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DEVELOPMENT OF POROUS TI-6AL-4V MIX WITH PALM STEARIN BINDER BY METAL INJECTION MOULDING TECHNIQUE

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

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ABSTRACT

Metal Injection Moulding (MIM) is a promising approach to produce a near net-shape product of intricate geometry with cost-effective production. To date, numerous studies have been done on implementing MIM to manufacture products for biomedical applications by employing Titanium and its alloy as a main subject. Titanium and its alloys are renowned materials with their biocompatibility, good mechanical properties and high corrosion resistance. This study was aimed to fabricate porous Ti-6Al-4V structure through MIM technique using palm stearin (PS) binder system. Titanium alloy powder (Ti-6Al-4V) was used to mix with sodium chloride (NaCl) as a space holder and binder components that consists of palm stearin (PS) as a primary binder and polyethylene (PE) as a backbone binder. Four different powder loadings were prepared in this study; 63, 64, 65 and 66 vol.% based on critical powder volume percentage (CPVP) experiment. The homogeneity and flowability of the feedstock were evaluated via torque rheometry data, scanning electron microscopy (SEM) observation and rheological characterization. Then, all feedstocks were injected in a cylindrical bar and tensile bar mould except 66 vol.% feedstock due to unstable rheological behaviour. All moulded specimens were then immersed in heptane and distilled water to remove PS and NaCl respectively. Thermal debinding process took place to remove PE in a high vacuum furnace before it was immediately sintered in the same atmosphere. Temperature of thermal debinding and sintering was set to 510°C and 1200°C where heating rate of thermal debinding and sintering was set to 0.5°C/min and 10°C/min respectively with 1 hour of soaking time. All tensile bar specimens were successfully sintered. However, sintering of cylindrical bar mould specimens was unsuccessful due to inappropriate sample geometry and inhomogeneity of moulded specimens. The characterization of physical properties, mechanical properties and microstructure of the as-sintered parts was performed The average porosity percentage for 63, 64 and 65 vol.% was 43.18, 37.02 and 35.15% and most of the pores were interconnected each other. As expected, high powder loading specimens (65 vol.%) has higher viscosity, strength, density and hardness compared to low powder loading specimens (64 vol.% and 63 vol.%). The elastic modulus of compressive strength and tensile strength for 65 vol.% specimens was 3.362 ± 2.62 GPa and 9.35 ± 2.62 GPa respectively. The ($\alpha+\beta$) phase was observed under optical microscope for all sintered specimens has verified that the as-sintered specimens have similar phase with Ti-6Al-4V phase. Overall, porous Ti-6Al-4V structure was successfully fabricated via MIM technique using PS as the binder system and NaCl as the space holder.

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CHAPTER ONE
INTRODUCTION

1.1 INTRODUCTION

Powder Metallurgy (PM) is a proven of advanced and sophisticated technology for producing net shape metal components in every imaginable design. It can manufacture a product in any configuration of sizes, ranging from tiny to huge. PM offers component designers and product manufacturers a lot of advantages when compared to other metal forming processes. It makes possible complex or unique shapes that would otherwise be impractical or even impossible. It also reduces machining as well as scrap.

One of the recent metal-processing technologies of PM techniques is Metal Injection Moulding (MIM). MIM can produce highly intricate shapes and relatively small parts in large quantities with a cost-effective production (Figure 1.1). Since the technology has been introduced in the 1980s, MIM has expanded to various fields on industrial manufacturing which produces automotive parts, hardware and computer, firearms and electrical applications (German, 2013). In the early 90s, a great number of research and development has been performed in MIM which focused more on biomedical applications especially for orthopaedic and orthodontic applications.

There are four main processing steps in MIM which are mixing; injection moulding; debinding; and sintering (German & Bose, 1997). Metal injection moulding (MIM) starts by mixing selected metal powder at certain size (μm) and binders at appropriate composition to synthesize a mixture called a feedstock. This step is a vital process in MIM. The binders provide lubrication during the injection by uniformly coating the metal powder and filling all gaps between the powder particles (Banerjee & Joens, 2012). Recently, Palm Stearin (PS) binder has been used by MIM research community in Malaysia as an alternative for multi-components conventional binder system (Mohamad Nor et al., 2013; Omar et al., 2011; Subuki, 2010). PS binder contained fatty acid like most general commercial binder is a simple binder system introduced by Iriany et al. (2001). Normally, PS binder is paired with Polyethylene (PE) binder to be mixed with metal powder.