Research Article

# EFFECT OF TITANIUM DIOXIDE AND TALC ON THE TENSILE STRENGTH OF COMPOSITE MATERIAL

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**ABSTRACT**

Epoxy was incorporated with titanium dioxide and talc at different concentrations (0, 0.5, 1, 2, and 4 wt%), and then that mixture was combined with carbon fiber via a hand lay-up process. The mechanical properties of the composites were determined using universal tensile testing. The tensile test results revealed that the mechanical properties of the polymer matrix composites were increased as a function of talc and titanium dioxide concentrations. The best tensile strength of the composite was obtained from the 0.5% talc and 1% titanium dioxide sides. Increasing the weight ratio of talc 1%, 2%, and 4% and 0.5%, 2%, and 4% of titanium dioxide in composite production doesn't exhibit a significant difference. Tensile testing behavior of talc and titanium dioxide reinforced composite specimens shows better results compared to unreinforced carbon fiber composites. As a result, this study provides a detailed explanation of how to improve the strength of carbon fiber composites.

**Key Words:** Composite, Carbon Fiber, Titanium Dioxide, Talc, Tensile Test

# TİTANYUM DİOKSİT VE TALK'IN KOMPOZİT MALZEMELERİN ÇEKME DAYANIMI ÜZERİNE ETKİSİ

**ÖZET**

Epoksi, titanyum dioksit ve talk ile farklı konsantrasyonlarda (ağırlıkça %0, 0,5, 1, 2 ve 4 oranında) dahil edildi ve daha sonra bu karışım elle yatırma işlemi ile karbon fiber ile birleştirildi. Kompozitlerin mekanik özellikleri, evrensel çekme testi kullanılarak belirlendi. Çekme test sonuçları, polimer matrisli kompozitlerin mekanik özelliklerinin talk ve titanyum dioksit konsantrasyonlarının bir fonksiyonu olarak arttığını ortaya koydu. Kompozitin en iyi çekme mukavemeti %0.5 talk ve %1 titanyum dioksitten elde edilmiştir. Kompozit üretiminde talkın %1, %2 ve %4 ve titanyum dioksitin %0.5, %2 ve %4 ağırlık oranlarının arttırılması önemli bir farklılık göstermemektedir. Talk ve titanyum dioksit takviyeli kompozit numunelerin çekme testi davranışı, takviye edilmemiş karbon fiber kompozitlere kıyasla daha iyi sonuçlar göstermektedir. Sonuç olarak, bu çalışma, karbon fiber kompozitlerin mukavemetinin nasıl iyileştirilebileceğine dair ayrıntılı bir açıklama sunmaktadır.

**Anahtar Kelimeler:** Kompozit, Karbon Fiber, Titanyum Dioksit, Talk, Çekme Testi

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## 1. INTRODUCTION

Composite materials exhibit a category of advanced engineering materials of technical and scientific interest (Puttaraju & Hanumantharaju, 2022). Composite materials occur by combining two or more different materials. Additives improve the mechanical and chemical properties of composite materials. Combinations of additives improve lightness, non-flammability, fatigue properties, a tendency to withstand environmental conditions, and a high modulus of elasticity at high temperatures at composite materials. (Bagatır, 2018).

Andrei et al. (2006) showed that Carbon fibers/polymer matrix composites are used widely instead of aluminum structures in the aerospace industry and aircraft. The requirement for strength, fuel-efficient and lightweight materials in industries is a big research interest. The mechanical and corrosion resistance characteristics of Titanium (Ti) and alloys, which have low specific gravity and strength, make them highly relevant to these industries (Topcu et al.,2019). Karataş and Gökkaya (2018) showed in their article that more than fifty thousand material types had been used in producing and designing a wide range of engineering products. Composite materials provide flexibility in design because they can be molded into various shapes (Khan & Javed, 2020). The composite material is created for producing material with high properties and desired qualities. The powerful material is the reinforcement, and the weaker material is the matrix. The production of composite materials aims to develop one or more of the following features (Jones, 2014).

- Strength
- Wear resistance
- Corrosion resistance
- Stiffness
- Weight
- Attractiveness
- Thermal insulation
- Temperature-dependent behavior
- Fatigue
- Acoustical insulation
- Thermal conductivity

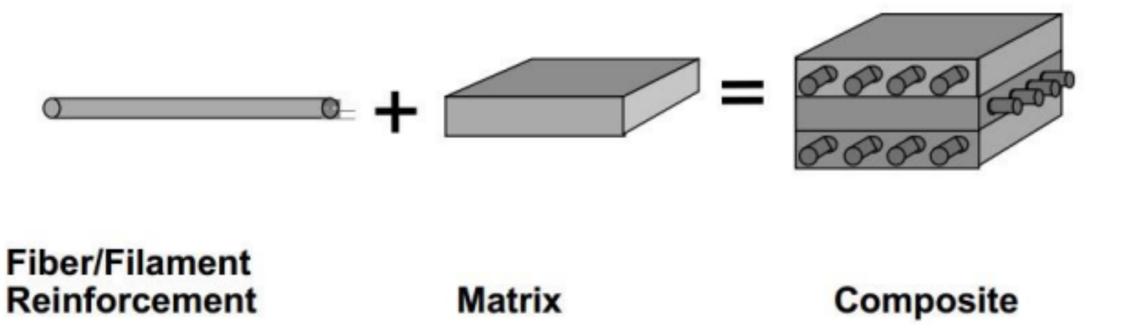


Figure 1. Fiber/Filament Reinforcement, Matrix, and Composite (Mrazova, 2013).

Strength and light structure are the difficult subjects for every industry. Composite Materials' have advantages such as smaller weight, galvanic corrosion elimination, tightness, good sealing, damping properties, good vibration, low production cost, energy, uniform stress distribution, and decreased stress concentrations (Ahmed, 2018).

Composite material rate of usage has reached a balance in various industries. Maritime 50 percent, wind energy 65 percent, electric and electronic 35 percent, and consumer goods 13 percent. In other industries, the share of composite material;

- Aviation and space will increase from 9 percent to 12 percent.
- Construction and building industry will increase from 6 percent to 10 percent.
- Tank and pipe will increase from 1 percent to 2 percent.

is expected (Konu, 2016).

Industrial and academic researchers have recently focused on composites, improving the developing research field. For example, researchers are improving the properties of composite by adding filler materials to maximize their potential.

Prasad et al. (2018) aimed to research the effect of $TiO_2$ in improving the mechanical, water absorption, and thermal properties of the flax fiber reinforced epoxy composites. $TiO_2$ enhanced the tensile, bending, impact, and interlayer shear strength values. The results exhibit a significant improvement in the strength of the composite with the addition of $TiO_2$. Naveen et al. (2019) researched the mechanical and tribological properties of nylon66 composites with $TiO_2$ at various investigations. Tensile strength, modulus, and flexural strength, compressive strength tests were used on specimens. The result of the test, in the development of the Tribological, mechanical, and thermal features of the composites with a decrease in coefficient of friction and wear rate up to 4 wt% of $TiO_2$ filled with the glass fiber.

Furthermore, it was analyzed that at 2 wt% of $TiO_2$ filled with 2 wt% glass fiber, there is an effective improvement in tribological features with a reduction in coefficient of friction and wear rate. Karol (2017), epoxy resin was used as the carbon fiber reinforced composite polymer. Also, silicon carbide, magnesium silicate (talc), and kaolin are preferred as additive materials. Although no action was taken to increase the wettability of the materials used as reinforcement, an increase was observed in the tensile and flexural strength values of kaolin and magnesium silicate added to carbon fiber composites.

Yetgin, (2017), mechanical properties such as impact and tensile of polypropylene, talc, ethylene propylene diene monomer composite samples were researched. Talc added to polypropylene polymer increased the tensile strength, and modulus of elasticity increased while impact strength increased.

Anaklı et al. (2018), in their study, among the inorganic powder materials, layered silicate clays such as the best-known montmorillonite, mica, talc, and hectorite are preferred in composite preparation due to their large surface areas and layered structures suitable for nanocomposite preparation. Talc, an aqueous magnesium silicate with the chemical formula $Mg_3Si_4O_{10}(OH)_2$, has a layered structure. Because weak Van der Waal's forces hold the layers, it has weak shear stress and can be easily dispersed in the polymer. Hence, it is used as a filling material with various polymers. In addition, it has been observed that when used with polymers, it decreases the crystallization half-life, increases the crystallinity, and reduces the processing time. Because of these features, researchers used talc to prepare nanocomposites with different insulating polymers. Talc/polypropylene nanocomposite exhibit both thermal and mechanical properties development.

This study investigated the mechanical properties of carbon fiber composite with 0, 0.5, 1, 2, and 4 wt% $TiO_2$ and talc added to epoxy. There are separate studies of $TiO_2$ and talc in the literature using different additives added to other fiber elements or materials. In the literature, researchers look into mechanical and tribological properties were investigated. On the other hand, the current study investigated the mechanical properties of $TiO_2$ and talc ratios, which are used as additives in carbon fiber epoxy resulting from the tensile test.

## 2. MATERIALS AND METHODS

### 2.1 Materials

#### 2.1.1 Properties of Talc Material

Talc is a raw material. Talc is used in many industrial products such as cosmetics, pesticides, pharmaceuticals, paper, food, paint, plastics, ceramics, and textiles (Ersoy et al., 2013).

Talc was provided from Omnis composite company. Chemical properties of talc materials is that MgO 32%, $SIO_2$ 62%, CaO 1,8max%, $Al_2O_3$ 0,3%, $Fe_2O_3$ 0,6% max. Physical properties are density (ISO 787/10) 2,73gr/ml hardness. There are some general properties of talc. For instance, Largest Grain ((average grain diameter) 99 %) is 23,7 µm. Also, average grain large ((average grain diameter) 50 %) is 4,52 µm and pH 8,2.

#### 2.1.2 Properties of Titanium Dioxide Material

Titanium dioxide is a widely used and known material. Its intrinsic electronic and structural properties make it extensively used. For example, titanium dioxide can be seen in white and colored paint. Titanium dioxide has UV-blocking properties. Because of this property, it is used for sunscreen products. Titanium dioxide is also present in plastics and coatings, especially for external uses as a UV light barrier, where the aging effect of light must be minimized (Korotcenkov,2020).

Titanium dioxide was provided from Omnis composite company-Dupont. The properties of titanium dioxide are $TiO_2$, wt%, min. 93, specific gravity 4, bulking value, L/kg (gal/lb) is 0.25 (0.03), pH 7.9, resistance at 30°C (86°F) (1,000 ohm) 8.1 and carbon black undertone 11.7.

#### 2.1.3 Properties of Carbon Fiber

Carbon fiber is also determined as graphite fiber, a very lightweight and strong material. Carbon fiber is five times stronger, two times lighter, and stiffer than steel, making it a significant production material for parts. Therefore, engineers and designers, who work in industrial manufacturing, prefer carbon fiber manufacturing (Bajpai, 2017).

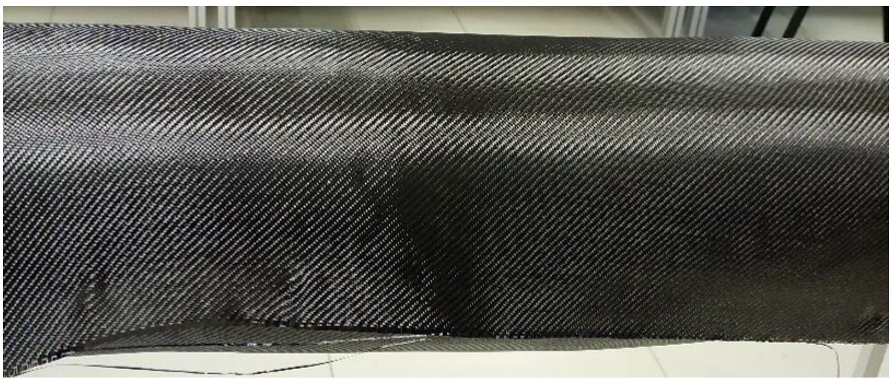

Figure 2. Carbon Fiber

#### 2.1.4 Epoxy Resin

Fibermak F-3486 activator and Fibermak F-1564 resin were used fabrication of the composite. Activator (34 wt% ) and resin (66wt% ) were combined with an epoxy mixture.

## 2.2 Method

### 2.2.1 Fabrication of Composites

Carbon fiber epoxy composite, reinforced with titanium dioxide and talc, was produced with a hand lay-up process. In the production of composite materials, carbon fiber fabric was used in six layers. Various concentration 0%, 0.5%, 1%, 2%, and 4% titanium dioxide and talc, which is added to epoxy, were used in reinforced composites. The specimens were designed with AutoCAD. After that, composites were cut with a water jet for the tensile test. Test specimens were prepared according to the ASTM D3039 standard.

### 2.2.2 Testing The Strength of Composites by Tensile Test

Mechanical properties are shown in materials specifications to compare different materials and understand their quality for applications (Asmatulu et al., 2015). The composite samples were tested using a Teskon tensile test machine. Tensile tests were done at the speed of 25 mm/min. Each specimen was placed between the grips of the Teskon tensile machine. The material tensile test's result was recorded spontaneously by the test machine. Then, the results were given as a stress-strain curve by the computer. Figure 4 shows the image of tensile testing of the samples.

Figure-3. Teskon Tensile Test Machine

## 3. RESULT AND DISCUSSION

The bar graph showed the result of tensile test values of carbon fiber composites in the presence and absence of titanium dioxide and talc. Figures 4 and 5 seem that the result of the tensile test, the best tensile strength was obtained from the 0.5 wt% talc and 1wt% titanium dioxide. In the comparison of 0 and 0.5 wt% of talc in the matrix, the tensile result of the samples increased from 329.5 MPa to 392 MPa, corresponding to a 19% improvement in the tensile strength. A significant increase was observed as a result of the tensile test in talc, and titanium dioxide reinforced composite samples. On the other hand, because of the non-homogenous distribution of additives observed the decrease of talc after 0.5 wt% and increase and decrease of $TiO_2$ additives tensile strength. In the comparison of unreinforced carbon fiber composites and reinforced carbon fiber composites, it has been understood that the tensile behavior of talc and titanium dioxide reinforced composite specimens have been significantly changed, added by reinforcement percentage.

Produced carbon fiber composite (unreinforced) and reinforced with titanium dioxide and talc carbon fiber composite's specimens tensile test average result is on the below figure 4 and figure 5.

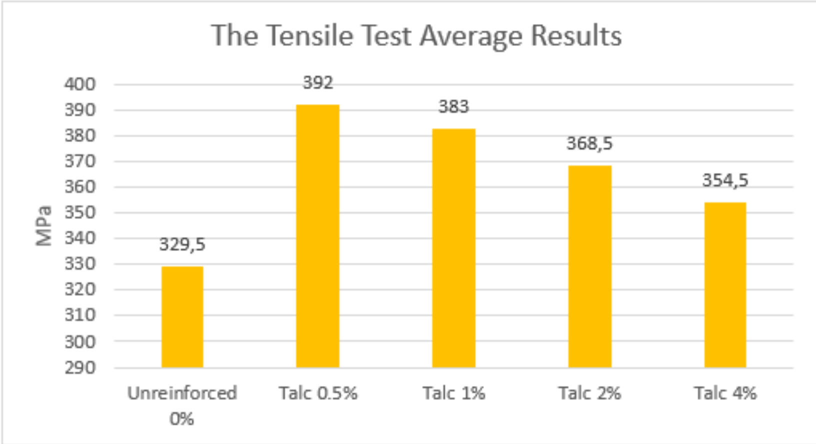


Figure-4. Carbon Fiber Epoxy Composite Unreinforced and Talc Tensile Test Results

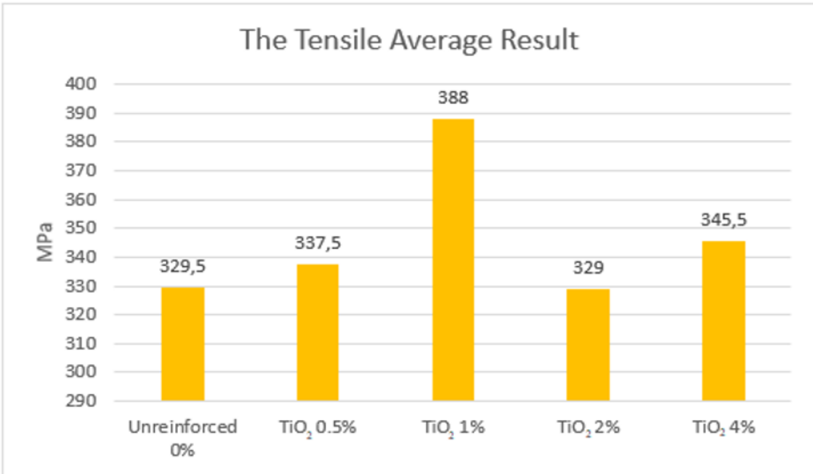


Figure-5. Carbon Fiber Epoxy Composite Unreinforced and $TiO_2$ Tensile Test Results

Prasad et al. (2018) aimed to research the effect of $TiO_2$ in improving the mechanical, water absorption and thermal properties of the flax fiber reinforced epoxy composites. $TiO_2$ enchanced the tensile, bending, impact and interlayer shear strength values. Karol, (2017), epoxy resin was used as the carbon fiber reinforced composite polymer. Also, silicon carbide, magnesium silicate (talc), and kaolin are preferred as additive materials. As a result, an increase was observed in the tensile and flexural strength values of kaolin and talc added carbon fiber composites.

Bagatır, T. (2018) showed that, 0%, 0.1%, 0.2%, 0.3%, 0.4%, 0.5% and 1% graphene was added to epoxy. Composite specimens were tested by a universal tensile test. Tensile test results exhibited the maximum tensile strength in 0.2% graphene reinforced epoxy composite. Although 0.4% Graphene reinforced fiber composites have the highest tensile strength, to compare 0.2% graphene reinforced fiber composite, it is understood to show no significant increase. The usage of graphene positively affected the strength of the composite. In this study, the usage of talc and $TiO_2$ additives also increased the strength of composites.

Topcu et al. (2020) showed the positive mechanical effect of using different concentration multi-wall carbon nanotubes in their article. Scanning electron microscopy (SEM) and X-ray diffraction (XRD) micrographs were used to determine the porosity, hardness, and density features to observe if they are affected or not concerning the performance of composites in different reinforced rate % MWCNT conditions. Along with XRD and SEM studies, this was exhibited by a successive increase in hardness and abrasion resistance.

Yaman, O.F. (2017) in the study that homogenization problems may occur during the mixing and spreading of carbon particles. Because of the mechanical mixing, regional differences may occur in the carbon plates.

## 4. CONCLUSION

Titanium dioxide and talc were incorporated with Carbon fiber, and the obtained composites were analyzed with a universal tensile test. Tensile test results showed that adding talc and titanium dioxide to carbon fiber composites increased the strength.

Carbon fiber epoxy composite reinforced with 0.5% talc and 1% titanium dioxide have the best tensile strength. However, comparing the weight ratio of 0.5 talc and 1, 2, 4 wt%, increasing the weight ratio at talc, the tensile strength decreased. Moreover, increasing the weight ratio of titanium dioxide by 0.5%, 2%, and 4%, a significant difference in tensile strength results was not found. Therefore, the result of the comparison of unreinforced carbon fiber composites with talc and titanium dioxide reinforced composite specimens showed that the reinforcement percentage by weight changed the composite's strength.

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The authors have no conflicts of interest to declare.

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