CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Advanced technology such as aerospace, chemical, nuclear, medical and even weaponry sectors has high dependency towards great quality of alloys in ensuring its reliability and durability in hostile environment and extreme operational conditions. Hasty development in the industrial sectors and advancement in the technology application demanded for materials that are lighter, stronger, stiffer, and useful at higher temperatures. Reducing structural weight is one of the major ways to reduce carbon emissions and improve aircraft performance. Lighter and stronger materials allow greater range and speed, and may also contribute to reducing operational costs. Tri-aluminide, especially titanium aluminide base alloys, are regarded as one of the most promising candidates for high temperature structural materials in the 21st century. This is due to their low density combined with good mechanical properties and corrosion resistance at medium high temperature range. Titanium aluminide is a group of intermetallics created by alloying of titanium and aluminum along with minor addition ternary elements. The combination of their low density (3.7 - 4.1g/cm^3), high specific strength and relatively good properties at an elevated temperature, good creep characteristics at temperatures up to 900 °C (Xiao et al., 2009) and, excellent oxidation and corrosion resistance makes them very attractive as high-temperature structural materials for aerospace, automotive and other applications (Lagos and Agote, 2013).

Titanium aluminide base alloys have been prototyped and tested for use in aircraft turbines engine, automotive and hypersonic airplanes. In particular, titanium aluminide base alloys offer a great reduction in weight and acceptable mechanical performance characteristics compared to nickel base super-alloys, which can help attain weight-savings and cost reduction goals. Hence, replacement of nickel base super-alloys parts and component with titanium aluminide base alloys in high performance aircraft's gas turbine engines is expected to reduce the structural weight by 20–30% and will produce leaner and efficient structural systems (Voice et al., 2005) which also contribute to fuel savings and the reduction of CO_2 emissions. In automotive industries, the high stability of titanium aluminide exhaust valve in hot environment has resulted in a significant improvement in engine performance from the reduced inertia and friction loss in normal engines (Froes and Suryanarayana, 1996). Eventually, this will increase the fuel efficiency and contribute in reduction of the pollutant emissions, along with noise reduction during operation.

Nevertheless, the attractive properties of titanium aluminide-based alloys were outweighed by poor ductility at ambient temperature below 700^{o}C, low strength at elevated temperature, and insufficient oxidation resistance above 850^{o}C (Al-Dabbagh et al., 2013). The low ductility of titanium aluminide further caused difficulties in processing and machining at room temperature, and resulted in high manufacturing cost. In order to overcome this problem, many efforts have been devoted to fabricate nano-structured titanium aluminide alloys, which have an additional advantage of giving rise to a good combination of strength and ductility (Farhang et al., 2010). The initial processing route for fabrication of titanium aluminide base alloys components was investment casting and wrought processing of ingot metallurgy materials. This method have received the most attention because of their potential for low cost and high volume production. However, Clemens and Kestler (2000) reported that this processing route can lead to fluctuations in the Al content of more than ± 2 at.%, leading to a non-uniform microstructure. These microstructures have a significant variation in the mechanical properties leading to the deterioration of the properties of the alloys. On the other hand, powder metallurgy (PM) technologies offers for more precise control of composition and microstructure, as well as reducing the fabrication costs of producing complex, near net shape components (Moll and McTiernan, 2000).

An innovative development of PM method has enable a viable commercial practice for cost effective materials to be produce with controlled, uniformly refined structures and optimum mechanical properties (Zhao et al., 1997). Amongst the wide options of PM method, the MA technique has been considered the most powerful tool for the fabrication of nano-structured materials because of its simplicity and relatively inexpensive equipment (Koch, 1993). MA has attracted the attention of a large numbers of researchers because of it ability for the production of fine dispersion of second phase (usually oxide) particles, extension of solid solubility limits, refinement of grain sizes down to nano meter range, synthesis of novel crystalline and quasi-crystalline phases, development of amorphous (glassy) phases and disordering of ordered intermetallics (Cahn et al., 1991). Courtney and Maurice (1989), praised MA technique as the “Aladdin’s lamp of powder metallurgy” because of the capability of this technique to produce alloys and compounds that are difficult or impossible to be obtained by conventional melting and casting techniques. In addition, this method has opened the possibility for producing materials with unique physical and mechanical properties at room temperature, which can be scaled up in large quantities up to several tons (Koch, 1997).

1.2 PROBLEM STATEMENT

The properties of titanium aluminide alloys are depend on their phases and strongly influenced by their microstructures, which is controlled by processing methods and composition modifications. Mechanical alloying (MA) is one of the techniques in PM route which employs a reputation that offers not only a refinement of crystallite size to nano-structure, but also for obtaining materials of high structural homogeneity (Farhang et al., 2010). Unlike ingot metallurgy and investment cast, materials produced from MA have a fine and homogeneous starting microstructure which can be an important advantage to achieve desired microstructure. However, the properties of specific materials obtained by MA are very sensitive to experimental conditions such as; milling type, rotation speed, type and amount of process control agents (PCA) and atmosphere (Suryanarayana, 2001). Recent publication by El-Eskandarany (2013) imply that the selection of these parameters, are vital in obtaining alloys in nano range crystallite size with specific phase and desired properties. Even then, all these process variables are not completely independent.