# The Effect of UV- Radiation on Mechanical and Chemical Properties of Polyurethane/ nanoTiO$_2$ Sizing by Unsaturated Polyester

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## Abstract:-

Polyurethane foams were fabricated with different percentages of nano titanium dioxide ($TiO_2$) and sizing by the unsaturated polyester. In these samples, the ($TiO_2$) nanoparticles were inserted to polyurethane foams as filler with different percentages (1%, 3%, 5% and 7wt %) to study the effect of UV radiation and ($TiO_2$) nanoparticles on some of mechanical properties, such as (impact resistance and bending strength) as well as the chemical resistance in salt media. Results showed the impact resistance increased with increasing of the ($TiO_2$) nanoparticles weight percentage until 3wt%. Moreover, the bending strength increased with rising in weight percentages of ($TiO_2$) nanoparticles until 5wt%. The optimum sample of chemical resistance was 5wt% of ($TiO_2$) nanoparticle. Finally, the UV radiation leads to decrease of the mechanical properties. Additionally, chemical resistance was decreased with UV radiation exposure. Sample with 5wt% has the best and lowest of weight loss than other samples.

**Keyword:** Nano titanium dioxide ($TiO_2$), Polyurethane foam, Sizing Mechanical properties, Chemical resistance.

## 1. Introduction:

Polyurethanes foams are individual polymer materials with vast extent from chemical and physical properties and can be designed to meet miscellaneous requirements of different applications as adhesives, coatings, thermoplastic elastomers, fibers and foams. These applications relying on the cell morphology, composition, vibration-decreasing properties, high mechanical strength, special strength to weather conditions, physical properties and resistance to organic solvents and oils. There are two types of foams as rigid and flexible [1, 2]. Rigid foam was utilized in many applications such furniture, building insulation, transportation and devices [3,4]. Polyurethane foams were produced by blending polyols and di or triisocyanates with blowing agents and activators and has better characterstics than other synthetic materials [5, 6, 7]. The mechanical and chemical properties of polyurethane foams increased after inserting nanofillers such as (TiO2) nanoparticle in this polymer as being observed in many researchers . Nikje et al. [8] investigated that the improvement of polyurethane properties can be obtained from combination a low weight ratio of nanoparticles in this polymer like high aspect ratio, low size and high specific surface. The thermal and mechanical properties may be influenced by utilized (TiO2) nanoparticles as the observation being done by Mahfuz et al.[9]. The increment in mechanical properties by addition a different weight ratio (0.1-0.7%) of nanosized silica was reported by D. V. Pikhurov [10]. In this research sizing the nanocomposite samples (PUF/nTiO2) by unsaturated polyester (UP) and investigated the effect of ultra-violet radiation (UV) on the mechanical and chemical properties of these samples.

## 2. Experimental Work:

### 2.1 Material used:-

**1**. The matrix material (polyurethane foam (PUF)) involved in this study was composed of part A and part B. Part A consisted of polyester polyol, surfactant, blowing agentand catalyst. Part B included diphenylmethane 4, 4′-diisocyanate. Theses part A and Part B manufactured by china company.

2. TiO2 nanoparticles with a particle size 10 nm was utilized in weight percentages of (1, 3, 5 and 7%) manufactured by Wuhan Tailai Chemical Technology Development Co. Ltd.

**3.** Unsaturated polyester resin (UPS) and hardener (methyl ethyl keton peroxide) was obtained from SIR Saudi company. The weight mixing ratio of UPS resin and hardener was (1:20).

## 3. Preparation of samples:-

### 3.1 Before UV radiation:-

1-Balancing 20g of part A (PUF) resin/ part B hardener and mixing of them in mechanical stirrer. Drying of sample performed by leaving it for 1 hr. in an oven at 50 ℃.

2- Sizing the sample in step (1) by emersion it in 10g of UPS (sample 1). Then was left for 24 hours at room temperature for curing. After that, the sample was placed in an oven at 100 $^{o}$C for one hour for post-curing.

3- Repeating step (1) to prepare fours samples reinforced with different ratio of ($TiO_2$) nanoparticles involve (1,3,5 and 7 wt%).

4- Exposure each one of samples in step (3) to ultrasonic frequency for five minutes at room temperature and power of 30 W for dispersion and obtaining homogenies samples.

5- Repeating step (2) for sizing all samples in step (3).

### 3.2 After exposure to UV radiation:-

The same method for nanocomposite fabrication in section 3.1 was performed, then it exposure to UV radiation for 72 hours by discontinuous shape as in fig. (1).

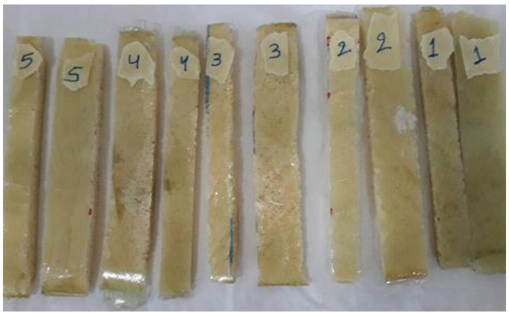

**Fig. (1): The samples utilized in this research.**

Table (1) shows the composition of samples.

**Table 1: Composition details for samples**

| Samples No. | Matrix | Titanium dioxide ($TiO_2$) (wt %) |
|---|---|---|
| 1 | PUF/ sizing by UPS | 0% |
| 2 | PUF/ sizing by UPS | 1% |
| 3 | PUF/ sizing by UPS | 3% |
| 4 | PUF/ sizing by UPS | 5% |
| 5 | PUF/ sizing by UPS | 7% |

## 4. Properties Measurement:-

### 4.1 Mechanical properties:-

#### 4.1.1 Bending test:-

The WDW-5E machine used to perform the bending strength test. The specifications of this machine are-

Load cells: 0.5 - 5 KN, crosshead speed range: 0.5 - 500 mm/min, return speed: 500 mm/min, crosshead speed accuracy: 0.1% of set speed, Testing type: bending, tension and compression.

The speed (5 mm/min) and the flexural strength (σf) was calculated from the following equation

$\sigma_f = 3PL/2bd^2$

**Where:**

$\sigma_f$: flexural strength (MPa), P: load at fracture (N), L: the distance between lower supports (mm), b and d the width and thickness of the sample (mm)

#### 4.1.2 Impact test:-

Charpy impact test involved the use of hammer blow that will be delivered to the sample until reaches to breaking point. The sample is positioned in such away that both of it's ends are fixed in position and the blow is dielvered to the middle part. Samples of impact device has a dimension of (10*55*3mm) according to ASTM (D4812). The apparatus used in this test is manufactured by (Testing Machines, Inc, Amityville New York). The following equation used to calculate the impact strength (I.S.):

**Where:**

I.S. =Uc/A

Uc: the fracture energy (Joule) from Charpy impact device.

A: the area of the samples ($m^2$) (cross-sectional).

### 4.2 Chemical resistance:-

The samples were placed in sodium chloride solution 5% (w/v) for different times ( 12, 24, 36, 48, 60, 72, 84 and 96 hours) before UV radiation and after exposure to UV radiation for 72 hour. The weight loss ratio was estimated from the following equation

Loss of weight = (W2-W1/W1) *100%

**Where:**

$W_1$: weight before emersion in salt solution (g).

$W_2$: weight after emersion in salt solution (g).

## 5. Results and Discussion:-

### 5.1 Mechanical properties:-

#### 5.1.1 Impact strength:-

Fig. (2) Shows the relationship between the weight ratio of (TiO2) nanoparticles, impact strength of samples and the effect of UV radiation on impact strength of samples. The impact strength of samples increased with increasing weight percentage of (TiO2) nanoparticles up to 3wt%. This is because the (TiO2) nanoparticles mixed dramatically with matrix materials and filled the space through the matrix materials. This lead to more consumed energy for sample failure. While the impact strength decreased after 3wt% weight ratio of (TiO2) nanoparticles because of increasing of brittleness of sample at higher weight ratio of (TiO2). On the other hands, the impact strength decreased by affecting the UV radiation. The potential reason is that the UV radiation increased crosslinking of sample which causes more brittleness [11].

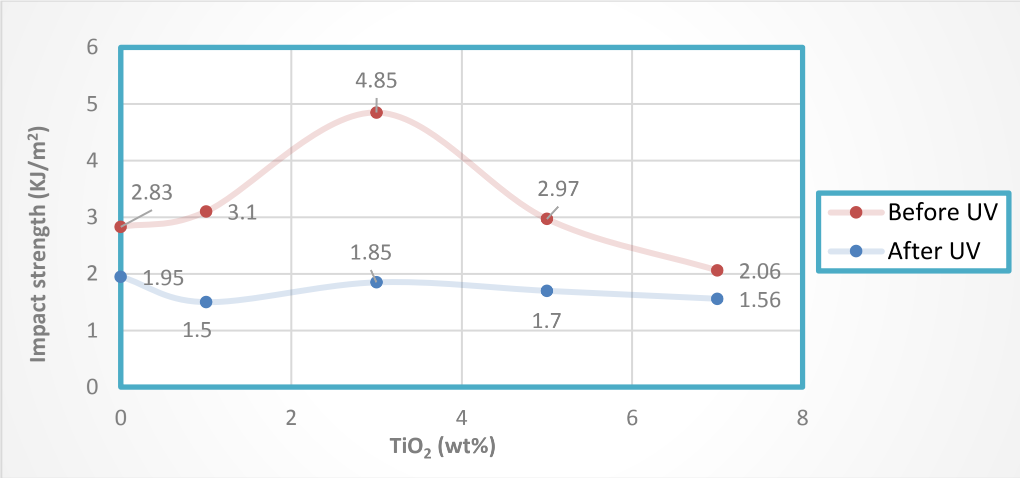


**Fig. (2): Effect of ($TiO_2$) nanoparticles and UV radiation on the impact strength**

### 5.1.2 Bending strength:-

Fig. (3) Illustrates the relationship between the weight ratio of (TiO2) nanoparticles, bending strength of samples and the effect of UV radiation on the bending strength of samples. The bending strength decreased at 1wt% (TiO2) because the low percentage from this filler work as a point defect in sample, While increasing of weight percentage of TiO2 nanoparticles causes a rising in bending strength of samples until 5wt% (TiO2) due to more interaction between matrix and filler and lead to less deflection in samples, whereas it decreased after 5% weight ratio of (TiO2) nanoparticles because increasing of brittleness of sample as a result of higher ratio of (TiO2) nanoparticles. The exposure to UV radiation could possibly decreasing the bending strength due to more crosslinking in the samples and less elasticity [11].

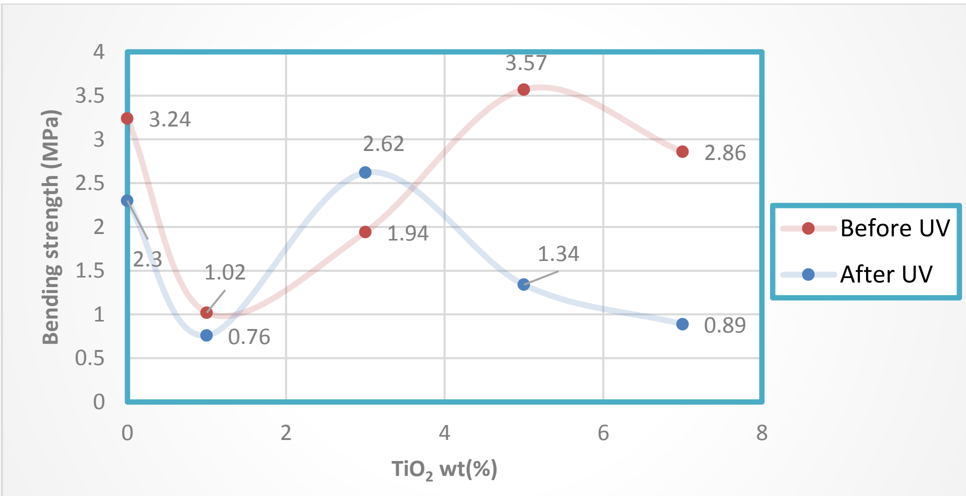


**Fig. (3): Effect of ($TiO_2$) nanoparticles and UV radiation on the bending strength.**

## 5.2 Chemical Resistance

This test was performed on all samples under different weight ratios of (TiO2) nanoparticles before UV radiation as fig. (4) and table (2) as well as after UV radiation table (3).

**Table (2): Weight loss ratio of all samples under different times of emersion in salt media before UV radiation**

| Emersion time (hr.) | $TiO_2$ (wt%) | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 3 | 5 | 7 |
| 12 | 0.023 | 0.018 | 0.005 | 0.002 | 0.009 |
| 24 | 0.055 | 0.042 | 0.012 | 0.004 | 0.025 |
| 36 | 0.053 | 0.062 | 0.019 | 0.01 | 0.035 |
| 48 | 0.052 | 0.073 | 0.033 | 0.017 | 0.05 |
| 60 | 0.041 | 0.106 | 0.017 | 0.013 | 0.054 |
| 72 | 0.046 | 0.125 | 0.014 | 0.009 | 0.058 |
| 84 | 0.071 | 0.13 | 0.006 | 0.013 | 0.066 |
| 96 | 0.093 | 0.05 | 0.005 | 0.016 | 0.069 |

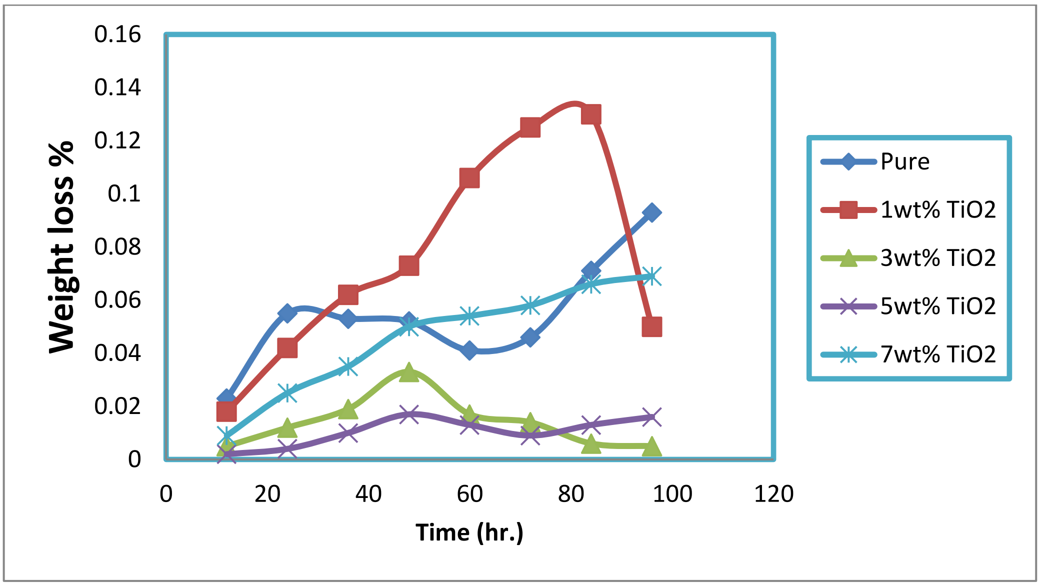


**Fig. (4): Weight loss ratio of all samples with exposure to salt media before UV radiation**

The weight loss of sample increased with increasing of exposure time of emersion in salt solution because of the progression of degradation of sample in salt media with time. The chemical resistance for the sample with 5% of ($TiO_2$) was more stable ratio than other ratios.

Fig.(5) and table (3) show the increase of weight loss of sample with increasing exposure time of emersion in salt water because the same reason in previous paragraph [12].

**Table (3): Weight loss ratio of all samples under different times of emersion in salt media after UV radiation**

| Emersion time (hr.) | $TiO_2$ (wt%) | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 3 | 5 | 7 |
| 12 | 0.017 | 0.009 | 0.001 | 0.0015 | 0.0015 |
| 24 | 0.047 | 0.034 | 0.007 | 0.0018 | 0.021 |
| 36 | 0.048 | 0.055 | 0.017 | 0.007 | 0.03 |
| 48 | 0.047 | 0.065 | 0.025 | 0.014 | 0.048 |
| 60 | 0.035 | 0.08 | 0.01 | 0.01 | 0.05 |
| 72 | 0.039 | 0.12 | 0.013 | 0.005 | 0.051 |
| 84 | 0.066 | 0.122 | 0.0055 | 0.01 | 0.063 |
| 96 | 0.087 | 0.047 | 0.0045 | 0.012 | 0.061 |

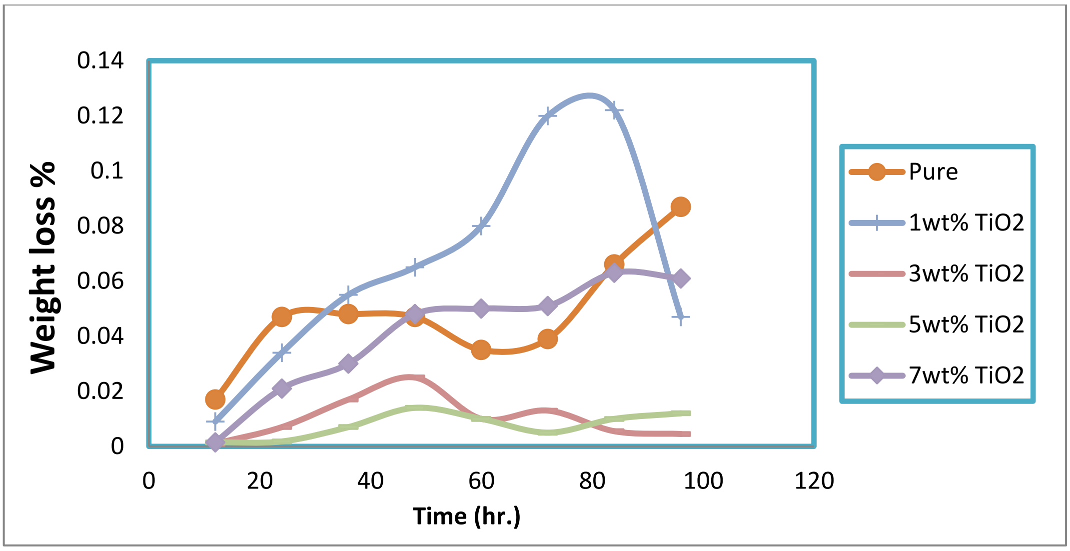


**Fig. (5): Weight loss ratio of all samples with exposure to salt media after UV radiation**

Chemical resistance was decreased with UV radiation exposure due to more crosslinking by the effect of UV radiation. 5% $TiO_2$ sample was better in terms of stability and less weight loss than other ratios.

## Conclusions:-

1- The optimum sample according to bending strength was 5% ($TiO_2$) nanoparticle.

2- In chemical resistance, 5% ($TiO_2$) nanoparticle sample was better in terms of stability and weight loss than other samples before and after exposure to UV radiation.

3- The optimum sample was 5% ($TiO_2$) nanoparticle because it has mid impact strength and optimum bending strength and chemical resistance in solid solution. This was led to success using in sandwich panel applications.

### CONFLICT OF INTERESTS.

- There are no conflicts of interest.

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# تأثير الاشعة فوق البنفسجية على الخواص الميكانيكية والكيميائية للبولي يوريثان المدعم بدقائق ثاني اوكسيد التيتانيوم النانوية المغلف بالبولي استر الغير مشبع

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**الخلاصة:**

تم في هذا البحث دراسة تاثير كل من زيادة النسبة الوزنية بدقائق ثاني اوكسيد التيتانيوم النانوية وكذلك تاثير الاشعة فوق البنفسجية على كل من الخواص الميكانيكية (مقاومة الصدمة ومقاومة الانحناء) والخواص الكيميائية المتمثلة بالمقاومة الكيميائية ضمن الوسط الملحي بتركيز 5%.

تم تحضير خمس عينات من البولي يوريثان المطلي بالبولي استر الغير مشبع والمسلح بدقائق ثاني اوكسيد التيتانيوم النانوية وبالنسب الوزنية (0، 1، 3، 5 و7) %.

اثبتت النتائج زيادة الخواص الميكانيكية بزيادة النسبة الوزنية لدقائق التيتانيوم النانوية قبل وبعد تعريضها للاشعة فوق البنفسجية اما نتائج خسارة الوزن فقد اثبتت ان أفضل نتيجة للمقاومة الكيمياوية كانت عند 5% من الدقائق النانوية.

اما نتائج الاشعة فوق البنفسجية فقد اثبتت نقصان الخواص الميكانيكية بعد التعرض للاشعة فوق البنفسجية. اما بالنسبة للمقاومة الكيمياوية فقد اثبتت النتائج ان تعرض العينات للاشعة فوق البنفسجية ادت الى نقصان الفقدان بالوزن وأدى الى استقرارية أفضل للعينات.

**كلمات الداله:** الدقائق النانوية لثاني اوكسيد التيتانيوم، رغوة البولي يورثان، الطلاء، الخواص الميكانيكية، المقاومة الكيمياوية.