Effect of water on impact strength of RTV silicon rubber / Thermosets blend reinforced with nanoparticles

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Abstract: Binary and ternary blends of epoxy resin (EP) and unsaturated polyester (UPE) with different weight fractions (0, 3, 5, 7, 10 and 20%) percentages of RTV silicone rubber (SR) were prepared by two different methods. Before that the silicone rubber (SR) was mixed well with sufficient amount of ethanol in one method, and without ethanol in the other method. It was found that the binary and ternary blends specimens that prepared with ethanol was chosen as the best samples have the highest experimental results of impact strength and a good homogeneous dispersion of silicon rubber in the resins as compared with the blends samples that prepared (without ethanol), which were selected to evaluate the lower mixing ratio (LMR) of these blends. The blends with (LMR) were selected and they are going to be considered as a matrix for the nano composite material to be reinforced by Al with 1% wt, and Al2O3 with 1% wt nanoparticles to develop the properties of (LMR) blends. Impact test was carried out on the blends with (LMR) and their nanocomposites at different environmental conditions before and after immersion in water for 4 weeks. Also hardness (shore D) test was carried out on the blends with (LMR) and their nanocomposites. The best results of this study before imarson in water were achieved with the nanocomposite material consisting of (LMR) binary blend reinforced with Al and (LMR) binary blend reinforced with Al2O3 nanoparticles. The results showed that after immersion period of 4 weeks, a decrease in the values of impact strength was observed for the samples of (LMR) binary and ternary blends without reinforcement. It also can be noted that impact strength was increased for the binary blends reinforcement with Al and Al2O3 nano particles after 4 weeks of immersion in water. Whereas it can be seen that ternary blends reinforcement with Al and Al2O3 nano particles would not achieve similar enhanced in impact strength as that of binary blends reinforcement with Al and Al2O3 nano particles after immersion in water.

Keywords: Polymer blends, Nano Composites, Lower mixing ratio, RTV silicon rubber, Mechanical properties.

1. Introduction
Polymers have recently been used more frequently as blends and composites, resulting in good technological qualities of each of the components. Polymer blend processing has emerged as an inexpensive and versatile route to control the micro structural characteristics of polymers and enhance
their properties [1–3]. Epoxy resins are one of the most important thermosetting polymers and have multiple uses as structural adhesives and matrix resins for fiber composites due to their high modulus and thermal stability. However, the highly cross linked nature of cured epoxy produces an undesirable characteristic, that is, cured epoxies are brittle and show poor resistance to crack growth [4, 5]. Also epoxy resin have low impact resistance, so less is used in applications requiring high impact strength. To enhance their toughness, the modification of epoxy systems by adding an unsaturated polyester (UPE) to epoxy to form polymer blends has proven to be beneficial to the overall properties of the prepared composite, especially the impact strength, in an attempt to manufacture high performance composites [6].

On the other side, many studies have been associated with the modified epoxy resin RTV silicone rubber with the aim to improve thermal stability, flexibility, water resistance, flame retardance, and to achieve important other properties. RTV silicone rubber is one type of elastomer that is rated capable of improving impact strength of thermostet epoxy. Additionally, sealant RTV (Room Temperature Vulcanizing) is a liquid form of adhesive. Typically, it looks, feels, and acts like a gel. RTV silicone rubber is also one type of elastomer which have glass transition temperature, Tg, which is very low, have high elastic properties, hydrophobic properties, as well as good resistance to thermal and oxides [7]. Good combination between an epoxy resin and RTV silicone rubber for applications requiring high impact strength is very promising. Therefore, we wanted to evaluate the mechanical properties of the mix between epoxy resin and RTV silicone rubber that can be applied. There are numerous numbers of previous studies related to RTV silicon rubber / thermoset blends and their nano composites for examples:

Rana Mahdi Salih, Prepared (epoxy/polyester) blends in different percentages (starting from 90:10) and ending with (50:50) of (epoxy/polyester) respectively. The optimum mixing ratio (OMR) of the components which had the highest value of impact strength, was chosen to be reinforced with three different weight fractions of (TiO2 and SiO2) reinforcement. The tested mechanical properties were flexural strength, impact strength, hardness, and water uptake and all the results were discussed[8].

Fahriadi Pakaya, et. al. Analyze effect of RTV silicone rubber composition (0, 5, 10, 15, 20) wt% of the mechanical properties and thermal stability of thermostet epoxy. Testing and characterization conducted on thermostet epoxy by the addition of RTV silicone rubber. In addition RTV silicone rubber: tensile strength, elongation at break and hardness has decreased, energy and impact strength increased maximum on the addition of 15% RTV silicone rubber respectively 0.294 J and 6175 J/m². The maximum degradation of temperature increase in the addition of 15% RTV silicone rubber is 328 and 349o C respectively at 5 and 10% degradation[9].

The aim of this research is to develop the properties of thermosets resins (Epoxy, polyester) by mixing them with different ratios of elastomer (sealant RTV silicon rubber with and without acetone) to create binary and ternary polymer blends to increase their toughness and impact strength in particular and to enhance the mechanical properties in general. Determining the lower mixing ratio (LMR) between the resin and the elastomer at which, the lowest value of the impact strength is obtained. Then reinforcing the blends, that have the (LMR) by Al 1% wt and Al2O3 1% wt nanoparticles to achieve the best mechanical properties before and after immersion in water.

2. Experimental Procedure

2.1. Materials

Unsaturated polyester resin (UPE) is a liquid with moderate viscosity which can be cured to the solid state by adding (Methyle Ethyle Keton Peroxide, MEKP) as a hardener, while cobalt octoate acts as a catalyst to accelerate the solidification process. Epoxy resin (EP) (Sikadur-52) is a two component, solvent-free, low viscosity injection-liquid, based on high strength epoxy resins. Complies with ASTM
C881-78 Type I, Grade 1 Class B+C. Mix ratio, (A) : (B) = 2 : 1 parts by volume and weight. SUPERMAX universal silicon sealant RTV (Room Temperature Vulcanizing) made in U.A.E. was used in this research, it is a liquid form of adhesive. Typically, it looks, feels, and acts like a gel. It has a different chemical make-up from other organic polymer-based adhesives. Silicone sealant is also one type of elastomer which have glass transition temperature, Tg, which is very low, have high elastic properties, hydrophobic properties, as well as good resistance to thermal and oxides.

2.2. Reinforcement Materials
Aluminum Oxide (Al₂O₃) nanoparticles (Alpha-Al₂O₃, 99.0%) purchased from Sky spring nanomaterials, Inc. USA, with average diameter of 40 nm, appearance: White Powder, a specific surface area of 60m²/g. Al Aluminum (Al) nanopowder (Purity: 99.0%) purchased from Hongwu International Group Ltd USA, with average diameter of 40 nm, appearance: Black Powder, a specific surface area of ~60m²/g.

2.3. Material Preparation

2.3.1. Mould Preparation
All the required test specimens were prepared by Teflon mould via cast molding method as shown in figure 1.

Figure 1. Shows Teflon mould used to prepare composite specimen.

2.3.2. Method of Preparation
Hand lay-up technique was used to prepare all the specimens, and the process involves two groups of specimens. All of them consist of binary blends of EP/SR and UPE/SR with different weight fractions (0, 3, 5, 7, 10 and 20%) percentages of silicone rubber (SR) and ternary blends of EP/UPE/SR and UPE/EP/SR with different weight fractions (0, 3, 5, 7, 10 and 20%) percentages of (UPE, SR) and (EP, SR) respectively. Before that the silicone rubber (SR) was mixed well with sufficient amount of ethanol in one group of the specimens, as shown in table 1, and without ethanol in the other group of specimens, as shown in table 2. It was found that the one group of the binary and ternary blends specimens with ethanol was chosen as the best specimens have the highest experimental results of impact strength and a good homogeneous dispersion of silicon rubber in the
resins as compared with the blends samples that prepared (without ethanol), which were selected to
evaluate the lower mixing ratio LMR of these blends. Six lower mixing ratios LMR of binary and
ternary blends were selected and they are going to be considered as a matrix for the nano composite
material to be reinforced by Al with 1% wt, and Al2O3 with 1% wt nanoparticles to develop the
properties of blends. The liquid mixture was vacuumed from bubbles for 30 min and cured at 50°C
for 3hrs, then left at room temperature for 24 hours in the mould. After that the blends were removed
from the Teflon moulds and cured further at temperature 70°C for (4) hours in an oven to treatment.

Table 1. The effect of silicon rubber content (wt %) on the (I.S) of binary and ternary blends
(with ethanol).

| Group Code | Blend No. | Material Concentration (wt) % | Description |
|------------|-----------|-------------------------------|-------------|
|            | SR%       | EP%                       |             |
| A Binary blend (EP/SR) | 1A | 0 | 100 | success |
|            | 2A | 3 | 97 | success |
|            | 3A | 5 | 95 | success |
|            | 4A | 7 | 93 | success |
|            | 5A | 10 | 90 | success |
|            | 6A | 20 | 80 | success |
|            | SR%       | UPE%                       |             |
| B Binary blend (UPE/SR) | 1B | 0 | 100 | success |
|            | 2B | 3 | 97 | success |
|            | 3B | 5 | 95 | success |
|            | 4B | 7 | 93 | success |
|            | 5B | 10 | 90 | success |
|            | 6B | 20 | 80 | success |
|            | SR%       | UPE% | EP% | Description |
| C Ternary blend (EP/UPE+SR) | 1C | 0 | 0 | 100 | success |
|            | 2C | 3 | 3 | 94 | success |
|            | 3C | 5 | 5 | 90 | success |
|            | 4C | 7 | 7 | 86 | success |
|            | 5C | 10 | 10 | 80 | success |
|            | 6C | 20 | 20 | 60 | success |
|            | SR%       | EP% | UPE% | Description |
| D Ternary blend (UPE/EP+SR) | 1D | 0 | 0 | 100 | success |
|            | 2D | 3 | 3 | 94 | Failure |
|            | 3D | 5 | 5 | 90 | Failure |
|            | 4D | 7 | 7 | 86 | Failure |
|            | 5D | 10 | 10 | 80 | Failure |
|            | 6D | 20 | 20 | 60 | Failure |
Table 2. The effect of silicon rubber content (wt %) on the (I.S) of binary and ternary blends (without ethanol).

| Group Code | Blend No. | Material Concentration (wt) % | Description |
|------------|-----------|-------------------------------|-------------|
| a          | 1a        | 0 100                         | success     |
| Binary blend (EP/SR) | 2a | 3 97  | success     |
|            | 3a        | 5 95                          | success     |
|            | 4a        | 7 93                          | success     |
|            | 5a        | 10 90                         | success     |
|            | 6a        | 20 80                         | success     |
| b          | 1b        | 0 100                         | success     |
| Binary blend (UPE/SR) | 2b | 3 97  | success     |
|            | 3b        | 5 95                          | success     |
|            | 4b        | 7 93                          | success     |
|            | 5b        | 10 90                         | success     |
|            | 6b        | 20 80                         | success     |
| c          | 1c        | 0 0 100                       | success     |
| Ternary blend (PE/UPE+SR) | 2c | 3 3  | Failure     |
|            | 3c        | 5 5 90                        | Failure     |
|            | 4c        | 7 7 86                        | Failure     |
|            | 5c        | 10 10 80                     | Failure     |
|            | 6c        | 20 20 60                     | Failure     |
| d          | 1d        | 0 0 100                       | success     |
| Ternary blend (UPE/EP+SR) | 2d | 3 3  | Failure     |
|            | 3d        | 5 5 90                        | Failure     |
|            | 4d        | 7 7 86                        | Failure     |
|            | 5d        | 10 10 80                     | Failure     |
|            | 6d        | 20 20 60                     | Failure     |

3. Measurements

3.1. Impact test

Charpy impact test involve the use of hammer blow that will be delivered to the sample until reaches to breaking point. The sample is positioned in such a way that both of its ends are fixed in position and the blow is delivered to the middle part. Samples of impact device has a dimensions of (10*55*10mm)according to ASTM (D4812). Figure1.shows the impact test specimens to carry the test.. The apparatus used in this test is manufactured by (Testing Machines, Inc , Amityville New York). The following equation can be used to calculate the impact strength (I.S.):[10]

\[ I.S. = U/A \quad \text{(1)} \]

Where I.S. is the impact strength (J/m²), U is the energy of fracture (J), and A is the surface area of fracture (m²). The test was carried out on the samples before and after immersion in water for one month.
4. Results and discussion

4.1. Impact Test

The charpy impact test is used to evaluate the impact strength of the binary and ternary blends that have (0, 3, 5, 7, 10 and 20)% of silicon rubber SR (with and without ethanol) in either of EP and UPE. The effect of rubber content on the impact strength values of the prepared blends with and without ethanol are shown in table 1 and table 2 respectively. It can be noted that the binary and ternary blends samples that prepared with ethanol have a highest impact strengths and a good homogeneous dispersion of silicon rubber in the resins as compared with the blends samples that prepared without ethanol.

The method of addition silicone rubber SR that was mixed well with sufficient amount of ethanol to EP and UPE is the right method to gain free movement for the chains to absorb as much energy as possible which means that interference between EP and SR leads to improvement of the compatibility between the two polymers EP and SR. It is clearly that the increase in impact strength due to additions silicone rubber causes the formation of second-phase that prevents cracking and inhibiting the growth of cracks. Basically elastomer is a material with high impact strength because it is very flexible. Silicone rubber elastomers able to withstand dynamic loads that given quickly and absorbs the energy derived from the kinetic energy of the dynamic loads. But addition of silicone rubber in the thermoset epoxy and polyester and maximum time of adding 20wt% silicone rubber will then decrease the impact properties of both the impact energy and strength of the material. This is because more and more silicone rubber that mixed, then the space for epoxy or polyester to react and to form cross link network more difficult.

In some journals also mentioned that addition silicone rubber have elastic properties that can increase the vibration of the atoms becomes larger. Vibration of atoms leads to easier movement of atoms in the material. The greater the vibrations of the atoms, the greater the energy and impact strength of the material. This explanation is in agreement with literature[11].

Impact strength of (thermoset/elastomer) blend is higher than that of brittle matrix itself, which implies the positive role of elastomer on the impact fracture toughness of brittle materials. Also Table 3 shows that the impact strength of binary blends EP/SR can be maximized to almost (15.5) KJ/m$^2$ on addition of (5) wt% of silicon rubber. While the impact strength of binary blends UPE/SR could be maximized to almost (11.67) KJ/m$^2$ on addition of about (10%) of silicon rubber. Whereas the impact strength of ternary blends EP/UPE/SR could be maximized to almost (15.22) KJ/m$^2$ on addition of about (5%) of silicon rubber. If the percentage of elastomer in the brittle matrix increased to more than the above-mentioned percentages, the impact strength would decrease to lower values.

This indicates that the impact strength of binary and ternary blends is not simply an additive, and its dependence on blend composition reveals the influence of blend morphology, state of dispersion and any other structural parameter on impact toughening of this blend. Occurrence of a maximum in the impact strength at a particular blend composition may be attributed to the critical size and geometry of dispersed phase domains.
Table 3. The effect of silicon rubber content (wt %) on the (I.S) of binary and ternary blends (with ethanol).

| Group Code | Blend No. | Material Concentration (wt %) | Impact Strength (I.S), KJ/m² |
|------------|-----------|-------------------------------|-----------------------------|
|            |           | SR%  | EP%                                |                             |
| Binary blend (EP/SR) |          |       |                                   |                             |
| A          | 1A        | 0    | 100                               | 9.99                        |
|            | 2A        | 3    | 97                                | 11.23                       |
|            | 3A        | 5    | 95                                | 15.5                        |
|            | 4A        | 7    | 93                                | 7.22                        |
|            | 5A        | 10   | 90                                | 7.22                        |
|            | 6A        | 20   | 80                                | 9.59                        |
|            | Binary blend (UPE/SR) |     |     |                                        |
| B          | 1B        | 0    | 100                               | 7.61                        |
|            | 2B        | 3    | 97                                | 5.88                        |
|            | 3B        | 5    | 95                                | 10.16                       |
|            | 4B        | 7    | 93                                | 8.45                        |
|            | 5B        | 10   | 90                                | 11.67                       |
|            | 6B        | 20   | 80                                | 8.79                        |
|            | Ternary blend (EP/UPE/SR) |     |     |                                        |
| C          | 1C        | 0    | 0                                 | 9.99                        |
|            | 2C        | 3    | 3                                 | 13.94                       |
|            | 3C        | 5    | 5                                 | 15.22                       |
|            | 4C        | 7    | 7                                 | 14.22                       |
|            | 5C        | 10   | 10                                | 13.95                       |
|            | 6C        | 20   | 20                                | 6.97                        |

Table 4. The effect of silicon rubber content (wt %) on the (I.S) of binary and ternary blends (without ethanol).

| Group Code | Blend No. | Material Concentration (wt %) | Impact Strength (I.S), KJ/m² |
|------------|-----------|-------------------------------|-----------------------------|
|            |           | SR%  | EP%                                |                             |
| Binary blend (EP/SR) |          |       |                                   |                             |
| a          | 1a        | 0    | 100                               | 9.99                        |
|            | 2a        | 3    | 97                                | 6.16                        |
|            | 3a        | 5    | 95                                | 8.4                         |
|            | 4a        | 7    | 93                                | 6.07                        |
|            | 5a        | 10   | 90                                | 8.13                        |
|            | 6a        | 20   | 80                                | 6.4                         |
|            | Binary blend (UPE/SR) |     |     |                                        |
| b          | 1b        | 0    | 100                               | 7.61                        |
|            | 2b        | 3    | 97                                | 5.13                        |
|            | 3b        | 5    | 95                                | 11.91                       |
|            | 4b        | 7    | 93                                | 5.71                        |
|            | 5b        | 10   | 90                                | 8.65                        |
|            | 6b        | 20   | 80                                | 6.2                         |
From the results in table 3 six lower mixing ratios LMR of SR in EP and UPE resins are chosen. The (LMR) are (7%SR and 20%SR) in EP and (3%SR and 7%SR) in UPE for binary blends and (5%SR&UPE) and (20%SR&UPE) in EP for ternary blends. The binary and ternary blends with (LMR) are presented in Table 5, and they are going to be considered as a basis for further investigation.

Table 5. The Lower Mixing Ratios (LMR) of SR in EP and UPE resins.

| Sample No. | Blend            | Lower Mixing Ratios (LMR)   |
|-----------|------------------|-----------------------------|
| 4A        | EP/SR (EP 93% + SR 7%) |                             |
| 6A        | EP/SR (EP 80% + SR 20%) |                             |
| 2B        | UPE/SR (UPE 97% + SR 3%) |                             |
| 4B        | UPE/SR (UPE 93% + SR 7%) |                             |
| 2C        | EP/UPE/SR (EP 90% + UPE 5% + SR 5%) |                     |
| 6C        | EP/UPE/SR (EP 60% + UPE 20% + SR 20%) |                     |

The best results of this study under L.C. were achieved with the nanocomposite material consisting of binary blend reinforced with Al and binary blend reinforced with Al₂O₃ nanoparticles. So the impact strength of the binary blends 4A (7% SR), 6A (20% SR) and 2B(20% SR) reinforced by Al or Al₂O₃ nanoparticles have a highest value as compared with pure binary blends. But the impact strength of the reinforced binary blends 4B (5% SR) has a lowest value as compared with pure binary blends as shown in figure 2. When the blend is reinforced, the energy required to break the reinforced samples increases because the reinforcements store most elastic strain energy in the polymeric composite. Also the Al₂O₃ nanoparticles form obstacles to the fracture to grow, which results in an increase in the toughness of the material.

Also it can be noted that the impact strength of the ternary blend 6C (20% SR& UPE) reinforced by Al or Al₂O₃ nanoparticles has a highest value as compared with pure ternary blend which implies the presence of nanoparticles dispersed within the matrix makes plastic deformation easier. Therefore, during the fracture of a composite in which the nanoparticle is well dispersed, the stress will have to be bigger to start the micro crack in the blend, and the impact energy will largely be absorbed by the exhibited plastic deformation, which occurs more easily around the nanoparticles. Hence, the good nanoparticles dispersion resulting in less agglomeration leads to a better impact strength of the nanocomposites. While the impact strength of the ternary blend 2C (5% SR&UPE) reinforced by Al or Al₂O₃ nanoparticles has a lowest value as compared with pure ternary blends as shown in figure 3. This decrement of impact strength implies that a larger aggregate is a weak point that lowers the stress required for the composite to fracture and hence the impact strength of the nanocomposites would be decreased [Chi-Ming Chan 2002 and J. Spnoudakis 1984][12,13].
Figure 2. Effect of Al and Al$_2$O$_3$ nanoparticles on impact strength of the binary blends.

Figure 3. Effect of Al and Al$_2$O$_3$ nanoparticles on impact strength of the ternary blends.

It was normally most blends and nanocomposites during application were affected by the surrounding environments, particularly humidity. The reason behind that is the possibility of permeating water molecules into those materials, which may lead to a reduction in the mechanical...
properties by weakening the bonds between the two phases of the blends or between the filler/matrix interface [14].

Therefore, the blends and their nanocomposites under test were immersed in water for (4 weeks) at room temperature. The impact strength of those samples were measured every one week and the results are showed in table 6. The external appearance of the immersed materials reveals that the soaked specimens do not undergo any swelling, but they are plasticized. The same above-mentioned table showed that absorbed water has limited effect on the impact strength of materials. This indicates that those materials are efficient to be used in humid conditions without significant deterioration in their impact strength.

Table 6. The impact strength (I.S) of (LMR) blends and their nanocomposites before and after immersion in water.

| Groups       | (LMR) Sample No. | Impact Strength (I.S), KJ/m² | Immersion in water (week) |
|--------------|------------------|------------------------------|----------------------------|
|              |                  |                              | 0 | 1   | 2   | 3 | 4 |
| Blends       | 4A               | 7.22                         | 8.57 | 7.56 | 6.47 | 6.33 |
|              | 6A               | 9.59                         | 7.92 | 12.47 | 8.81 | 7.64 |
|              | 2B               | 5.88                         | 5.55 | 5.46 | 5.54 | 5.32 |
|              | 4B               | 8.449                        | 13   | 5.21 | 10.57 | 6.22 |
|              | 2C               | 13.94                        | 8.33 | 8.14 | 12.75 | 9.75 |
|              | 6C               | 6.971                        | 16.6 | 14.59 | 11.47 | 6.81 |
| Blends+Al 1% | 4A+Al 1%         | 10.23                        | 12.60 | 10.79 | 9.5 | 13.99 |
|              | 6A+Al 1%         | 11.73                        | 8.16 | 9.53 | 6.26 | 12.33 |
|              | 2B+Al 1%         | 4.68                         | 9.84 | 5.19 | 7.99 | 6.43 |
|              | 4B+Al 1%         | 6.54                         | 7.99 | 6.57 | 7.68 | 10.5 |
|              | 2C+Al 1%         | 10.15                        | 12.32 | 11.34 | 14.14 | 6 |
|              | 6C+Al 1%         | 7.77                         | 13.74 | 8.22 | 8.37 | 6.59 |
| Blends+Al₂O₃ 1% | 4A+Al₂O₃ 1% | 13.76                        | 10.08 | 8.33 | 10 | 14.41 |
|              | 6A+Al₂O₃ 1%      | 11.19                        | 10.92 | 7.81 | 8.94 | 12.9 |
|              | 2B+Al₂O₃ 1%      | 9.16                         | 7.2  | 10.45 | 6.52 | 9.95 |
|              | 4B+Al₂O₃ 1%      | 6.7                          | 11.27 | 5.72 | 7.6 | 7.71 |
|              | 2C+Al₂O₃ 1%      | 11.72                        | 12.71 | 11.5 | 10.55 | 10.24 |
|              | 6C+Al₂O₃ 1%      | 12.11                        | 9.55 | 10.91 | 9.63 | 7.59 |

After immersion period of 4 weeks, a decrease in the values of impact strength was observed for the samples of binary and ternary blends without reinforcement, as shown in table 6. This could possibly be explained, the epoxy and polyester resins show moisture sensitivity due to interactions between some polar groups of the macromolecule and the water molecules, which leads to a reduction of both glass transitions temperature and mechanical properties [15, 16].

It also can be noted that impact strength was increased for the binary blends reinforcement with Al and Al₂O₃ nano particles after 4 weeks of immersion in water, as shown in figure 4 and figure 5. This
increment of impact strength after immersion in water, due to plasticization effect that led to more energy absorption in order to fracture. Also the water molecules act as an inter phase between the interface and the matrix causing reduction in interfacial shear. This will increase the energy absorption ability at the interface resulting in the increase of fracture toughness of the composite material [17]. Also the increase of impact strength of the nano blend is due to the increase in surface area (aspect ratio) as its associated quantum effects exhibited by nano particles as the size of the particles decreased, the proportion of the number of atoms present on the surface will be more as compared to the atoms present in the bulk form [18]. The nano fillers are believed to have the high specific surface area needed to reduce the effects of applied mechanical stresses, in addition to their filling effect that serve the same purpose [19]. whereas it can be seen that ternary blends reinforcement with Al and Al2O3 nano particles would not achieve similar enhanced in impact strength as that of binary blends reinforcement with Al and Al2O3 nano particles after immersion in water, as shown in figure 6.

![Figure 4](image_url)

**Figure 4.** The impact strength of LMR binary blends nanocomposites specimens before and after immersion in water for 4 weeks.
Figure 5. The impact strength of LMR binary blends nanocomposites specimens before and after immersion in water for 4 weeks.

Figure 6. The impact strength of LMR ternary blends nanocomposites specimens before and after immersion in water for 4 weeks.
5. Conclusions

Based on experimental results, which are presented in this work, the following conclusions can be drawn:-

1. The samples prepared with ethanol showed higher impact strength and a good homogeneous dispersion of silicon rubber in the resins than the samples prepared without ethanol for all ratio percentage of RTV silicon rubber.
2. RTV silicon rubber an excellent impact modifier to (EP, UPE) when they are added in specified percents (5%, 10%) respectively for binary blends and in specified percents (5%,) for ternary blend and as they act to reduce the brittleness of the resins.
3. RTV silicon rubber cannot be used as an impact modifier for (UPE/EP/SR) ternary blend but RTV silicon rubber do, when they are added for (EP/ UPE/SR) ternary blend.
4. When the RTV silicon rubber content of the blend increases, the impact strength increases too and then gradually decreases where phase separation between the two phases begins to take place.
5. The best results of the impact strength under L.C. were achieved with the nanocomposite material consisting of binary blend reinforced with Al 1% or Al₂O₃1% and ternary blend reinforced with Al 1% or Al₂O₃1% nanoparticles due to the good nanoparticles dispersion resulting in less agglomeration leads to a better impact strength of the nanocomposites.
6. Impact strength decreased after immersion period of 4 weeks in water for the samples of binary and ternary blends without reinforcement, because of the epoxy and polyester resins show moisture sensitivity due to interactions between some polar groups of the macromolecule and the water molecules, which leads to a reduction of both glass transitions temperature and mechanical properties.
7. Impact strength was increased for the binary blends reinforcement with Al and Al₂O₃ nano particles after 4 weeks of immersion in water. This increment of impact strength after immersion in water, due to plasticization effect that led to more energy absorption in order to fracture.

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