INVESTIGATION OF TOOL WEAR AND SURFACE ROUGHNESS WHEN MACHINING AISI 1045 USING ALUMINA CERAMIC CUTTING TOOL

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INVESTIGATION OF TOOL WEAR AND SURFACE ROUGHNESS WHEN MACHINING AISI 1045 USING ALUMINA CERAMIC CUTTING TOOL

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

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Engineering Process) (Hons). The member of the supervisory committee are as follow:

……………………….................................

(Ir. Dr. Mohd Hadzley B Abu Bakar)

ABSTRAK

Laporan ini membentangkan penilaian haus perkakas dan kekasaran permukaan semasa pemesinan AISI 1045 menggunakan perkakas seramik alumina. Perkakas pemotong diperbuat daripada serbuk alumina yang disembur kering melalui kaedah pemadatan Tekanan kepadatan bermula dari 6, 7, 8 hingga 9 tan untuk setiap perkakas pemotong. Kemudian, serbuk yang telah dipadatkan akan disinter pada suhu 1700^0C selama 4 jam. Perkakasa pemotong yang siap disinter akan melalui ujian pemesinan menggunakan mesin pelarik CNC dalam berkeadaan kering dan prestasi perkakas pemotong dinilai dari segi kekerasan, haus perkakas dan kekasaran permukaan. Bahan kerja yang digunakan ialah keluli karbon sederhana AISI 1045 yang mempunyai kandungan karbon sebanyak 0.45 hingga 0.50%. Parameter yang digunakan semasa ujian pemesinan telah ditetapkan iaitu 35 m/min kelajuan pemotong, 0.05 mm/rev kadar suapan dan 1 mm kedalaman pemotongan. Dapatan menunjukkan kekerasan perkakas pemotong semakin meningkat dipengaruhi oleh peningkatan nilai tekanan pemadatan ke atas serbuk. Nilai tekanan tertinggi iaitu 9 tan menghasilkan nilai kekerasan sebanyak 86.1 Hv. Bagi haus perkakas pula, ia menunjukkan kadar haus perkakas semakin menurun apabila tekanan kepadatan perkakas semakin meningkat. Nilai kadar haus yang terendah ialah 0.0025 mm/s apabila perkakas pemotong 9 tan digunakan. Penilaian kekasaran permukaan menunjukkan bahawa perkakas pemotong 6 tan memberikan nilai Ra yang tertinggi iaitu 3.56 mikron. Manakala, perkakas pemotong 7, 8, dan 9 tan memberikan purata nilai Ra sebanyak 1.24 mikron. Kajian ini membantu menununjukkan fabrikasi perkakas pemotong menggunakan serbuk alumina disembur kering serta kesan tekanan pemadatan terhadap nilai kekerasan perkakas. Tambahan pula, ia membantu memahami kesan nilai kekerasan perkakas terhadap haus perkakas dan kekasaran permukan apabila pemesinan bahan keja AISI 1045 dilakukan.

ABSTRACT

This report presents the evaluation of tool wear and surface roughness when machining AISI 1045 using alumina ceramic cutting tool. The insert for cutting tool was made from dry sprayed alumina powder by using compaction method. The compaction pressures were varied from 6, 7, 8 and 9 ton for each cutting tool. Then, the compacted powder was sintered at temperature of 1700^0C for 4 hours sintering time. The insert then undergone machining test by CNC lathe turning at dry condition. Their performance were evaluated based on hardness test, tool wear and surface roughness. The workpiece material used was AISI 1045 medium carbon steel which having carbon content range from 0.45 to 0.50% carbon. The test were held at constant cutting speed of 200 m/min, feed rate of 0.05 mm/rev and depth of cut of 1 mm. The results show that the hardness of the cutting tool increased when the compaction pressure of the powder increased. Highest hardness value recorded at 86.1 Hv when the pressure was set at 9 ton. For tool wear, it was found that the wear rate decreased when the compaction pressure of the cutting tool increased. The lowest wear rate was recorded at 0.0025 mm/s when the 9 ton cutting tool was used. The surface roughness evaluation show that 6 ton cutting tool prodcued the highest Ra value which is 3.56 µm. Meanwhile, for 7, 8, and 9 ton compaction pressure, the cutting tool gave average Ra value around 1.24 µm. This project enable the industry to understand the correlation between compaction pressure and hardness of each cutting tool on tool wear and surface roughness when machining AISI 1045.

DEDICATION

To my beloved parents and dear friends

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CHAPTER 1

INTRODUCTION

This chapter is about the explanations of background, objectives and scope of the study. The type of material used, CNC lathe machine, cutting tool and performances of machining that need to be analysed is discussed in background. The objective of this project and the scope covers all things regarding this project.

1.1 Background of Study

Machining process is used in order to produce component parts by removing the material into required shaped. It is widely used in major industrial practice such as automotive, aerospace, medical, nuclear, oil and gas. In order to increase the performances of this process, three major factors must be concern which are cutting tools, type of workpiece, and cutting parameters. Nowadays, machining of material is getting leading as various advancements of new alloy and engineered material which improve the mechanical properties of the material itself such as having high strength, toughness, and others. In manufacturing operations, it is essential to view machining operations as a system including the workpiece, machine tools, cutting tools and also production personnel. Without a detailed knowledge of the interaction of these four components, machining cannot be carried out efficiently or economically (Kalpakjian & Schmid, 2014).

In order to evaluate the performances of machining, surface integrity must be concern as one of the service life. Surface topography and surface metallurgy can be categorized under surface integrity. Surface topography is about the appearance of outer surface of the workpiece while surface metallurgy more about the nature of the altered layers below the surface with respect to the base or matrix material. The value of surface roughness must be lower in order to achieve good quality product in industry (Gupta & Kumar, 2015). It is important to study surface roughness to relate the condition of machined surface with certain parameter.

There two conditions in machining which is dry and wet. Wet machining process involve usage of cutting fluid during the machining process while dry machining not using any cutting fluid. Dry machining usually applied during finishing process to gray cast iron or powder base material. Dry machining help to reduce cost and hazard to environment. Dry machining has been proved to give better surface roughness due to softening cause by heat generation during machining the material (Azevedo, 2013). Despite those advantages, it may affect the life span of cutting tool.

In dry machining there are many cutting tool available. Some examples are carbide, ceramic, diamond and cubic boron nitride. Selection the suitable cutting tool is important to produce a high dimensional accuracy and good surface finish product. One of the cutting tool that significant in dry condition is alumina based cutting tool. Alumina(AL_2O_3) based cutting tool popularly used as cutting tools due to their excellent hardness and abrasive resistance, good chemical stability and high temperature performances (Zhou et al., 2016). These properties enable alumina cutting tool to be the materials research in order to develop its capabilities as a cutting tool. The nature of alumina cutting tool such as alumina that hard, high wear resistance and chemical stability is suitable as research material in order to develop its capabilities as a cutting tool.

Methodology involve in this project is experimental procedures. By observation through the whole experiment that will be done, the tools must undergo machining test at certain condition before it been analyse. The evaluation of this research will be examined using Portable Surface Roughness Tester, Stereo Microscope (SM) and Scanning Electron Microscope (SEM).

1.2 Problem Statement

Today in manufacturing industry, there are many existed ceramic tool used in machining process. Some of them are mainly composed by several powders in order to increase their mechanical properties and the results perform very well. However, there are new ceramic powder is produced by the industry known as advanced ceramic powder which reported to have high abrasive resistance. These newly produce ceramic powder has improved in their mechanical properties and can perform well in high temperature during machining at high speed. This shows that these new powders are able to perform well in dry machining. It is very important to fabricate a new ceramic cutting tool with the new powder. Thus, it may improve the mechanical properties of the existed powder and enhanced the performance of the ceramic cutting tool.

Alumina based cutting tool suitable for machining hard materials in high cutting speed. This cutting tool suitable to be used at 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 behaviours of machined surface would change. For instance, high temperature may lead to formation of molten metal which would promote material deformation. All of this would generate poor surface finish and hence high surface roughness. On the other hand, effect of cutting parameters also could affect the surface integrity, especially when it is not applied correctly. All the factors significantly contributed to the final properties which in the end could affect the accuracy and fatigue strength of the product. Therefore it is necessary to study the machining capability of alumina based cutting tool during dry machining and the affect to surface roughness of the workpiece.

1.3 Objectives

The objectives of this project are:

1. To fabricate ceramic cutting tool based on alumina powders.
2. To evaluate the performance of fabricated cutting tool based on the surface integrity.
3. To propose improvement for further study of alumina zirconia cutting tool.

1.4 Scope

This project involves fabrication alumina based cutting tool. Specific amount of alumina will be mixed with zirconia. These powders will be processed in ball mill in certain period. Then, the composition of powders will be press inside the mould. On this time, preliminary study to evaluate the suitable pressure to form ceramic insert for density will be studied. The compacted ceramic will be ejected to make sure that the ceramic would not break. The process will be replicated to produce many inserts for series of sintering. In term of sintering, these inserts will be located inside furnace. Series of sintering will be implemented by varied the temperature and soaking time. The finest properties of ceramic insert will be selected for further machining performance evaluation. Here, the evaluations of criterion are density, hardness, microstructure and grain size.

As the fabrication of cutting tool is done, the powder will be machined at specific cutting parameters. machining process which will be carry out using CNC lathe machine where it has high reliability in varying parameter such as cutting speed and feed rate while the depth of cut kept constant. The performance of the machining test will be evaluated by surface roughness value. Surface roughness considers as performance measure and need further evaluation by using surface roughness tester. Microscope will be used to observe the surface profile in details. The effect of cutting parameter on surface integrity will be analyse and evaluate in details. This project consist five chapter including introduction, literature review, methodology, results, discussions and conclusion. The scope of this study is summarized on Table 1.

Table 1.1: Summary of project scope

Scope	Detail
Material of ceramic cutting tool fabrication	• Alumina based powder • Yttria stabilized zirconia powder • Chromia powder
Process	• Ball milling • Slip casting • Pressing • Sintering
Evaluation of the properties	• Hardness • Microstructure • Density • Grain size
Performance evaluation	• Surface integrity • Surface roughness • Surface profile

CHAPTER 2

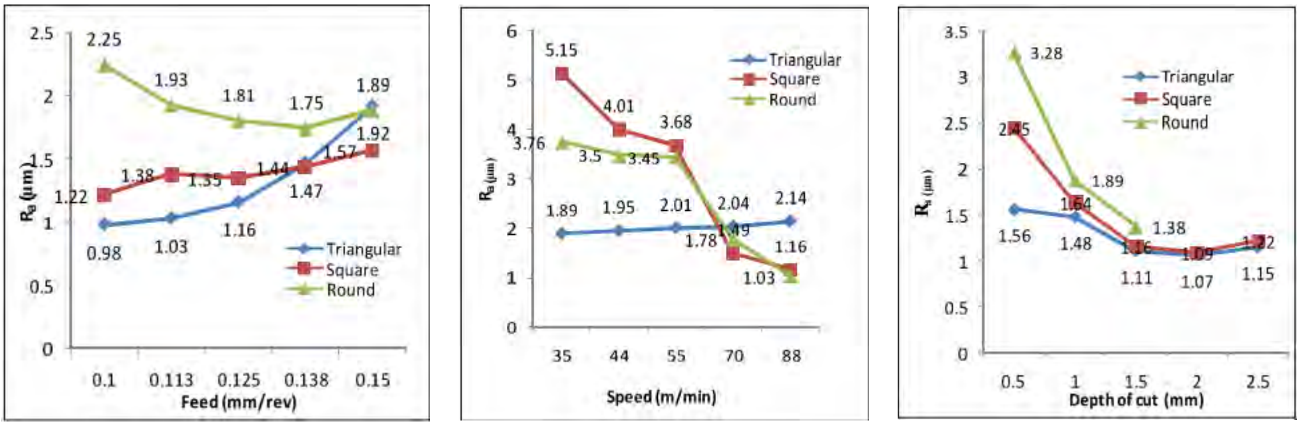
LITERATURE REVIEW

This chapter consist of information about the project in order to get the whole fact and data about workpiece material, cutting tool and lathe machine which will give the knowledge to conduct the project. In addition, it is show information about related study done by previous researcher as guidance. All the information based on journal, book and other source on the internet that may relate to this project.

2.1 Design of Cutting Tools.

There many type of cutting tools that can be used in lathe machining according to their desired machining process. for instance, insert cutting tools is one of the cutting tools that usually used to perform process such as straight turning, facing, profiling and grooving. In lathe machining, insert cutting tool is very commonly used as cutting tools. The ability of this cutting tool to perform machining process is depending on the parameter that applied such as the depth of cut, feed rate and rotational speed. In addition, the designing of the insert cutting tools also significantly affect to the cutting quality. There are many specification of cutting tools that must be concern before fabrication process such as the shape of the cutting tools, edges, thickness, trace, coating effects and nose radius that may determines the strength and fracture resistance of the tools. Besides those specifications, the condition of the machining and the position of the cutting tools also make impact to the lathe machining process.

Rohit Uppal et al (2013), have done an experiment to investigate the effect of insert shape to the surface roughness of machining AISI 4140. They done the experiment by using lathe machining at specific cutting parameters and used three different type of insert shape which is triangular, square and round. The results from the experiment is shown in Figure 2.1.



(a) (b) (c)

Figure 2.1: Graph of Surface roughness versus (a) feed rate (b) cutting speed and (c) depth of cut at three different shape of insert cutting tool (Rohit Uppal et al, 2013).

The result shows that triangular insert shape produce lower values of surface roughness rather that square and round shape. Furthermore, that round insert shape produce chattering during machining process when higher depth of cut is applied rather that triangular insert shape.

2.1.1 Tool geometry

One of the factors that influenced machining operation is the various angles in a single-point cutting tool (Kalpakjian & Schmid, 2014). Coordinate system is used to measure the three major axes of tool shank. Unfortunately, after the tool is mounted to the tool holder, some of these angles may be different from calculated data. There are five types of angle in tool geometry that may influence the machining operation.

1. Rake angle

   It is significant in holding both way of chip flow and the strength of the tool tip. Besides, positive rake angle can lead to decrease the force and temperature during cutting operation. Anyway, positive rake angles also affect small angle of the tool tip which leading to early or soon tool chipping and failure, depending on the toughness of the tool material.

2. Side rake angle

   It is the angle formed by the face of the tool and the centreline of the workpiece if viewed behind the tool down the length of the tool holder. Positive side rake angle will tilts the tool face toward floor while negative side rake angle tilts the face up and toward the workpiece.

3. Cutting edge angle

   This angle affects the cutting force, chip formation and tool strength during machining operation.

4. Relief angle

   Help to control interference and rubbing at tool and workpiece interface. If the angle is large, it is possible to the tip of the tool to chip off. If the angle is too small, flank wear may occur to the tool.

5. Nose radius

   Nose radius affect the strength tool tip and surface finish of the product. Smaller radius of nose, the tool tip may sharp and the surface finish happens to be rougher. Smaller nose radius may cause the tip to chip off due to lower strength of the tool. But, larger nose radii may cause tool to chatter.

Recommended tool geometry for turning process for various workpiece materials shown in Figure 2.2.

General Recommendations for Tool Angles in Turning

	High-speed steel					Carbide inserts				
Material	Back rake	Side rake	End relief	Side relief	Side and end cutting edge	Back rake	Side rake	End relief	Side relief	Side and end cutting edge
Aluminum and magnesium alloys	20	15	12	10	5	0	5	5	5	15
Copper alloys	5	10	8	8	5	0	5	5	5	15
Steels	10	12	5	5	15	-5	-5	5	5	15
Stainless steels	5	8-10	5	5	15	-5-0	-5-5	5	5	15
High-temperature alloys	0	10	5	5	15	5	0	5	5	45
Refractory alloys	0	20	5	5	5	0	0	5	5	15
Titanium alloys	0	5	5	5	15	-5	-5	5	5	5
Cast irons	5	10	5	5	15	-5	-5	5	5	15
Thermoplastics	0	0	20-30	15-20	10	0	0	20-30	15-20	10
Thermosets	0	0	20-30	15-20	10	0	15	5	5	15

Figure 2.2: General recommendations for tool angles in turning (Kalpakjian & Schmid, 2014)

2.1.2 Selection cutting tools

One of the important factors in machining technology is cutting tool. Based on previous study, the cutting tool is not being indicated due to lack of knowledge impact of selection type of cutting tool to the machining process. Today, tooling technologies are concern in order to optimize the production output and consistency of machined product activities are being realised (Kalpakjian & Schmid, 2014).

2.2 Ceramic Cutting Tool

Nowadays, machining technologies more concern about the application of ceramic cutting tool which has been widely used in cutting hard material. Unfortunately, ceramic cutting tool are limited due to their design and manufacturing constraints. Basically, ceramic cutting tool have unique physical and mechanical properties especially at high temperature where it has ultra-high hardness, high wear resistance, low chemical reactivity with steel and many other materials. Generally, ceramic cutting tools are suitable to machine super hard materials that are hard to be carried out with traditional tool materials. Besides, the optimum cutting speed of ceramic cutting tools is three to ten times bigger than ordinary cemented carbide tools with same dimensional shape. This advantage helps to improve the efficiency of the process dramatically (Wang & Liu, 2016).