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PREPARATION AND MODELLING OF COMPOSITE MATERIALS (POLYESTER-ALUMINA) AS IMPLANT IN HUMAN BODY

Zainab S. Al-khafaji
Information Technology Center, Al-Mustaqbal University College, Babylon, Iraq

Nabaa S. Radhi and Sura A. Mohson
Doctor, University of Babylon, College of Materials Engineering, Iraq

ABSTRACT

Due to spreading the composite materials in different life areas, there have been many researches dealing with composite materials. This research aims to study the possibility of manufacturing materials composite particles of Unsaturated Polyester reinforced by ceramic particles of Alumina. Unsaturated polyester resin used widely in different industries because of good mechanical and physical properties such as stability of dimensions, the ability of interaction as well easy to forming and low cost. In this research the effect of adding Alumina as a strength phase to unsaturated polyester resin has studied, in this study the unsaturated polyester resin strengthen with different percentage (2.5, 5, 10)% from Alumina has been executed and then the mechanical behaviour of prepare samples has been studied. The tests include (bending, density, water absorption, hardness and Modelling ANSYS) and the results show that composite materials have less density al 10% Al_2O_3 *which is decreased by 6%and largest result for bending which is 60% and also less water absorbing which is 0.6%. On the other hands adding* Al_2O_3 *in any ratio (2.5, 5, 10)% increase the hardness of unsaturated polyester resin as well as reduction the strain as shown in ANSYS Modelling.*

Keywords: Alumina, Absorption, ANSYS, Bending, Density test, Hardness, Unsaturated Polyester Resin.

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1. INTRODUCTION

The composite materials were appeared and using widely in many applications that improved the life quality since hundreds years ago. The later usage of composite materials indicate presence of many characteristics that suitable for many industrial applications because these materials combine the properties of two or more substances that exceed the disadvantages of each material. In addition, they have the ability to control their properties either by the type and proportions of their constituent materials or by their design and manufacturing methods, (Kereem, 2002& K. N. Kadhim and Ghufran 2016).

Therefore, the designers and engineers are focused on the effective role of engineering materials that have entered the various industrial fields. They have been manufactured by multiple and successive processes to produce the required design and construction structures that fit the functional performance as well as analysis its failure in this performance. In response to the requirements of development and renaissance Which is aimed at improving the performance of the product in terms of design and manufacturing. In structural engineering there are an attempts to form structures characterise of strength, durability and reliability in terms of their durability and resistance to corrosion (Hand book, 2002).

In 1976, Lerchenthal & Brenman used epoxy and unsaturated polyester resins reinforced with cement and inorganic materials such as kaolin and talc as fillings ranging from (85-20%) for the purpose of obtaining high resistance and light weight of materials in non-metallic structures. Hence bending resistance was calculated for different volume fractions With different types of granules. The results showed a decrease in epoxy bending resistance due to poor bonding between the overlapping phases of the material while polystyrene showed better results.

Also the Toughness of Fracture (Kc) for the composite substance granules are affected by the type and size of the added particles and the nature of bonding between the phases. Maik & Krysztafkiewicz (1981), they studied the strengthen of the materials by using particles, and concluded that the interaction of particles with Plastic material in any form leads to better results. And the particles are classified on this basis into inactive particles and active particles, and the processing of inactive particles by the bonding material becomes more effective. While Turner and Haque studied the effect of adding ceramic particles on the hardness of polymeric material. And they were concluded that adding small ratio of ceramic particles ranged (5-3%) reduce the hardness of polymeric material due to the stresses combined at the defects that caused by the addition of the particles. While the hardness is increased when the volumetric fracture is increased.

On the other hand, a group of researchers dealt with particle composite materials from another side, Sardar (2011) studied the distribution of particles in the polymeric composite material depending on the intensity of the distribution of particles and their volumetric fraction. In the conclusion he found that the mechanical properties improved when the particles were more uniformly distributed.

Marur, et.al.(2004) study the effect of the particles size and volumetric fracture on the fracture durability for the epoxy resin supported by the particles of alumina spherical which are in different particles volume. And they calculated the strength of the fracture and found that the particles size had an important effect on the fracture strength at a 5μm particles fracture size.

Many years ago, Polyester fiber used in wide variety of useful purposes as an industrial applications such as garments clothes and home furnishings like bedspreads, sheets, pillows, furniture, carpets and even curtains. While Unsaturated Polyesters which is organic material, generally the product of natural or synthetic origin with a high molecular weight and with no melting point Polyesters are used worldwide as the matrix material for reinforced composites, or RTP (reinforced thermoset plastics). Everyone is familiar with the use of this material for boats, recreational vehicles, and a wide variety of other structural applications, such as tanks and portable shelters, (Budinski and Budinski, 1999). While this research will show different usage for Unsaturated Polyesters resin after reinforced it with Alumina particles, (using of Unsaturated Polyesters resin and Alumina mixture in medical applications specially in bones repair and dental industry.

2. MATERIALS AND METHOD

2.1. Materials

2.1.1. Unsaturated Polyester Resin

Unsaturated Polyester resin (UP) was used as a base material from Saudi Arabia company SIR in the form of a viscous liquid at room temperature, a type of thermosets (1200Kg / m3) (MEKP) (Methyl- Ethyl Keton Peroxide) in the form of a transparent liquid and added to the polysaccharide resin saturated with 2gm of crucified per 100gm of polystyrene resin Unsaturated at room temperature. The durat ion of hardening of the resin used is 3 hours at room temperature, but this period varies according to the amount of added sulphate and laboratory conditions surrounding the experiment.

Table 1 Some properties of unsaturated polysaccharide resin (Rabab, 2009).

Density (kg/m^3)	Thermal conductivity ($W/m.^oC$)	Tensile strength (MPa.)	Coefficient of elasticity (GPa.)	The durability of the fracture ($MPa.m^{0.5}$)
1200	0.17	70.3 -103	2.06 – 4.41	0.6

2.1.2. Aluminium Oxide AL_2O_3

Alumina is considered an inorganic Insulators and Alumina primary source is kaolin feldspar and clays. Alumina is characterized by high resistance to high temperatures and maintains this resistance over to 1200° C. It is also gives high hardness (4-2) times the hardness of Tungsten carbide or Zirconium and is highly resistant to abrasion and chemical attack, Table 2 shows some properties of physical alumina., (Auerkari, 1996).

Table 2 Some physical properties of alumina, (Auerkari, 1996).

Property	Fusion temperature (c*)	Density (g/cm^3)	Molecular weight	Expansion ($*10^{-6}/c*$)
Value	2040	3098	102	0.063

2.2. Sample Preparation

The manufacturing methods for composite materials are numerous and each one has advantages and disadvantages, as well as each method apply in the appropriate field. In this research the manual method had been used to prepare and pour the samples which could summarised in the following steps:

1. Weight a quantity of unsaturated polystyrene which should be weighed according to the size of the mould and then(0.5%) of the catalyst with (2%) of the hardened materials added to the mixture.

2. Weighting the required amount of strengthen material (Alumina powder Al_2O_3) depending on the required proportion of reinforcement (2.5, 5 & 10)%.
3. Then mixing the base and the strengthen materials together along with the catalyst and the hardened materials at the room temperature. And the mixing process should be slowly to avoid bubbles and continuously for 10 minutes until homogenized the mixture and raise the temperature of the mixture which refers to start the reaction process. The mixture must have a specific operation viscosity to prevent and protect particles against deposition.
4. The liquid mixture poured as a stream form from one side of the glass mould which shown in Figure 2. To prevent production of air bubbles in sample mass which causes failure). So casting process should be flow continuously and regularly into all mould areas until the mould is filled to the desired level for this reason the mould must be completely flat.
5. Then leaving the mixture at the mould for 24 hr. to get hardness in whole sample which then dried at the oven for one hour and at a temperature of 70° C. And this process is important to complete the polymerization and obtain the best tangle and to remove the stresses that generated during the manufacturing process.
6. To perform the tests, the samples should be cut according to the specifications of each experiment by using a strip saw with very smooth teeth to ensure that no vibration during cutting the sample and the smoothness of the teeth of the saw will avoid the distortions that may occur during cutting. While using the casing machine for adjusting the dimensions of the sample and the polishing process is done by using polishing sheets with 400 degrees.

Polymer samples that used in the experimental part prepared by using Unsaturated Polyester alone, and other samples of prepared from unsaturated polyester with Alumina powder in three proportions (2.5, 5 & 10%) for each ratio there were three sample for each test to obtain high accuracy in results.

Figure 2 The Casting Mould.

2.3. Experimental Work

The experiments as following:

2.3.1. Bending Strength

According to American standard (ASTM D-790) the test was carried out and the dimensions of the sample was (4.8 × 13 × 191) mm as shown in Figure 3, (ASTM Standard)

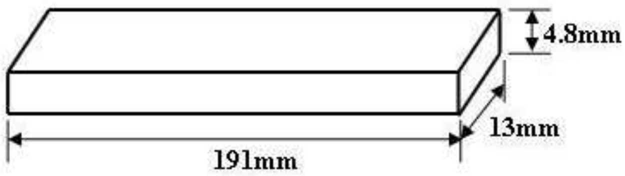

Figure 3 A sketch of bending resistance sample.

2.3.2. Density Test

According to American standard (ASTM-D792) the test was carried out on samples consist of unsaturated polystyrene reinforced with different Alumina powder (Al_2O_3) proportions (2.5, 5 & 10)%. Firstly, the dry samples weighted and then immersed in a graduated glass flask filled with distilled water Then apply the following equation:

$$Specific\ gravity\ S.G = Wd/Wd - Wi \qquad (1)$$

Where:

Wd: the dry weight of the sample in grams; Wi: the weight of the sample is suspended and immersed in distilled water in grams.

Specific gravity S.G can be converted to a density by multiply a specific gravity (S.G) by the density of distilled water which equal to (0.9975), (ASTM Standard).

2.3.3. Water Absorption Test

According to American standard (ASTM-D570) the test was carried out on samples consist of unsaturated polystyrene reinforced with different Alumina powder (Al2O3) proportions (0, 2.5, 5 & 10)% and then the sample placed in glass flask filled with water at room temperature (25 ± 2). The weights of the samples was calculated before and after immersion in water every 24 hours and the process of extracting, drying, weighting and then returned the sample to the water was continued for four days. And the absorption ratio for each sample can be calculated by using the following formula (Al-Kadi, 2004):

$$\text{Water Absorption\%} = (Ws-Wd) / Wd * 100 \qquad (2)$$

where:

Wd: The dry weight of the sample.

Ws: sample weight after immersion in distilled water at room temperature for 24 hours.

2.3.4. Modelling

The ANSYS program is one of the most powerful internationally recognized in the field of advanced studies and researches. The program began marketing in 1970 and is now used all over the world in the fields of civil engineering, space science, self-propulsion, industry, nuclear research, energy services, electrical engineering and electronics. In addition, many consulting companies and hundreds of advanced universities in the world use the program for education, research and interpretation of phenomena, (Samer, 2009).

In the current research, ANSYS version 15 and Element 10 of Node 187 were used while the materials properties which used in the research were as shown in Table 5.

The Young modulus and density properties of the materials used were theoretically calculated based on the rule of mixture (Jones, 1975 & Bolten, 1998).

Table 5 The Young modulus and density properties of the materials, (Jones, 1975 & Bolten, 1998).

Samples Proportions	**0% (Al_2O_3) + 100% (PE)**	**2.5% (Al_2O_3)+ 97.5% (PE)**	**5% (Al_2O_3)+ 95% (PE)**	**10% (Al_2O_3) + 90% (PE)**
Young modulus (Gpa)	4.41	13.67	22.93	41.47
Density(kg/m^3)	1200	1270	1339	1478

3. RESULTS AND DISCUSSION

3.1. Bending strength test

The bending properties usually depend on the nature of the bonds between the fillers (strengthen materials) and the base material as shown in Figure 4 which shows the relationship between the bending resistance and the volumetric fracture proportion (0, 2.5, 5 & 10)% (Alumina ratios that added to Polyester). Figure 4 shows that increasing in bending resistance when the Alumina ratio increased and the maximum stress had been gotten a 10% Alumina (Al_2O_3) ratio due to the nature of the ceramic material (the reinforcing phase) which is characterized by its strength and its good mechanical properties compared to the base phase. Where the reinforcement phase plays a major role in restricting and preventing the continuation of sliding Polyester strings as well known, these strings need a great effort to bend to be able to pass through the narrow spaces between the reinforcement particles **(Joyce and Bronzino, 2007)**.

3.2. Density test

Figure 5 shows the relationship between the density of the samples and the amount of alumina (Al_2O_3) that used to strengthen them. Figure 5 shows a positive relation between the density of the samples and (Al_2O_3) ratio because Al_2O_3 density is 3.98 g/cm^3 while the density of unsaturated Polyester is 1.2 g/cm^3 and any (Al_2O_3) ratio will increase the whole density of the composite materials samples. This increasing because the density as known is equal to (mass/volume) and the volume is constant for all samples so the increasing in the mass will lead to increasing the density depending on the following formula:

$$\rho_c = \rho_m * v_m + \rho_r * v_r \quad (3)$$

whereas:

ρr: the density of the reinforced phase with (Al_2O_3), ρm: the density of the base phase (Polyester), ρc: density of composite material in g/cm3.

Vr: volumetric fraction for the reinforced phase, Vm: the volumetric fraction for the base phase.

3.3. Water Absorption Test

Figure 6 shows the relationship between the water absorption percentage and the ratio of additive reinforcement materials (Al_2O_3) that added to unsaturated polyester. The proportion of absorbance is affected by the particles size and surface area of the reinforcement particles (Aziz, 2009). As notice from Figure6 the relationship between weight of the samples with the duration of water immersion in days is positive relation which conclude that with the increase the immersion period the absorption percentage will increase. And this result is expected because the base phase is a polymeric material which is unsaturated, that means it has the ability to absorb water. However; with the increase of the amount of the reinforcement materials will notice a significant decrease in the percentage of absorption for the same testing time. So, the 10% of (Al_2O_3) has the lowest absorption rate and this is due to adding a reinforcement phase, which is a ceramic material with stable physical properties.

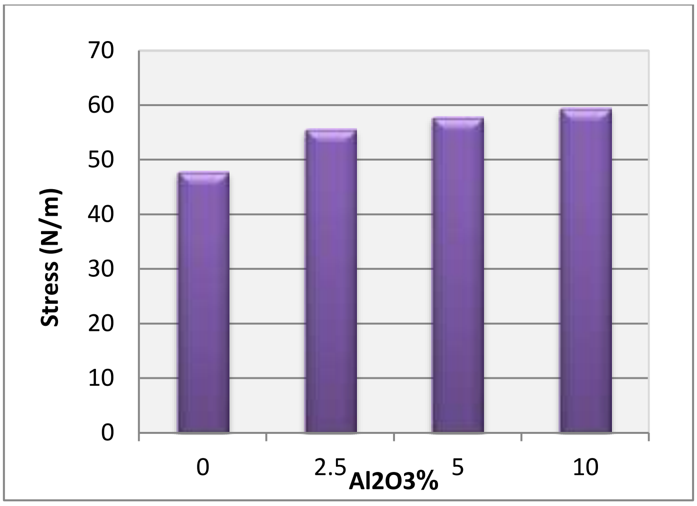

Figure 4 The relationship between the required stress for bending and the proportion of Al_2O_3.

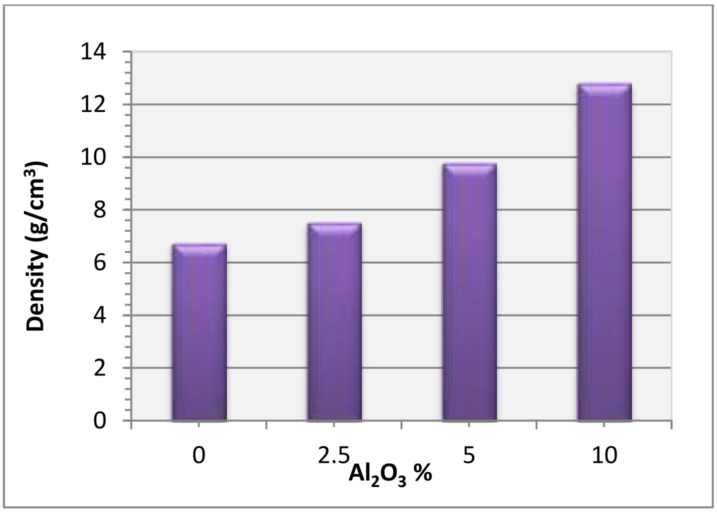

Figure 5 The relationship between density and the proportion of Al_2O_3.

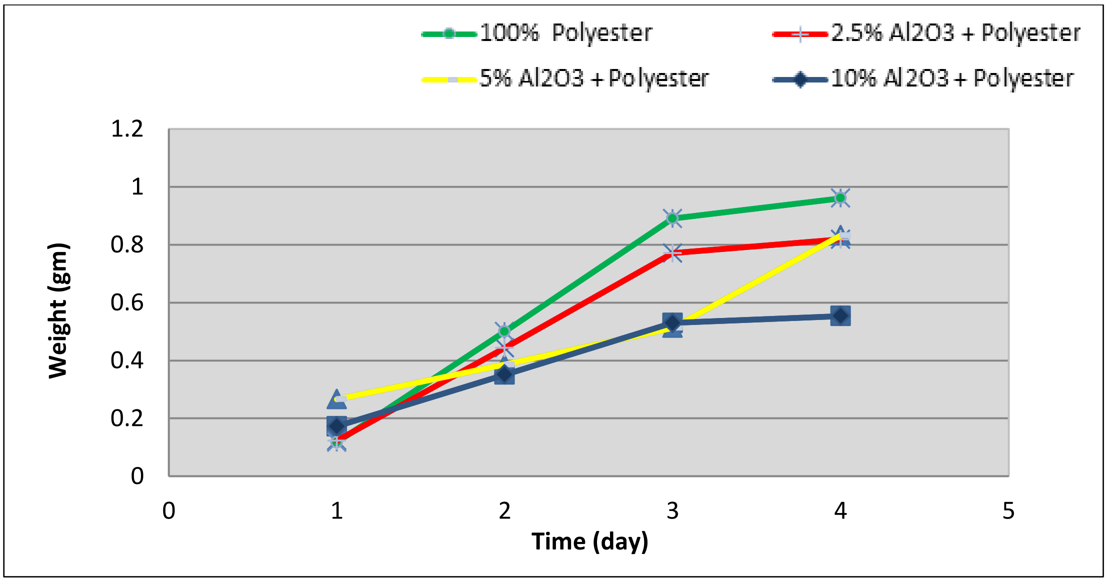

Figure 6 Absorption test

3.4. Modelling (ANSYS)

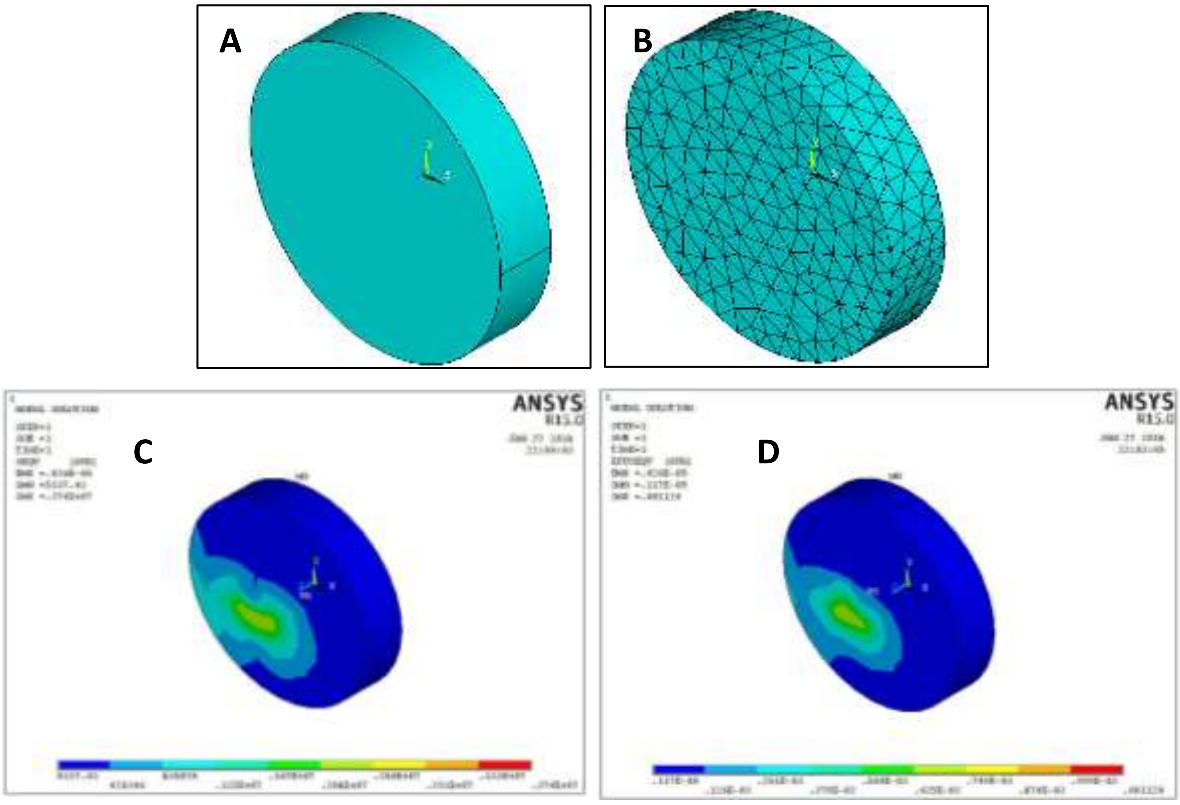

Figure 7 A poly-ester model without reinforcement (A)Model created by using the ANSYS program, B) Make a mesh for the model, (C) Calculate the stress, (D) Calculate the strain.

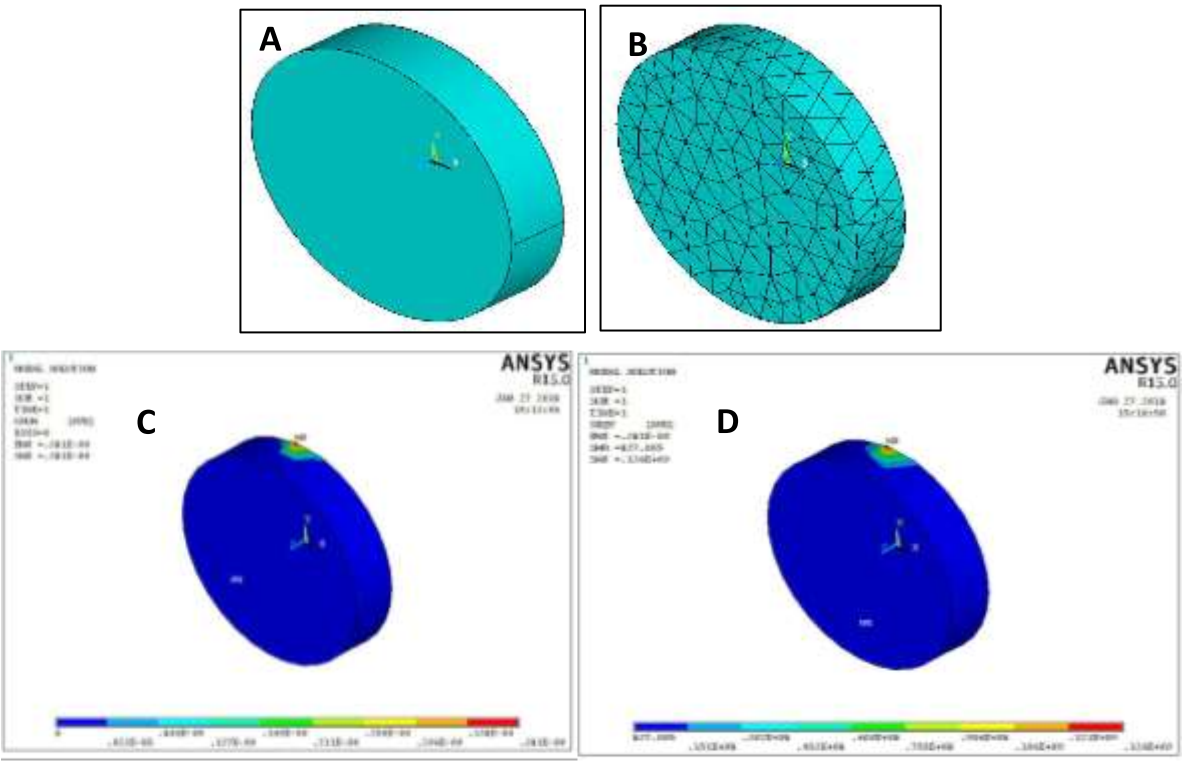

Figure 8 A reinforced polystyrene model with 2.5% Al_2O_3 (A) Model created by using the ANSYS program, B) Make a mesh for the model, (C) Calculate the stress, (D) Calculate the strain.

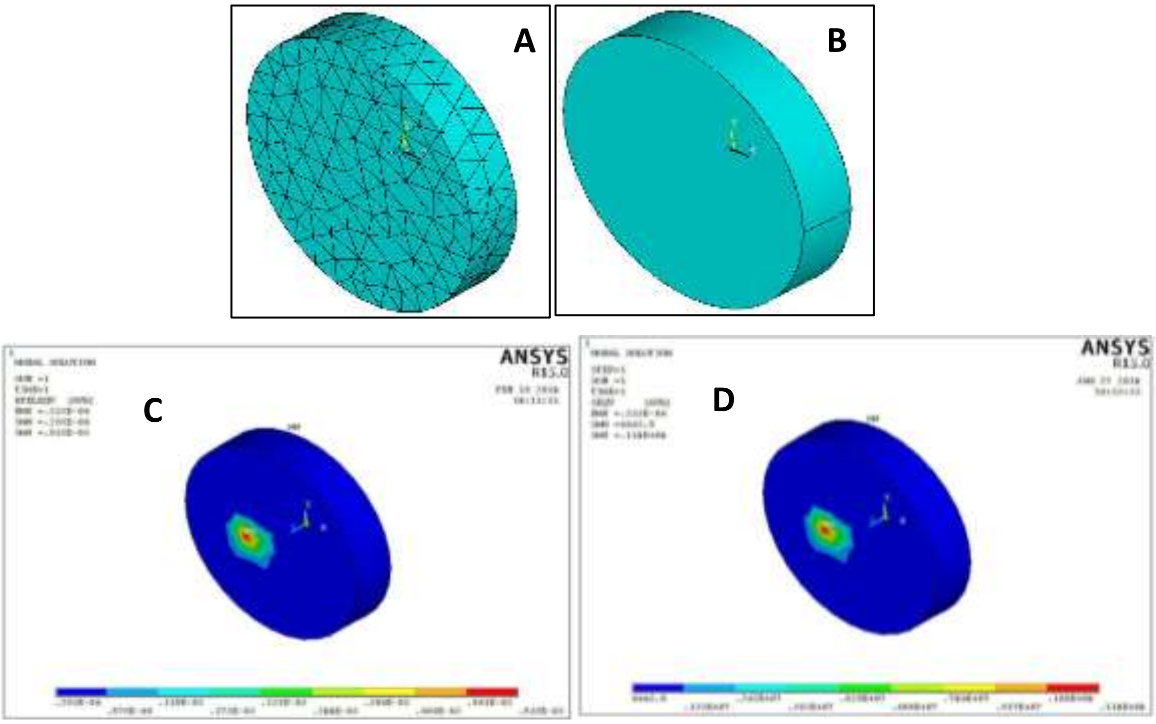

Figure 9 A reinforced polystyrene model with 5% Al_2O_3 (A)Model created by using the ANSYS program, B) Make a mesh for the model, (C) Calculate the stress, (D) Calculate the strain.

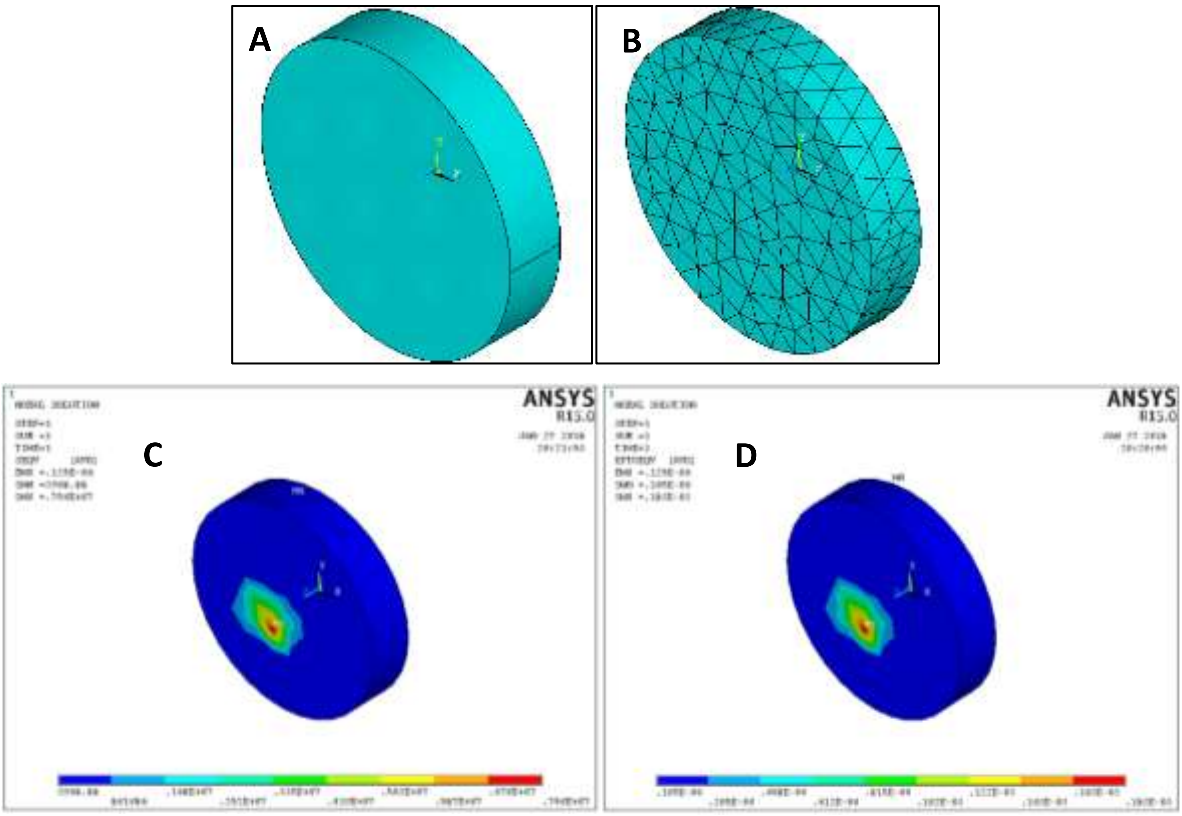

Figure 10 A reinforced polystyrene model with 10% Al_2O_3 (A)Model created by using the ANSYS program, B) Make a mesh for the model, (C) Calculate the stress, (D) Calculate the strain.

4. CONCLUSION:

This work included the improvement of the unsaturated polyester resin by alumina filler particles, with different volume fractions of filler particles. Also, some of mechanical properties and water absorption percentage, which the conclusions are as follows:

1. The improvement of the unsaturated polyester resin by alumina filler particles leads to an increase in the blending strength, hardness and density as the volume fraction of the filler particles increases until it reaches a maximum value of (10%), of prepared composite material.
2. Water absorption percentage of the prepared composite materials decreases with Increasing volume fraction of alumina filler particles.
3. The maximum Von Misses stresses are found in the prepared composite materials and the positive value of residual stresses at 500N for PE=3.74 MPa,10% Al_2O_3=2.54Mpa, 2.5% Al_2O_3=1.36Mpa, 5% Al_2O_3=1.1Mpa.
4. The maximum Von Misses strains are concentrated in the prepared composite materials and the positive value of strain at 500N for PE=0,001124,5% Al_2O_3=0.519e-3, 10% Al_2O_3=0.103e-3, 2.5% Al_2O_3=0.310e-4.

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