CHAPTER I

Introduction

1.1 Background

Ceramics have attracted wide interest as advance materials for high temperature applications due to their advantages such as high modulus, high hardness, high melting temperature, and high corrosion resistance. Of a broad range of ceramics, titanium carbide and aluminide have developed into one of the most interesting ceramics since they have high strength and good wear resistance at elevated temperature. Producing $TiC\text{-}Al_2O_3$ from low cost material (TiO_2) is less expensive than that of their elemental powders. The combustion synthesis (CS) process offers significant advantages to fabricate ceramic materials since it produces high exothermic reaction and a short processing time. The objective of this study is to investigate the combustion synthesis of $TiC\text{-}Al_2O_3$, the effect of reactant compositions on the combustion process, microstructure and mechanical properties of synthesized products. The combustion synthesis is carried out in a combustion chamber in an atmosphere of inert gas. The ignition technique to initiate the CS is studied. The microstructure and mechanical properties of synthesized products are observed. The result of this research will benefit for producing a high performance ceramic material obtained from low cost material with efficient process.

There has been a lot of interest in ceramic materials such as TiC, TiB_2, WC, SiC, and Al_2O_3 as hard protective coatings in a wide range of industrial applications since they have high hardness and high wear resistance (1)

(2)(3)(4). Of these materials, titanium carbide has developed into the most interesting ceramic for high temperature application due to its high modulus, high hardness, high melting temperature, and high corrosion resistance (3). However, the application of single phase ceramic in high temperature is limited due to its poor fracture toughness. Therefore, the TiC particle has been widely investigated as a candidate for use in the reinforcing phase for various composite materials such as metallic matrix composite(5), intermetallic matrix composite (6), and ceramic matrix composite(6). Some studies have observed the reinforcement of TiC in the NiAl/TiC composite system (6)(7)(8). Such composites have showed high wear resistance due to the high hardness of TiC. The studies have also shown that the combination of high hardness and the excellent stability of TiC at high temperature, together with the strong atomic bonds of the nickel aluminides, has produced composites that have excellent wear resistant at room and high temperatures (9).

Alumina ceramic systems such as TiC–Al_2O_3 have also been widely found in high temperature applications since they have high hardness and low density. It was also reported that the binary ceramic composites of TiC–Al_2O_3 could improve the fracture toughness of the individual ceramic materials, either TiC or Al_2O_3. Further investigations have showed that ternary ceramic composites exhibited higher fracture toughness than those of binary ceramic composites. The addition of 10 % ZrO_2 into Al_2O_3–TiC prepared from TiO_2, Al, and C using combustion synthesis and followed by hot pressing was able to increase the fracture toughness of Al_2O_3–TiC–10 wt.% ZrO_2 by approximately 20% more than that of Al_2O_3–TiC composite (10).

There are many processing techniques to produce ceramic. Generally, ceramic matrix composite is prepared from elemental powder using mechanical densification. Several studies were carried out to produce ceramic using pressureless sintering, hot pressing, and hot isostatic pressing (11). However, due to their high degree of covalent bonding and low self diffusion, densification is difficult. In addition, the high melting temperature of ceramics requires a long exposure at high temperature for the sintering process to achieve full density. High temperatures in the processing route of ceramic also influence the microstructure of the product, such as grain growth (3).

High energy ball milling has been investigated to be powerful method to induce the synthesis of a TiC system producing nanocrystalline product. Fabrication of Al_2O_3–TiC nanocomposites using mechanical ball milling was reported by E. Mohammad Sharifi ref to (11). The effect of milling time and heat treatment was observed. The result showed that the reactant powder composed by $Al/TiO_2/C$ had experienced a SHS process after 40 hours of milling and the crystal of synthesized Al_2O_3–TiC was less than 10 nm. Annealing at 900 °C has kept the size of product. However, the crystallite size of the product was bigger after increasing the annealing temperature to 1200 °C.

Combustion synthesis has offered an alternative to produce ceramic via a short and simple process (12). However, the product synthesized by the SHS process is usually porous (13). The additional application of pressure is sometimes required during the synthesis process in order to improve the density of product (10). The addition of liquid metal as diluents was also studied to increase the density of product by reducing the combustion temperature. Different techniques to produce high density product of ceramic using a relatively low temperature were carried out by spark plasma sintering (SPS) (14). The sintering process in the SPS technique is very short due to the heating process which is accomplished through spark discharge generated by instantaneous pulsed direct current. Other techniques to improve the density of ceramic have also been carried out by combining the SHS process with pressure obtained from the dynamic compaction using high explosive detonation (3).

Combustion synthesis is a process of which transforms reactants into products in a highly exothermic reaction. The combustion process is initiated by heating the front part of the sample to its ignition temperature using an external heat source. After the reaction is ignited, the heat produced by combustion reaction then propagates and heats up the adjacent layer to the ignition temperature so that the combustion waves can self propagate through the whole sample. Another type of combustion synthesis is known as thermal explosion or simultaneous combustion in which the combustion of the whole part of the compact occurs simultaneously once the ignition point is achieved (15)(12).

Over the past four decades the SHS process has become very attractive since it offers several significant advantages. The combustion reaction is highly exothermic ensuring the combustion process proceeds to completion. The high temperature of combustion synthesis can reach a temperature above the low boiling point of some impurities in the element. The combustion reaction can therefore boil off the impurities to produce a better purity of product. The combustion rate is also very rapid resulting in better homogenization of the product. This is due to the fact that the heating rate affects the completeness of the reaction. When using the same ignition energy, the reaction front in a rapid heating propagates faster such as occurs in high density pellet. The rapid heating hence reduces the heat loss and results in the completeness of reaction to obtain homogeneous microstructure. Since the reaction occurs in a short time, the operation becomes more effective. From a technological point of view, a short combustion process would produce high productivity, and therefore less power consumption (15). Another benefit is that SHS process is self sustaining. After the heat due to ignition is imparted, the combustion reaction will self-propagate by itself. The heat from the combustion of the front layer will produce an ignition heat to other layers. The additional heat source required by other types of process to maintain the combustion process can therefore be eliminated thus making the process very efficient. Given these significant advantages, the SHS process has been considered as an alternative to conventional furnace technology which requires complex process preparation and expensive equipment (12).

1.2 Problem Statement

The problem how is to produce an aluminium alloy material using combustion synthesis proces and understand the effect of different reactant compositions on the product.

1.3 Objective of Study

The objectives of this final project research are as follows:

1. To produce an aluminium alloy material by combustion synthesis process.
2. To observe the composition of synthesized product.
3. To evaluate the mechanical properties of the synthesized product.

1.4 Problem limitations

The problem limitations on this research are:

1. The material that used on this research are TiO_2, C, and Al.
2. Process heating is done by Arc flame and Argon.
3. Material characterization testing is done by SEM and XRD machine.
4. Mechanical property testing is also done by Micro Hardness test.

1.5 Expected Results

At the end of this research we supposed to understand more about combustion synthesis process to produce new alloy material, the effect of reactant composition, the formed phase of the synthesized products and the hardness of products.

1.6 Outline of the Report

Chapter I Introduction

This chapter contains backgrounds that tell about the idea of the research, problem statement, objective of the study, problem limitation, results, and systematic writing.

Chapter II Literature reviews

This chapter is talking about the basic theory of the research that writer taken such as combustion synthesis, ceramic, and ignition technique.

Chapter III Research methodology

This chapter contains the steps of the research from preparation of the tools until burning the specimens.

Chapter IV Results and discussion

This chapter contains the results from the test SEM, XRD, and Micro hardness.

Chapter V Conclusion and suggestion

This chapter contains the conclusion of the experiment and the suggestion for the further work.