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AN OVERVIEW ON MECHANICAL PROPERTIES OF PARTICULATE REINFORCED TI6AL4V METAL MATRIX COMPOSITES

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ABSTRACT

The main objective of this paper is to study the composite of titanium alloy (Ti6Al4V) processing methods and influence of the reinforcement particle addition in the matrix phase. The Ti6Al4V alloy is used in the aerospace and automotive components for the critical applications. The new developments are required to create new materials to overcome the day-to-day problems. The metal matrix composite is the best alternative to improve the performance of the conventional materials. The researchers have to work and find the materials for the betterment of the challenges. In this paper, the previous researchers' results have been discussed in the aspect of reinforcement particle sizes, manufacturing methods and its influence in microstructure, properties of composites and the environment for processing of composites. The most of the researchers' have used powder metallurgy technique to reduce the fabrication cost and hot isostatic pressing (HIP), cold isostatic pressing, hot pressing, hot extrusion and spark plasma sintering was used to achieve a higher relative density of the composites.

Keywords: titanium alloy, particle size, sintering, metal matrix composite, hot extrusion, microstructure, powder metallurgy.

1. INTRODUCTION

The modern industrial components require superior mechanical and physical properties to meet out the challenges against the development of new technologies in the area of aerospace and automotive industries. The researchers have been working to overcome such a challenge by replacing the traditional metals and alloys through composite materials.

Titanium alloys are attracted due to high strength, low weight ratio and outstanding corrosion resistance by the manufacturer of aerospace, automotive, medical instruments, oil industry, power generation equipment's and chemical plant components [1-3]. But the titanium alloys have poor abrasion resistance and low hardness. Due to these properties, Titanium alloys are limited to their usage in some industrial applications [4-5]. The titanium alloy (Ti6Al4V) chemical composition influences the major role to build a microstructure in the material properties. The formation of microstructure is a vital parameter to obtain the desired properties for the specific application [6]. The metals and alloys which are reinforced with hard ceramic particles to enhance the properties of matrix (metals or alloys) material is called metal matrix composites (MMCs). These type of composite have acknowledged great attention due to superior strength, stiffness and better wear resistance [7].

The major drawback for using titanium and its alloys in engineering application is limited due to the high cost of the final product as compared with the product made by other materials. The cost of the titanium and its alloys are mostly related to complicated processes and fabrication techniques due to the poor machinability, high reactivity in atmospheric conditions and low thermal conductivity. Froes et al [8] have discussed the techniques to reduce production cost of the titanium and alloys in detail. Particulate-reinforced MMCs are having specific attention due to easy manufacturing technique, low cost, and isotropic properties [9]. The grain size can be easily controlled in a single pressing to enable for reaching a higher density by hot pressing technique. [10, 11]. The main aim of this paper is to review the titanium and titanium alloys composite properties for various applications. The previous researcher's views and findings are to be discussed in details to help the future researchers. The properties of composites are discussed based on the fabrication technique and influence of the hard ceramic particles.

2. TITANIUM AND TITANIUM ALLOY COMPOSITES

Titanium and titanium alloys are used as matrix materials and hard ceramic particles like Titanium carbide (TiC), Silicon carbide (SiC), Aluminium oxide (Al_2O_3), Yttrium oxide (Y_2O_3) etc. is used as reinforcement materials for manufacturing composites. These composites are attracted by the many industries due to their superior properties. The hard ceramic particles are added, based on the properties required for a specific application for an industrial component. The researchers have developed a lot of composites for various applications through the addition of various ceramic particles with different compositions. The researchers have also enhanced the properties of titanium and its alloys through the various processing techniques used to fabricate composites.

3. FABRICATION OF METAL MATRIX COMPOSITES

The powder metallurgy technique is mostly used to fabricate composites by the many researchers. It is a low cost processessing technique, even though sintering is the critical process due to the reactivity at atmospheric condition. The efficient controlled atmosphere is required for the effective sintering processes. The sintering processes are mostly done in vacuum environments. The various sintering techniques such as hot isostatic pressing (HIP), hot extrusion and hot pressing methods are mostly used by the recent researchers for the fabrication of composites and nano-composites to achieve better mechanical and physical properties [12]. Instead of single pressing, a two-step hot pressing technique is used to enable for getting composite with higher densities with controlled grain size [13.14].

4. TITANIUM ALLOY COMPOSITE CHARACTERISTICS

Heeman *et al* fabricated the Ti-Al-4V/ 7.5% TiC -7.5% W hybrid composites through powder metallurgy technique using combined actions of cold and hot isostatic pressing and investigated the mechanical properties such as tensile, compressive and hardness. The same composition of composite was made through extrusion and casting methods to compare the composite history of fabrication processes. It is concluded that superior mechanical properties was identified in the cast composite which shows that the presence of titanium carbide limits the dissolution of tungsten powder in the matrix of Ti-6A-4V. But the ductility is the negative effect in the cast composites compared to others [15].

Chen *et al* [16] studied the Ti-17Al-27Nb/Yttrium oxide composites through powder metallurgy route and proved that the matrix of alloy's tensile elongation and grain refinement was improved due to the addition of yttrium oxide.

Yang *et al* [17] prepared the Ti6Al4V/3.5vol%TiB composite by using pre-sintering and hot extrusion method and reported that sintering temperatures and time are the major factors on the densification behaviour and mechanical properties. They proved that the composites sintered at 1100ºC for 1 hr was the optimum condition for comprehensive properties and cost.

Xiang *et al* [18] studied the microstructure and mechanical properties of TiC/Ti6Al4V composites with different composition of yttrium(Y) elements and concluded that the addition of Y from 0.1 -0.5% wt addition increased the properties and microstructure where as 1.0% -2.0 of Y addition in the matrix metal produced the negative effect on the properties and microstructure. It is also proved that the hardness and compressive strength were reached peak values at 0.5% Y element addition.

Huiyang *et al* [19] fabricated the composite of a TiB/Ti6Al4V through powder compact extrusion from a blended powder. The tensile test results directed that the composite with a distribution of fine TiB whiskers with great aspect ratios revealed high ultimate tensile strength (UTS) and yield stress (YS) and a nearly better ductility mirrored by an elongation to fracture of 5.6% was also achieved. The strength and ductility attained were greater to those achieved by other methods.

The different amount of boron were mixed in the TiC/Ti6Al4V composites and fabricated through casting method by Wang *et al* [20] and investigated that the boron additions influence on the microstructure, mechanical properties of composites. The compressive strength and hardness were increased in all ranges of boron additions even though remarkable benefits obtained below 0.06 wt% of boron addition.

Salehikahrizsangi *et al* [21] investigated the Ti6Al4V/(Ti–B) nano-composite which is fabricated through cold pressing from the milled powder and sintered at 1000ºC for 4 hr. The wear test conducted and reported that the wear rate of the nano-composite was reduced and highest friction coefficient obtained due to the addition of nano Ti-B particles. And also discussed that the nano-grains of reinforcement particles influenced the higher hardness in the matrix phase.

Min *et al* [22] investigated the Ti6Al4V sample which prepared through magnetic pulse compaction in the air at 200ºC by varying the parameters such as voltage, capacitance and discharge time. The experimental results indicate that the increase in voltage influenced the great changes in the improvement of relative density, compressive strength and hardness. The composite sample microstructure was observed and reported that the pores were identified in between the particles.

Zhao-hui *et al* [23] fabricated the TiB/Ti-1.5Fe-2.25Mo composite in situ using the spark plasma sintering (SPS) method for a temperature range from 850ºC to 1150ºC and report says that the relative density increased with increase in sintering temperatures. The composite exhibits highest bending strength at 1150ºC due to the formation of TiB whiskers in the matrix of titanium.

Wang *et al* [24] prepared a composite of Ti6Al4V/TiB using direct laser fabrication by injection of pre-mixed powders and studied the characteristics of the composites. The report says that the modulus of elasticity, yield strength and ultimate strength have been increased due to the presence of TiB particles in the matrix of Ti6Al4V alloy. The considerable amount of wear resistance was improved.

5. CONCLUSION

The various Ti6Al4V metal matrix composites have been studied from the experimental investigation of previous researchers and the following are the concluded remarks:

- Most of the researchers used the powder metallurgy technique to reduce the fabrication cost and the various sintering techniques followed such as furnace sintering, hot pressing and spark plasma sintering (SPS) to investigate the composite.

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- The composites were produced through the processes of HIP, cold isostatic, hot pressing and extrusion produced higher relative density. But the magnetic pulse compaction method produced the pores in composite structures compared to other methods.
- The nano ceramic particle reinforcement in the matrix of Ti6Al4V is the most suitable to achieve the high performance materials for various applications.
- The controlled atmosphere is required to process the Ti6Al4V composite which increases the fabrication cost.

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