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Study of Improving Mechanical and Thermal Property using Nano-, Micro-, and No Filler Material in Titanium Alloy Composite

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Abstract: **This paper is to evaluate the Structural and Thermal behavior of Titanium Alloy Composite. Generally, the properties of the composite vary depending on the various materials, fillers or resins used. In this study we are comparing the property variation with increment or decrement in Structural and Thermal property of Titanium Alloy with Nano filler, Micro filler and with No filler material and thus comparing the variation and finding the better filler material which increases certain properties of Titanium Alloy Composite. Since, Titanium is generally high temperature alloy material thus by using filler material defining the increased property of composite material. Thus, by using ANSYS Software, the variation in the property is determined for the result which gives variation of Structural and Thermal property can be determined.**

Keywords: **Structural analysis, Thermal analysis, Titanium alloy, Nano filler, Micro filler, No filler.**

1. INTRODUCTION

Titanium alloys are known for very high tensile strength and toughness, light weight, corrosion resistance and the ability to withstand extreme temperatures. The superior and unique ability results in a high cost of both materials and processing, limiting use to military applications, aircraft, automotive, spacecraft, medical devices and consumer electronics. Titanium alloy is used in high stress environments due to its durable properties. Titanium is a strong, light metal, as strong as steel but 45% lighter. It is also twice as strong as aluminum but only 60% heavier. So it is mainly considered as a High Temperature Material. Generally, the properties of the Ti composite vary depending on the various materials, fillers or resins used. In this study we are comparing the property variation with increment or decrement in structural and thermal property of titanium alloy depending on filler material used. We are designing titanium alloy with Nano filler, Micro filler and with No filler material and thus comparing the variation and finding the better filler material which increases certain properties of titanium alloy composite. The fillers are generally used to increases the strength in the composite material thus by comparing with this three types and defining the increased structural and thermal property. Since, titanium is generally high temperature alloy material thus by using filler material defining the increased property of composite material. Thus, by using Analysis Software, the variation in the property is determined for the result which gives pictorial representation in variation of Structural and Thermal property can be determined.

2. MATERIALS OF COMPOSITE

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. The main consistent of Composite are
1. Metal Matrix Material
2. Reinforcement
3. Fillers

Table 1.Table below refers the Materials Used

Metal Matrix	Titanium Alloy(Ti)
Reinforcement	Silicon Carbide(SiC)
Fillers	Micro and Nano

Titanium Alloy

A titanium alloy composite material of the present invention is obtained by dispersing carbon fibers coated with a layer containing an element which forms carbide in reaction with carbon and the carbide formed thereby in crystal grains of the titanium alloy. That is, the layer coating the carbon fibers is formed of the carbide formed through a partial reaction between the element and the carbon fibers, and an unreacted element. This layer serves as a layer for suppressing reactions between the carbon fibers and titanium during formation of a composite and improves wetness with the titanium alloy, and thus properties of the carbon fibers as a reinforcing material are maintained after formation of the composite. In the present invention, such coated carbon fibers are dispersed in crystal grains, to thereby significantly improve mechanical strength such as tensile strength, Young's modulus, toughness and hardness. In the present invention, a state in which the carbon fibers are dispersed in crystal grains of the titanium alloy refers to a state in which the carbon fibers are at least partly incorporated in fine crystal grains of the titanium alloy while moderate dispersibility is maintained through plastic flow during plastic working.

Silicon Carbide

The Silicon Carbide reinforced titanium composites described here utilize continuous lengths of silicon carbide monofilament as reinforcement. This monofilament is produced by chemical vapour deposition of silicon carbide fibre on a continuous length of carbon or tungsten filament substrate. There are currently three commercial producers of this silicon carbide fibre for composite use in the world, two based in America and one in the UK. The UK supplier produces fibre on a tungsten filament and is available in long lengths in excess of 30km which enables long lengths of fibre to be produced in single batches and hence improves economics compared to other substrates. The fibre has an outer carbon barrier layer, deposited during production, which was developed for titanium composite processing. This carbon coating provides a suitable interface and the appropriate load transfer when used in a composite. Other coatings are possible for different matrix systems.

Nano Filler

Nanofillers can be either small spherical particles or rod shaped objects and flakes with at least one critical dimension below 100nm. In general, the properties of filler materials are determined through particle size, particle geometry and chemical coatings, or functionalization. Smaller particles provide new functionalities such as control of Rheological properties, improved mechanical properties, an increased transparency or electrical conductivity, or enhanced flame retardancy. They can be also used to ensure the free flow of powders and to prevent the settling of pigments. Fillers are widely used in the construction sector in adhesives and sealants, in paints and coatings, but also in plastics, rubber and concrete. Synthetic fillers are now gaining more importance; they allow the production of smaller particle sizes with controlled surface chemistry or tailored chemical functionalization. Ultra-fine grades or so called nanofillers are under investigation. Besides downsizing existing filler materials, completely new technological approaches can also be observed such as organic-inorganic hybrid materials in polymers or nanotubes as reinforcing filler material in concrete. However, the share of nanofillers in today's construction filler market is negligible. An example of well-established nanofillers can be found in another sector; carbon black filled tyres for longer life and improved performance.

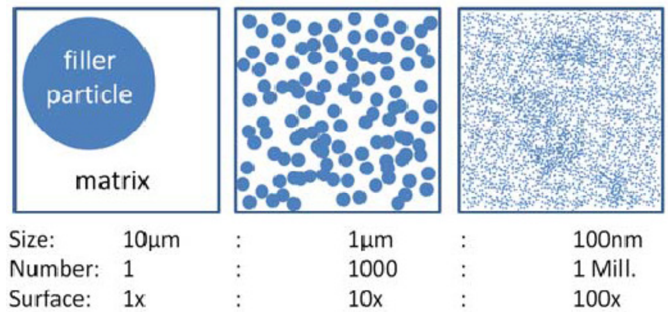

Figure 1. Different Filler Particle Sizes at the same Filling Level. Going from 10µm To 100nm; a Million Times more Particles exhibit a 100-fold Increased Inner Surface Area (Adapted Form).

Micro Filler

Glass fiber is commonly used as an insulating material. It is also used as a reinforcing agent for many polymer products; such that it is considered as micro filler to form a very strong and light fiber reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), popularly known as "fiberglass". Glass fiber has roughly comparable properties to other fibers such as polymers and carbon fiber. Although not as strong or as rigid as carbon fiber, it is much cheaper and significantly less brittle.

3. MANUFACTURING ROUTES

State of Art

According to the manufacturing process, metal matrix composites can be divided into ex-situ and in-situ. When the reinforcement is externally added to the matrix, ex-situ composite materials are created. In situ synthesizing of metal matrix composites involves the production of reinforcements within the matrix during the fabrication process. Ex-situ manufacturing techniques can be further grouped into solid state, liquid state and semi-solid processing. Among solid state techniques, powder metallurgy and mechanical attrition are the most popular ones. The nano-scale can be easily reached, although the cost of the powder is significantly high. Interfacial and surface wetting issues are considerably diminished. This is because both phases remain in the solid state, where diffusivity is much lower. The final products are generally affected by a high amount of porosity, which strongly decreases the fatigue resistance and requires further metal working. Also, when the process involves attrition at high temperatures, chemical modification of the initial constituents is likely to happen. Liquid state routes can be sorted into four major categories: infiltration, agitation, spraying and ultrasonic cavitation based solidification. Semi-solid processing involves electromagnetic stirring and semi-solid casting. Liquid metal is generally less expensive and easier to handle than powders, and the shape flexibility constitutes a significant advantage. Liquid state processes are generally fast and easy to scale-up. Despite this, they are affected by the lack of wettability of the reinforcement and by interfacial reactivity. Moreover, they are often limited to low-melting point metals. In-situ metal matrix composites are not affected by the shortcomings typical of ex-situ composites, although control of process variables still remains an issue. In-situ fabrication methods can be divided into two major categories according to the physics of the process itself:

- "Reactive" routes: the reinforcement is synthesized within the metal matrix through a gas-liquid, liquid-liquid, or solid-liquid reaction.
- "Morphological" routes: a favorable composite architecture evolves as a consequence of processing. Deformation processes and directional solidification of eutectics alloy belong to this category.

The features of ex-situ techniques and their drawbacks will be discussed in the following paragraph. In addition to this, the advantages of in-situ composites will be illustrated and the most popular in-situ methods described.

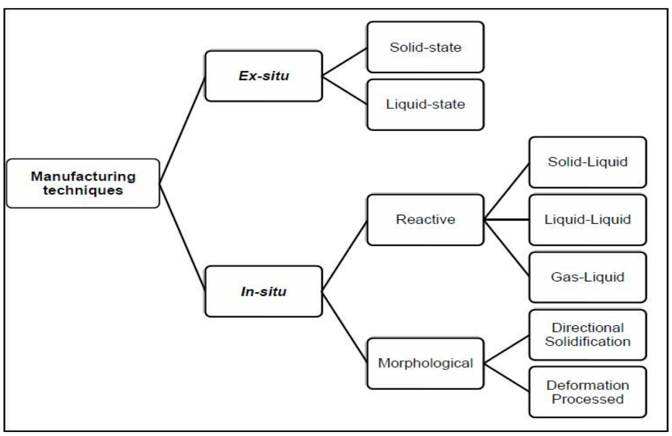

Figure 2. Manufacturing methods for metal-matrix composites

"Powder metallurgy"

Most of prior work in synthesizing Nano composites involves the use of powder metallurgy techniques, which are usually affected by high costs. Blending of matrix and reinforcement powders followed by hot or cold pressing and sintering is a standard fabrication sequence. A schematic of a typical powder metallurgy procedure is shown in Figure 3. In the majority of powder metallurgy process, agglomeration can be minimized only if the size of the matrix powder is close to the side of the reinforcement phase. In addition to this, further working of products attained via powder metallurgy may cause the reinforcement phase to break up and deform the surrounding matrix, leading to stress concentration and cracking. The advantages of the process are flexibility and near-net shape products. Moreover, the size range of metal powder offered by the market is very wide and can meet the needs of different purposes. Powder metallurgy has been used to add 50 nm alumina particles to aluminum powder. The process consists in wet mixing (aluminum powder mixed with varying volume fraction of Ti_2O_3 powder in a pure ethanol slurry), followed by drying at 150 ºC and cold isostatic pressing to compact the powder. The compacted powder is then vacuum sintered at 620 ºC (approximately 60 ºC below the melting temperature of aluminum). Massive clustering has been observed, and its occurrence increases with decreasing particle size. Metal fabricated via powder metallurgy nanometric silicon-nitride reinforced aluminum composites. They reported the presence of several agglomerates in the aluminum matrix. Pengetal created a novel and simplified process for producing aluminum matrix Nano composites reinforced with oxide particles. The novelty lays in the use of TI_2O_3 surface layers existing on matrix aluminum particles as the ceramic reinforcement. A good distribution has been achieved, although the process does not allow a satisfactory control of the phase of layers break-up and spreading. Moreover, the effectiveness and the scalability of the method have not been proved yet.

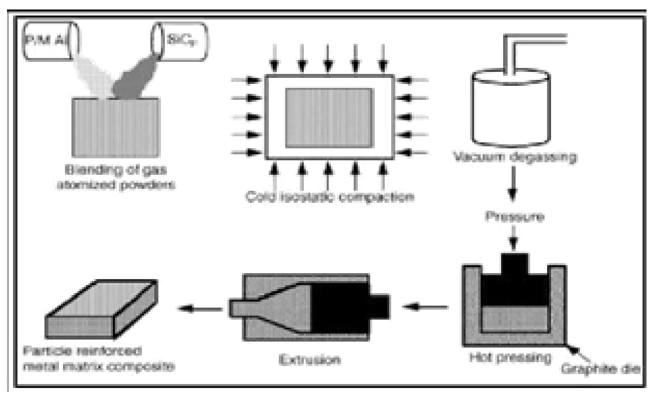

Figure 3. Powder Processing, Hot Pressing

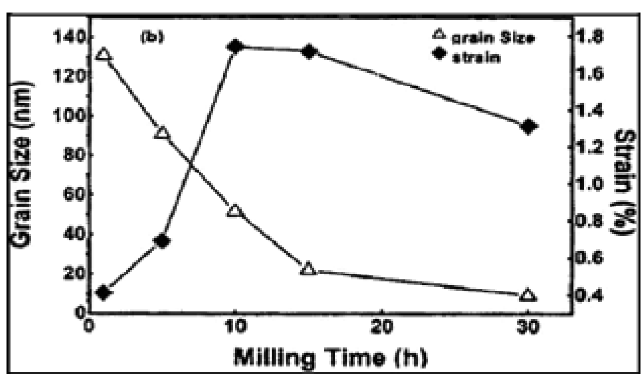

Figure 4. Grain Size and Strain vs. Milling Extrusion Process for Particulate Reinforced Composites Time for WC Particles

Ultrasonic cavitation based solidification

High-intensity ultrasonic waves (above 25 W/cm²) can generate strong nonlinear effects in the liquid such as transient cavitation and acoustic streaming. They produce a dispersive effect ideal to homogenize the microstructure of the composite material. In order to benefit from such effect, an ultrasonic probe has been immerged into the melt to create the acoustic field – Figure5- and nano-sized particles have been added during the ultrasonic process.

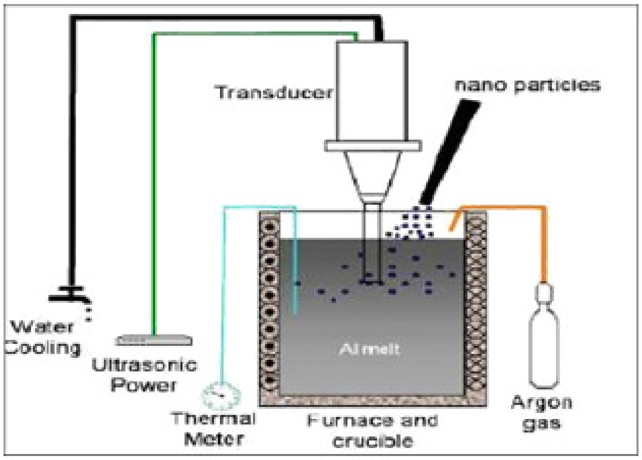

Figure 5. Schematic of Ultrasonic Solidification

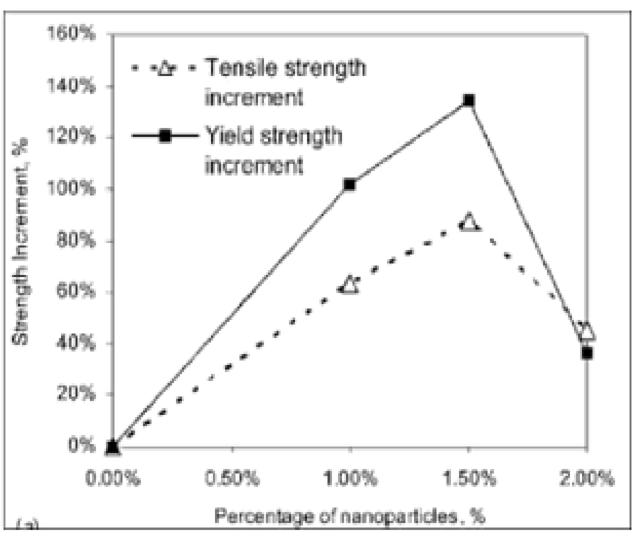

Figure 6. Strength vs. Nano-Particles Percentage

The acoustic bubbles burst, creating hot micro-spots that locally raise the temperature of the melt. This enhances particle wettability and thus, favors a good dispersion. It has been measured that with a 3.5 kW ultrasonic power, the ultimate strength and yield strength were improved more than 60% and 100% -Figure 6-. In addition to this, 2.0 vol% SiC nano-particles improve hardness by 20%.

4. COMPARISON OF NANO-, MICRO-, NO FILLER BY ANALYSIS

Generally, the nano filled resin performed better in all mechanical properties tested than did the micro filler. The different filler material with same amount of loading condition is applied such that the structural and thermal properties of all the three models of Nano-, Micro-, No filler is tested analytically using the software ANSYS which is shown in the figure

The result obtained from the figure when comparing with nano fillers have various values of Total Deformation, Stress, Strain and Thermal or Temperature distribution which is obtained using ANSYS and is figured below. Thus by comparing the value of Nano with already obtained value of micro and no filler is compared and found that Nano have high property comparing other filler composites.

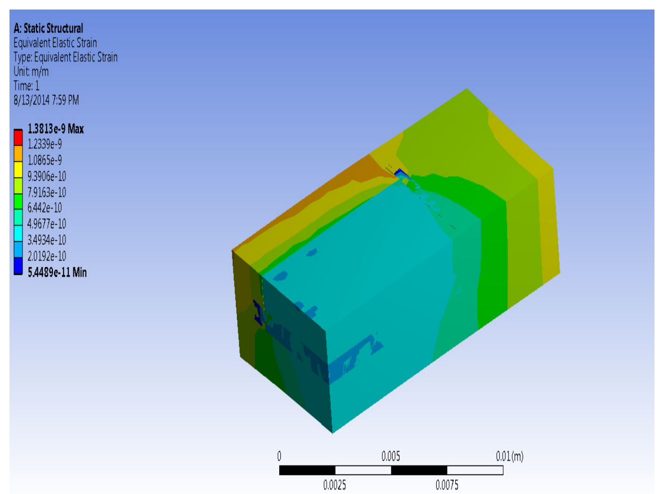

Figure 7. Figure shows the Strain of Nano Filler

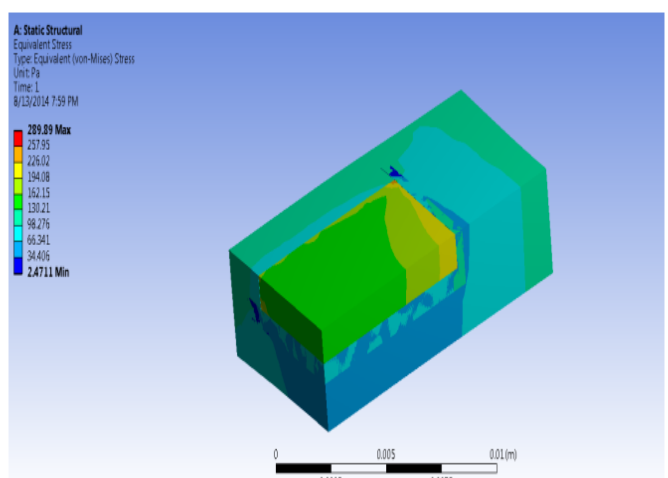

Figure 8. Figure shows the Von Mises Stress of Nano Filler

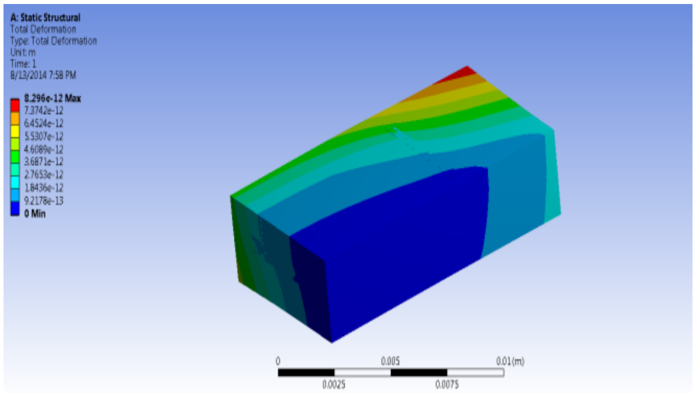

Figure 9. Figure shows the Total Deformation of Nano Filler

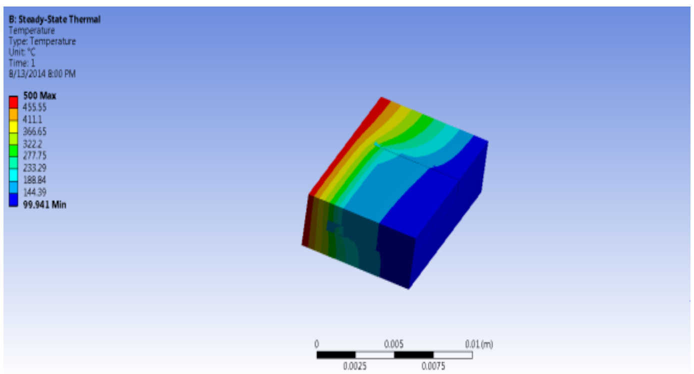

Figure 10. Figure shows Temperature Distribution of Nano Filler

5. RESULT

Nano fillers are characterized by their particle size, specific surface area, particle geometry and chemical functionalization. Smaller filler particle sizes provide new functionalities such as improved mechanical strength and control of rheological properties. The high specific surface area of nanomaterial provides a route towards novel properties and decreased filling levels than micro fillers. Hybrid materials provide a route towards fully dispersed nanomaterial and superior Nano composites. Critical issues are exfoliation and dispersion of nanomaterial, and poorer process ability.

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