EFFECT OF SINTERING TEMPERATURE AND SOAKING TIME ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF ALUMINA-CHROMIA CUTTING TOOL

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

by

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DECLARATION

I hereby, declared this report entitled "Effect of Sintering Temperature and Soaking Time on Microstructure and Mechanical Properties of Alumina-Chromia Cutting Tool" is the result of my own research except as cited in references.

Signature : ……………………………………
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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 (Hons). The member of the supervisory committee is as follow:

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

(PM Ir. Dr. Mohd Hadzley bin Abu Bakar)

ABSTRAK

Dalam kajian ini, alat pemotong yang berasakan alumina telah difabrikasi dengan penambahan chromia (Cr_2O_3). Secara amnya, seramik berasaskan alumina memerlukan suhu persinteran yang tinggi untuk meningkatkan kekuatannya bagi memperoleh pemotongan dengan sifat mekanikal yang baik. Alat pemotong Alumina-Chromia telah difabrikasi menggunakanteknik preprocessing serbuk. Sarouk alumina dan chromia dicampur, dipadatkan dan disinter pada suhu sintering yang berbeza; 1500°C, 1600°C and 1700°C dengan masa merendam 4 jam, 5 jam dan 6 jam. Kajian ini tertumpu kepada penilaian suhu sintering yang sesuai dan masa merendam apabila alat pemotong Alumina-Chromia difabrikasi dinilai berdasarkan ketumpatan dan tribologi. Mikrostruktur dan kekerasan alat pemotong yang difabrikasi berdasarkan ketumpatan maksimum dan minimum disiasat. Hasil kajian ini adalah untuk membina model matematik menumpukan kepada hubungkait antara pembolehubah (suhu sintering dan masa rendaman) dan hasil produk (ketumpatan dan tribology) menggunakan reka bentuk factorial penuh. Analisi varians (ANOVA) digunakan untuk mengenal pasti factor ketara yang mempengaruhi ketumpatan dan tribology dengan menggunakan perisian Design Expert 6.0. Bagi ketumpatan dan tribology, analisis ANOVA menunjukkan pembolehubah yang paling mempengaruhi hasil ketumpatan adalan suhu sintering diikuti oleh masa rendaman. Nilai paling tinggi kekerasan dicatatkan pada 1700 ° C untuk 4 jam. Kondisi mikrostruktur halus yang telah dihasilkan pada 1700 ° C untuk 4 jam. Kajian ini memberi pemahaman yang lebih baik tentang bagaimana suhu sintering dan masa merendam mempengaruhi mikrostruktur dan sifat mekanikal alat pemotong untuk menghasilkan alat pemotong berprestasi tinggi.

ABSTRACT

In this study, alumina based cutting tool was fabricated with addition of chromia (Cr_2O_3). Generally, alumina-based ceramic requires high sintering temperature to improve its toughness obtained a cutting tool with good mechanical properties. The alumina-chromia cutting tool were fabricated using powder processing technique. The powder of alumina and chromia were mixed, compacted and sintered at different sintering temperature; 1500°C, 1600°C and 1700°C respectively, with soaking time of 4 hours, 5 hours and 6 hours. The study is focussed on evaluating the appropriate sintering temperature and soaking time when fabricated Alumina-Chromia cutting tool based on density and tribology. The microstructure and hardness of fabricated cutting tool based on maximum and minimum density were investigated. The intent of this research is to develop regression model focused on the relationship between parameter (sintering temperature and soaking time) and product outcome (density and tribology) using full factorial design. Analysis of variance (ANOVA) were employed to identify significant factors that influenced the density and tribology by using Design Expert 6.0 analysis software. The ANOVA analysis shows that for density and tribology, most influenced parameter was sintering temperature followed by soaking time. The highest hardness value recorded at 1700°C for 4 hours. A fine microstructure condition was produced at 1700°C for 4 hours. This study gives better understanding on how the sintering temperature and soaking time affect the microstructure and mechanical properties of cutting tool to produce high performance cutting tool.

DEDICATION

This project is specially dedicated to my beloved family for being my greatest inspiration, for endless support and way of insisting me to believe in myself and my dreams along my journey in completing my degree. This project is also dedicated for my supervisor and all my friends who have help me along in completing this dissertation.

ACKNOWLEDGEMENT

In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project successfully without difficulty.

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I would like to give a special thanks to my best friends who gave me much motivation and cooperation mentally in completing this report. They had given their critical suggestion and comments throughout my research. Thanks for the great friendship. My deepest gratitude and special thanks also went to my beloved, father and mother, Abdul Aziz bin Ahmad and Azniza binti Idris and also my sister and brothers for their unconditional love and support.

Finally, I would like to thank everybody who was important to this FYP report, as well as expressing my apology that I could not mention personally each one of you. One page only.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Al_2O_3	-	Aluminum Oxide
MgO	-	Magnesium oxide
BN	-	Boron nitrides
Si_3N_4	-	Chemical vapour deposition
TiB_2	-	Titanium Diboride
TiC	-	Titanium carbide
Ni	-	Nickel
Cr_2O_3	-	Chromium (III) Oxide
Al^{3+}	-	Aluminum ion
Cr^{3+}	-	Chromium ion
YSZ	-	Yittria Stabalized Zirconia
Li-ion	-	Lithium ion
SEM		Scanning Electron Microscopy
PEG		Polyethylene Glycol
DoE		Design of Experiment
ANOVA		Analysis of Variance
CIP		Cold Isostatic Process

LIST OF SYMBOLS

m	-	Metre
%	-	Percent
g/cm^3	-	Grams per centimetre cube
wt. %	-	Weight percentage
mm	-	Millimetre
MPa	-	Mega Pascal
GPa	-	Giga Pascal
Ksi	-	Kilopound per square inch
°C	-	Degree Celsius
kg.cm3	-	Kilogram centimetre cube
N	-	Newton
kg	-	Kilograms
mm/min.	-	Millimetre per minute
rpm	-	Revolution per minute
kN	-	Kilo newton
W_m	-	Matrix mass
Ff	-	Load at fracture
L	-	Distance between span
R	-	Specimen radius, mm
p_m	-	Matrix density
°C/min	-	Degree celsius per minute

CHAPTER 1
INTRODUCTION

This chapter discusses the background of the project, the development of Alumina cutting tool with addition of chromia will be further explained in this chapter. The background of study, problem statement, objectives, scope of research, research methodology, significance of the study and organization of the report are elaborated in order to have better visualization about the study of the project.

1.1 Background of Study

Cutting tools can be considered the needs of key industries as it is used in the production. Cutting tools installed on the remote machine and used to cut materials. Cutting tools must be makes by materials which harder than the materials to be cut and can withstand the heat generated from the cutting process in order for the job done more efficiently and economically. Thus, a cutting tool must have these characteristics:

- Hardness/Hot Hardness – hardness and strength of the cutting tool must be preserved at high temperature.
- Toughness – toughness of the tools is necessary so that the tool does not chip or fracture particularly during the operation.
- Wear Resistance – is the achievement of the acceptable tool life before the tool needs to be substitute.

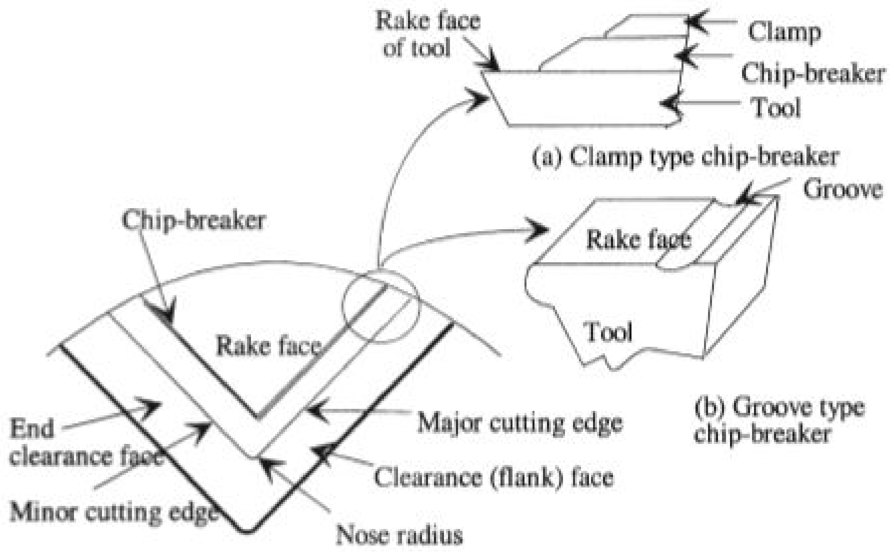


Figure 1.1: Cutting Tool Terminology

There are many types of cutting tool available in the market such as Carbon Tool Steel, Cubic Boron Nitride tool (CBN), High Speed Steel Tool (HSS), Cemented Carbide, Ceramics Tool and Diamond Tool. These cutting tools have different properties and made up of different materials. The cutting tools chosen depends on; what type of machining, material to be machined, quantity and quality of the production. In this study, we are using ceramic type of tool materials since Alumina and Chromia are being used.

The development of ceramic cutting tool happen rapidly in these years since it's had a lot of advantaged than other cutting tools in certain areas. The advantages such as highest melting point, high strength, high chemical stability, highest oxidation resistance, heat resistance, corrosion resistance, which increases the production efficiency and reduces the processing cost (Li et al. 2017). Thus, Ceramic cutting tools show higher heat and wear resistance over carbide and HSS. Ceramic is a class of material which can retain their hardness at high temperature and low reactivity with steel. It also has an excellent wear resistance at high cutting speed. However, there are limitation to use the ceramic materials in cutting area because ceramic have their own weakness such as lack of toughness and sensitivity to mechanical or thermal shock. Most of the ceramic cutting tool are able to machine at high speed during the operations where the used of feed rate and cutting depth is slightly light. So, special care is needed when machining is being programmed.

Alumina is the most known ceramic material uses in making cutting tool which have high hardness, high abrasion resistance and chemical inertness against the environment and the workpiece, (Azhar et al.) but low toughness and cause failures during the machining. Thus, alumina has a brittle material with poor thermal shock resistance. The mechanical properties of the alumina can be improved by strengthen it with a phase having good thermal stability, high strength and high elastic modulus. Alumina can be adding with Titanium, Magnesium, Chromia or Zirconia to make an improvement of the tool toughness. So, we use chromia as an additive substance in the cutting tool.

Chromia have crystal structure that consists of the hexagonal close packed array of oxygen anions with two-third of the octahedral interstitials are occupied by the cations, (Nath et al. 2016). It forms an isovalent solid solution when particles atom or ion substitutes particles atom or ion of the same charge in the parent structure which leads to high refractoriness and chemical stability. The addition of Chromia to Alumina improves the hardness, tensile strength and thermal shock resistance of the Alumina. Hence, the grain become larger and increase the fracture toughness of the Alumina. However, fracture strength reduces due to the addition of the Chromia.

Methodology involve in this project is experimental procedures. By observation through the whole experiment will be done, the tools must undergo severe test at certain condition to be analyze. Thus, the microstructure and mechanical properties of Alumina-Chromia toward sintering temperature and soaking time were investigated and the influence of the addition Chromia were discussed.

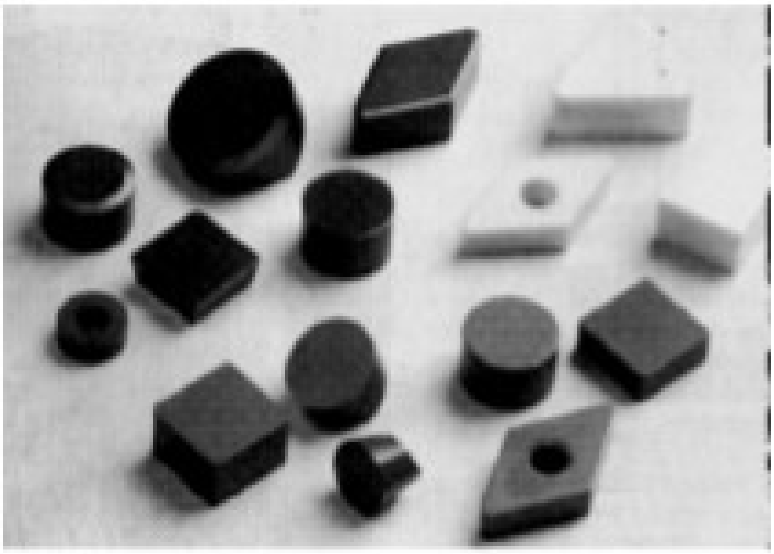


Figure 1.2: Ceramic Cutting Tool (Lacalle et al.)

1.2 Problem Statement

(Aslan et al. 2007) stated that development in cutting tool for few decades have made advantages for manufacturer to cut material in hardened state. The manufacturer can reduce machining cost, reduce lead times, reduce the number of machine tools, and produce better surface integrity as the material used in cutting tool is alumina-based ceramic. Alumina can cut hard and brittle materials with high cutting speed due to the correlation of alumina and aluminum. Alumina ceramic tools can be used for aluminum and aluminum alloys materials which causes severe wear when machining. Alumina based ceramic have high hot hardness, wear resistance and chemical inertness but it also has drawback such as low toughness and high brittleness which lead to failures during the machining. Cutting tool toughness can be improving with the addition of chromia into the alumina.

Development of cutting tools involves processes such as mixing, pressing and sintering with parameters such as sintering temperature, soaking time, pressing time, pressing pressure, grain size and powder composition. This parameter has an important impact on microstructure and mechanical properties of the green compact that have been produce after sintering process. These processes and parameters are important for ceramic to be good candidates for cutting tools and machine tools especially in high temperature and high-speed conditions. The addition of filler material such as Chromia could improve the structure of Alumina due to its abrasive properties. Thus, in this study, we are using design of experiment (DoE) software Expert 6 find suitable parameter and number of run and then evaluate the effect of sintering temperature and soaking time on microstructure and mechanical properties of Alumina-Chromia cutting tool such as hardness, density, and tribology.

1.3 Objectives

In this study, there are three main objectives that will be covered. They are:

1) To fabricate the cutting tool based on Alumina-Chromia.

2) To evaluate the appropriate sintering temperature and soaking time when fabricated alumina-chromia cutting tools based on density and tribology.

3) To investigate the microstructure and hardness of fabricated cutting tool based on maximum and minimum density.

1.4 Scopes of Research

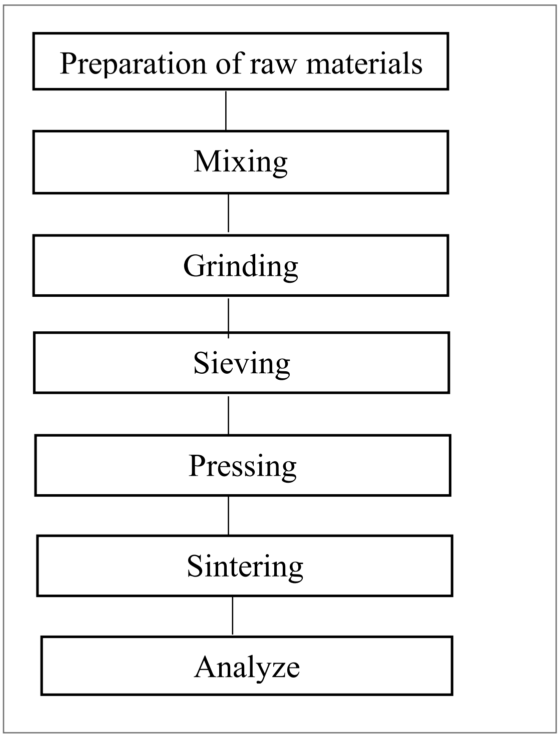
This study was carried out using powder metallurgy technique to fabricate alumina-chromia cutting tool. Specific amount of alumina will be mixed with chromia. The powder will be mixed properly in ball mill for certain period. Then, the mixed powder will be press inside the mold become compact powder. The process will be repeated to produce many inserts for with different sintering process. The sintering process will be implemented by varying the temperature and soaking time. In term of sintering process, these inserts will be placed inside furnace. For further machining performance, the finest properties of ceramic inserts are selected for evaluation. The evaluation criterion are density, hardness, microstructure and tribology. The effect of sintering temperature and soaking time will be analyzed and evaluate in detail.

1.5 Significant of study

This study will contribute to the improvement of cutting tool performance when machining at high cutting speed as it giving some potential benefits to the machining industry after the completion of this study. The studies goal is to fabricate the cutting tool based on the alumina-chromia, evaluate the appropriate sintering temperature and soaking time when fabricated alumina-chromia cutting tools based on density and tribology and investigate the microstructure and hardness based on maximum and minimum density.

1.6 Research Methodology

This study was conducted using powder metallurgy technique. The first step of this project is mixing the powders according to the specified amount to produce samples. Next processes that will be involved in completing this project is grinding, pressing, CIP, and lastly, sintering. After sintering, the samples will be tested for machining process. The aim of this project is to study the properties of alumina-chromia in terms of hardness, density, tribology and microstructure. Furthermore, the obtained data during the test will be correctly interpreted, analyzed and correlated. A conclusion will be made after analyzed all the data get.



Alumina (Al_2O_3)
Chromium (III) Oxide (Cr_2O_3)

Mix all raw materials

Ball milling machine

Sieving the powder mixture

Hydraulic hand pressing machine

The samples will sinter with varying sintering temperature

Density, hardness, microstructure and tribology

Figure 1.3: Flow chart of work

1.7 Organization of Thesis

This study is organized into three chapter, where;

- Chapter 1: Introduction

  This chapter discusses the background of the study and cutting tools background. Problems are identified through observation and research from the reading materials. This is followed by objectives to be achieved throughout the study and scope of the study.

- Chapter 2: Literature Review

  This chapter provides the basic theories from the previous study and research topic from the journal, articles, book and internet written by the professional researchers that can be related to this project. The method for evaluating study and proposing alternative are described.