PHYSICAL BEHAVIOUR OF POWDER CERAMIC PART USING COLD ISOSTATIC PRESSING (CIP) PROCESSES

SARIZAL BIN MD. ANI

A project report submitted in partial fulfilment of the requirement for the award of the degree of Master of Engineering (Mechanical-Advanced Manufacturing Technology)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

NOVEMBER, 2006

Kepada isteri saya yang disayangi: Wan Noor Azna Binti Abdul Rahim

Anak saya: Siti Syazwani

Kedua ibubapa saya: Md. Ani Bin Ahmad dan Zaiton Binti Ahmad

Kawan-kawan saya

TERIMA KASIH atas segala jasa dan sokongan yang telah diberikan

ACKNOWLEDGENT

I would like to express my sincere appreciation to my supervisor Assoc. Prof. Dr. Safian Sharif for his guidance, encouragement and patience throughout this master project. I also would like to thank to UTM lecturer, Japan-Malaysia Technical Institute staff and who have contributed to the success of this project.

ABSTRAK

Proses Penekanan Sestatik Sejuk (CIP) digunakan secara meluas bagi tujuan pra-pembentukan serbuk sebelum penumpatan selanjutnya melalui proses pensinteran. Penekanan sestatik boleh menghasilkan tekanan yang tinggi secara seragam melalui semua arah komponen produk di mana kepadatan adalah konsisten bagi seluruh keratan dan ketepatan yang tinggi berbanding dengan penekanan searah. Hal yang demikian akan menghasilkan penumpatan yang lebih seragam dan pemadatan yang sangat baik. Melalui kajian ini kesan parameter CIP terhadap kelakuan pengecutan, kekerasan dan ketumpatan bagi serbuk alumina akan dapat diketahui. Kesan suhu pensinteran terhadap kebulatan, kesilinderan dan kekasaran permukaan bagi bahagian seramik juga akan dapat diperolehi. Melalui kajian ini juga hubungan di antara parameter proses dan tindakbalas proses bagi bahan alumina akan dapat ditentukan di mana keputusan yang diperolehi boleh digunakan bagi menghasilkan produk yang hampir kepada bentuk pembuatannya.

ABSTRACT

Cold Isostatic Press (CIP) is mainly used for pre-forming of powder parts prior to a further densification by sintering. Isostatic pressing can apply very high pressure uniformly in all directions producing parts, which are consistent in density throughout their cross sections and highly accurate as compared to those produced uniaxially. This results in more uniform density and greater compaction. In this study the effect of CIP parameters on the shrinkage, hardness and densification behaviour of the alumina oxide powder are examined. The effect of sintering temperature on the roundness, cylindricity and surface roughness of the ceramic parts are also investigated. As a result of this study the relationship between the process parameters and the responses of alumina powder were established and can be used to produce product with the near net shape manufacturing.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 General Background

Isostatic presses are used for many applications ranging from casting repair to ceramic ball bearings. The process can be cold, warm or hot to accomplish the desired task. Cold Isostatic Press (CIP) are used mainly for pre-forming of powder prior to further densification by sintering. CIP come in two types; wet bag and dry bag.

In a wet bag CIP the pressure container is full of water and the rubber bag (mold) is removed after each cycle and refilled. This type of press is common when large, complex or many different parts are required. The main benefit of isostatic pressing is uniform density, which results in predictable and repeatable shrinkage upon sintering [1].

For small parts a uniaxial die press can produce acceptable parts, but for long tubes or large complex parts, the die friction causes non-uniformity [1]. This is where isostatic presses comes is selected. Most cold pressing is done with some form of binder to hold the part shape. This binder is eventually burnt out of the part in a furnace or during the sintering process.

This project is undertaken with the aims in understanding the effect of CIP and sintering process on the physical behaviour of powder ceramic part with respect to shrinkage, hardness, density, roundness, cylindricity and surface roughness.

1.2 Problem Statement

Cold Isostatic Press (CIP) process involved various parameters such as pressing pressure, pressing time 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. In this study, the effect of the CIP parameters on shrinkage, hardness, roundness, cylindricity, surface roughness and densification behaviour of the ceramic powder will be examined. Eventually the results obtained will be used to design and produce a more accurate mold in complying with the near net shape manufacturing.

1.2.1 Mechanical Properties

Compared to metals, ceramics have the following relative characteristics: brittleness; high strength and hardness at elevated temperatures; high elastic modulus; and low toughness, density, thermal expansion, and thermal and electrical conductivity [2]. However, because of the wide variety of ceramics material composition and grain sizes, the mechanical and physical properties of ceramics vary significantly.

Because of their sensitivity to flaws, defects, and surface or internal cracks, the presence of different types and level of impurities, and different methods of manufacturing, ceramics can have a wide range of properties [3]. For Cold Isostatic Press (CIP) processes, mechanical properties of ceramic depend on the pressing pressure and pressing time process parameters. The relationship between these process parameters will be studied to determine the hardness and density of alumina powder after compaction and sintering processes.

1.2.2 Geometrical Dimensioning Tolerance (GDT)

The sintering process causes merging of the particles by diffusion. This mechanism causes the powder particles to move a little closer and therefore some amount of shrinking occurs in the size of the green compact. If the shrinkage is non-uniform or if some dimensions are critical, then the sintered part must be subjected to finishing operations to maintain its specification [4].

The main benefit of CIP process is uniform density, which results in predictable and repeatable shrinkage upon sintering. The fluid pressure acts uniformly in all direction, therefore no die to control shape but must understand shrinkage relationships [4]. By CIP processes geometrical dimensioning tolerance, surface roughness and shrinkage of ceramic maybe depend on pressing pressure and pressing time or sintering temperature process parameters. The relationship between these process parameters will be studied to determine roundness, cylindricity and shrinkage of alumina powder after sintering.

1.3 Objective

Two specific objectives have been defined to simplify the main objective of the project. There are:

1. To study the effect of CIP parameters on the shrinkage, hardness and densification behaviour of the green compact of alumina.
2. To investigate the effect of sintering temperature on the roundness, cylindricity and surface roughness of the ceramic part.

1.4 Scope of the Project

The scopes of the project are as follows:

1. Cold Isostatic Press (CIP) process and sintering process will be employed in producing the ceramic part.
2. The material used for the compaction and sintering process is Aluminium Oxide (Al_2O_3).
3. Input parameters to be used included are pressing pressure, pressing time and sintering temperature.
4. Output responses to be investigated include shrinkage, hardness, density, roundness, cylindricity and surface roughness.

1.5 Expected Results

This project attempts to evaluate the effect of the pressing pressure and pressing time of Cold Isostatic Press (CIP) process and sintering temperature in order to obtain good physical behaviours (hardness and density) and dimensional accuracy of the ceramic part. Based on the literature review and suppliers recommendations, the following results are expected:

1. The relationship between the process parameters and the responses of alumina powder will be established.
2. The acceptable process parameters for producing the appropriate responses of alumina powder will be determined.
3. The predicted results and repeatable shrinkage upon sintering will be used for designing the rubber mold, to achieve a near net shape product.
4. The result of physical behaviours (hardness and density) will be used for determine the suitable function and application.
5. An accuracy within ± 0.7mm is expected through the GDT analysis.