) stated that the gray cast iron grades of larger mechanical resistance, FC300, present more refined graphite and a matrix essentially pearlitic, providing of these materials a better surface finish and a higher hardness than FC200.

During the milling process of FC300 gray cast iron, carbide end mill is the milling cutter that was used to perform milling operations. End Mill series is produced using sintered Tungsten Carbide (WC) with a cobalt binder that is both vigorous and very durable. It is particularly suited to the High Speed CNC machining of an extensive variety of steels, composites and other material which likewise run in hardness and metallurgical properties (Union tool, n.d.). Tungsten Carbide end mill is a very precise cutting tool that forms the intricate tip geometries and flute designs. Kalpakjian and Schmid (2001) have explained that Tungsten Carbide is a composite material comprising of tungsten carbide particles bonded together in a cobalt matrix. The amount of cobalt present essentially influences the properties of carbide tools. As the cobalt content increases, the strength, hardness, and wear resistance of WC decrease, while its toughness increases because of their higher toughness of cobalt. Tungsten carbide tools are generally used for cutting steels, cast irons, and abrasive nonferrous materials.

One of the important factors in machining stamping die is surface integrity. Surface integrity is a critical consideration in manufacturing operations because it influences properties like fatigue strength, resistance to corrosion, and service life. The surface integrity of any material consists of two basic components, including the topography and internal surface features of the product. Topography reflects changes on the outer surface of a material, and includes things like smoothness, bumps or waves, pitting and cracks. Internal features address changes just beneath the external surface, for example, deformation and changes in strength or hardness. In the other words, stamping die must be free from scratches, pores, pitting and pin holes, because the fine surface finish is essential not only to provide optimum heat transfer during quenching process. In order to get a better surface integrity at stamping die, the stamping die will be machined at High Speed Machining (HSM) and then is polished manually.

This study investigates the machinability of FC300 gray cast iron in terms of surface integrity, such as surface roughness, surface profile, and subsurface microstructure by using uncoated carbide flat end mill. The machining is held on a 3 axes CNC vertical milling machine under various spindle speeds, including 4000 rpm, 4500 rpm, 5000 rpm, 5500 rpm, and 6000 rpm. The data is created based on the surface integrity of FC300 and it is then tabulated. Meanwhile, the expected outcomes from this study are to have the database, guidance to machine FC300 efficiently and also has a good machinability cost.

1.2 Problem Statements

The quality and performance of a product is directly related to the surface integrity achieved by final machining. There are many kinds of surface integrity problems reported in literature, such as tears and laps related to the built-up edge formation, residual stresses, white layer and the work hardening layers, as well as microstructural alterations can be studied in order to improve surface qualities of end products. Many parameters affect the surface quality of the workpieces. Feed rate, depth of cut, cutting speed, tool geometry and preparation, workpiece properties, and tool wear are among the most important ones worth to investigate.

According to American Foundry Society (n.d.), gray cast iron is inclined to built-up edge (BUE) at low cutting speeds, and the tools also are exposed to abrasive (flank) wear. Thus, it is recommended to machine at higher cutting speeds. Apart from that, Davim (2010) was conducted a research regarding the milling process of gray cast iron. He stated that there are a number of strange results obtained in his tests at low cutting speeds, where the surface roughness is higher. If the machining process takes place at the optimum cutting speed, the built-up edge does not form at all, so, it does not have any effect on the surface finish (Davim, 2010).

FC300 gray cast iron has wide applications in the stamping die industry. However, it is difficult to be cut due to its high strength and hardness that varies from 179 to 285 HB (Tupy, n.d.). Therefore, an optimum cutting parameter should be guaranteed to obtain satisfied machining precision during the machining process. The uncoated carbide flat end mill is the preferred tool materials for high speed machining of the gray cast iron in this study. Its lower price compared to the coated carbide is one of the important reasons why it was selected. Apart from that, it is also relatively high in fracture toughness, high hardness, high strength, and it is suitable to be used for high speed machining, accounts for its excellent performance during gray cast iron machining.

As getting inspiration from this kind of situations, this researchis conducted to investigate the surface integrity of FC300 gray cast iron. The selected process is milling, which will be performed using a 3 axes CNC vertical milling machine. The parameter varying is cutting speed, while feed rate and depth of cut will keep constant.

1.3 Objectives

There are three main objectives by doing this project:

a) To analyze the effect of cutting parameter on surface roughness.
b) To examine the surface profile for the expected cutting parameters.
c) To analyze the microstructure alteration beneath the machined surface.

1.4 Scope of Project

This project is focused on investigating the surface integrity when machining FC300 gray cast iron in order to analyze the optimum cutting speed. On this project, 3 axes CNC vertical milling machine is used to machine the material by using uncoated carbide flat end mill. This research has covering the cutting speeds from 4000 rpm to 6000 rpm with constant depth of cut (0.2 mm) and feed rate (100 mm/min). When all the data are obtained and recorded, they are then tabulated and analyzed. In analyzing the data, graph of results is shown in the results and discussion sections. The results obtained from this analysis will be useful for a machinist in planning their machining, especially for the material of FC300 gray cast iron in order to maximize the surface quality of end products.