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Mechanical Properties for Unsaturated Polyester Reinforcement by Glass Fiber using Ultrasonic Technique

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Abstract

In this study, the unsaturated polyester (UP) composite resin was used for binding the reinforcement such as glass fibers (GF) and polyvinylchloride (PVC) powder.Some mechanical properties of polymer composite have been investigated, by ultrasonic techniqueat 26 KHz, these properties are density, ultrasonic velocity, shear modulus, passion's ratio and elasticity modulus.Results show that all these propertieswere increase with increasing the concentration of GF% in the composite expect elasticity modulus and passion ratio decreasing.As passion's ratio is decrease until reaching 15%GF ratio where no further decrease occurs with increasing GF ratio.

Keywords: *Unsaturated polyester, glass Fiber, PVC powder, Ultrasonic wave.*

1. Introduction

The work in this investigation was planned in order to obtain further information about the effect of addition of glass fiber to the unsaturated polyester resin on the some mechanical properties of polymer composite. Fiber reinforced polymer composites have a number of advantages when used as components for the aerospace, navel, automotive or construction industries. Due to their high strength-to- weight and stiffness-to-weight ratios as well as their fatigue and corrosion resistance, it is possible to produce components that exhibit significant weight savings and improved service-time performance over that of more traditional materials (steel and aluminum alloys) [1]. It is known that the mechanical properties of fiber reinforced composites, among others, highly depends on fiber content variations[2,3,4,5]. It is also known that propagation of ultrasonic waves is sensitive to the variations in the microstructure and mechanical properties, because the mechanical wave propagation highly depends on elastic properties and density of the medium [6,7].Composite materials structural integrity can be compromised via many mechanisms including presence of discontinuities or loss of mechanical properties. Ultrasonic velocity measurements are relatively simple to make in bulk solids and can be related to the various elastic modules, especially for isotropic solids. For these bulk solids the sound speed may be weakly related to the crush or abrasion strength of the material [8,9].

The method of measuring the speed of ultrasound was by measuring the thickness of the sample and the time it takes inside the sample [10].

$$V = \frac{x}{t} \quad (1)$$

Where (x) is the sample thickness measured by digital vernier ; (t) is the time that the waves need to cross the samples[11].

The passion's ratio (σ) is the ratio of transverse contraction strain to longitudinal extension strain in the direction of stretching force. Tensile deformation is considered positive and compressive deformation is considered negative. While calculate by the following equation [12,13,14].

$$\sigma = \frac{1-2(V_T/V_L)^2}{2-2(V_T/V_L)^2} \quad (2)$$

Where (VL) is the ultrasonic longitudinal velocity; (VT) is the ultrasonic transverse velocity.

The shear modulus (G) for isotropic materials, is defined as the ratio of shear stress to the shear strain; its base unit is the Pascal (pa.) was calculated by the following equation [15,16].

$$G = \rho^* vT2 \quad (3)$$

Where (ρ) is the density of composite materials and calculated from equation.

$\rho c = \rho f * Vf + \rho m * Vm$ (4)

ρf: fiber density, ρm: matrix density, Vf: volume fraction of fiber,Vm: volume fraction of matrix.

The elastic modulus(E) is the mathematical description of an object or substance's tendency to be deformed elastically (i.e., non-permanently) when a force is applied to it. The elastic modulus of an object is defined as the slope of its stress–strain curve in the elastic deformation region[17,18]. As calculate by the following equation.

$$E = \frac{V_L^{2}\rho(1+\sigma)(1-2\sigma)}{(1-\sigma)} \quad (5)$$

2. Methods Used In the Ultrasonic Measurement Technique

The most often applied methods of ultrasonic testing are the pulse velocity method, the echo method, and the resonance method. Methods of ultrasonic wave are:

The ultrasonic pulse velocity method (called also transmission method) is one of the oldest and simplest methods of materials testing. The method consists in the determination of the travel time, over a known path length of the longitudinal ultrasonic wave after its transmission through the tested medium (see Figure. 1). Both the emitting and receiving transducers are usually placed on the opposite sides of the tested sample (coaxially if possible). Other transducer arrangements are also used in concrete testing (Figure.1b, c). They can be placed on the perpendicular surfaces (Figure.2b) or on the same side of the tested member (Figure.1c).

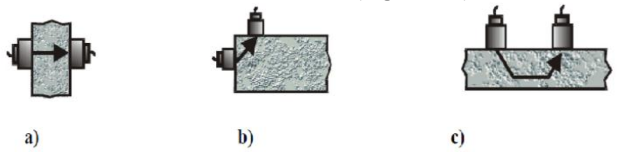

Figure 1: Ultrasonic pulse velocity method: a) direct method, b) semi-direct method, c) indirect (surface) method

The ultrasonic echo method is often used for defect detection in metal members. The method consists in generation of a short impulse of the ultrasonic wave by the transmitting transducer (Figure.2).

(a) (b)

Figure 2: Testing the concrete by ultrasonic echo method: a) transmitting-receiving transducer, b)double transducer

The resonance method consists in the introduction of an ultrasonic wave into the tested medium, which is of the constant thickness g, in such a way that a resonant standing wave, of wavelength λ, will be formed under the condition:

$g = n (\lambda/2)$ (6)

where n = an integer that defines the harmonic number.

3. Experiment

This section describes the materials used in the production of the specimens, mix proportion and the method of testing. The specimens were cast, it are cured for one hour in 100 °C.

3.1 Matrix Material

Unsaturated polyester resin (UP) was used as the matrix in the preparation of composite material polymeric and manufactured by the (Industrial Chemical of resins Co. LTD) inSaudi Arabia. This resin transforms from liquid to solid state by adding (Hardener) and this hardener is manufactured by the company itself and it is a (Methyl Ethyl Keton Peroxide) coded (MEKP) and be in the form of a transparent liquid. It is added to the unsaturated polyester resin 1% percent at room temperature, and in order to increase the speed of hardening, catalyzer materials on interaction is used as a catalyst (Catalyst) called accelerators. Cobalt Napthenate which are mixed directly with the resin and manufactured by the same company.

3.2 Reinforced materials

In this research glass fibers used from type (E-Glass) as strengthening phase in the form of choppy glass fibers with different percent (5%, 10%, 15%, 20% and 25%), average diameter of filament for this choppy glass fibers is (8–16 μm)and with length is (0.02-0.08 mm).These fibers provided by (Mowding LTD. UK)English company.

Table 1: demonstrate the physical and mechanical properties of GF

Specific Heat J/kg. K	810
Thermal conductivity W/m.K	1.3
Coefficient of thermal expansion 10-6 (˚C)-1	5
Percent Elongation (EL%)	4.3
Tensile strength MPa	3450
Diameter	08-14
Density g/cm3	2.58
Modulus of elasticity GPa	72.5

While PVC is a thermoplastic polymer. It is a vinyl polymer constructed of repeating vinyl groups (ethenyls) having one of their hydrogens replaced with a chloride group. PVC is the third most widely produced plastic, after polyethylene and polypropylene. PVC is widely used in construction because it is cheap, durable, and easy to assemble. In this study PVC (density 1.39 g/cm^3) was used in constant percentage (10%) with size particulate (300,154 and 125 μm). This mixture transforms to solid state for one hour and the mixture was used as fixed length 165 mm. Ultrasonic measurements were made by pulse technique of ultrasonic concrete tester (CSI)type (cc – 4 as shown in Figure 2 .

4. Results

Figure (3) shows that density of composite is increased with increasing GF ratio because GF density approximately twice the density of UP therefore such density increase is reasonable.

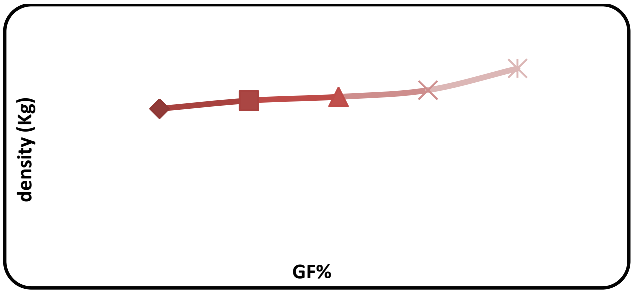

Figure 3: illustrate density with GF percentage

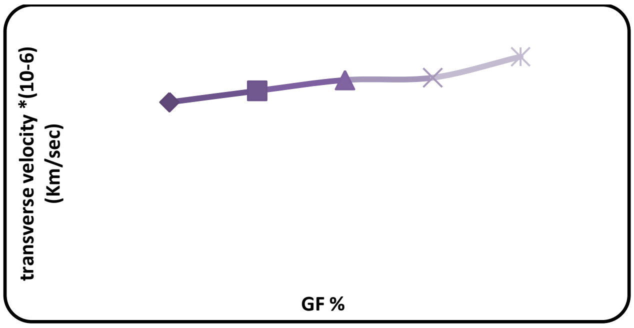

Figure 4: show transverse velocity increase with increasing GF percentage

The transverse velocity is increased by increasing GF ratio as shown in Figure (4). This is due to increase in composite density.

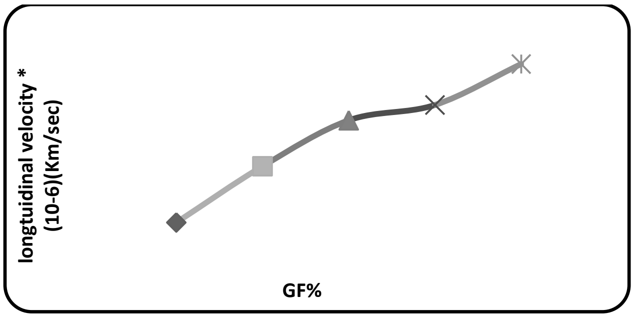

Figure 5: illustrate longitudinal velocity with GF percentage

By observer Figure 4 and 5. We can conclude that the behavior longitudinal velocity is increased shapely from behavior transverse velocity because longitudinal wave transmission is parallel to the direction of wave propagation while transverse wave transmission is perpendicular to direction of wave propagation.

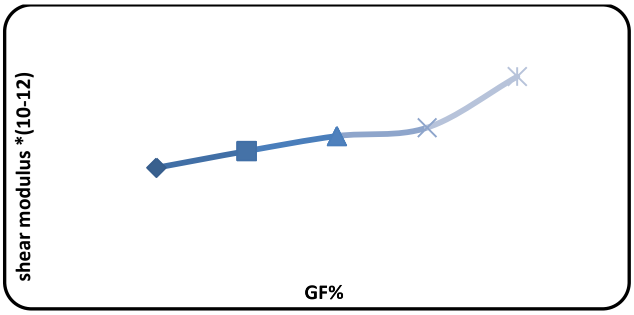

Figure 6: show shear modulus with GF percentage

Shear modulus is increase with increasing GF ratio as in Figure (6) because increasing GF ratio increase both density and transverse velocity and according to equation (3) shear modulus is increase.

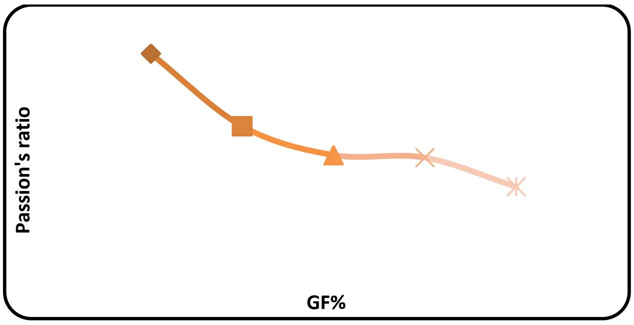

Figure 7: illustrate passion's ratio with GF percentage

From Figure 7 passion's ratio decrease with increasing GF ratio because increasing density makes composite materials rigid .therefore passion's ratio is decrease until reaching 15%GF ratio where no further decrease occurs with increasing GF ratio.

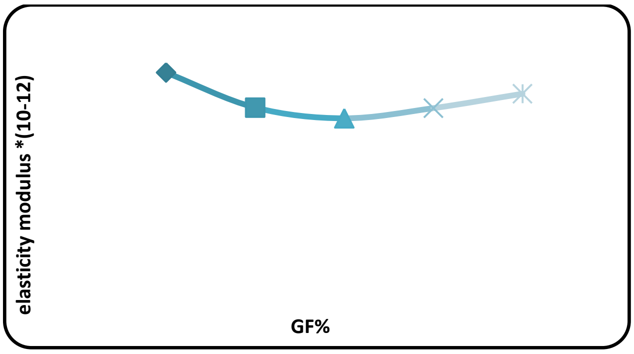

Figure 8: illustrate elasticity modulus with GF percentage

Equation (E=2G(1-σ)) shows that elastic modulus depends on shear modulus and passion's ratio, since passion's ratio is considerably decreased and shear modulus is increased therefore elastic modulus is decreased.

5. Conclusion

1- density of composite,transverse velocity and longitudinal velocity is increased with increasing GF ratio. This later is due to increase in composite density.

2-Shear modulus is increase with increasing GF ratio because increase both density and transverse velocity and according to equation(G = ρ*vT2).

3- passion's ratio is decrease until reaching 15%GF ratio where no further decrease occurs with increasing GF ratio.

4- elastic modulus is decreased according to equation(E=2G(1-σ)).

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