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Study of the mechanical and thermal properties of Polyester Composites Prepared with Nylon66

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***Abstract*---**In this research, polymeric composites were prepared from unsaturated polyester resin as a base material with Nylon 66 as a reinforcement material with different weight percentages (1%,2%,3%,4%,5%) and through the results it was found that the highest value was (Hardness strength, Compressive strength, Impact strength) when reinforced by weight (5%) at room temperature, but when treated at temperatures (8.55) ℃, it was found that both the tensile strength and compressive strength increased at 55 ℃ and decreased at 8 ℃, while Impact resistance decreases at temperatures (8.55) ℃ It was also found that the thermal conductivity decreased at all temperatures (8.55)℃, which indicates that the polymeric composites consisting of unsaturated polyester resin reinforced with Nylon 66 are good heat insulators.

***Keywords*---**unsaturated polyester resin, Nylon 66, Hardness strength, Compressive strength Compressive strength, Impact strength, Thermal conductivity.

Introduction

Polyester resin has high thermal stability and high weather resistance which made it a popular matrix for fabricating fibre reinforced plastic (FRP) products, insulation coatings and pultrusion components [1-2]. More so, its popularity is because of its low cost, its mechanical and chemical stability and its flexibility to many fabrication techniques [3]. FRP is a composite material comprising plastics (resin) and fiber glass whereby the resin is the matrix and the fiber glass is the reinforcement [4], The FRP which is known as Fibre reinforced polymer

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composites are becoming more preferable day by day as a substitute for infrastructure components that are used in traditional civil engineering materials which are concrete and steel. Fibre reinforced polymer composites are more popular because of certain characteristic like light in weight, no corrosive, exhibit high specific strength and specific stiffness. Because of these advantageous characteristic[5], Fibre reinforced polymer composites are being used in new construction, rehabilitation of structures, reinforcement in concrete, decks, modular structures, formwork, and external reinforcement for strengthening & seismic upgrade[6]. Composite materials are artificial or it can be natural. Composite materials are made up of two or more constituent materials which have significantly different physical or chemical properties which remain separate and distinct throughout within the finished structure. Most composites materials are having strong stiffness fibres in a matrix which is weaker or it can have less stiffness. The objective behind using composite it to make a component which is stronger and having high stiffness and it should have low density[7]

Below ambient temperature, Nylon fiber reinforced unsaturated polyester resin performed a uniform brittle property, but it exhibited reasonable ductility at and above ambient temperature [8], As for low-density unsaturated polyester resin (LDUPR), novel foaming methods and theoretical models have been highlights of present research [9]. Those methods and models were established in the presence of a single initiator [10-13] , Different sizing agents lead to different softness of Nylon fibers. Direct yarn is soft. Besides, there are two kinds of plied yarn, which are stiff plied yarn and soft plied yarn. Direct yarn and soft plied yarn are appropriate for filament winding, pultrusion, fabric, etc. Stiff plied yarn is appropriate for spray-up and chopped strand mat. Accordingly, scientific issues, such as the category of Nylon fiber, reinforcement of different lengths of chopped Nylon fibers, different initiations for unsaturated polyester resin cross-linking, are novel explorations of resin matrix composite materialsp[14],Those are also active research areas in chopped Nylon fiber reinforced low-density unsaturated polyester resin. In this study, chopped Nylon fiber was firstly applied to reinforce low-density unsaturated polyester resin to prepare chopped Nylon fiber reinforced low-density unsaturated polyester resin (LCNFR-LDUPR), Different initiations were explored in order to obtain the optimal preparation parameters[15-16], the proper initiation system, and excellent mechanical properties. Effects of chopped Nylon fibers in different types on the distribution of chopped Nylon fiber in resin glue were observed and compared in order to select proper type and proper length of chopped Nylon fiber, Gel time experiment was necessary to determine the proper ratioOptimal preparation parameters, the proper initiation system,

Practical part

First, the materials used in the research

In this research, the following materials were used, from which the models were made:

1. Basic material

   Unsaturated polyester, which is Turkish in origin and has a density of (1.17) grams / centimeter, which contains two types of substances that help hardening, which is ethyl methyl ketone peroxide (as an initiator of the polymerization process, which is a colorless liquid, and the second substance is tin ketones (tin_2_ethylhexanol), which is an accelerator To disintegrate the initiator, it is an oily liquid with a purple color, where the hardener is added to an unsaturated polyester in a ratio of (2:100) whereby samples suitable for manual molding can be obtained at room temperature.

2. Reinforcement materials
   The reinforcement materials used in the research were nylon 66 fibers which were supplied from the local market. Where the trade name for nylon is (polyamide) and nylon is prepared from condensationDiamines & Dicar boxylicacids or their derivatives.

Second: the method of preparation
An unsaturated polyester is used after adding the hardener in a ratio of (2:100) to turn into a gelatinous hardening at room temperature. Nylon 66 reinforced materials are prepared in different weight ratios (1%, 2%, 3%, 4%, 5%). The technique was followed Manual molding, where special molds are made for each measurement before reinforcement and after reinforcement with nylon 66 fibers, where nylon 66 fibers are placed in the special mold according to the measurement and then an unsaturated polyester mixture is placed on them in the molds, where 24 hours are left to complete the solidification process at room temperature in order to complete the process Solidification and to reduce the stresses during the casting process and the interference and complete homogeneity between the particles and the effect of heat is studied to show the effect of the winter and summer heat on the prepared composites, so the molds are placed after being removed from the mold at temperatures (8.55) ℃.

Preparing models
Hardness test

A Durometer Shore (Shore-D) device supplied by (WoLPERT-Germany) was used to measure the hardness of polymeric materials. The device consists of a compass with a needle located in the middle; this needle was stitched vertically on the surface of the model. After 3 seconds, the hardness values were collected automatically for the desired samples.

Impact test

Impact test models were prepared according to the standard specification (ASTM-D256-87) with dimensions (10*10*55 mm^3) as shown in figure 1. Samples can be tested with the notch angle (45°) and the depth of notch (2 mm), which the amount of energy absorbed in fracturing the test-piece is measured by using Charpy impact instrument supplied from Tokyo koki seizosho LTD.

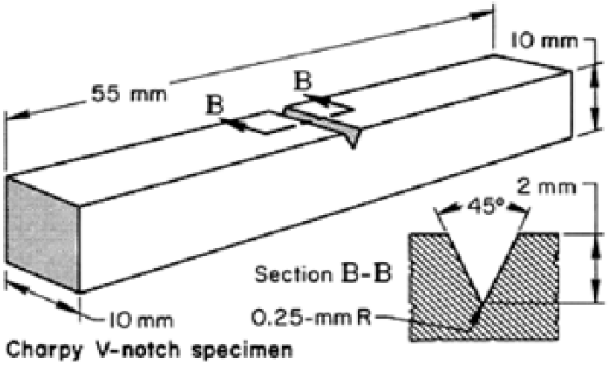

Figure 1: The shape and dimensions of the sample prepared for the impact strength test

Compressive test

These models were prepared according to (ASTM-D618) specifications and are cylindrical in shape, using a hydraulic press (Testing Machine Co. LTD) supplied by (WoLPERT-Germany).

Fig. (2) Shows the shape of the sample prepared for compressive resistance testing

Thermal Conductivity

Models were used in this test with a diameter of (112.5 mm) and a thickness of (5mm), as shown in figure 2. It is apparent from figure 3 that five circular shapes of prepared samples were carefully designed to examine its thermal conductivities.

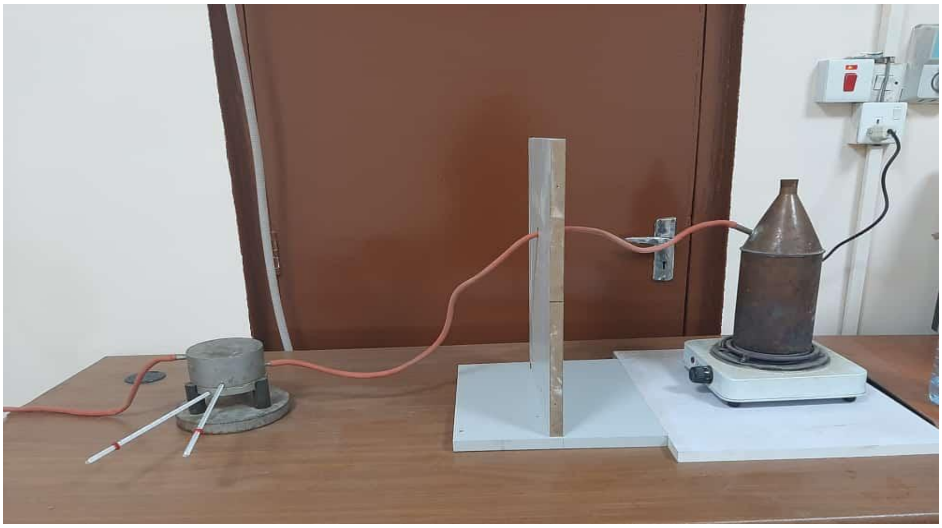

Figure 3: Thermal conductivity instrument

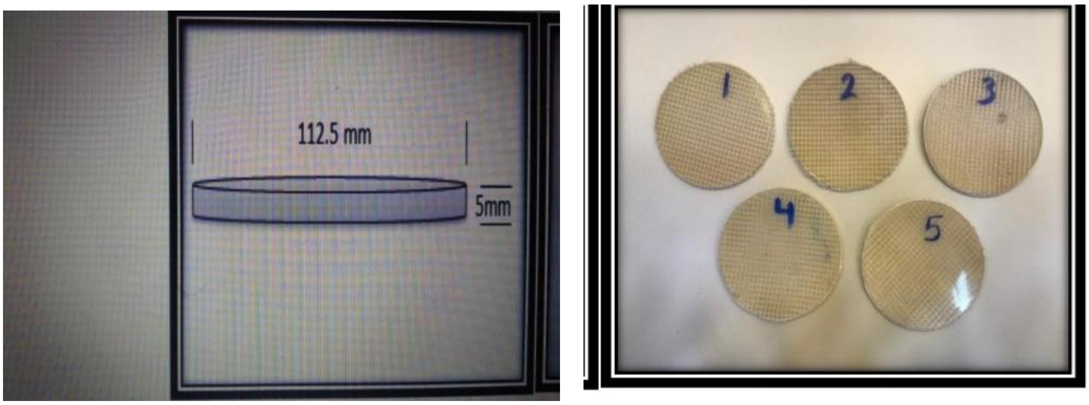

Figure 4: The shape and dimensions of the sample for thermal conductivity test

Results and Discussion

Hardness

It is the resistance of the surface of the material to permanent deformation that occurs through methods: cutting, wear, penetration, scratching, and the hardness of the material depends on heat treatment and high temperature in addition to the bonding strength between atoms or molecules, type of surface (17). Reinforcing unsaturated polyester with Nylon 66 leads to an increase in hardness resistance. This can be seen from Figures (4) and (5) as well as Table (1) due to crosslinking and interference between unsaturated polyester with Nylon 66 and because of cross-linking that reduces the movement of polymer molecules and thus increases the hardness, which leads to an increase in resistance to deformation[18-19]. The hardness values decrease with increasing temperatures due to the increase in the ductility of the material, which leads to an increase in the movement of the primary units and a loosening of the bonds between them, and this causes a weakness in its resistance to stitches and scratching [20].

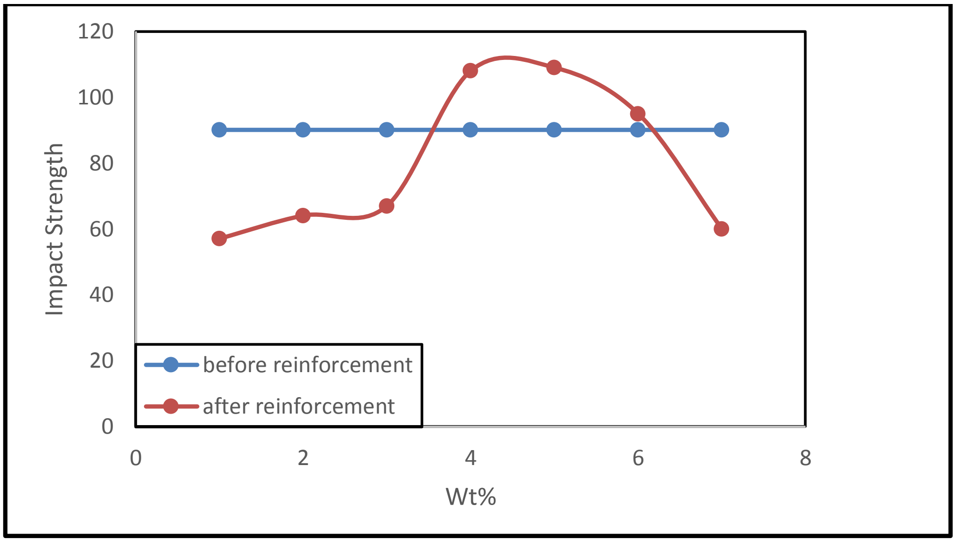

Figure 4: The Relation between Hardness and weight ratios for unsaturated polyester before and after reinforcement at 25°C

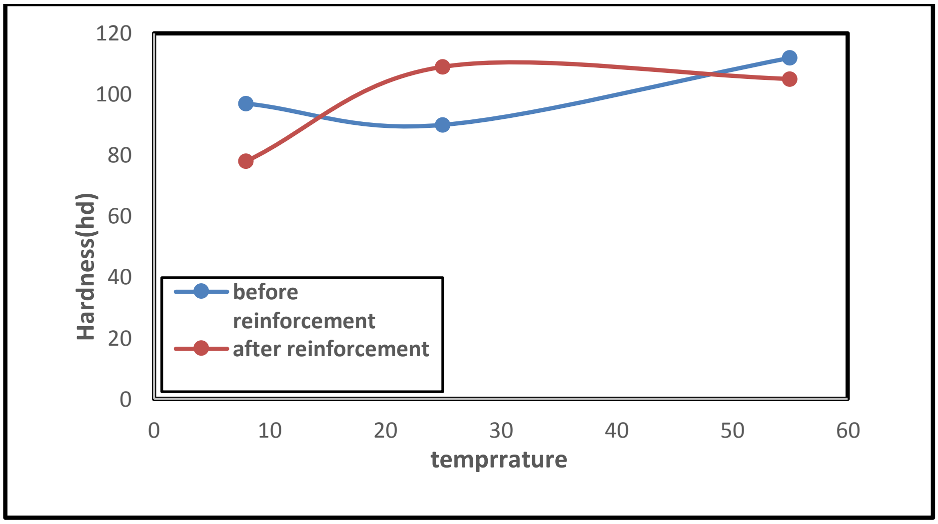

Figure (5) Relationship between Hardness and Temperatures ℃ (8,25,55) before and after reinforcement

Table 1
Hardness values of unsaturated polyester before and after reinforcement at 25°C

Composite at 25℃	Hardness after reinforcement
UPE	90
UPE+ N66 1%	57
UPE+N66 2%	64
UPE+N66 3%	67
UPE+N66 4%	108
UPE+N66 5%	109
UPE+N66 6%	95
UPE+N66 7%	60

Impact strength
The impact strength test from a scientific point of view is of great importance, and that can be used to evaluate the strength by calculating the energy required to break the model[21], as it is considered one of the important tests in the quality control laboratories as well as the design laboratories for plastic materials[22].

This test is intended to measure the strength of polymeric materials and their resistance to fracture under the influence of sudden loads at high speed. Impact strength is expressed in joules [23], From the relationship below, the Impact strength can be calculated:

$$I = \frac{\text{energy of fracture (J)}}{\text{area of cross section } (m^2)}$$

From the observation of Figures (6) and (7) and Table (3), it was found that the impact strength resistance of epoxy is low due to its fragility, but the values of the Impact strength increase after strengthening it with Nylon 66 fiber because Nylon 66 improves this resistance because it bears the bulk of the Impact energy applied to the composite material [24].

Figures (6,7) show that the impact factor is low for unsaturated polyester due to its fragility, but after reinforcement withNylon 66 fibers, the hardness value increases because the fiber bears the largest part of the impact energy applied to it, which improves this resistance at ℃ 25 degrees than when processing samples at temperatures (8,55 ℃) We found a decrease in the shock values at these degrees, because we notice a decrease in the shock values at the high and low temperature, due to the increase in the ductility of the material due to the movement of units and the loosening of the bonds of materials at high temperatures, while at low temperature the shock decreases due to the crystallization of parts of the polymer in a non-wave shape, which leads to brittle rupture as in Table (2)

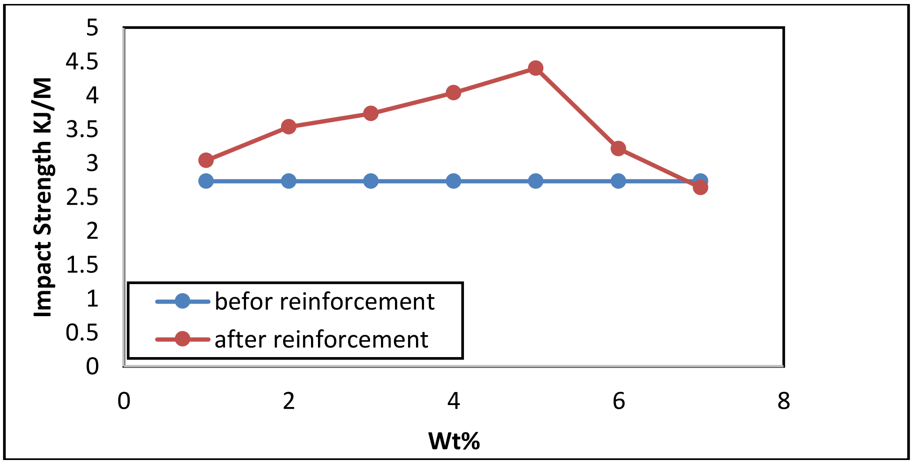

Figure 6: The Relation between Impact strength and weight ratios for unsaturated polyester before and after reinforcement at 25° C

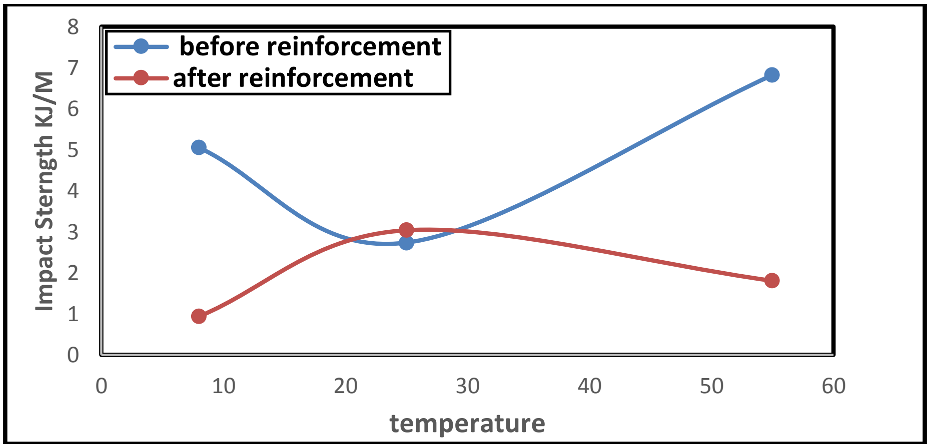

Figure (**7**) Relationship between Impact strength and Temperatures ℃ (8,25,55) before and after reinforcement

Table 2
Impact strength values of unsaturated polyester before and after reinforcement at 25°C

Composite at 25℃	Impact strength after reinforcement(KJ/M2)
UPE	2.73
UPE+N66 %1	3.04
UPE+N66 % 2	3.37
UPE+N66 %3	3.53
UPE+N66 %4	4.04
UPE+N66 % 5	4.40
UPE+N66 % 6	3.21
UPE+N66 % 7	2.64

Compressive strength test

It expresses the greatest stress that a rigid material bears (the ideal state of a finite body in which deformations are considered) under vertical stress, and from the ratio of the load applied to the unit area of the section.
It is the following equation [25]:

$$C\ (\text{MPa}) = \frac{\text{Force (N)}}{\text{Area } (\text{m}^2\ )}$$

We observation from Figures (8), (9) and Table (3) increase the compressive strength of the composite material resulting from strengthening polymers with Nylon 66 fibers, due to the efficiency of the bonding between the base material and Nylon 66 fibers, as well as the distribution of the load imposed on Nylon 66 fibers and this leads to an increase in the compressive strength [26-27].

At 25 ° C, but when processing the models at a temperature of 8 ° C, the compressive strength decreases, but at 55 ° C, the compressive strength increases. The reason is that with a decrease in temperature, the rate of crystallization increases, and thus decreases the compressive strength due to the restriction of the movement of the polymeric chains, but with an increase in the temperature, the compressive strength increases to increase the mobility of polymeric chains and increase the size qualitative

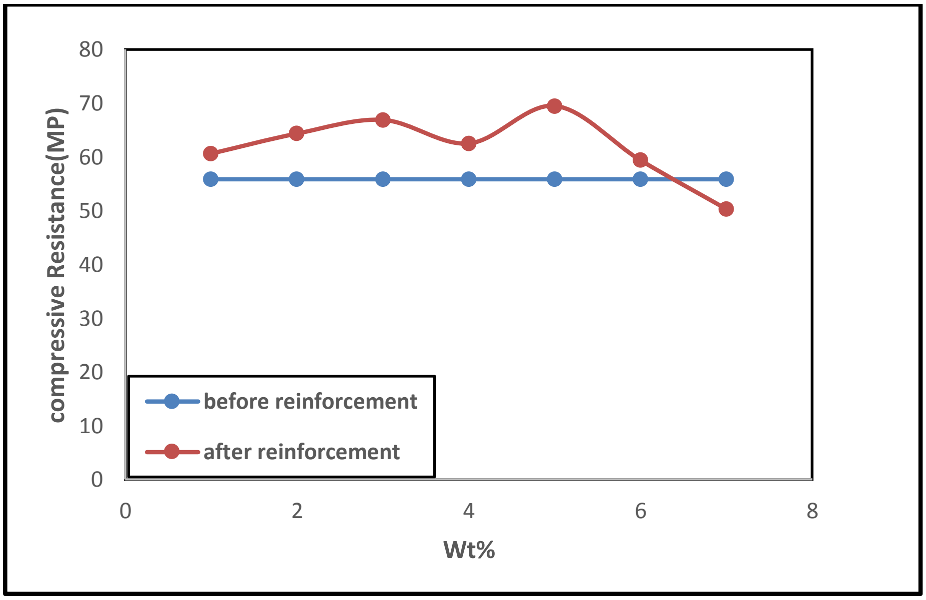

Figure 8: Relation between Compression strength and weight ratios of unsaturated polyester before and after reinforcement at 25˚C

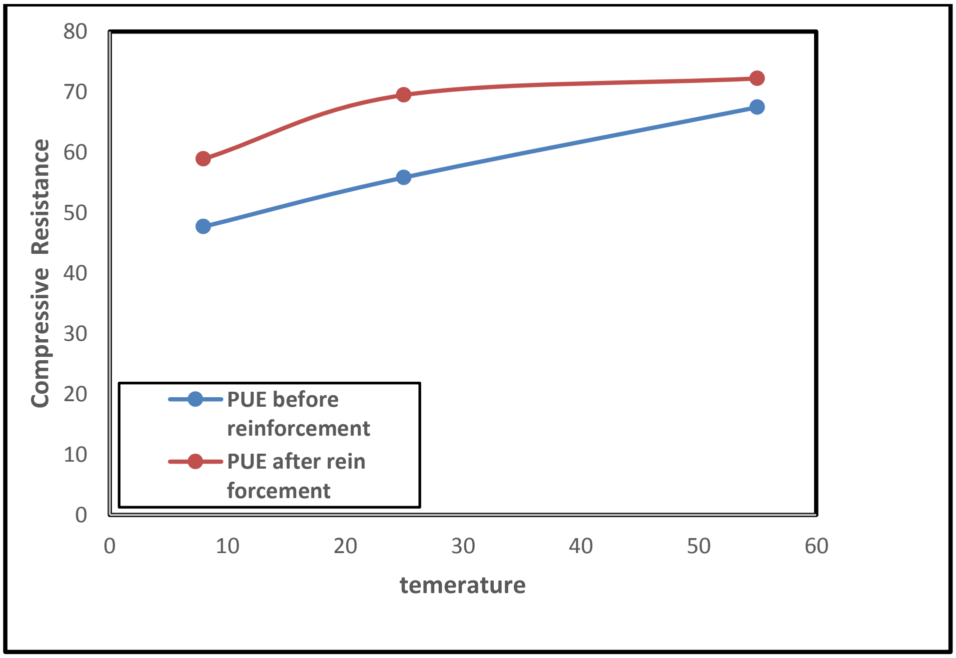

Figure (9): Relationship between Compression strength and Temperatures (8,25,55) ℃ before and after reinforcement

Table 3
Compression strength values of unsaturated polyester before and after reinforcement at 25°C

Composite at 25 ℃	Compression strength after reinforcement
UPE	55.8
UPE+N66 %1	60.6
UPE+N66 % 2	64.32
UPE+N66 %3	66.87
UPE+N66 %4	62.5
UPE+N66 % 5	69.47
UPE+N66 % 6	59.37
UPE+N66 % 7	50.31

Thermal Conductivity

The ability of the material to transfer heat from areas of high temperature to areas of low temperature, Each material has a specific thermal conductivity value, each according to the state of the material (solid, liquid, gas) and from knowing the thermal conductivity values of the compound material of unsaturated polyester and Nylon 66 fibers, it turns out that it is an insulating material.

There are several factors on which thermal conductivity depends, including the orientation of the molecules, the degree of purity, and the crystal size. Non-metallic resin materials do not have electron transfer or be very weak and thus thermal conductivity includes structural vibrations and this makes polymeric materials less conductive of heat, while metals have higher thermal conductivity [28].
Thermal conductivity can be calculated using the law [29].
:

$$\lambda.\frac{1}{4}\pi D^2\left(\frac{T_2 - T_1}{d}\right) = \text{mass of disc. CS. PN}\backslash\text{QN. 1 / 60}$$

Since polymers do not contain free electrons, which led to a decrease in thermal conductivity, as shown in Figure (10), because thermal conductivity depends on structural vibrations in its internal structure, as the fillings in the polymer impede vibration and these vibrations decrease upon addition, and thus a decrease in thermal conductivity. Nylon 66 added to epoxy is also a poor conductor of heat, so the thermal conductivity has decreased to this degree[30].

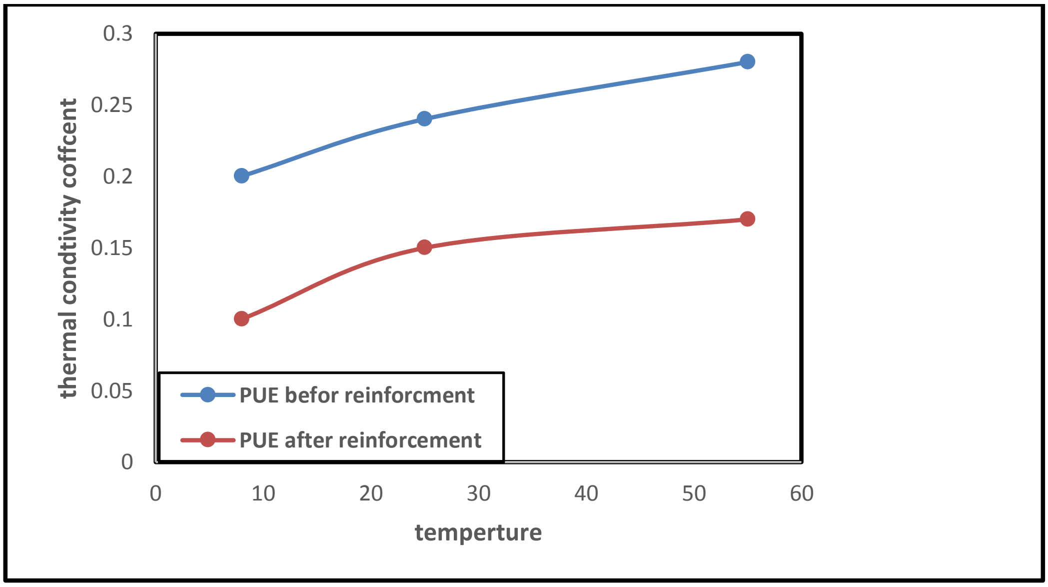

Figure (10): Relationship between thermal conductivity and Temperatures ℃ (8,25,55) before and after reinforcement

Conclusion

1. Hardness and Compressive strength increase when reinforced with Nylon 66 fibers at room temperature, but decrease when treated at 8℃ and increase at 55℃
2. Impact strength increase when reinforced with Nylon 66 fibers at room temperature, but decrease when treated at 8℃ and 55℃
3. Thermal conductivity decrease when reinforced with Nylon 66 fibers at room temperature, as well asdecrease when treated at 8℃ and 55℃

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