DEVELOPMENT OF CERAMIC CUTTING TOOL INSERT OF ALUMINA (Al_2O_3) AND ZIRCONIA (ZrO_2) FOR TURNING HARDENED TOOL STEEL

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ABSTRAK

Proses penghasilan mata alat dengan kaedah teknologi serbuk adalah satu kaedah yang digunakan secara meluas pada masa kini terutama untuk mata alat yang diperbuat daripada bahan seramik. Teknologi serbuk yang digunakan melibatkan tiga kaedah utama dimana yang pertama bahan mentah akan dijadikan serbuk bersaiz nanometer, kemudian proses yang kedua, serbuk akan dipadatkan dengan menggunakan acuan dan tekanan tinggi dan yang ketiga serbuk yang telah dibentuk dengan proses pemadatan akan di bakar atau ‘sintered’ dengan suhu yang tinggi mengikut jenis bahan yang digunakan. Di dalam kajian ini, dua serbuk seramik bersaiz nanometer akan dicampurkan mengikut komposisi yang bersesuaian untuk menghasilkan produk akhir yang mempunyai ciri-ciri yang lebih baik. Konsep pembuatan ini adalah bersamaan dengan penghasilan bahan ‘Ceramic Matrix Composite’ dimana satu bahan penguat atau ‘reinforce’ dimasukkan kedalam bahan asas seramik atau ‘ceramic matrix’ untuk menguatkan atau memperbaiki sifat-sifat keseluruhan bahan tersebut. Untuk proses pembakaran pula terdapat beberapa proses yang boleh digunakan misalnya pembakaran dengan menggunakan ‘normal sintering furnace’ iaitu furnace biasa tanpa tekanan dan vacum, ‘hot isostatic furnace’ yang menggunakan tekanan semasa pembakaran dan ‘vacum sintering furnace’ yang menggunakan vacum semasa pembakaran. Produk akhir yang dihasilkan dengan kaedah ini akan mempunyai ketumpatan, kekuatan dan kekerasan yang tinggi, sesuai untuk penggunaannya sebagai mata alat pemotong.

ABSTRACT

The production of cutting tool insert using a powder technology is a process that is widely use today especially for ceramic cutting tool. The powder technology that has been use involve three phases which is, firstly the raw material will be grind to nanometer size powder. In second phase, the powder will be compacted using special mold with high pressure, and after that sintering process will take place for the third phase. In this study, two nanometer size ceramic powders will be mixed together with a suitable composition to produce a better final product. This production concept is similarly with the production of 'ceramic matrix composite' material which is the reinforce material will be added to the ceramic base material or ceramic matrix. There are several sintering process that can be use for this study, for example, normal sintering process, and hot isocratic process with high pressure furnace.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 General Background

The increasing demand for ceramic composites as cutting tools for machining steel based alloys in machining industries nowadays, is mainly due to the trend towards high speed machining, dry cutting and the need for tools with complex geometry. Because of these reasons, the ceramic material for examples alumina and zirconia which have well known as hard and brittle materials are being developed as cutting tools to penetrate the tooling market with new features, such as longer tool life, able to cut difficult to machine material such as hardened steel, nickel alloys etc.

Hot isostatic press (HIP) is one of the pressing technique that available in the manufacturing of ceramic inserts. HIP have a wide range of applications such, as a repair work for casting product or fabrication of metal matrix composite (mmc) and ceramic matrix composite (cmm), and HIP is also used as part of the sintering process.

Alumina is one of the major ceramic material in ceramic matrix composite (cmc) field. It is also popular because of it's excellent thermal and electrical insulator behavior. Annual world production of alumina is approximately 65 million tones, over 90% from it is used to produce aluminium metal. Other major use of alumina is in refractory (furnace wall), polishing/abrasive (grinding wheel), cutting tool inserts, water filter and mixer (ball mill jar and ball) applications.

Zirconia sometimes known as zirconium dioxide is one of the most popular ceramic material that has been explored. Zirconia is very useful because of its

stable condition. It is mostly use as refractory material, in insulation, abrasive, enamels, ceramic glaze and thermal barrier coating in jet turbine and diesel engines.

The composite that will be produced by mixing this two ceramic material (alumina and zirconia) is known as zirconia toughen alumina (ZTA). In cutting tool industry, ZTA cutting insert has been introduced but the secret formulation to produce this product from the manufacturers make, it's quite intresting to be investigated.

This project is undertaken with the aims to evaluate the effect of HIP and vacuum sintering process on the physical behaviour of composite ceramic part of alumina and zirconia with respect to shrinkage, hardness, density, surface roughness and machinability.

1.2 Problem Statement

Developing ceramic insert through powder technology involves basic processes such as mixing, compaction and sintering with various parameters such as powder composition, pressing pressure, pressing time, sintering temperature and grain size of the ceramic powders. These parameters significantly affect the mechanical and physical properties of the 'green' or 'as-pressed' compact before and after sintering process such as density, hardness, strengthness and dimensional accuracy. This processes and parameters are usually kept as company secret by most cutting insert manufacturers.

In this study, the effect of the zirconia contents in alumina matrix composite (commercially known as zirconia toughened alumina (ZTA)), and sintering process, parameters on shrinkage, hardness, surface roughness, densification behaviour and machining performance of the cutting insert were examined. Eventually the results obtained will be used to design and produce an acceptable mold and to determine the suitable content of zirconia in alumina based cmc.

1.3 Objectives

Three specific objectives have been defined for this study. they are:

1. To develop ceramic inserts of alumina with zirconia using HIP and vacuum sintering processes.
2. To evaluate the effect of zirconia content on the various responses such as densification, surface roughness, shrinkage and machining performance.
3. To carried a comparative study between HIP and conventional sintering process.

1.4 Scope of the Project

The scopes of the project are as follows:

1. Ball milling, manual compaction, hot isostatic press (HIP) process and vacuum sintering process were employed in fabricating the ceramic insert.
2. The material used for the compaction and sintering process were aluminium oxide (Al_2O_3) and zirconia / zirconium oxide (ZrO_2).
3. Independ variables were zirconia content and sintering process .
4. Output responses included shrinkage, hardness, density, surface roughness and tool life performance.

1.5 Expected Results

The following results are expected from this study :

1. The relationship between the process parameters and the responses of alumina-zirconia composite powder will be established.

2. The acceptable process parameters for producing the appropriate responses of alumina-zirconia composite powder will be determined.
3. The predicted results and repeatable shrinkage upon sintering will be used for designing the insert mold, to achieve a near net shape product.