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Preparation and study of mechanical and thermal properties of polymeric composites of unsaturated and polyester cellulose fibers

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***Abstract*---**In this paper, polymeric composites were prepared from unsaturated polyester as a base material with cellulose in different weight ratios (1.2%, 3%, .4%, 5%) as reinforcement material. After comparing the unsaturated polyesters before and after reinforcement for the prepared composites, it was found that there is an increase in the values of mechanical properties (Impact strength ، Hardness, Compressive Strength, Tensile strength). After the unsaturated polyester reinforcement process at a temperature of 25 ℃ and then it was found that the weight ratio in which the mechanical properties (hardness, shock, tensile, compressive) increase is 2% and when treated at temperatures (8.55) ℃ it was found that the shock resistance It increases at 55 ℃ and decreases at 8 ℃, while the hardness, tensile and compressive strength decrease at (8.55) ℃.

***Keywords*---**unsaturated polyester resin, Cellulose fibers, Hardness strength, Compressive strength Compressive strength, Impact strength, Thermal conductivity.

Introduction

Technology and modern industries need materials that have a mixture of unusual properties that cannot be found in traditional materials such as metals, alloys and ceramics.The manufacture of materials with special specifications that meet specific needs has aroused the interest of engineers for several years. Aircraft engineers are looking for specifications that are low in density, but that are strong, rigid, and resistant to impact and abrasion and Corrosion. These qualities

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cannot be easily collected [1]. The application of natural fiber reinforced polymer composites and natural-based resins for replacing existing synthetic polymer or glass fiber reinforced materials in huge. Automotive and aircrafts industries have been actively developing different kinds of natural fibers, mainly on hemp, flax and sisal and bioresins systems for their interior components. High specific properties with lower prices of natural fiber composites are making it attractive for various applications [2-3] , The applications of natural fibers are growing in many sectors such as automobiles, furniture, packing and construction. This is mainly due to their advantages compared to synthetic fibers, i.e. low cost, low weight, less damage to processing equipment, improved surface finish of moulded parts composite, good relative mechanical properties, abundant and renewable resources [4] , studied the impact and hardness test of the composite material consisting of the base material, which is unsaturated polyester polyester supported by rice straw, and the study showed that the Impact and tensile values are improved both by adding rice straw .

The researcher[5] studied the thermal properties of pure unsaturated polyester, which grafte with silica oxide and cellulose with different thickness under the influence of temperature and found that the mechanical properties and the thermal conductivity coefficient change with the change of temperature and thickness,But researchers [6] studied the mechanical properties of the hybrid composites with an epoxy basis, reinforced by glass fibers and silicone carbide particles, It gave the highest hardness, highest tensile strength and highest impact resistance. The researcher [7] studied polymeric compounds of polyester reinforced with glass fibers, and the results showed positive effects in improving the mechanical properties.

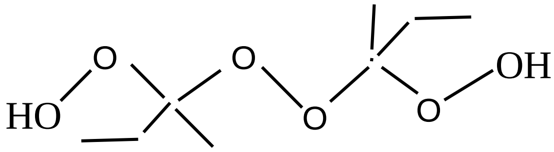
Experimental Part:

First, the materials used in the research

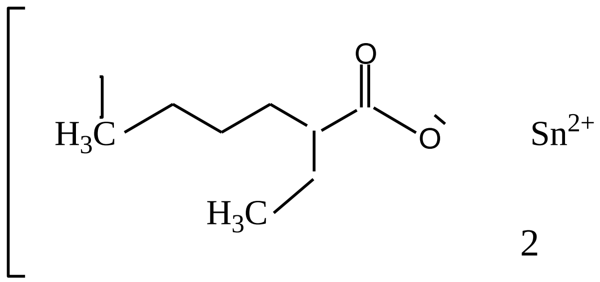
In this research, the following materials were used, from which the models were made:

Matrix Material

The base material used in the research is unsaturated polyester resin, which is commercially called (palate) in Turkey. It is a transparent resin with a specific gravity of (1.17), which contains two types of materials that help the resin hardening, namely ethyl methyl ketone peroxide (as an initiator of the polymerization process), which is a colorless liquid.



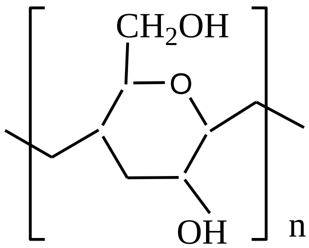
The second substance is tin octate (tin-2-ethylhexanoyl), which is an accelerating agent for the disintegration of the initiator. It is an oily liquid with a purple color.



The hardener is added to the unsaturated polyester resin in a ratio of (100:2) and samples suitable for manual hardening can be obtained at room temperature.

Reinforcing Materials:

Cellulose fibers were used for the reinforcing process and to strengthen the unsaturated polyester resin. Cellulose fibers obtained from the local markets were added. Cellulose n(C6H10O5) is the main component of cotton, on which all operations center and has a simplified polymeric structure [8] as shown below



Second: The method of preparation

The hardener is added to the unsaturated polyester resin to complete the process of hardening the unsaturated polyester, and the addition was by weight ratio (100: 2) (unsaturated polyester resin: the hardener) in order to turn into a substance that hardens at room temperature. Then samples were prepared for composite materials of unsaturated polyester. Impregnated reinforced with cellulose fibers by weight (1%,2%,3%, 4%, 5%), where the hand-lay molding technique was followed before the reinforcement.

And then with cellulose fibres, and then the mixture is placed in the molds designated for each examination. After the solidification process is completed, the interference and complete homogeneity between the particles and the reduction of the internal stresses formed during the solidification process, the material is left for 24 hours at room temperature at 25 °C and removed from the mold, and the effect of heat was studied to show the effect of the winter and summer heat on the prepared compounds, so the molds were placed after lifting them of the mold at temperatures (8,55) ℃

Third: Preparation of samples
Four types of models were prepared for mechanical tests

Impact test samples:

Impact test models were prepared according to the American Standard Specifications (ASTM-D256-87) with dimensions (10 x 10 x xoom3) and suitable for examination. Grooving angle of (45) and grooving depth in the model (2mm) where the absorbed energy required for the fracture to occur is obtained from the instrument chirpy impact device supplied by Scicocho, LTP Tokyo Koki as shown in Figure (1).

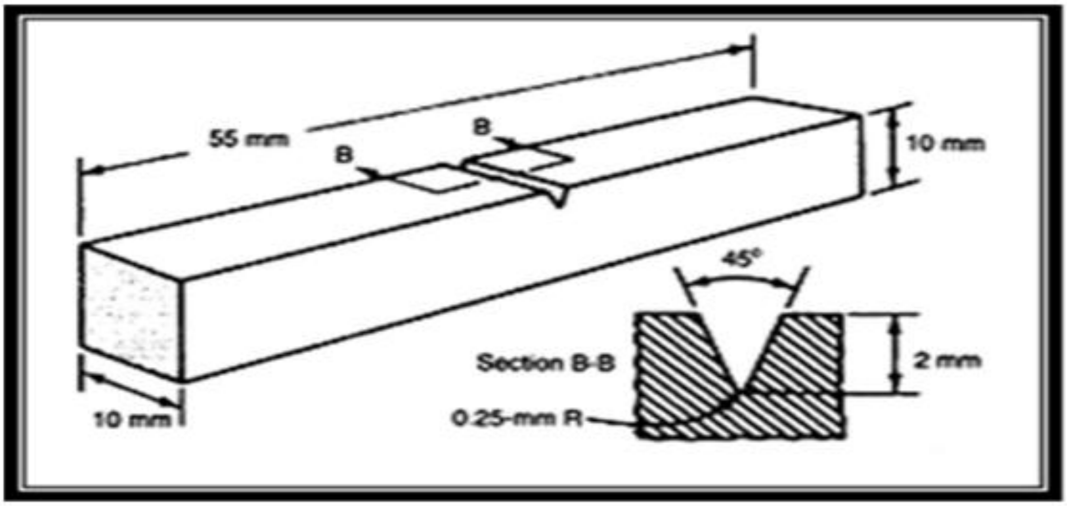


Figure 1: The shape and dimensions of the sample prepared for the impact strength test

Hardness test samples:

The Durometer shore type (Shore-D) supplied by the Germany-WOLPERT company is used to measure the hardness of polymeric materials. The device is similar to a compass. It is a needle in the middle. The method of test is to place the device perpendicular to the sample to be measured. The hardness is until the needle is inserted into the surface of the material, after which it waits for 3 seconds and then we take the value of the hardness from the device.

Compressive test samples:

Compressive test samples have been prepared according to specifications (MSTM-D168) and are cylindrical in shape, where a hydraulic piston type (Testing machine, Co. LTD) is used.

Figure 2: Shows the shape of the sample prepared for compressive resistance testing

Tensile test samples

Where the standard specifications (ISO-R527) are adopted in preparing tensile strength test samples (the models were in slices). Use this test to know the properties of the composite material under the influence of a two-way axial tensile load and use the (Universal test machine) supplied by (ELE-England) company. In measuring this characteristic and with a load rate (50 KN).

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

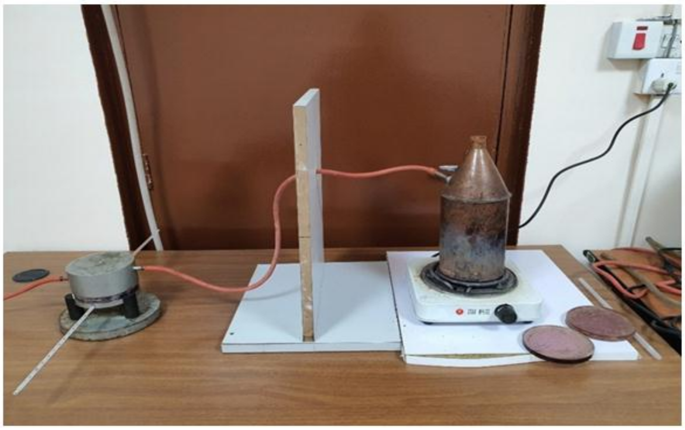


Figure 3: Thermal conductivity instrument

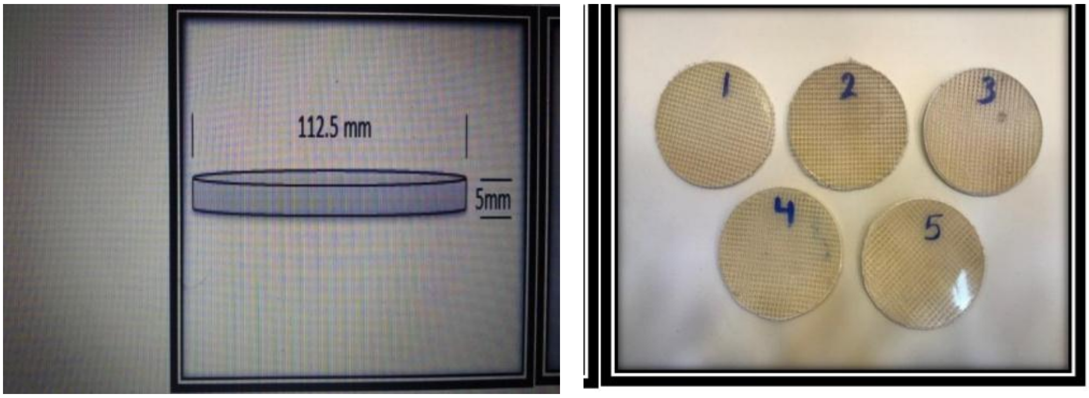


Figure 4: The shape and dimensions of the sample for thermal conductivity test

Results and discussion

Impact strength (I.S):

The Impact strength test is one of the scientific methods that give a correct indication in the descriptive form of the strength and resistance to fracture under the influence of stresses at high speed [9]. The Impact strength was calculated using the relation ship:

Impact strength (I.S) = $\frac{\text{Freature energy}}{\text{Area (m)}^2}$

Impact strength is generally low for unsaturated polyester due to its fragility, but after strengthening with cellulose fibers, we note that the Impact strength increases after strengthening at room temperature. This is because the fibers bear the greater part of the Impact energy applied to the Composite material, which improves this resistance and thus increases the Impact resistance, The highest value of Impact resistance was obtain at the weight ratio 2%, as shown in Table Figure (5) and Table (1)

Table 1:
Impact strength and weight ratios values for unsaturated polyester before and after reinforcement at 25°C

Composite at 25C^0	) مقاومة الصدمةKJ/m^2(
UPE	2.73
UPE + Cell %1	3.55
UPE + Cell%2	4.82
UPE + Cell% 3	4.20
UPE + Cell% 4	4.10
UPE + Cell 5%	3.63

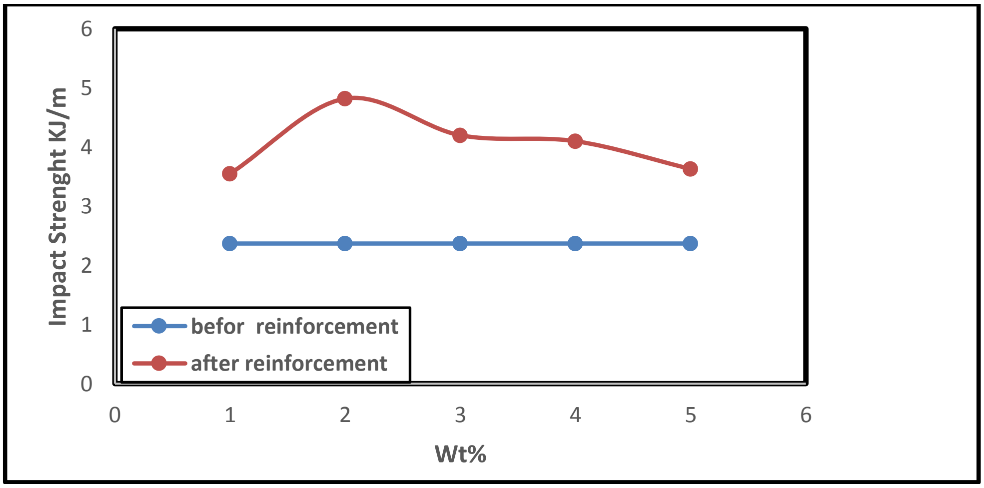


Figure 5: The Relation between Impact strength and weight ratios for unsaturated polyester before and after reinforcement at 25° C

When treating polymeric compounds at temperatures ℃ (8.55), we find that the Impact resistance decreases when the temperature decreases in order to restrict the movement of the polymeric chains and thus cannot move, but increases with the increase in temperature as a result of the loosening of bonds between the molecules of the material and the movement of the polymeric chains increases, which gives it the possibility of absorbing Part of the energy that leads to the distribution and spread of the energy needed to break in the form of mechanical decay [10-11], as shown in Table (2) and Figure (6).

Table 2
Impact strength values of unsaturated polyester at (8,25,55) ℃ before and after reinforcement

Temperatures°C	Impact strength befor reinforcement	Impact strength after reinforcement
8	2.29	3.44
25	2.73	4.82
55	3.55	6.52

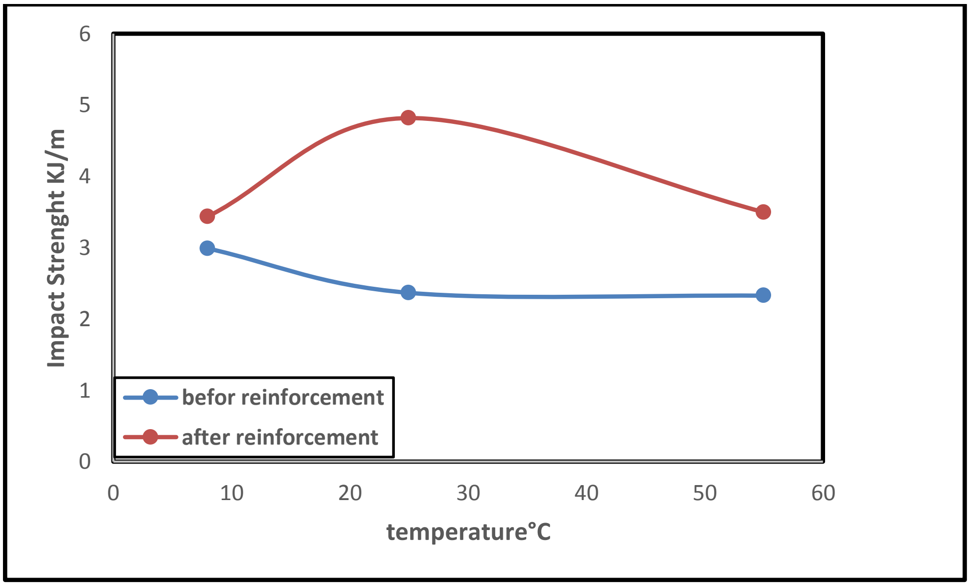


Figure (6) Relationship between Impact strength and Temperatures ℃ (8,25,55) before and after reinforcement

Hardness

The hardness property is one of the important surface mechanical properties, and it is defined as a measure of the deformation experienced by the material under the influence of external stress applied to it as a result of its exposure in general to scratching and burning by equipment that is harder than it while using it in various applied fields [12]. Reinforced with fibers The hardness values increase compared to non-fibre-reinforced polyester due to the physical affinity between cellulose fibers and polymeric chains and
highest value of hardness was obtian at the weight ratio 2%, as shown in Table (3) and Figure (7).

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

Composite at $25C^0$	Hardness Shove-D
UPE $25C^0$	90
UPE + Cell.1%	116
UPE + C ell2%	118
UPE + C ell3%	117
UPE + C ell4%	100
UPE + C ell5%	110

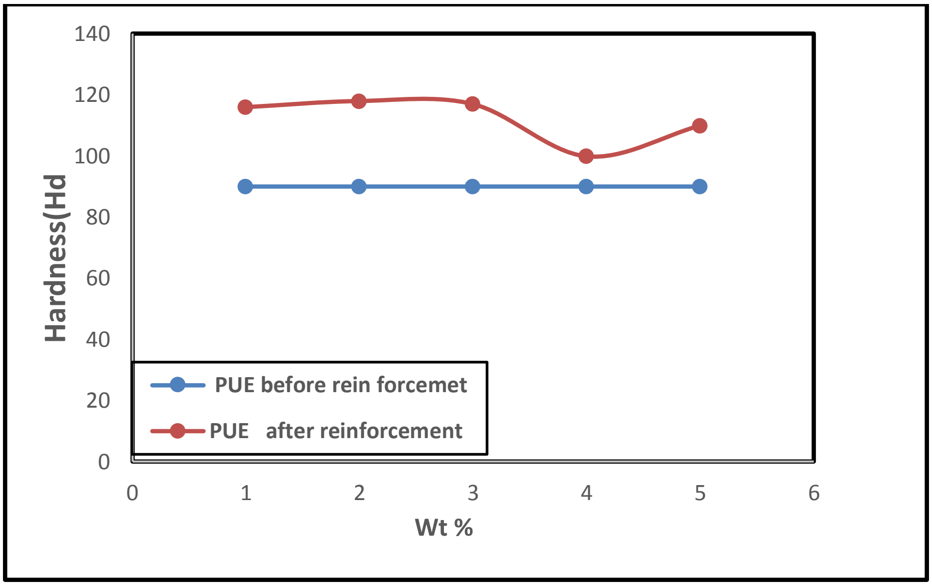


Figure 7: The Relation between Hardness and weight ratios for unsaturated polyester before and after reinforcement at 25°C

When heat treatment at temperatures (8.55 ℃), it was found that the hardness values at 55 ℃ were lower than at 25 ℃, because the increase in heat leads to an increase in the ductility of the material due to the movement of the units and the loosening of the bonds between them and this leads to a decrease in the resistance to scratching and stitches But at 8 ℃ with a decrease in temperature, the polymeric chains become bound and cannot move, which leads to a weak resistance [13]. as shown in Table (4) and Figure (8).

Table 4
Hardness values of unsaturated polyester before and after reinforcement at (8,25,55) ℃

Temperatures°C	Hardness befor reinforcement	Hardness after reinforcement
8	97	99
25	90	118
55	112	97

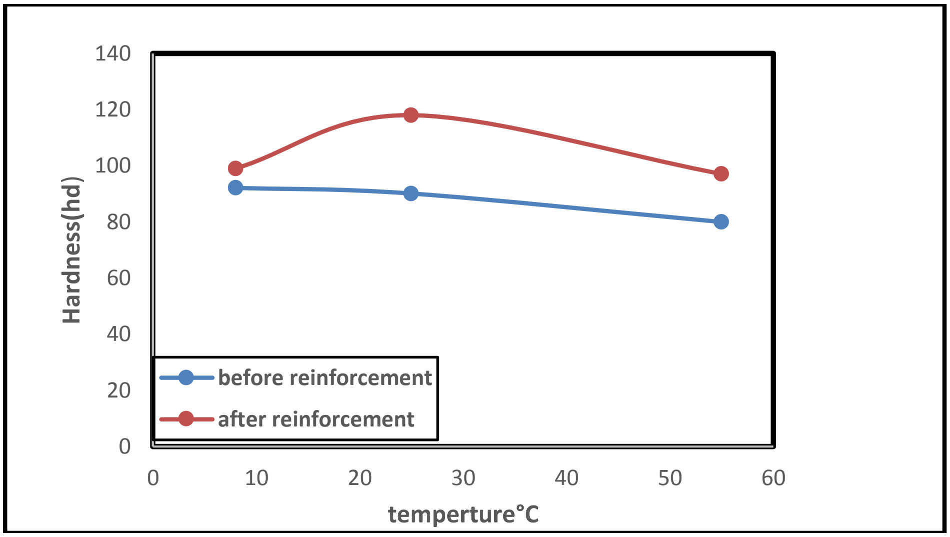


Figure 8: Relationship between Hardness and Temperatures (8,25,55) ℃ before and after reinforcement

Compressive Strength

It is one of the important tests to determine the extent of the bearing strength of the polymer and there are a number of materials that may be brittle in the tensile state, but they appear to be ductile in the compressive state. Therefore, the compressive test is used to determine and know the yield strength in addition to knowing the amount of compressive strength [14-15] and it is defined as the amount Mechanical stress that the solid material can withstand under the amount of vertical stress and without breaking or shattering and changing its shape after the stress is removed [16-17].
The results showed that the compressive strength increased when strengthening, and several weight ratios were taken. Through experiments, it was found that the highest compressive strength was at 2% by weight. The reason is that the fibers bear most of the effort applied to the material, in order to distribute the effort on the fibers, as well as for the efficiency of linking between the base material and the reinforcing fibers as well. Shown in Table (6) and Fig.(8) [18-19].

Table 5
Compressive Strength values of unsaturated polyester before and after reinforcement at 25°C

Composite at 25C^0	Compressive Strength
UPE 25C^0	55.8
UPE + Cell %1	121
UPE + Cell.2%	152
UPE + Cell 3%	89
UPE + Cell 4%	114
UPE + Cell 5%	133

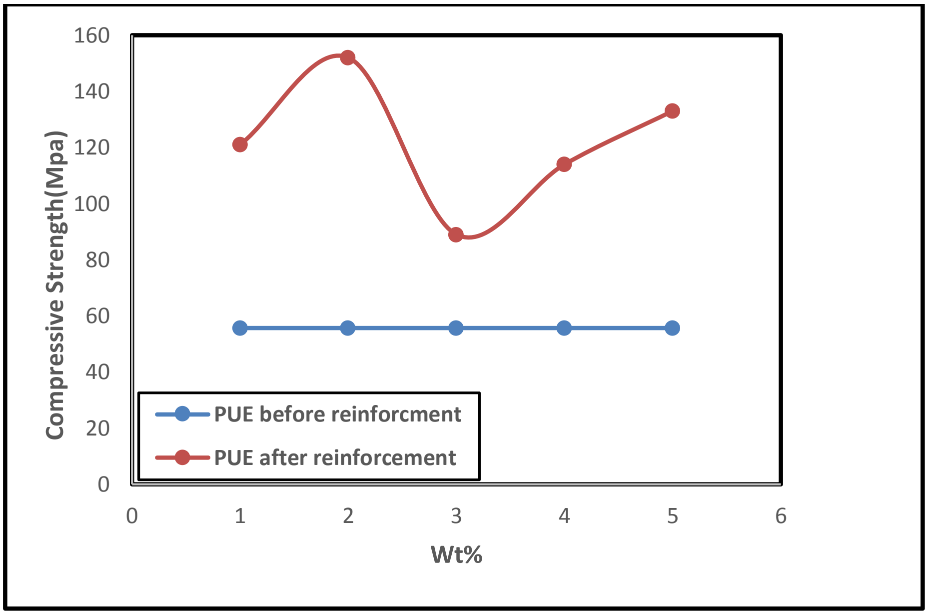


Figure 9: The Relation between Compressive Strength and weight ratios for unsaturated polyester before and after reinforcement at 25°C

When heat treatment at temperatures (8.55 ℃), it was found that the compressive strength values at 55 ℃ were lower than at 25 ℃, because the increase in temperature leads to an increase in the ductility of the material due to the movement of the chains and the relaxation of the bonds between them and this leads to a decrease in the compressive strength But at 8 ℃ with a decrease in temperature, the polymeric chains become bound and cannot move, which leads to a weak resistance, and thus the compressive strength decreases [20-21]as shown in Table (6) and Figure (10).

Table 6
Compressive Strength values of unsaturated polyester before and after reinforcement at (8,25,55) ℃

Temperatures°C	Compressive Strength befor reinforcement	Compressive Strength after reinforcement
8	47.7	**9.55**
25	**55.8**	**152.8**
55	67.4	**15.92**

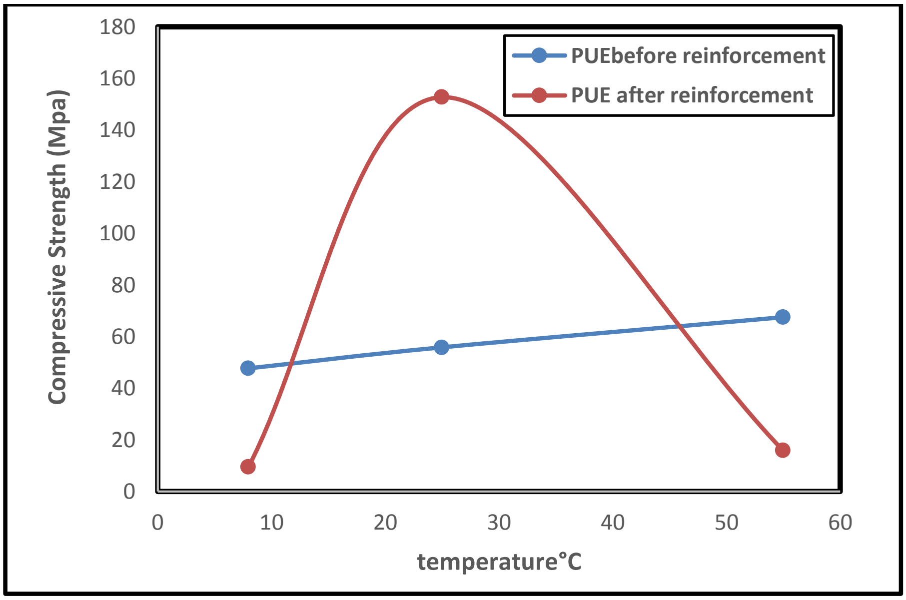


Figure 10: Relationship between Compressive Strength and Temperatures (8,25,55) °C before and after reinforcement

Tensile strength

The tensile strength is a measure of the material's resistance to the static forces that try to pull the material and break it, so the overlapping material is made of strong fibres immersed in the base material[22-23], where resins are considered brittle materials where their tensile resistance is very low and when fibers are added, their tensile resistance is clearly improved And this is for the fibres to withstand the applied effort, and through the research that the highest tensile strength was obtained at a weight ratio of 2% at a temperature of 25 °C as shown in Table (7) and Figure (11)

Table 7
Tensile strength values of unsaturated polyester before and after reinforcement at 25°C

Composite at $25C^0$	Elasticity
UPE $25C^0$	3000
UPE + Cell 1%	18500
UPE + Cell 2%	19500
UPE + Cell 3%	6533
UPE + Cell.4%	8750
UPE + Cell.5%	6666

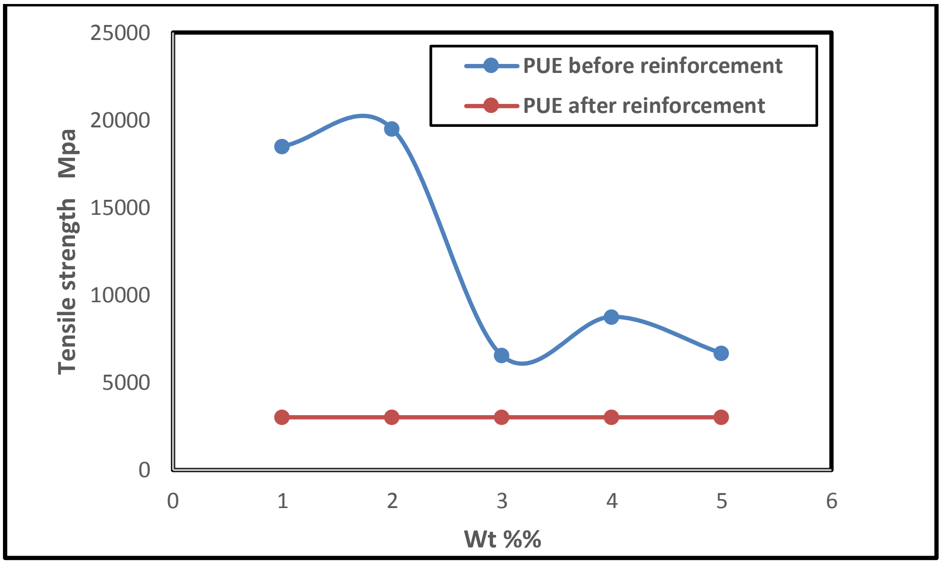


Figure11: The Relation between Tensile strength and weight ratios for unsaturated polyester before and after reinforcement at 25°C

And when treating at temperatures (8.55) ℃ and by testing a weight ratio of 2%, we notice that the tensile values decrease at a temperature of 55 ℃ due to the loosening of the bonds resulting when the temperature increases, but when the temperature decreases 8 ℃, this leads to a decrease in the tensile strength due to the restriction of the bonds The polymeric chain and its movement moved, which made it brittle, as in Table (8) and Figure (12).

Table8
Tensile strength values of unsaturated polyester before and after reinforcement at (8,25,55) ℃

Temperatures ℃	Tensile strength befor reinforcement	Tensile strength after inforcement
8	8125	4875
25	6191	19500
55	8850	5000

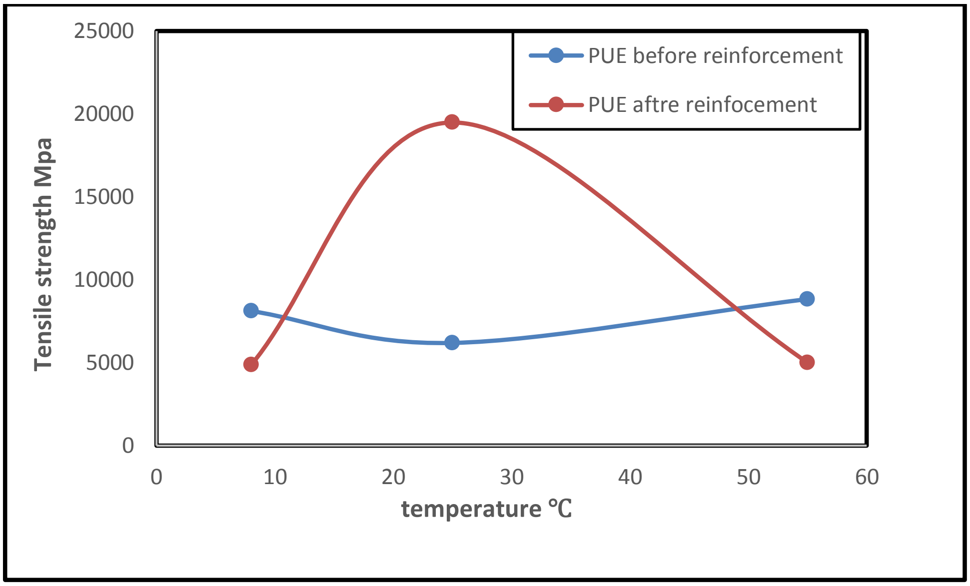


Figure 12 : Relationship between Compressive Strength and Temperatures (8,25,55) ℃ before and after reinforcement

Thermal Conductivity

Heat is a form of transferred energy, it moves from a region with high temperatures to a region with low temperatures in a number of forms (conduction, convection, radiation) and heat may be transmitted in one or more of these forms [24-25] (Abtan, 2013). It is worth noting that heat transfer by conduction or convection is slower than heat transfer by radiation, because the speed of radiation is equal to the speed of light, which is (3-2 x 108 km.sec). Where the molecules are free to move[26-27].

Through the research, we showed a decrease in thermal conductivity after the process of reinforcing the unsaturated polyester with cellulose fibres, as it was before the reinforcement, and that the polymers do not contain free electrons in heat transfer, where the thermal conductivity depends on the structural vibrations in its internal structure, as these vibrations decrease when adding Fillings to the polymer, which re-vibration and thus reduced conductivity as in Figure (13)

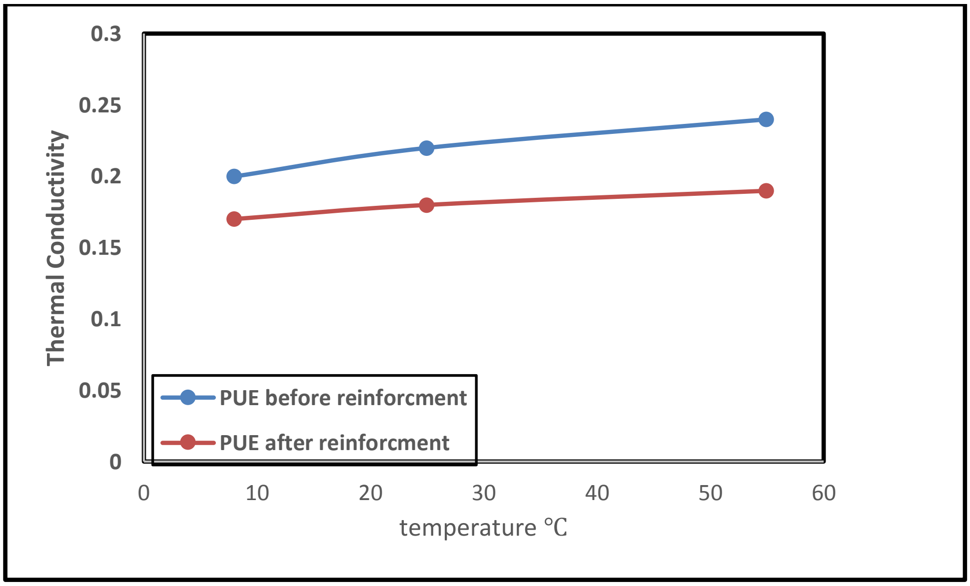


Figure 13: Relationship between Thermal Conductivity and Temperatures (8,25,55) °C before and after reinforcement

Conclusions

The most important conclusions reached during the research are summarized as follows:

1. The addition of cellulose fibers to unsaturated polyester led to an increase in the values of mechanical properties represented by the properties (Impact resistance, hardness, modulus of elasticity, compressive strength).
2. The values of Impact resistance increase when treated with a temperature of 55 °C, but decrease at 8 °C, but the values of (Compressive Strength, Hardness and elasticity) decrease when treated with temperatures (8.55°C)
3. Decreased thermal conductivity of unsaturated polyester after reinforcement at room temperature and temperature (8,55 °C).

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