Nahrain University, College of Engineering Journal (NUCEJ) Vol.15 No.2, 2012 pp.197 - 205

The Effect of Curing Time on The Mechanical Properties of Polystern Reinforced Alumina Particular Composite

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Abstract:

The goal of the present research was to study the effect of curing time on the mechanical properties of particular composite. Of critical importance was the capability to predict resin flow and compaction during cure. Such a model could be used to determine optimum cure cycles without a need for experimental trial and error.

The experimental work includes steps .The first step is mixing the polyester with the Alumina powder with particular size ranged from 25 to 36 μm with different weight ratios (0, 10, 20, and 30%) and the second steps is putting it in the heater furnace at 70^oC at different curing time (1, 2 and 3 hours) to known the properties acquired and the third step is tested in the tensile test for all specimens. The conclusion of this test is summarized that the curing time of the presented composite is about 2 hour with 70^oC.

1. Introduction:

Particular composites are commonly used today in many aerospace and industrial applications. They offer a wide range of attractive material properties, both mechanical and physical, that cannot be achieved using conventional engineering alloys. These enhanced materials properties are the direct result of the interaction between the matrix and the reinforcement[1].

In a particular composite materials system, the reinforcement strengthens the matrix both extrinsically, by load transfer to the particle reinforcement, and intrinsically, by increasing dislocation density [1, 2]. The interaction between the particulate reinforcement and the matrix is the basis for the enhanced physical and materials properties associated with particular composite materials systems. Composite materials properties can be tailored to meet specific engineering requirements by selecting a particular reinforcement and varying the amount added to the matrix. In this fashion, the physical and mechanical properties of the composite materials system can be controlled with some independence[3].

Increasing the reinforcement volume in a composite system increases mechanical properties, such as elastic modulus, ultimate strength, and yield strength, while reducing the thermal expansion and, in some cases, the density of the composite system. Unfortunately materials properties such as ductility and fracture toughness typically decrease with increasing reinforcement volume.

The increase in both the elastic modulus and strength (ultimate and yield) is believed to be due to the difference in thermal expansion between the reinforcement particles and the matrix during solidification and curing. During the production of these composites, both the reinforcement and matrix are heated to processing temperature, brought to curing condition of matrix, and then allowed to cool. The thermal contraction of the matrix during cooling is typically much greater than that of the reinforcement, which leads to a geometric mismatch. At the particle-matrix interface, this geometrical disparity creates mismatch strains that are relieved by the generation of dislocations in the matrix originating from sharp features on the ceramic reinforcement. Discontinuously reinforced matrix composite materials systems are commonly used in applications that require high specific materials properties, enhanced fatigue resistance, improved wear resistance, controlled expansion. Additionally, composite may be designed to yield a materials system that offers multiple roles[4].

Some examples of multiple roles are particular composite materials systems that offer high strength and fatigue resistance for aerospace and mechanical applications, moderate strength and neutron absorption capabilities for nuclear applications, high strength and wear resistance for heavy equipment applications, and impact/energy dissipation for armor applications. The correct selection of reinforcement is very important in yielding desired resultant materials properties. An improper reinforcement selection may lead to less-than-desirable composite materials properties, difficulty in fabrication of end product, and high cost [5].

The curing of polyester is at temperature range from 65^{o}C to 75^{o} C [2-6] for pure polyester and the curing time is depend on the additives used as a reinforcement[3].

Then the curing process through composite preparation is very important to specify the mechanical properties of particular composite, this is the reason of doing presented work. The matrix used is polyester resin and the particles used is alumina particles with different Alumina weight percentage of particles as a reinforcement.

2. Materials And Preparation

2.1 Materials Used:

2.1.1 Polyester Resin

Polyesters are macromolecules that are prepared by the condensation polymerization of difunctional acids or anhydrides with difunctional alcohols or epoxy resins. Unsaturated polyester resins, commonly referred to as “polyester resins,” are the group of polyesters in which the acid component part of the ester is partially composed of fumaric acid, a 1,2-ethylenically unsaturated material. Maleic anhydride is the predominant source of this fumarate. Maleic anhydride is incorporated into the polyester backbone and then isomerized to provide fumarate esters (commonly referred to as unsaturated polyesters). In most cases, the polymer is dissolved in styrene to provide a solution that will typically have a viscosity in the range of 0.2 to 2 Pa · s (200–2000 cP). Other reactive vinyl monomers, such as vinyl toluene, diallyl phthalate, or methyl methacrylate may be used to obtain specific properties. The resin viscosity is tailored for specific fabrication processes in which the resin is ultimately “cured” via a free-radical process. A final formulation may include resin, inorganic filler, fiberglass reinforcement, and a free-radical initiator, such as an organic peroxide. This final formulation is formed against a mold prior to the cross-linking reaction between the unsaturated polymer and the unsaturated monomer. The “curing” is a cross-linking chain reaction, converting the low-viscosity solution into a three- dimensional thermoset plastic [3]. This is referred to as the cure. Terminology has developed to distinguish between various types of UPEs[5].

The term curing TPs (Thermoplastics’) occurred since at the beginning of the 20th century the term curing was accurately used for TSs. At that time TSs represented practically all the plastic used worldwide. Thus TPs took on the incorrect term curing even though there is no chemical reaction or curing action [4]. The additives that make the curing reaction go slower are inhibiters, styrene, filler oxygen, flame retardants, reinforcements and mold heat capacity. While the additives that make the curing reaction go faster are Initiators (catalysts), Heat, Part thickness, Wax or films and Post cures [6]

Some resins used with this prepreg, designed to allow out-of-autoclave manufacture of large parts that previously required autoclaving, cure at temperatures as low as 70^{o}C. The resins typically maintain their handling properties for nearly a month of intermittent exposure to ambient temperatures (1 month out-life).

Figure 1 shows the curing cycle of polyster resin at 70^{o}C. It was shown that small amount of pressure were used [7]. This curing temperature is fixed using 1200^{o}C metallurgical furnace with ±1^{o}C accuracy thermostat. This furnace was used in metallurgical tests in the materials laboratory of Nahrain University/ mechanical engineering department. The causes of using this furnace is the acceptable temperature accuracy and because it is available.

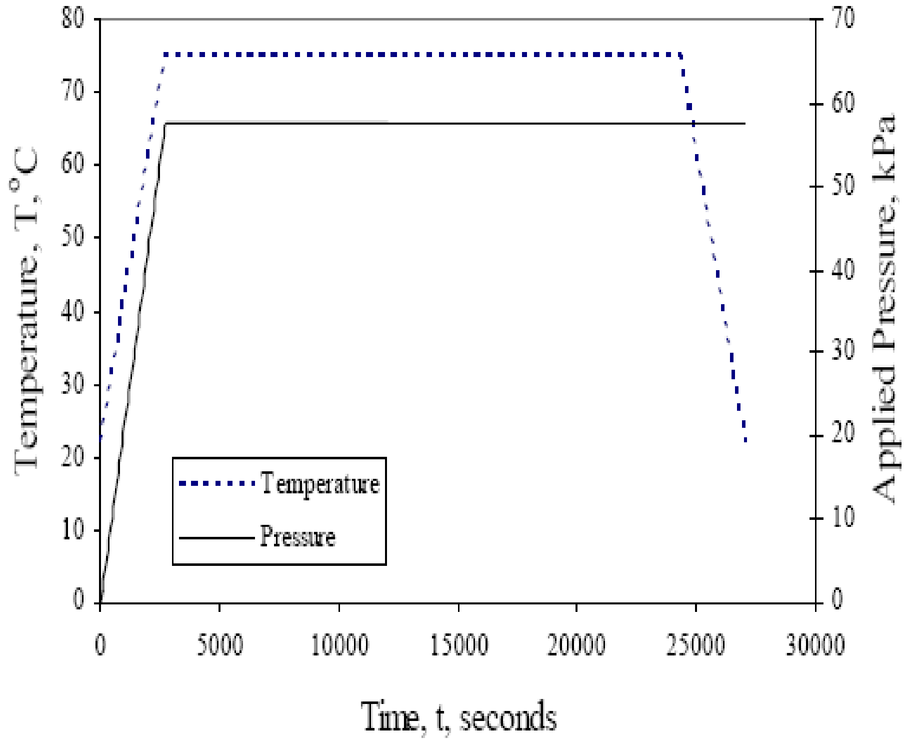


Figure 1. Curing polyester at about 70°C

2.1.2 **Alumina Particals**

Aluminum alloys reinforced with a tow-based alumina reinforcement are commercially available and can be significantly cheaper than graphite/epoxy OMCs. As a result, these are finding applications in industries that are typically very cost-sensitive. Fiber-reinforced MMCs are now entering applications in limited areas where the metal like behavior is important, including high bearing strength, good wear resistance, high electrical conductivity, and elevated temperature operation[8].

The fracture properties for higher volume fractions are lower, but these materials are used widely for wear-resistant applications and for thermal management and electronic packaging [9]. The relatively low cost and ease of manufacturing makes it an affordable material where high structural efficiency is required.

The Alumina powder used in the presented tests with particular size ranged from 25 to 36 μm and with different weight ratios (0, 10, 20, and 30%)

2.2 **TESTING OF SPECIMENS**

The moulds used are produced from paste of panes rolled out at pane and then formed the shape of each sample on it. The tensile test specimens have been produced according to (ASTM D638) as shown in Fig. 2

To produce the samples for the compression a plastic pipes with a diameter (D=10mm, L= 24mm). The compression test specimens have been produced according to (ASTM-D695M-89), where the length to diameter ratio is approximately 2:1.

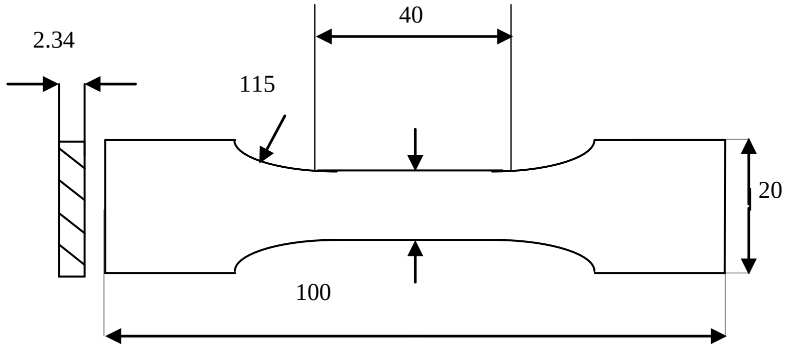
Flexural test specimens have been produced according to (ASTM D790-89) with length to depth ratio equal to 32:1, depth (3.2mm), a width (25mm) and a length (127mm).

There are four groups of specimens according to the Alumina weight percentage of alumina (0%, 10%, 20%, and 30%), all group are divided to four sub group of specimens according to the curing time at 70°C[4,8] (0hr, 1hr, 2hr, 3hr),so the summary of the specimens used are shown in table 1

The tests used for examining the specimens are tensile, flexural and compression tests as shown in figure 4

Table1.specimens formed in curing temperature of $70^{o}C$

Specimen no.	$W_{al\ (\%)}$	T_c (hr)
1	0	1
2	0	2
3	0	3
4	10	1
5	10	2
6	10	3
7	20	1
8	20	2
9	20	3
10	30	1
11	30	2
12	30	3



(a) All dimensions in (mm).

Figure 3. Tensile test specimens dimension according to ASTM D638

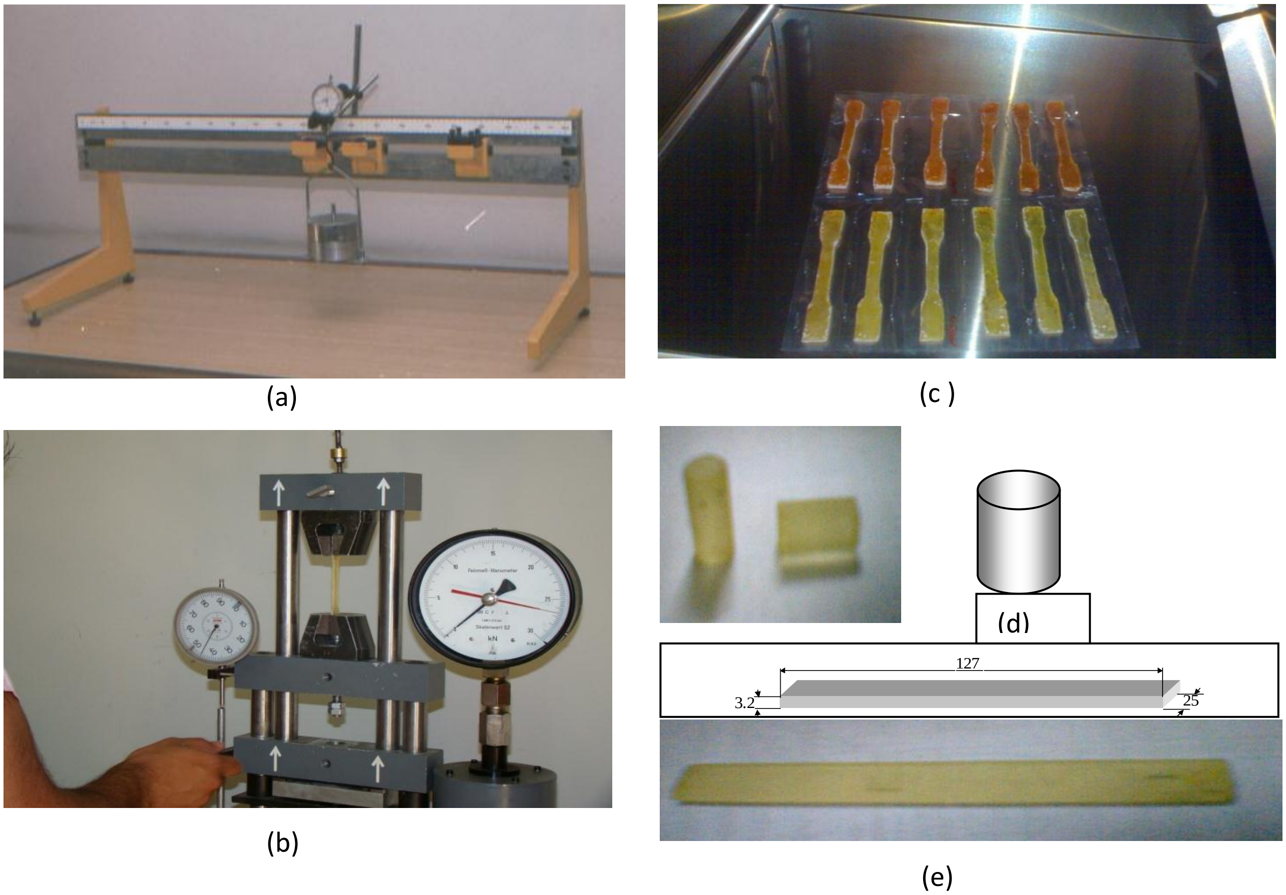


Figure 4. Testing devices and specimens

(a) Bending Test devices
(b) Tensile Test Instrument
(c) Tensile Specimens
(d) Compression Specimens
(e) Bending Specimen

3 Results And Discussion

The specimens were cured at different curing time (1, 2, and 3 hours) while keeping curing temperature fixed at 70^{o}C.

The resultant specimens ware examined to find the tensile stress relations, which were shown in figures 5, 6 and 7 for different curing time. The results show that as the alumina Alumina weight percentage increase, the mechanical properties will be improved, this is conclude that the alumina particles can be used as a reinforcement to the polyester risen matrix. The fracture strain will be decreased as the alumina fraction increase because of its hard behavior. When making comparisons through the figures the conclusion reaches is that the best curing time is about 2hours, which is give balancing between the tensile strength and Young modulus while this curing period give a high fracture strain. The increasing curing time after 2 hours will decrease the fracture strain because of brittle chemical behavior of polyester resin will takes place.

The Young Modulus and tensile strength of specimens were plotted versus curing period in figure 7 and 8 respectively

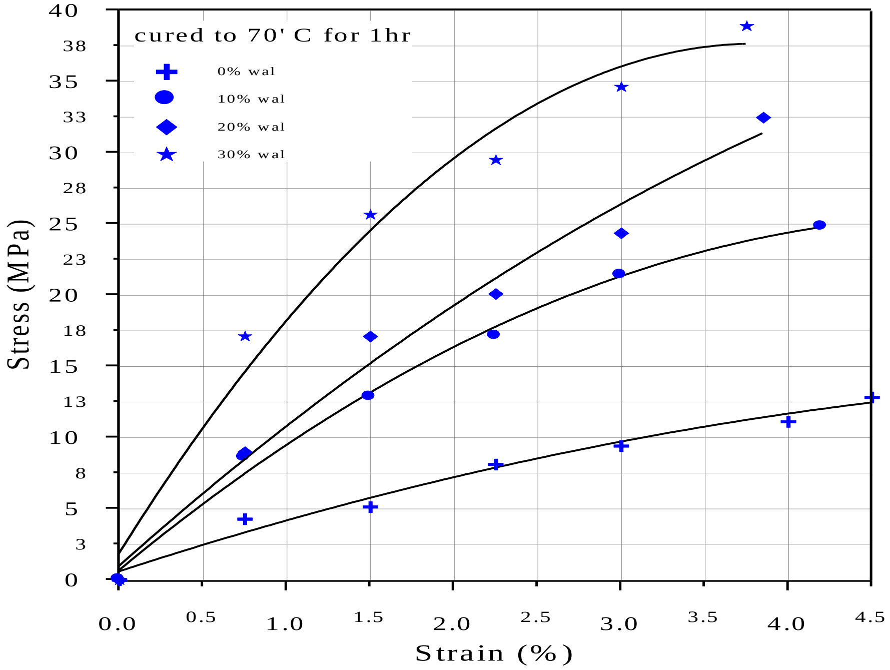


Figure 5. stress strain curve for polyester reinforced by different Alumina weight percentage of alumina particles for 1 hour curing period

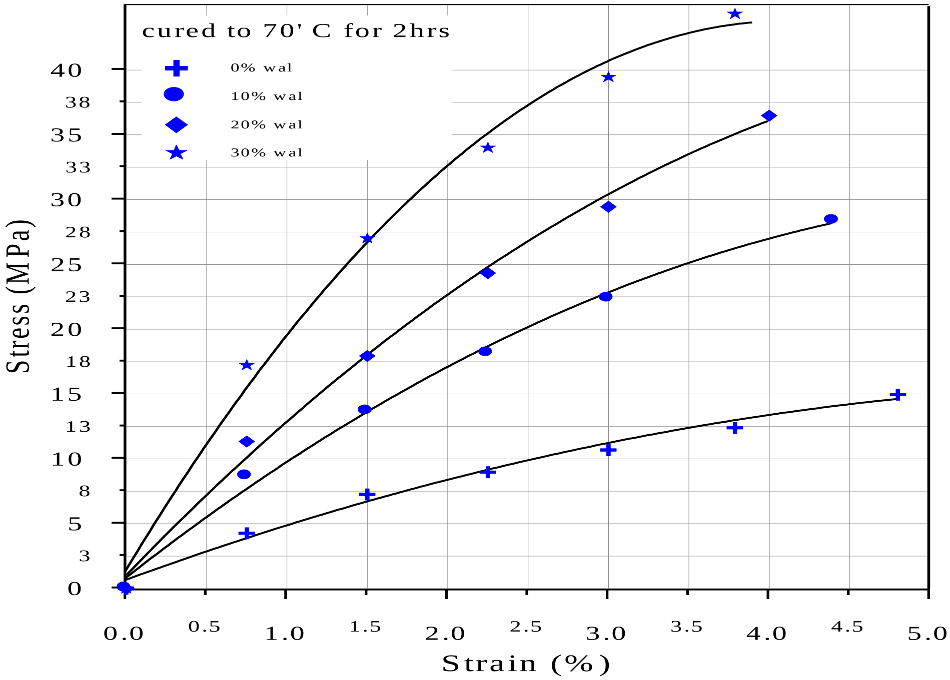


Figure 6. stress strain curve for polyester reinforced by different Alumina weight percentage of alumina particles for 2 hours curing period

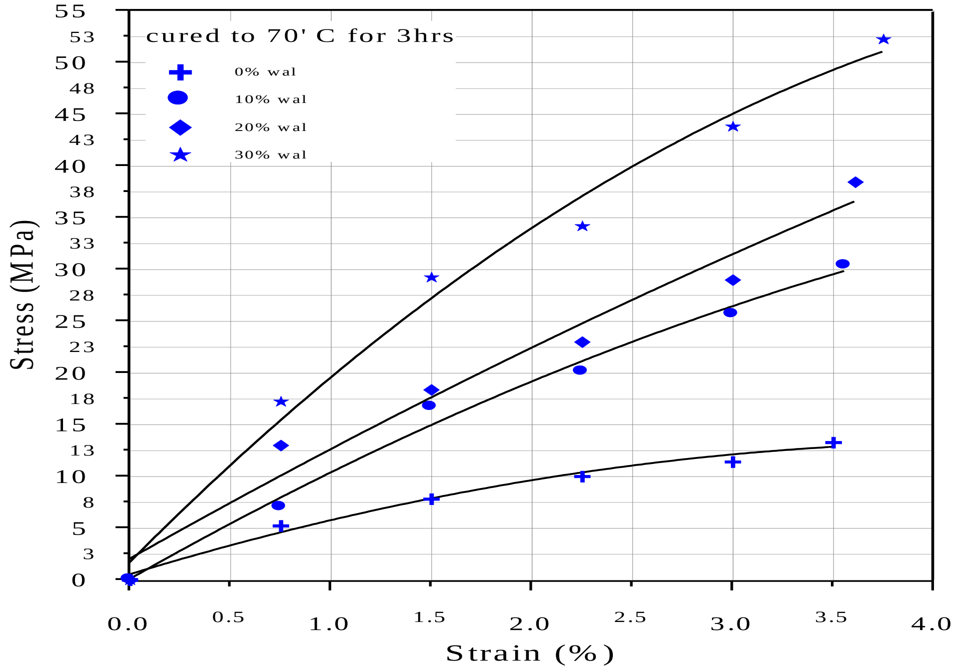


Figure 7. stress strain curve for polyester reinforced by different Alumina weight percentage of alumina particles for 3 hours curing period

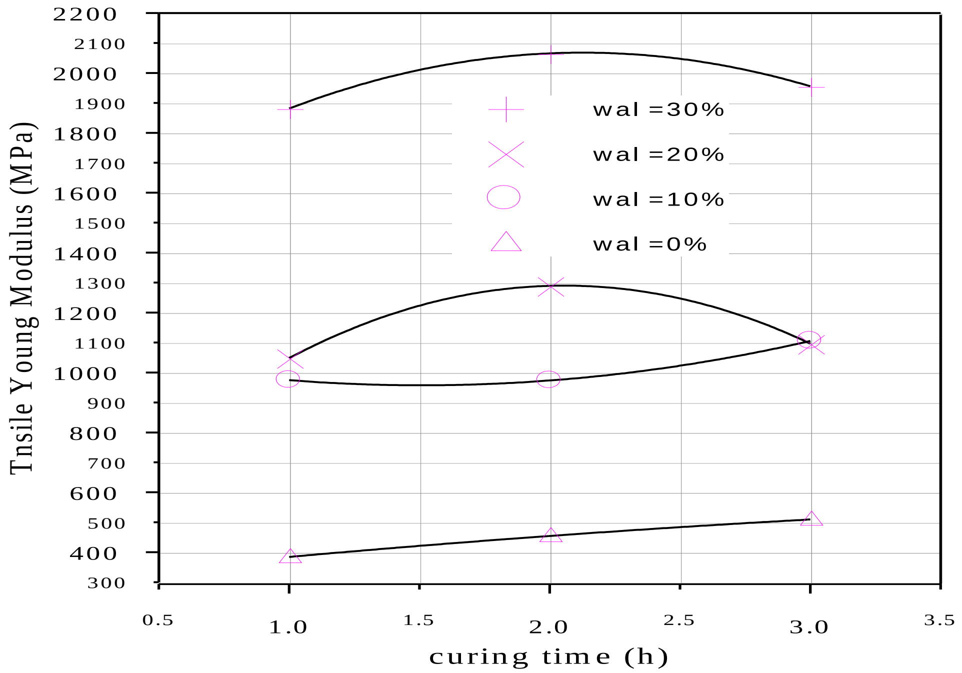


Figure 8. Tensile Young Modulus verses the curing time for composite with different Alumina weight percentage of alumina particles.

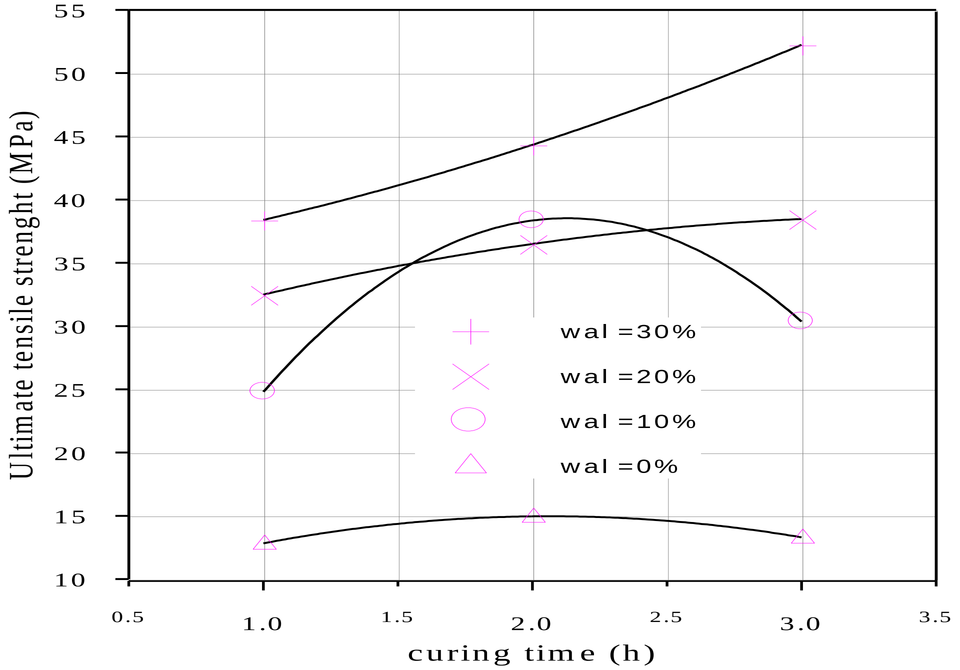


Figure 9. Ultimate tensile strength verses the curing time for composite with different Alumina weight percentage of alumina particles

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It was shown that tensile Young modulus was increased with increasing curing time until reaching to the value which represent the optimum curing time then the increasing curing time give decreasing in Young modulus because of increasing the oxidation occurs and brittle chemical results, which is give brittleness and loss in mechanical properties, which is agree with results by Joseph Earl Thompson [7] and reference [8]. Figure 8 shows that the optimum curing time that give higher young modulus is about 2+ hours.

The ultimate tensile strength verses curing time was plotted in figure 9 . For pure polyester and low Alumina weight percentage, the ultimate tensile strength will increased with increasing curing time until reaching optimum curing time value for ultimate tensile strength which is 2 hours then will be decreased. The ultimate strength for Alumina weight percentage greater than 10% will be increased above continuously with curing time but the value of strain will be decreased which is causing decreasing in Young modulus, therefore the curing time for polyester reinforced by alumina particles composite is about two hours.

4 Conclusions

The experimental study of mechanical properties of polyester reinforced alumina composite was presented at 70^{o}C curing temperature and with different curing time (1, 2 and 3 hours) and alumina volume fraction (0%, 10%, 20% and 30%). From previous conditions, the main conclusions for this study are:

1. The fracture strain will be decreased as the alumina fraction increase
2. The 2 hours curing time represent the optimum time form presented composite.
3. Young modulus was increased with increasing curing time until reaching optimum curing time (2 hours), then well be decreased.
4. The ultimate tensile strength was increased as the curing time increases

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تاثير زمن التخمير على الخواص الميكانيكية للمواد المركبة من راتنج البولستر المقوى بدقائق الالومينة

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الخلاصة:

الهدف من هذا البحث هو لدراسة تاثير زمن التخمير على الخواص الميكانيكية للمواد المركبة الدقائقية. من خلال ذلك يمكن معرفة الظروف المثلى للتخمير و الحصول على افضل عملية تلاصق وخواص وضمن شروط تخمير يمكن بها تحديد دورة التخمير للمادة المركبة دون الحاجة للمحاولة و الخطأ التجريبية.

اشتمل العمل التجريبي على تحضير عينات من خلال خلط دقائق الالومنة مع البولستر بنسب وزنية مختلفة هي (0, 10, 20, و 30%) ومن ثم وضعت في فرن بدرجة حرارة ثابتة عند 70 درجة سليزية ولازمان تخمير مختلفة هي (1, 2, و 3 ساعات). ومن ثم اجريت الاختبارات الميكانيكية للعينات المختلفة. وجد ان ظرف التخمير الامثل اي الذي يعطي افضل الخواص الميكانيكية ولمختلف النسب الوزنية للالومينة هو70 درجة سلزية و لمدة ساعتين.