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Determine the Response of Structural and Mechanical Properties to Heat Treatment For (PMMA) Matrix Reinforcement By (Al_2o_3) Powder

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ABSTRACT

Poly (methyl methacrylate) (PMMA) was used as a matrix for fabrication samples of polymer matrix composites (PMCs). The matrix was reinforcement by (Al_2O_3) powder with a volumetric ratio (20%) and an average grain size (40 ±5) μm. The manufactured samples were treated after conducting the surface treatment operations thermally with different temperatures (50,70 and 90 ° C) and with different treatment times (2,4,6,8, and 10 hours). The samples were subjected to a set of mechanical and microscopic tests, whereby the effect of thermal treatment on the bending fatigue life of the manufactured samples, and the effect of thermal treatment on the ability of the material to resist shear stress, flexural strength, wear, compressive resistance and impact resistance. The results showed that there was an improvement in fatigue life, shear stress, flexural strength, compressive strength, wear resist, and impact resistance after heat treated samples. The best fatigue life, shear resistance, wear resist, and flexural strength occurred for 6 hours post cure time, while it was observed that the best improvement in compressive resistance and impact resistance occurred after the passage of (4hours) of the post cure time. The results also showed that the best thermal treatment temperature is (T=70° C).

Introduction

There are many polymeric materials that have the ability to develop their basic properties in general and their physical properties in particular. one of these methods is changing the polymerization method of these materials, another method is by using the hybrid process between more than one types of polymer. It is also possible to achieve this goal through the so-called composed materials. In addition to this, the properties of polymeric materials can be improved by placing them under the influence of a specific factor. Among these materials is (PMMA), as this material is characterized by its ability to change its properties with the change of the method of polymerization, and it may also be a good matrix material in (PMCs). Moreover, it has shown its ability to develop its properties by subjecting it to an appropriate physical effect. [1]

One of the main disadvantages of polymeric materials is their thermal properties, that more than (70%) of known polymeric materials cannot maintain their properties if it is exposed to thermal fields exceeding (150 ° C) [2], as the polymeric material starts in such a case with a transition to a new physical state [3] and will find suitable ways to deal with thermal energy supplied to the material. One of these ways is the consumption of thermal energy by dismantling parts of The substance, And if this procedure was not enough either, the material dismantling of the elements and molecules of the substance itself, To reach the material in the case of high thermal fields to the stage of non-existence, where the entire material is transformed into an entirely new body and phase that may not have any association with the body or the matrix phase before it is exposed to the thermal field [4]. Despite the tragic scenario that the polymeric materials go through during their dealings with thermal fields, however, in the case of choosing the appropriate thermal field at an appropriate time and at an appropriate energy supply rate it is possible in certain cases to make a positive change either in the structure, behavior, characteristics and characteristics of the polymeric materials, this change the outcome depends on three main factors: [5]

1- The nature of the composition arrangement of the polymeric structure.
2- The nature and type of bonds between different chains and between single chain elements or molecules.
3- The nature of the thermal field exposed to the polymeric material, and the rate of energy supply to the polymeric material.
In the case of finding a type of coordination to control the three factors mentioned above, it may be possible to develop some properties of polymeric materials using thermal fields despite the weak thermal properties of these materials. [6]

Materials Used:

Poly (methyl methacrylate) (PMMA) was used as a matrix to manufacture the polymer matrix composites (PMCs). The matrix was reinforcement by using (Al_2O_3) Powder ά-type, with degree of purity (95%), gain size (40 ± 5) μm and volume ratio (20%). The solvent chloroforms were used at a rate of (12%) of the total volume of material that used to fabricating the matrix and in multiple stages for the purpose of dissolving the material (PMMA) and converting it into the gel phase for the purpose of pouring it into special models for samples fabrications suitable for every test. The dimensions of the manufactured samples are {(120 x 10 x5) mm}, which are then cut according to the appropriate dimensions for each test. Aluminum plate (1mm) thickness is used for the purpose of manufacturing casting samples. Smoothing sheets of silicon carbide with gran sizes (400, 1200, 2000 M) were used for the purpose of surface treatment of samples.
Below are the general physical properties and mechanical properties of (PMMA) material used as the matrix for samples fabrication.

Table 1: general physical properties and mechanical properties of (PMMA) material

Physical Properties		***Mechanical Properties***	
Density (ρ)	1.17–1.20 g/cm^3	Young's modulus (E)	1.9–2.1 GPa
Refractive index (n)	1.4905 at 589.3 nm	Tensile strength (σt)	50--70 MPa
Flammability	V0-V2	Elongation (ε) to crash	70-130%
Reducing the oxygen index	23-25%	Compressive strength (σc)	> 50 MPa
Water absorption - balance	0.13-0.25%	Poisson ratio (ν)	0.31
Water absorption - 24 hours	0.12%	Hardness – Rockwell	M60
Radiation resistance	Fair	The power of the Izod effect	500--750 Joules / m
UV resistance (1-380 nm)	Fair	Sharpay effect	15--30 kg J / m2
		Abrasion resistance	10-13 mg/1000 rotation
		Coefficient of friction (μ)	0.28
		The speed of sound	2230 m / s

Equipment and Technologies:

The German-built Binder convection oven, which has the ability to supply a thermal energy, which its temperature reaches up to (300 C^0) and for a period of (72) hours, is used for the purpose of conducting thermal treatments. HsM20 fatigue test machine used for the purpose of bending fatigue test, this machine is produced by the English company (Hi-Tech) which is a generation developed from a device (Rotating Fatigue Machine HsM19) Rotating & Bending Stress.
In Flexural Strength test we use Three-point turn-off test device which was made by an English company (Steel Power Co.), as this device consists of two cylindrical made of stainless steel placed on two sliders that allow to adjust the distance between them by a graduated ruler. Use these two predicates to fix the sample during the test, where the sample is placed between the two stands, then the load is gradually applied from the top by a cylinder of the same diameter and quality.
The same device was also used for the purpose of determining the shear stress of the manufactured samples after making some modifications to the base of the sample and the stress shedding arm. Due to the relatively weak mechanical properties of polymeric materials in general and the ability of these materials to resist compression in particular, a manual hydraulic press of the Graseby Spesac sample was used. As this type of press is used to prepare and compress a wide range of cylindrical samples at a maximum compressing strength of 25 Tons, after a simple modification of the plunger surface of the sample for the purpose of making it suitable for compressive strength test. The ability of manufactured samples to resist impact was determined by using the charpt impact test, where using the Izod Charpy Tension Impact Test Instrument, manufactured by Testing Machines, Inc, Amityville New York.
By using the mechanical wear determent dives, the wear rates obtained in the samples are determined at a time period of five minutes and at a speed of rotation of the friction disk (90 rpm) with the roughness level (2000 #) and by placing a load on the sample fixing arm of (5 N).
Calculations were performed by using American Society for Testing and Materials (ASTM) with NO: D3039 system
Optical microscopes type of (YUJIE YJ – 9106E 1000X) were used for the purpose of conducting microscopic tests of the manufactured samples with magnification strength of (*x400*).
The samples were filmed by using the Huawei mobile digital camera, which has a resolution of 16 M Pixel.

Results and Discussion

Bending Fatigue Tests:

Figure (1) represents the bending fatigue life for thermally and non-thermally treated samples at different treatment temperatures (50,70 and 90 ° C) and for different treatment time (2,4,6,8 and 10 hours) where subject to bending fatigue stress of 25 MPa.

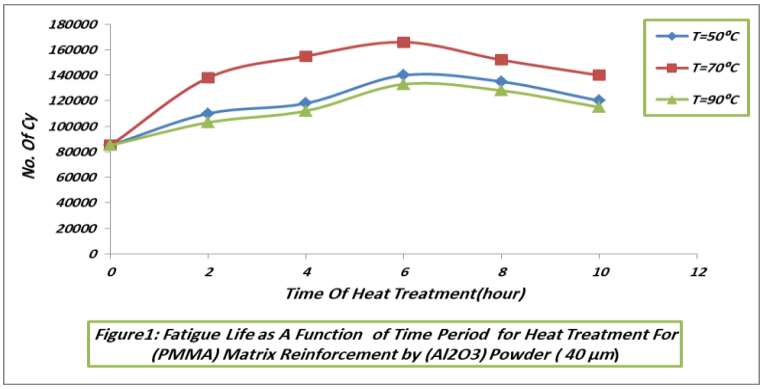

Figure1: Fatigue Life as A Function of Time Period for Heat Treatment For (PMMA) Matrix Reinforcement by (Al2O3) Powder (40 µm)

Where it is observed from the figure that there is an improvement in bending fatigue life as a result of exposing the samples to heat treatment, and that the best improvement in fatigue life is at a treatment time of (6 hours), It was also observed that there are effects for the temperature of the heat treatment as the thermal treatment Showed improvement in fatigue test at temperature (T=70 ° C).

For the purpose of explaining the improvement in the efficiency of fatigue performance of heat-treated samples, we find that whenever the material is able to contain the stress effect on it and distribute it regularly throughout the entire body of the sample and reduce the aggregation of polymer chains, we find that the effectiveness of this stress decreases and thus the material's strain decreases, which will also lead to an improvement in the properties of fatigue and an increase in the fatigue life [7]. The thermal treatment will improve the ability of the matrix to distribute the stress applied on it and prevent its aggregation at specific points, thus obtaining a kind of increase in fatigue life and enhancement in the efficiency of fatigue performance of the substance. The real effect of the thermal treatment on the polymer matrix composites (PMCs) is to develop the continuity property of the matrix, since the continuity property in (PMCs) means the uniformity of the reinforcement material distribution over all parts of the sample body and reducing defects in the body of the sample [8]. Whereas, the thermal treatment will address some of the defects in the matrix, which can be formed during the sample fabricating processes, and it can also improve the surface properties of the sample in terms of surface uniformity and free from cracks and holes , and that the greater the continuity characteristic of the material body, the greater the ability of the material to contain external stresses and distribute it to the entire body of the sample and prevent its aggregation at specific points and thus an increase in the fatigue life and fatigue efficiency of the material [9]. Therefore, we find that all samples showed an improvement in fatigue performance efficiency and an increase in the fatigue life after heat treatment.

Figure (2) shows a section of a sample that is not thermally treated, where it is observed from the figure that the section contains some defects, which makes the continuity property in it be weak, while it is observed from Figure (3), which represents a section of a sample of thermally coefficient for a period of (6 hour.) and a treatment temperature Its value (T=70° C) is that the defects are relatively few, which makes the continuity property of this sample better than the non-heat treated sample.

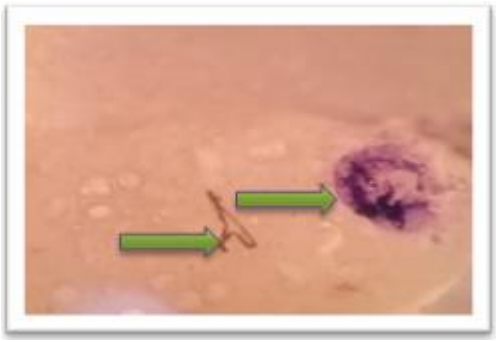

Fig. 2: Microscopic examination of a section of a non-thermally modified sample showing locations of some defects in the body of the sample (*x400)*

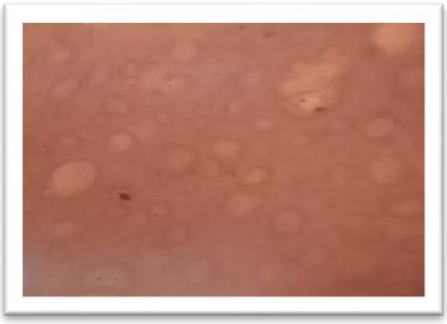

Fig. 3: Microscopic examination of a section of a thermally treatment sample for a period of (6hours) and with a treatment temperature (T=70° C), It shows almost no defects. (*x400).*

The process of treating samples thermally means, in the strict sense, providing the sample energy. This energy is absorbed and stored in the sample at specific storage sites and in specific quantities. The sample remains able to absorb this energy as long as it is able to store it [10]. At this stage, this stored energy improves the properties of The material in general where this energy is considered as the energy required to treat the points of imbalance in the material and thus a kind of improvement in the properties of the material, when the energy stock in the material reaches to a maximum value, we find that the ability of the material to absorb energy stops due to the lack of storage sites that can the material can be used to store additional energy. This increase in the energy supplied to the material will compel the material to deal with it and provide containment and storage sites [11], it is represented in the polymeric materials by arranging the polymeric chains one by the other and creating additional bonds in one chain as well as the bonding of the chains with each other by side bonds, thus an increase in the energy stock of the material and an additional improvement in the properties of the material. When the material becomes uncommon to the formation of new storage sites, this energy supplied to the sample begins with a shift from positive energy to negative energy as the material will be forced to consume this additional amount of energy by breaking some bonds between the different chains and in the event that this process is not sufficient to consume energy additional bonds of one chain break and thus reduce the degree of polymerization of one chain [12]. This process will lead to weakening the properties of the material, and the matter may even lead to a breakdown of the properties of the material while increasing the amount of additional energy supplied to the material (increasing the time period for the heat treatment). Therefore, it was observed that the treatment of the samples thermally led to an improvement in fatigue life and gradually with an increase in the time period of the treatment, until the improvement reached the best condition after the passage of a period of time (6hour), after that the fatigue life of all the samples began to decrease.

The energy supply rate for materials in general and polymeric materials in particular has an effect on the properties of the material and its improvement, as there is always a specific energy supply rate that is appropriate for the material so that this rate leads to the best improvement in the properties of the material [13]. The best rate for supplying materials energy depends mainly on two factors; the first is the nature of the material, while the second is the nature of the energy supplied. Therefore, we note that the best improvement in fatigue life was obtained from heat treatment with a temperature of (T=70° C), which represents the best energy supply rate for manufactured samples.

Shear Stress Tests:

Figure (4) represents the shear stress resistance of the manufactured samples as a function of the time period for thermal treatment and different treatment temperatures (50,70 and 90 ° C) and for different treatment time (2,4,6,8 and 10 hours).

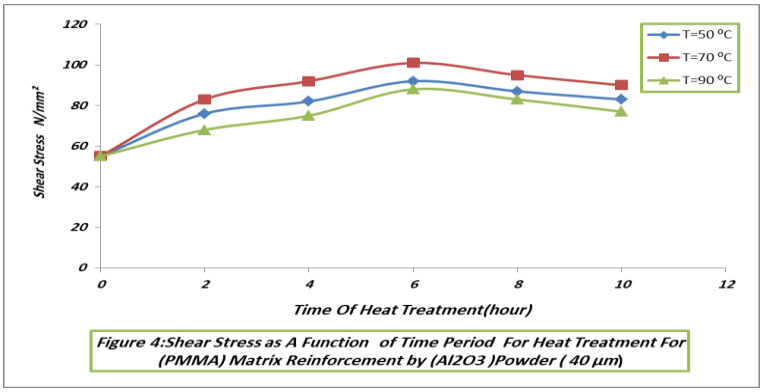

Figure 4:Shear Stress as A Function of Time Period For Heat Treatment For (PMMA) Matrix Reinforcement by (Al_2O_3) Powder (40 µm)

As it is observed from the figure that there is an improvement in the shear stress resistance of the heat treated samples and that the best ability to resist shear stress occurred at a treatment time of (6hours) In addition, the thermal treatment with a temperature of (T=70 ° C) was the best in improving the ability of the samples to resist shear stress.

When external stress is applied to the material so that the vertical direction of this effect is parallel to the cross section of the material, this stress will separate and move the parts of the material that are located at the site of influence in opposite directions, leading to events of either deformation of the material as a result of the partial creeping of the components of the material layers or separating or cutting the layers of the material as a result of reaching to the yield point of being subjected to this stress. Thermally treating plastic materials leads to an increase in the bonding of the layers of these materials, which makes the process of distorting the arrangement of polymeric chains or separating them from each other is more difficult [14], and the process of thermal treatment of manufactured samples has led to reducing the defects in the matrix by creating some kind of side bonds. It increases the consistency of the parts of the material, as well as improving the agglutination of polymeric chains and their uniformity in their direction, so we note an improvement in the ability of the material to

resist shear. The best shear stress for heat treated samples occurs when the material reaches the highest level of energy stock after the creation of new storage sites in the material. This case occurred in the heat treated samples after a treatment period of (6hur). The energy supplied to the sample after this period was a negative energy that led to a kind of reduction in the link between the different chains, as it may have led to a reduction in the degree of polymerization of one chain in the matrix. Also, the best energy processing rate for manufactured samples occurred when these samples were treated thermally at a temperature of (T=70 ° C).

Flexural Strength Test:

Figure (5) shows the flexural strength of untreated and treated manufactured samples thermally as a function of the treatment time periods (2,4,6,8 and 10 hours) and at different temperatures (50,70 and 90 ° C).

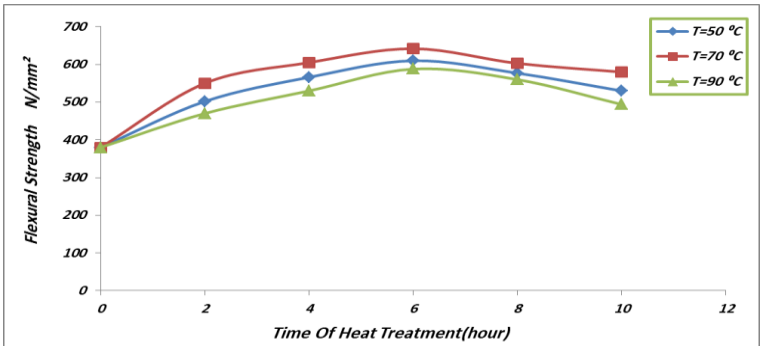

Figure 5: Flexural Strength as a Function of Time Period For Heat Treatment For (PMMA) Matrix Reinforcement by (Al2O3) Powder (40 µm)

Where it is observed from that the figure that the flexural strength of the manufactured samples increases with increasing the thermal treatment to reach the best flexural strength after the passage of (6hours) of the thermal treatment, the figure show also that the best treatment temperature was at (T=70° C), which led to the best flexural strength.

When exposing a substance to an external stress factor that causes the bend of this substance, the location of the effect of this stress on the material is subject to three effects that work at the same time, the first is the tensile effect that appears in the lower side of the effect site, and the second is the effect of compression, which appears on both sides and the top side of the effect site, while the third is the shear effect, which appears in the layers of the stress effect site. Whenever there is a kind of balance between the first and the second effect (tension and compression), the weaker the effect of the third factor (shear) becomes, so the resistance of the material to crack formation increases and thus the material's ability to resist the bend increases [15]. Many polymeric materials have the ability to improve some of their properties by treating them thermally. Among these characteristics are the tensile, elongation and compression characteristic [16]. Therefore, it is noted that the result of the improvement of these characteristics led to a kind of balance between these characteristics, and that this balance led to a reduction in the effects of the stress shear formed as a result of the effect of the bending factor, and thus the material's ability to resist bending increased. Also, reaching the highest energy storage level in the manufactured samples was achieved at a time of heat treatment of (6hours) And that the best rate of energy supply was at a treatment temperature of (T=70° C).

Compressive Strength Test:

Figure (6) represents the compressive strength of untreated and treated manufactured samples thermally as a function of the treatment time periods (2,4,6,8 and 10 hours) and at different temperatures (50,70 and 90 ° C).

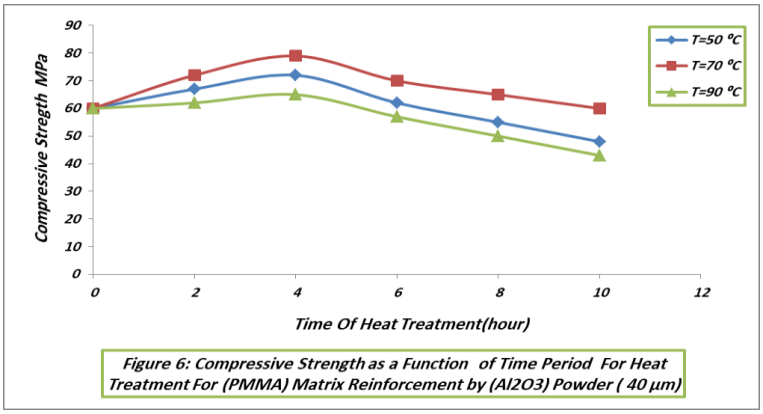

Figure 6: Compressive Strength as a Function of Time Period For Heat Treatment For (PMMA) Matrix Reinforcement by (Al2O3) Powder (40 µm)

Where it is observed from the figure that there is an improvement in the ability of manufactured samples to resist compressive after being treated thermally, this improvement is at its best after the passage of (4hours) from the treatment time, also we can noted that the best heat treatment occurs when the temperature of the treatment is (T = 70 ° C).

The compressive resistance property is considered to be one of the most direct properties that influence with the structure arrangement of the composition of materials, wherever the material is of a uniform compact structure, the material has the ability to resist compressibility due to external influences [17]. Polymeric materials are considered to be materials that have the ability to show a response to thermal treatments, as these materials are characterized by their ability to increase the agglutination of their polymeric chains when exposed to heat treatment and that this response is in the form of a kind of the bonding of the chains with each other by side bonds that will lead to an increase in the convergence of the polymeric chains from each other, which It will thus cause the polymeric chains to go in almost one direction, making their structure more uniform and less defective [18]. This condition will directly lead to an increase in the material's ability to resist compressibility by the influence of external pressure factors. Therefore, we find that the ability of manufactured samples to resist compression increases after exposure to heat treatment.

As is known, in the case of the thermal treatment of the material, the part that is more likely to be affected than the other parts of the body is the surface of the material, where it is possible that the surface of the material has reached a certain physical state that differs from the physical state of the other parts of the sample, there are some mechanical properties That are closely related to the properties of specific layers of matter. When the properties of this layer are broken down, this characteristic of the substance completely collapses [19]. One of these characteristics is compressive resistance, as this characteristic is characterized by a great correlation with the surface of the material and the collapse of the surface's ability to resist compressibility will lead to the collapse of this characteristic throughout all parts of the sample, and since the surface's exposure to thermal energy is greater than the other parts of the sample, we find that the thermal treatment at the time period (4hours) It is sufficient to reach the surface layers of the material to the highest level of energy storage and that after this period the energy supply to the surface layers is a negative energy supply and thus the material begins to lose its ability to resist compressibility which will lead to the loss of this characteristic throughout the body of the sample. As in the previous cases, it was observed that the best rate of energy supply was obtained when the temperature of the heat treatment is (T=70 ° C).

Wear Resist Test:

Figure (7) shows the change in the ability of the material to resist the wear of untreated and treated manufactured samples thermally as a function of the treatment time periods (2,4,6,8 and 10 hours) and at different temperatures (50,70 and 90 ° C).

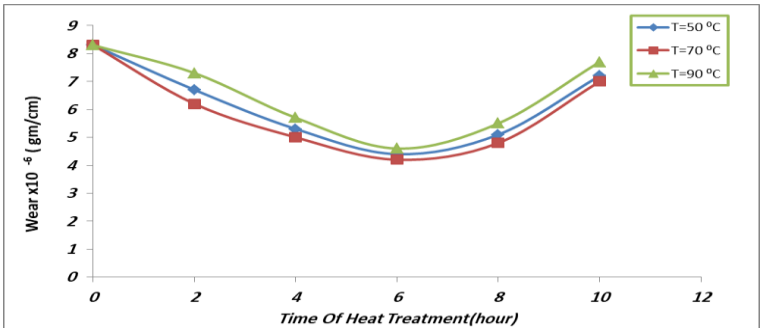

Figure7: Wear Resistance as a Function of Time Period For Heat Treatment For (PMMA) Matrix Reinforcement by (Al2O3) Powder (40 µm)

where it is observed from the figure that the ability of the manufactured samples to resist the wear after treatment is thermally improved and that the best improvement in the wear resistance occurred after the passage of (6hours) hours of the treatment. Also noted from the figure, that the best energy processing rate for the manufactured samples was when treated thermally at a temperature of (T=70 ° C).

The more the material has a great cohesion force between its different parts, as the mechanical wear rate decreases during its different working conditions, an increase in the material's ability to resist wear. This rule can be achieved in different materials in different forms (source), since for each nature the composition of a particular material there are different bodies and states that can lead to an increase in the ability to reach a greater cohesion state between its different parts, and thus link to a higher wear resistance [20]

In PMCs there are two sides of the material through which an increase in the coherence strength of its various parts can be achieved [21]. The first side is an increase in the coherence strength of the matrix itself. This state can be achieved by having the best

geometrical arrangement of the polymeric chains. By creating an arrangement in which the polymeric chains are arranged in a manner that is close to one another, and that this arrangement will lead to an increased probability of some kind of chemical or physical correlation between adjacent chains. In which case the thermal treatment can do this task, as one of the effects of the thermal treatment of polymeric materials is that they cause convergence in the polymeric chains as it is possible that these chains are equipped with enough power to form additional connections between adjacent chains [22]. As for the second aspect, it is represented by increasing the ability of the matrix to contain the ideal and regular containment of the reinforcement material as well as providing the best link between the reinforcement material and the matrix(source). Here, too, the thermal treatment can lead to a kind of increase in the ability of the material to provide ideal containment opportunities with a higher density by reducing the rate of defects in the matrix, which in turn will lead to a regular distribution of the reinforcement material (source). Also, it is possible that the energy supplied by heat treatment is the energy needed for a correlation between the reinforcement materials and the matrix, and thus the strength of the consistency of the parts of the material increases with each other, which in turn will be reflected in reducing the mechanical wear rate that occurs in the material, an increase in wear resistance [23].Therefore, it is noted from Figure (7) that the wear rates for heat treated samples are less than the wear rates for the non- heat treated sample. It is also noted that the treatment of the samples for a period of time of (6hours) has led to the lowest wear rate in the sample, the highest wear resistance. As this time period may be the necessary period for the sample to reach the highest energy storage level and thus the energy supplied to the sample during this period it is a positive energy, which then turns into extra energy, which gives a negative effect on the material's ability to resist mechanical wear. It is also noted that the best rate time for the energy supply to the sample was achieved when the heat treatment temperature (T = 70º C).

Figure (8) shows the microscopic examination of a section of the friction surface that is not subject to heat treatment, where it is observed from the examination that the cuts occurring in the friction surface due to the friction process are large and irregular, indicating a weak ability to contain the reinforcement material as well as the weak correlation of the parts of the matrix, which in turn It will lead to a weakness in the association of the different sample procedure, which made the wear rate of this sample high, While it is noted from Figure (9) that the wear and tear that occurs in the contact surface of the heat treated sample for a period of (6hur) and with a treatment temperature of (T = 70º C) is uniform and that the cuts are about the same level as the surface, which indicates that the consistency of the parts of this sample is large and Therefor the wear rate decreased and the material's ability to resist wear increases.

Fig. 8: Microscopic examination of a section of the friction surface that is not subject to heat treatment. (x400)

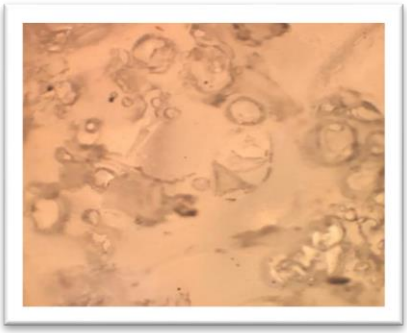

Fig. 9: Microscopic examination of a section of the friction surface that is subject to heat treatment for a period of (6hur) and with a treatment temperature of (T=70º C). *(x400)*

Impact Resist Test:

Figure (10) shows the change in the ability of the material to resist the impact of untreated and treated manufactured samples thermally as a function of the treatment time periods (2,4,6,8 and 10 hours) and at different temperatures (50,70 and 90 º C).

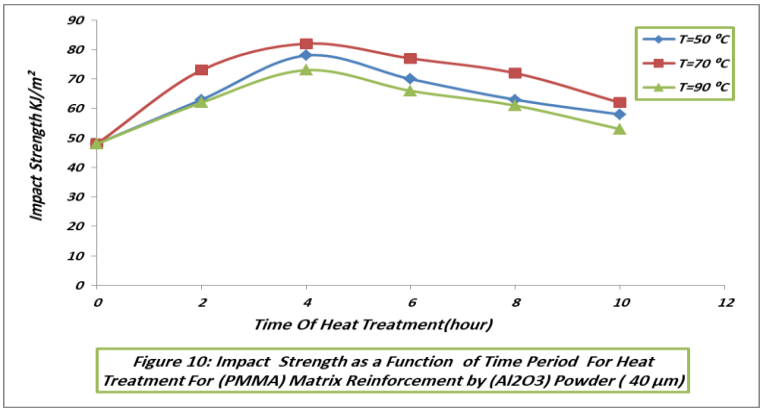

Figure 10: Impact Strength as a Function of Time Period For Heat Treatment For (PMMA) Matrix Reinforcement by (Al_2O_3) Powder (40 µm)

It is observed from the figure that the ability of the manufactured samples to resist the impact after treatment is thermally improved and that the best improvement in the impact resistance occurred after the passage of (4hours) hours of the treatment. Also noted from the figure, that the best energy processing rate for the manufactured samples was when treated thermally at a temperature of (T=70 ° C).

When supplying a quantity of energy to a specific area during a very short period of time, the ability of the material to absorb this energy and distribute it to all parts of the body without causing damage represent the impact resist resulting from this energy, the ability of the material on impact resistance depends directly on two main factors; The first is the ability of the substance to rapidly absorb energy, which improves dramatically with increasing locations that have the ability to contain and store this energy, the second factor is the efficient to rapid distribution of the amount of energy absorbed to all parts of the body of the material [24].

The thermal treatment of plastics materials leads relatively to the provision of storage and energy consumption sites by reducing the separation between the polymeric chains and this condition can increase the chance of a side bond between the different chains, which is one of the methods of energy consumption. Also, in the case of polymer matrix composites (PMCs), the thermal treatment can cause an improvement in the ability of the material to contain the reinforcement material as these materials carry out the task of transferring quantities of energy from one specific site to another within relatively short periods of time [25]. Therefore, a kind of improvement is observed in the material's ability to resist the impact due to its thermal treatment. As the impact resistance property is also one of the properties that are directly related to the properties and characteristics of the surface of the material, so we find that the best improvement in the ability of the material to resist the impact occurred after the passage of (4hours) of the heat treatment, and the best rate of processing of the energy resulting from the heat treatment It happened when the heat treatment temperature was (T=70° C).

Figure (11) represents the microscopic examination image of a section of a non-heat treated sample, where it is noted the irregularity of the sample section, which means the weak ability of the material to contain the reinforcement material. While we notice from figure (12), which represents the microscopic examination image of a section of a thermally treatment sample with a temperature of (T=70° C) and for a time period of (4 hours) The uniformity of the sample section means an increase in the ability of the material to contain the reinforcement material.

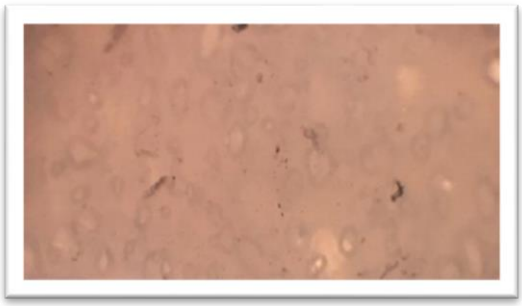

Fig. 11: Microscopic examination image of a section of a non-heat treated sample. (x400)

Fig.12: Microscopic examination image of a section of a thermally treatment sample with a temperature of (T=70° C) and for a time period of (4hours).(x400)

References

1- Cristina V.; Dimitrios G. P.; Fei L; Zheling L.; Ben F. S.; Robert J. Y.; Ian A. K., (2020). PMMA-grafted graphene Nano platelets to reinforce the mechanical and thermal properties of PMMA composites, *Journal. of Carbon*, **157(1)**: 750-760, https://doi.org/10.1016/j.carbon.2019.10.075Get rights and content.

2- Yuxuan Z.; Guoqiang L.; Ruizhi Z.; Peng C.; Qiwen L.; Jian Z.; Yi S.; Jinsong L.; Qiang S.; Lianmeng Z. (2020). Numerical simulation of static mechanical properties of PMMA microcellular foams", *Composites Science and Technology*, **192(1)** :442-456 *108110***,** https://doi.org/10.1016/j.compscitech.2020.108110Get rights and content

3- Yasir Ul-H.; Imran M.; Sadaf M.; Rizwan U.; Mahmood I.; Zeeshan ul-H.; Awais A. Q.; Shahid. (2020). Dielectric, thermal and mechanical properties of hybrid PMMA/RGO/Fe2O3 Nano composites fabricated by in-situ polymerization**",** *Ceramics Internationa* l, **46(5)**: 5828-5840**,** https://doi.org/10.1016/j.ceramint.2019.11.033Get rights and content

4- Ömer B. M.; Ertan A.; Gülşen A. E. (2020). Electrical, mechanical, and optical changes in MWCNT-doped PMMA composite films". *Journal of Composite Materials*, 7(2):792-813. https://doi.org/10.1177/0021998319898507.

5- Jose J.; George V T.; Akhil P.M.; Nambissan P.; Nandakumar K.; Sabu T., (2020). Positron annihilation spectroscopic characterization of free-volume defects and their correlations with the mechanical and transport properties of SBR-PMMA interpenetrating polymer networks". *Journal of Materials*. **113(1)**:148-168. https://doi.org/10.1039/D0CP01417F.

6- Jacek A.; Marek S.. (2020). A poly (L- lactic acid) monofilament with high mechanical properties for application in biodegradable biliary stents. *Journal of Solid State Chemistry*. **239(1)**: pp. 121-130.

7- Soran H. ; Seyed M. H. .(2020) . On the strain-life fatigue parameters of additive manufactured plastic materials through fused filament fabrication process" , *Additive Manufacturing* .**32(1)** : 188-204.

8- Wenbin C.; Xuan C.; Chao C.; Li C. , Junliang D.; Hui Z.. (2020). Very High Cycle Fatigue (VHCF) Characteristics of Carbon Fiber Reinforced Plastics (CFRP) under Ultrasonic Loading. *Journal of* Materials. ***13*** **(4)**: 891 -908; https://doi.org/10.3390/ma13040908.

9- Rozhnov A.B.; Pantsyrny V.I; Kraynev A.V.; Rogachev S.O.; Nikulin S.A.; Khlebova N.E.; Polikarpova M.V.; Zadorozhnyy M.Y.. (2019). Low-cycle bending fatigue and electrical conductivity of high-strength Cu/Nb nanocomposite wires. *International Journal of Fatigue*, **128 (1)**: 779-791 https://doi.org/10.1016//j.ijfatigue.2019.105188

10-Mohamed M. N.; Hamdani S. (2000). Thermal degradation behavior of radiation grafted FEP-G-Polystyrene Sulfonic acid membranes", *polymer degradation and stability*, **70(2)**:497-504, WWW.elsevier.nl/locate/polydegstab.

11- Hong B. K.; Jo W. H. (2000). Effects Of Molecular Weight Of SEBS Triblock Copolymer On The Morphology, Impact Strength, And Rheological Property Of Syndiotactic Polystyrene / Ethylene – Propylene Rubber Blends ", *Journal Of Polymer* **41(2)**: 2069 – 2079, whjpoly@plaza.snu.ac.kr.

12- Chang K. ; Luo H.; Geise G. M., (2019) . Water content, relative permittivity, and ion sorption properties of polymers for membrane desalination. *Journal of Membrane Science* , 574 (1): 24-32.

13-Yasser Z.; Kyong Y. R. (2020). Analysis of Critical Interfacial Shear Strength Between Polymer Matrix and Carbon Nanotubes and Its Impact On The Tensile Strength Of Nanocomposites " *Journal Of Mater. Res. Technol*, **02(039):** 1016-1026 https://doi.org/10.1016/j.jmrt .

14-Huichao Y., Guodong Z., Weitao W., Mao P. (2018). Effect of Polymer-Grafted Carbon and Nanotubes on The Interlaminar Shear Strength and Flexural of Fiber / Epoxy Multiscale Composites. *Journal of Composite Structures*, **195(2018)**: 288-296. https://doi.org/10.1016/j.compstruct.2018.04.082.

15-Huichao Yao; Guodong Zhou; Weitao Wang; Mao Peng. (2018). Effect of Polymer-Grafted Carbon and Nanotubes on The Interlaminar Shear Strength and Flexural of Fiber / Epoxy Multiscale Composites ", journal of of Composite Structures, **195(2)** :288-296. https://doi.org/10.1016/j.compstruct.2018.04.082.

16-Manjun Li; Hongyuan Fang; Mingtui Du; Chao Zhang; Zhang Su; Fuming Wang; (2020). The Behavior of Polymer – Bentonite Interface Under Shear Stress. *Construction and Building Materials*. **248(2)**118-130, http://doi.org/j.conbuildmat.2020.118680.

17-Bing W.; Guodong F.; Xiaojun T.; Jun L.; Jingran G.; Shuo L., (2020). Investigation on The Longitudinal Compressive Strength of Unidirectional Carbon Fiber / Nanoparticle Reinforced Polymer Composites Using FFT-Based Method. *Journal of Composed Structure*. **4(3)**:111-123., http://doi.org/10.1016/j.compstuct.2020.112448 .

18-Bing W.; Guodong F.; Xiaojun T.; Jun L.; Jingran G.; Shuo L.; (2020). Investigation on The Longitudinal Compressive Strength of Unidirectional Carbon Fiber / Nanoparticle Reinforced Polymer Composites Using FFT-Based Method", *Journal Composed Structure*. **3(1)**:626-639. http://doi.org/10.1016/j.compstuct.2020.112448 .

19-Anastasiia K.; Guido D. B.; Francesco G., Wim V. P., (2016). Dynamic Compressive Strength and Crushing Properties of Expanded Polystyrene Foam for Different Strain Rate and Different

Temperatures", *Journal of Polymer Testing*. **55(1)**: 61-68. http://WWW.composites.ugent.be, http://WWW.lazersport.com .
20- Shiguang P.; Lin Z.; Guoxin X.; Yue G.; Lina S.; Jianbin L., (2019). Friction and wear behavior of PTFE coatings modified with poly (methyl methacrylate). *Composites Part B: Engineering*, 172 (3): 316-322, https://doi.org/10.1016/j.compositesb.2019.04.047
21-Liza, S.; Haseeb A. S. M.A.; Masjuki, H. H. (2014) Wear behavior of PMMA against 316L stainless steel under dry and lubricated conditions. *Industrial Lubrication and Tribology*. **66 (5)**: 601-608. https://doi.org/10.1108/ILT-01-2012-0012 .
22- Zhang J., (2012). Study on friction and wear behavior of PMMA composites reinforced by HCl-immersed TiO2 particles. *Journal of Thermoplastic Composite Materials*, **7(2):**892-904. https://doi.org/10.1177/0892705712453153
23-Huang Y.L.; Ma C.C.; Yuen S.M. C.; Kuan C.Y.; Chiang H.C. (2011). C-L Effect of maleic anhydride modified MWCNTs on the morphology and dynamic mechanical properties of its PMMA composites. *Mater Chem Phys*. *129(3)*: 1214–1220.
24-Glyn D.; Philip I. (2020). Impact, Post – Impact Strength, And Post – Impact Fatigue Behavior of Polymer Composites. *Polymer Composites in The Aerospace Industry*. **5(3)**:111-129 http://doi,org/101016/B978-0-08-102697-3.00011-3
25- Felipe R. P.; Yong Z., (2019), " Interfacial Shear Stress Transfer nanowire – polymer Interfaces With Van der Waals Interaction And Chemical Bonding " *jurnal of the mechanics and physics of soiled*, **127(2)** : 191-207, https://doi.org/10.1016/j.jmps.2019.03.013.

تحديد استجابة البنية التركيبية والخواص الميكانيكية للمعالجة الحرارية للمادة الاساس (PMMA) المدعمة بمسحوق (Al_2O_3)

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الملخص

استخدمت مادة البولي (ميثيل ميثا اكريلات) (PMMA) كمادة اساس في تصنيع نماذج من مادة متراكبة بوليمرية المادة الاساس (PMCs). دعمت المادة الاساس بمسحوق (Al_2O_3) بنسبة حجمية (20 %) ومتوسط حجم حبيبي مقداره µm (5 ± 40). تمت معالجة العينات المصنعة بعد إجراء عمليات المعالجة السطحية حرارياً بدرجات حرارة مختلفة (50,70,90 ° C) ولازمان معالجة مختلفة (2,4,6,8,10) ساعة، اخضعت النماذج المصنعة لمجموعة من الفحوصات الميكانيكية والمجهرية، والتي تم بموجبها تحديد تأثير المعاملة الحرارية على عمر كلال الانحناء للعينات المصنعة، وتأثير المعاملة الحرارية على قدرة المادة على مقاومة إجهاد القص واجهاد الانحناء والبلى الميكانيكي ومقاومة الانضغاطية ومقاومة الصدمة. اظهرت النتائج أن هناك تحسنًا في عمر الكلال وتحسن في مقاومة القص، الانحناء، الانضغاط، البلى الميكانيكي، ومقاومة الصدمة بعد معاملة النماذج حراريا. وأن أفضل عمر كلال، ومقاومة القص، ومقاومة بلى، ومقاومة انحناء حصل بعد مرور (6 hours) من المعاملة الحرارية، بينما لوحظ أن أفضل تحسن في مقاومة الانضغاط ومقاومة الصدمة حدث بعد مرور (4 hours) من المعاملة الحرارية. كما أظهرت النتائج أن أفضل درجة حرارة للمعاملة الحرارية هي ($T = 70C^0$).