UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF TOOL WEAR AND SURFACE ROUGHNESS WHEN MACHINING AISI 1045 WITH CIP PRESSED CERAMIC CUTTING TOOL

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

by

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DECLARATION

I hereby, declared this report entitled "Investigation of Tool Wear and Surface Roughness When Machining AISI 1045 with CIP Pressed Ceramic Cutting Tool" is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka 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 follow:

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(IR. DR. MOHD HADZLEY BIN ABU BAKAR)

ABSTRAK

Pemotong perkakas seramik merupakan antara perkakas yang kerap digunakan dalam operasi pemesinan terutama pada kondisi kering. Kelebihan seramik seperti kekerasan panas tinggi dan refraktori tinggi membolehkan perkakas pemotong ini diaplikasikan dalam pemesinan besi keras. Kajian ini tertumpu kepada aplikasi tekanan isostatik sejuk dalam penghasilan pemotong perkakas seramik beasaskan alumina. Serbuk alumina semburan kering digunakan sebagai bahan mentah untuk menghasilkan perkakas pemotong ini. Serbuk ini dimampatkan menggunakan penekan hidraulik pada tekanan 8 tan sebelum dimampatkan lagi melalui tekanan isostatik sejuk pada tekanan 30000 psi. Jasad anum kemudiannya dikeringkan dan dibakar pada suhu 1700 °C selama 4 jam. Perkakas pemotong tersebut diuji melalui operasi larik ke atas besi AISI 1045 pada kelajuan pemotongan yang berbeza. Haus rusuk perkakas dan kasar permukaan besi dianalisa menggunakan mikroskop dan penguji kasar permukaan. Keputusan ujikaji menunjukkan perkakas alumina yang ditekan melalui tekanan isostatik sejuk mencapai kekerasan 83.2 HRA dan mampu memotong besi AISI 1045. 7% pengecutan serbuk alumina daripada jasad anum kepada jasad yang dibakar telah direkodkan. Dari segi haus rusuk, perkakas pemotong alumina menunjukkan penurunan kadar haus apabila kelajuan pemotongan dinaikkan daripada 150 m/min kepada 200 m/min. Dari segi kasar permukaan pula, corak penurunan ditunjukkan apabila kelajuan pemotongan meningkat. Kajian ini membolehkan industri untuk memahami cara-cara penhasilan perkakas pemotong mereka sendiri untuk memudahkan proses pemesinan.

ABSTRACT

Ceramic cutting tool is among frequently used cutting tool in machining operation especially in dry condition. The advantages of ceramic including high hot hardness and high refractoriness enable this cutting tool to be applied in machining various hardened steels. This study focuses on the application of cold isostatic press (CIP) to produce alumina based ceramic cutting tool. Spray dried alumina powder was used as a raw material to produce the cutting tool. The powder was pressed using hydraulic press at 8 tons before compressed through CIP at 30000 psi. Green body then was dried and sintered at 1700 °C at 4 hours sintering time. The cutting tools were then tested in turning operation to machine AISI 1045 with different cutting speeds. Flank wear of the cutting tools and surface roughness of the AISI 1045 were analyzed using stereo microscope and surface roughness tester respectively. The results shows that CIP pressed alumina cutting tool obtained the hardness of 83.2 HRA which is considered adequate to machine AISI 1045 steel. The shrinkage of alumina powders recorded about 7% form green compact to sintered body. In terms of flank wear, the alumina cutting tool demonstrated decreased wear rate as the cutting speed increased from 150 m/min to 225 m/min. In term of surface roughness, the trend demonstrated decreased in surface roughness as the cutting speed increased. This study enables the industries to understand how to fabricate their own cutting tool for better feasibility in machining.

DEDICATION

To mom and dad

I love you.

ACKNOWLEDGEMENT

First and foremost, I would like to express my greatest gratitude to Almighty God for giving me strength and courage to finally complete my bachelor degree project with the best I could. Indeed, without His help and blessings, nothing will be accomplished.

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CHAPTER 1

INTRODUCTION

This chapter provides an introduction of the project background including the ceramic cutting tools, alumina, wear performance and surface roughness. The problem statement, objectives and the scopes of this project on the fabrication of ceramic cutting tool and the evaluation of the wear performance and surface roughness will be introduced.

1.1 Background of Study

Ceramic cutting tool is a material produced by the combination of ceramic powders that are compacted and applied at machining operations. There are many example of ceramic cutting tool such as silicon nitride, silicon carbide, sialon and titanium carbide. Ceramic cutting tools have been widely used in machining hard material due to its excellent properties especially in high temperature and high speed machining. Alumina based materials are among the most popular choices to be used to fabricate cutting inserts because it has high hardness, high resistance to abrasion and chemical inertness against the enviroment and the workpiece. Therefore, these materials are usually used in the applications involving abrasive wear enviroments such as ball mills, coal chutes, grinders and mixers. However, the limitation of alumina based cutting inserts are the low toughness of the ceramics which can cause chipping and breakage during machining. In order to overcome this problem, additional materials such as yttria stabilized zirconia, titanium carbide, silver and ceria are used to increase the fracture toughness of the alumina (Azhar et al, 2011).

Ceramic cuting tool can be fabricated by the powder metallurgy process. Specific composition of ceramic powder can be processed with mixture and milling with other reinforced material to create refractory body for high perforamcne in tribology application. There are many technique to process ceramic powders such as cold isostatic pressing (CIP), slip casting, ball millling and slurry mixing. Another processes that involve are pressing, casting and sintering. Therefore, many factors contribute to the efficiency of ceramic production including properties of powders that are used as raw materials, additive materials and sintering temparature. In order to evaluate the performance of ceramic compact, several criteria can be employed such as hardness, density, wear performance and surface roughness of machined surface.

Alumina is considered as one of the hardest ceramic powder that exists in the world. Alumina is obtained from Bayer process. The Bayer process is the most economical process to extract alumina from bauxite. This powders possesses different powder size depend on the purity. In the application of alumina as a cutting tool, important criteria such as microstucture, grain size, grain uniform and reinforced particle are very important. Fine and uniform grain size would provide high resistance to wear when this powder compact engages with other materials. Therefore, most of alumina based cutting tool were fabricated with additive secondary powders such as zirconia and chromia to provide additive advantages not only to claim the high hardness but also to resist wear from the tribological and heat actions during machining.

Wear performance of ceramic compact is very important in order to run prolong machining operation. The major causes of tool wear are mechanical, thermal, chemical and abrasion. Fatigue on the tool cutting edge is the result of the cyclic mechanical forces. As the cutting velocity increase, the temperature of the tool increases (Gu et al,1999). Most of the cutting processes in turning are done by the nose of the inserts. The stability and reliability of the process rely on the wear characteristics of the tool material. Flank and crater wear control the tool life. While flank wear keep on progressing, the thermal and chemical conditions generate the formation of crater on the rake face of the tool. Catastrophic failure of the tool will happen due to the excessive crater wear whch debilitates the cutting edge (Ozel et al, 2007).

The purpose of this project was to fabricate ceramic cutting tool based on the specific composition of alumina powder. As the ceramic powders were compacted and sintered, the performance of ceramic cutting tool was evaluated based on wear performance and surface roughness of the machined surface. Selected cutting tool was used to machine AISI 1045 by the CNC machine at various cutting parameters. The evaluation of this research was examined using stereo microscope. This project also presented the failure mode of the newly fabricated cutting tool to highlight the possible weaknesses from the manufacturing processes. In the end, this result will be used to porpose some improve or refinement for the cutting tool development in the future.

1.2 Problem Statement

Nowadays, there are many ceramic-based cutting tool produced in the industry. Some of the ceramic cutting tools are cemented carbide, cubic boron nitrite, silicon carbide and diamond. These ceramic cutting tools has been widely known for their excellent performance in high speed and high temperature machining (Kalpakjian and Schmid, 2013). This is because the ceramics possess variety properties such as high hardness, high thermal shock resistance and high chemical stability. However, due to recent development and advancement in ceramic technology, some better quality of ceramic powders have been discovered and reportedly have excellent performance in machining (Azhar et al, 2010). The ceramic powders are prepared from various type of preocesses in order to enhance the properties so that the powders can be manufactured into excellent products. Therefore, it is a very good oppurtunity to fabricate a cutting tools from these ceramic powders and study the performance of the ceramics in machining.

One of the pure ceramics that has been widely found as cutting tools in the industry is alumina. This material is commonly used as the base of a cutting tool. Alumina based cutting tool is suitable for machining hard materials in high cutting speed. This cutting tool is suitable to be used in dry condition. In dry condition, it is expected that the temperature would be higher as compared to the wet condition. Therefore, it is expected that some behaviour of the tool surface would change. For instance, high temperature may lead to formation of molten metal which would promote material deformation. All of this would generate high tool wear. This problem will also affect the surface roughness of the machined surface. On the other hand, effect of cutting parameters could also affect the tool wear and surface roughness, especially when it is not applied correctly. All of the factors significantly contribute to the final properties which in the end could affect the accuracy and fatique strength of the product. Therefore it is necessary to study the machining capability of alumina based cutting tool during dry machining and its performance based on tool wear and surface roughness.

1.3 Objective

The objectives of this project are as follows:

i. To fabricate ceramic cutting tool based on spray dry alumina powder.
ii. To evaluate the hardness of the fabricated cutting tool.
iii. To evaluate the performance of the fabricated cutting tool based on tool wear and surface roughness.

1.4 Scope of Study

This study involved fabrication of alumina based cutting tool. Specific amount of spray dry alumina was prepared and shaping process was done in a mould by pressing using hydraulic hand press. Then, the green body was pressed using cold isostatic press (CIP). At this time, preliminary study to evaluate the suitable pressure to form ceramic cutting tools for density was studied. The process was replicated to produce many cutting tools for series of sintering. Series of sintering were implemented by using specific temperature and soaking time. The finest properties of ceramic cutting tools are selected for further machining performance evaluation. The hardness of these cutting tools was tested.

After the fabrication process of the ceramic cutting tools, the tools were tested in lathe machining using various parameters. Machining process involved different cutting speeds while the depth of cut and feed rate were kept constant. The performance of the cutting tools was analyzed based on wear performance and surface roughness.

CHAPTER 2

LITERTURE REVIEW

The literature review consists of the summarizing of the project in order to get the whole data about ceramic powders, cutting tools, machining, tool wear and surface roughness ehich will give an idea to run the project. This chapter presents related study done by previous research and will be working as a reference, to give information and guide based on journal, book and other sources on the internet that could contribute to this project.

2.1 Metal Machining

Machining is a manufacturing process where unwanted material from a workpiece is removed in the form of relatively thin layers called chips. The process is usually called metal cutting or metal removal if it the workpiece is a metallic material (Black and Kohser, 2008). Shear deformation of the workpiece occurs during the cutting action to create a chip and exposing a new surface when the chip is removed (Groover, 2010). Figure 2.1 shows the illustration of cutting process.

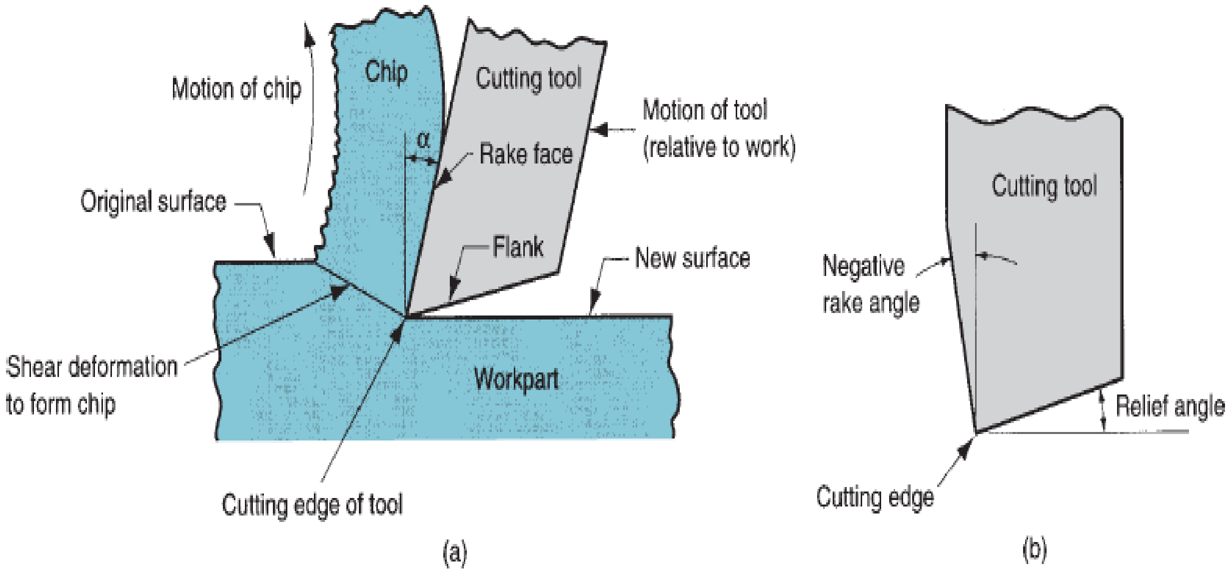

Figure 2.1 Metal machining (a) A cross-sctional view of the cutting process. (b) Negative rake angle of the tool, compare to positive rake angle in (a). (Groover, 2010)

According to Trent (2000), formation of the chip and moving it across the rake face of the cutting tool requires a relatively huge anount of energy. Energy is also required to form new surfaces which are the machined surface and the under surface of the chips. However, the proportion of the latter energy is insignificant to plastically deform the removed material. The machining process is a very complex process where it involves variety of inputs and outputs (Figure 2.2).

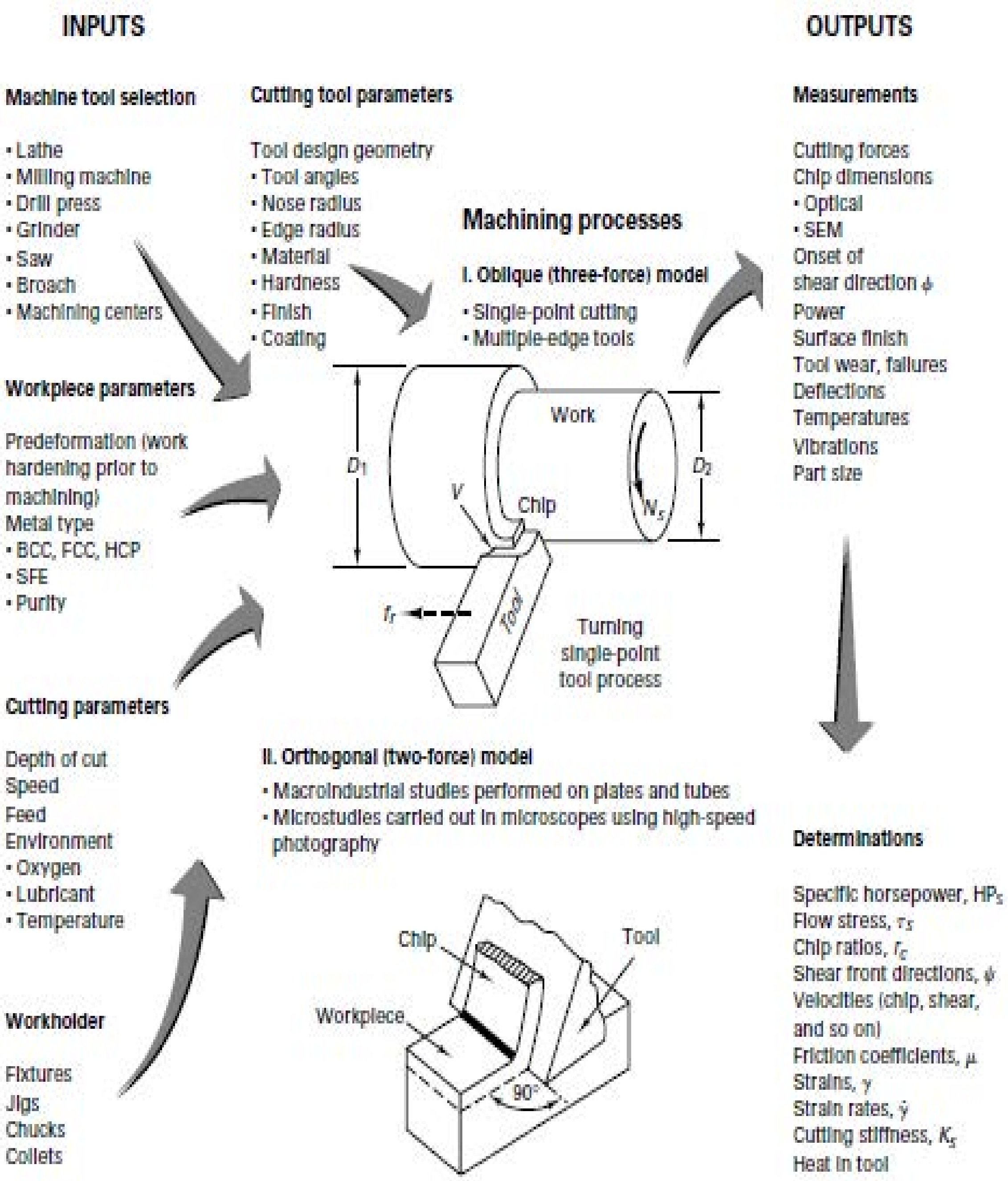

Figure 2.2 Fundamental inputs and outputs involved in machining process (Black and Kohser, 2008)

2.1.1 Chip Formation

The formation of chips has significant influence on the surface finish of the workpiece and overall aspect in cutting operation including tool life, chatter and vibration (Kalpakjian and

Schmid, 2013). During the cutting process, all types of chips produced are influence by a shearing of work material occur in the region between the tool edge and the position where the chips leave the cutting surface. In this region, a huge amount of strain in a very short interval of time is produced and this strain may fracture some materials which cannot withstand it (Trent, 2000). The failure of the material only happen at the sharp cutting edge of the cutter and separate the chips from the parent material. The mechanical energy is consume along the shear plane in machining and causing the material to deform plastically (Groover, 2010).

Basically, the control of the chips formation are influenced by the material properties of the workpiece and the cutting parameters. The cutting parameters including dynamic flow stress, strain rate, behaviour of workpiece with regard to strain and the cutting temperature (Trent, 2000). Figure 2.3 illustrates four basic types of chip formed during machining.

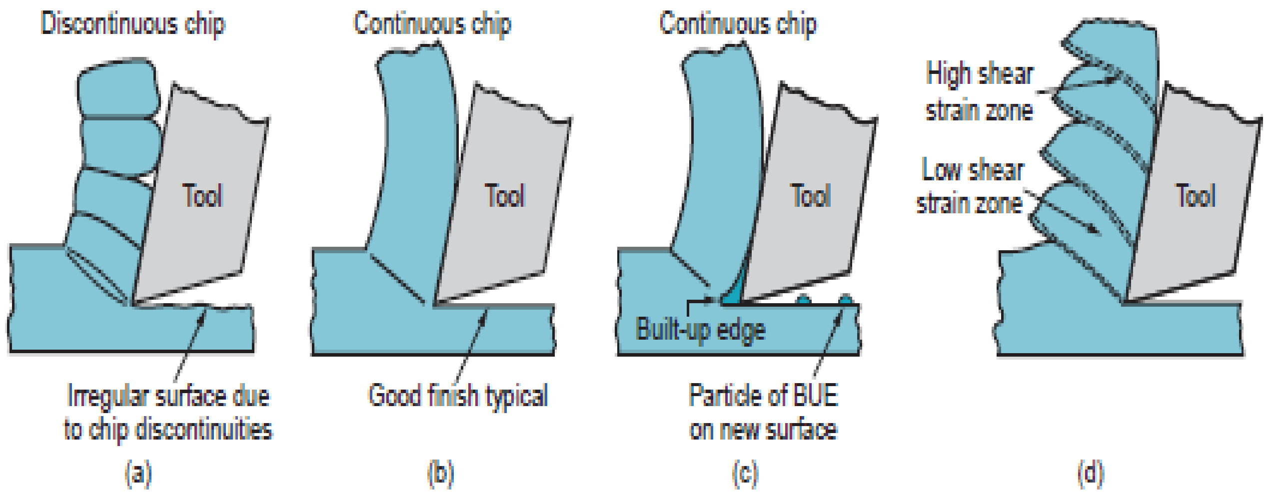

Figure 2.3 Chip formation (a) Discontinuous (b) Continuous (c) Continuous with built-up edge (d) Serrated (Groover, 2010)

(a) Discontinuous chips

Discontinuous chips (Figure 2.3 (a)) consists of segments which are separated or loosely attached to each other. The formation causes an irregular texture to the surface of the workpiece. This usually occurs in the low speed cutting of relatively brittle material. The formation of discontinuous chips is promoted by high tool-chip friction due to large feed rate and depth of cut. (Groover, 2010)

(b) Continuous chips

Continuous chips (Figure 2.3 (b)) commonly found in the cutting of ductile work materials at high speed and small feed rate and depth of cut. The formation of this type of chips results in a good surface finish. The sharp cutting edge on the tool and low friction between tool and chip promotes the long continuous chips formation. This type of chips may cause some problems in turning as the chips usually tangle around the tool, hence, the operation has to be stopped to dispose all the tangling chips. Cutting tools with chip breakers can be used to avoid the problems. (Groover, 2010)

(c) Continuous chip with built-up edge

The formation of the built-up edge (BUE) occurs when ductile work materials are machined at low to medium cutting speed. The tool-chip friction during the machining causes the portions of the workiece material to stick to the rake face of the tool near the cutting edge. The BUE forms and grows on the machined surface breaks off. The BUE may be diposed along with the chip or may break tiny portions of the rake face of the tool which reduces thelife of the tool. Some portions of the BUE which are not disposed from the surface will embedded and promote a rough texture to the newly formed surface. (Groover, 2010)

(d) Serrated chips

Serrated chips or shear-localized chips are semi-continuous which have a saw-tooth appearance. The formation of this type of chips is cyclical and induced by alternating high shear strain followed by low shear strain. This chips commonly found during the high speed machining of the metals with low machinabilty such as austenitic stainless steels, titanium alloys and nickel-based supperalloys. It can also occur when machining common work metals at high speed. (Groover, 2010)