UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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PHYSICAL PROPERTIES AND MICROSTRUCTURES OF ALUMINA-BASED CERAMICS

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

by

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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 (Process and Technology) with Honours. The member of the supervisory is as follow:

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ABSTRACT

The modern machining industries are widely used in manufacturing fields. The main focuses of the modern machining industries to increase the productivity are the capability of cutting tool to be used in the machining process. The cutting tools should provide a good surface finish, high production rate and minimum wear to produce the high quality of products. Therefore, this project presents the experimental investigation for physical properties and mictrostructure of alumina based ceramics. The cutting insert was fabricated via the solid state processing route in dry condition. The materials used in the experiment were Al_2O_3, Cr_2O_3 and YSZ. The value of bulk density, relative density, apparent porosity and percent of shrinkage were observed for variable parameters. The parameters used were 0.6 wt% PEG (1600°C), 0.6 wt% PEG (1700°C), 0.0 wt% PEG (1600°C) and 1.5 wt% PEG (1600°C) with different sintering profile. The values of bulk density of sample were 4.10734, 4.07937, 4.01494 and 3.27250 g/cm^3. These value were determined by using Archimedes principle. The length (a and b) and thickness of samples before and after sintered were measured in order to calculate the percent of shrinkage. Meanwhile, a scanning electron microscopy tester has been used to determine the microstructure of the sample. The pore area produced were observed for additional data and discussion of this study. From the analysis, the result showed that the sintered temperature and amount of PEG binder were influence the physical properties and microstructure. The results also showed that porosity occurred on the green body with different parameters. This study, will help to understand the physical properties and microstructure of alumina based ceramics in dry condition and identify the optimum parameters based on the characterization study.

ABSTRAK

Industri pemesinan moden digunakan secara meluas dalam bidang pembuatan. Fokus utama industri pemesinan moden untuk meningkatkan produktiviti adalah keupayaan alat pemotong yang akan digunakan dalam proses pemesinan. Alat pemotong seharusnya memberikan kemasan permukaan yang baik, kadar pengeluaran yang tinggi dan kehausan yang minima untuk menghasilkan produk yang berkualiti tinggi. Oleh itu, projek ini membentangkan eksperimen bagi mengkaji ciri-ciri fizikal dan mikrostruktur seramik berasaskan alumina. Alat pemotong telah dibentuk melalui laluan pemprosesan pepejal dalam keadaan kering. Bahan-bahan yang digunakan dalam eksperimen ini ialah Al_2O_3, Cr_2O_3 dan YSZ. Nilai ketumpatan pukal, ketumpatan relatif, keliangan ketara dan peratus pengecutan diperhatikan dengan parameter yang berlainan. Parameter yang digunakan adalah 0.6% berat PEG (1600°C), 0.6% berat PEG (1700°C), 0.0% berat PEG (1600°C) dan 1.5% berat PEG (1600°C) dengan profil pensinteran yang berbeza. Nilai-nilai ketumpatan pukal bagi setiap sampel adalah 4,10734, 4,07937, 4,01494 dan 3,27250 g/cm^3. Nilai ini telah ditentukan dengan menggunakan prinsip Archimedes. Panjang (a dan b) dan ketebalan sampel sebelum dan selepas tersinter telah diukur untuk mendapatkan peratus pengecutan. Sementara itu, imbasan mikroskop electron telah digunakan untuk menentukan mikrostruktur pada sampel. Kawasan liang yang dihasilkan diperhatikan sebagai perbincangan dan data tambahan untuk pembelajaran ini. Daripada analisis yang dibuat, keputusan kajian menunjukkan bahawa suhu tersinter dan jumlah pengikat PEG telah mempengaruhi sifat-sifat fizikal dan mikrostruktur. Keputusan juga menunjukkan bahawa keliangan berlaku pada badan hijau dengan parameter yang berbeza. Kajian ini akan membantu untuk memahami sifat-sifat fizikal dan mikrostruktur seramik berasaskan alumina dalam keadaan kering dan mengenal pasti parameter yang optima berdasarkan kajian gambaran sifat yang telah dilakukan

DEDICATIONS

This project is specially dedicated to my beloved family, project supervisor and all my friends for being my great pillars of support throughout my journey of education.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

Al_2O_3	-	Aluminum Oxide
C	-	Carbide
Cr	-	Chromium
Cr_2O_3	-	Chromium Oxide
DC	-	Direct Current
HSS	-	High Speed Steel
Mo	-	Molybedenum
MPa	-	Mega Pascal
Ni	-	Nickel
PEG	-	Polyethylene Glycol 400
Rpm	-	Revolutions per minute
SEM	-	Scanning Electron Microscopy
SiC	-	Silicon Carbide
Si_3N_4	-	Silicon Nitride
SPS	-	Spark Plasma Sintering
TaC	-	Tantalum Carbide
TiC	-	Titanium carbide
WC	-	Tungsten carbide
XRD	-	X-ray Diffraction
Y_2O_3	-	Yttrium Oxide
YSZ	-	Yttria Stabilized Zirconia
ZrO_2	-	Zirconium Oxide
ZTA	-	Zirconia-toughened-alumina
^0C	-	Degree Celsius
μm	-	Micrometre
g/cm^3	-	Gram per cubic centimeter

mm	-	Millimeter
mm/min	-	Millimeters per minute
wt%	-	Weight Percent

CHAPTER 1
INTRODUCTION

1.1 Project Background

Nowadays, modern machining industries are widely used in manufacturing fields. The main focuses of the modern machining industries to increase the productivity are the capability of cutting tool to be used in the machining process. The cutting tools must provide a good surface finish, high production rate and minimum wear to produce the high quality of products. Cutting tool is used to remove material from workpiece by shear deformation and able to endure at a high temperatures during cutting process. The tool materials that have been widely used as a cutting tool are high-carbon steels, ceramics and diamonds.

Ceramic cutting tool technology is rapidly advanced from time to time in a manufacturing field. The new ceramic composite cutting tools are developed by improving their physical and mechanical properties. However, ceramic cutting tools have some limitations in a machining process such as hardness and fracture toughness. Many types of ceramic composites have been introduced for many engineering applications by their rapid development (Kumar et al., 2003). The improvement in the microstructure of basic ceramic have leads to the growth of ceramic composite to be used in machining processes.

One of the most popular ceramics used to produce cutting inserts is alumina based materials due to chemical inertness and high abrasion resistance against workpiece and environment. Hence, it constantly utilized in the rough wear environment such as ball mill and coal chutes. However, the base material has low thermal shock resistance capability and low fracture toughness can contribute to the failures such as breakage and chipping during machining (Azhar et al., 2012).

Yttria stabilized zirconia (YSZ) is used as secondary materials to overcome the low fracture toughness. This project used chromia (Cr_2O_3) as an additive material to enhance the physical properties of alumina. Chromia (Cr_2O_3) is classified as the most potential additive which able to enhance physical properties of alumina (Azhar et al., 2012). Yttria stabilized zirconia (YSZ) acts as toughening agent to increase the toughness of alumina, reduced the sintering temperature and can customize the microstructure as well as improve the product properties.

Even though the study of Al_2O_3-Cr_2O_3 has been done in the previous years, the studies were carried out separately with the different approach. However, the development in a ceramic cutting tools by using alumina, chromia and yttria stabilized zirconia powder has been done before but not widely used by any researcher. In this study, the physical properties and microstructure of alumina-based were investigated and the influenced of sintering temperature on its microstructure and physical properties were discussed.

1.2 Problem Statement

The cutting tools are a major issue in today's metalworking industry in order to produce the high quality of products. This is because the cutting tool industry is not ready to meet the challenge of modern metal-cutting application. The lack of understanding of the application-specific tools and basics of tool geometry of standard can affect the integrity of the machined surface, tool life and machining efficiency. The major issue of this problem makes manufacturing engineers have to face the difficulties to increase the productivity. Besides, the demands of the product with a high quality product also increase day by day in many manufacturing industries.

The only oxide that successfully used in machining operations until the 1980s was aluminium oxide due to good properties and low solubility in steel at the high temperatures (Nicola et al., 2004). Hence, alumina tools can cut the steel at high speeds compared to conventional cemented carbides. In contrast, alumina has some limitations of low thermal shock resistance capability and low fracture toughness due to non-metallic bond. Therefore, the alumina cutting tools are brittle and lead to some failures or damaged to the workpiece.

In order to produce the hardened cutting tools and increase productivity by using alumina-based without coated, the other materials need to use are YSZ and Cr_2O_3. This is because these materials can increase the toughness and the physical properties of alumina. The used of yttria stabilized zirconia (YSZ) is to develop the fracture toughness of aluminum oxide while chromia as an addictive material to increase the physical properties of aluminum oxide (Azhar et al., 2011). The chemical composition of each material has been decided in order to balance the mixture.

1.3 Objectives

The objectives of this project are:

i. To prepare a new cutting tool material from alumina-based ceramics.
ii. To characterize the properties of alumina with variable parameters.

1.4 Project Scope

This work is mainly focused on a study of variable parameters in order to produce a strong cutting tool of alumina-based. In this project, the temperatures that used for samples are 1600 and 1700°C. The purpose of using different parameters is to enhance their densification. Several characterizations of the samples will be used are X-ray diffraction (XRD) and scanning electron microscopy (SEM). Besides, determination of the bulk density on alumina-based ceramics will be evaluated by using the Archimedes' method. In addition, the apparent porosity, relative density and percent of shrinkage will be calculated using the formula. The project flow can be simplified as in Figure 1.1.

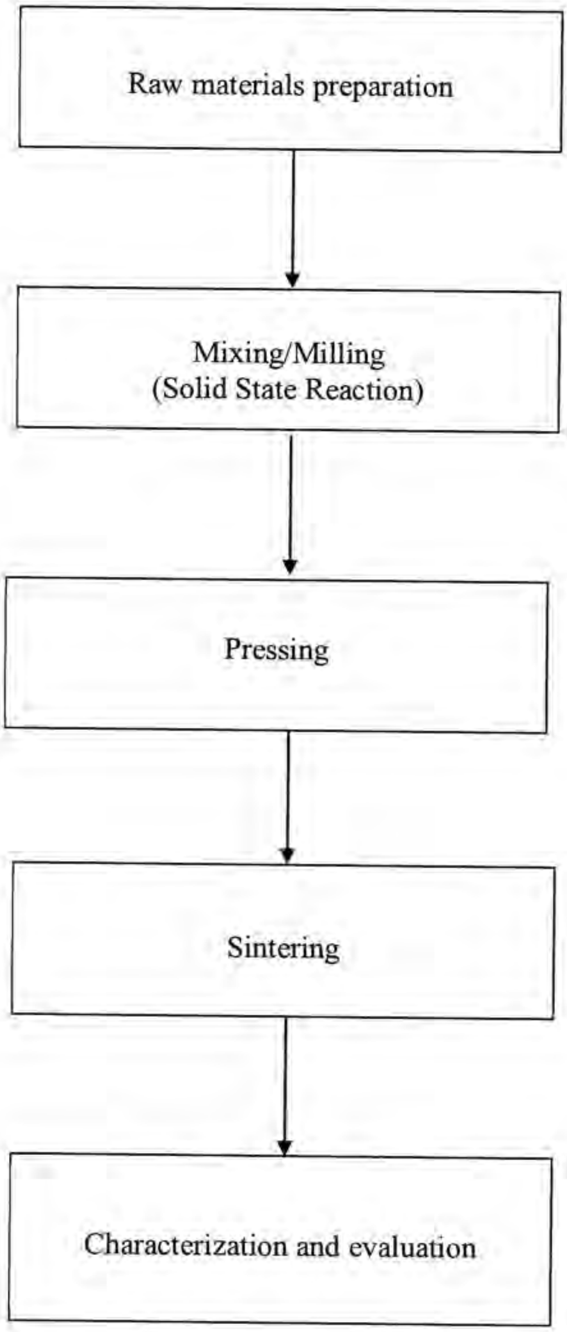

Figure 1.1: Overall of project flow to produce alumina-based ceramics

1.5 Significant of Project

This research is to study on the properties of a new cutting tool prepared from alumina-based. In order to produce the cutting tool with excellent performance, the physical properties of alumina-based will be mixed by adding chromia (Cr_2O_3) and yttria stabilized zirconia (YSZ). Previously, there is little work to develop these materials as a new ceramic cutting tool for lathe machine. Thus, it is believed that the outcome of this project will give a new contribution in the area of manufacturing industry in terms of a material aspect.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will provide some explanation regarding to the purpose of this research. The overview of this research and the previous research that has been done by researchers will be discussed in this chapter. This chapter will be identifying the relevance of the research and new approaches that related to the research. The details on this research will be discussed in the next chapter.

2.2 Turning Process

Turning is a method of machining by cutting in which the workpiece carried out the main rotary motion while the tool performs the linear motion. The process is used for external and internal turning of surfaces. The turning process has two basic motions, which are primary motion and auxiliary motion. Primary motion is the rotary motion of the workpiece around the turning axis while the auxiliary motion is a linear motion of a tool, also called the feed motion. Figure 2.1 shows the basic motions of the turning process.

Turning process can be classified into two classes according to the direction of tool feed, which are straight turning and taper turning. Straight turning occurs when the direction of the feed motion is parallel to the turning axis while taper turning occurs when the direction of the tool-feed motion intersects with the turning axis. In addition, traverse turning occurs when the direction of the tool feed motion is perpendicular to the turning axis. This can be divided into facing and radial turning. Single-tool and multipoint tools are distinguished depends on the number of tools cutting simultaneously. Multipoint turning can be performed with divided feed or divided depth of cut.

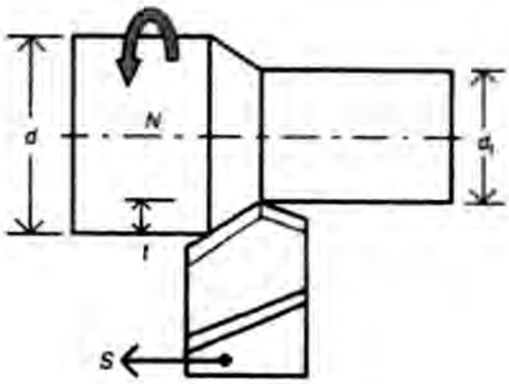

Figure 2.1: The basic motion of turning process (Hassan, 2007)

2.2.1 Tool Wear

Cutting process is the process involved the movement of cutting tool and the workpiece to produce fragments of material. Therefore, the tool edge is exposed to stress and high temperatures. Which applies pressure on the tool edge cause wear occurs. The effect of wear is affected by heat generation, the adhesion of the workpiece, the workpiece absorption and chemical reactions. Therefore, the cracking and chipping can occur on the edge of the machining tool due to excessive load (Mehrotra 1998). In addition, the tool wear can also be affected by the materials of the tool. Mechanical and chemical properties of tool and workpiece material can cause wear mechanism in the tool wear of a cutting tool (Jef Vleugels, 2006). Figure 2.2 shows the machining time versus tool flank wear to study the tool life of the different cutting tools.

2.3 Cutting Tool

The cutting tool is the vital element in machining processes which is removing extra material from workpiece and used for product finishing. The tool has divided into two classes of cutting tools, which is a single-point and multi-point tool. Single-point cutting tools are used for shaping or turning, and the multi-point tools used in milling or drilling process. In addition, cutting tools have their own characteristic based on type and parameter of machines to be used in cutting processes. Surface quality, accuracy and machining efficiency can be determined by the performance of cutting tool (Guangyong et al., 2016).

The material of manufacturing plays a major role in determined the performance of cutting tool. A quality of cutting tool should have important characteristics such as toughness, hardness and resistance to wear. In contrast, nowadays, the cutting tool faces difficulty in cutting operations due to their high wear and fewer life cycles. Therefore, the cutting tool should have good mechanical and physical properties such as high thermal stability, hardness and chemical inertness in order to reduce costs and increase the productivity. Figure 2.3 shows an example of cutting tool used in a machining process.

2.4 Materials For Cutting Tool

The materials of cutting tool are important element which is can affect the performance of the manufacturing process. An excellent cutting tool should be able to withstand of hardness and strength, high wear resistance and can produce a good surface finish. The weakness or limitation of the cutting tool will contribute negative effect to the rework cost and quality of product (Vagnorius et al., 2010). The figure 2.4 shows some uses of cutting tool material in manufacturing industries.