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Preparation and Study Some of Properties of Unsaturated Polyester/Soda Lime Glass-Sawdust Hybrid Composite

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Abstract: In the current research, composite content three materials polyester resin as a matrix and the reinforcement material with the percent of 2: x for sawdust soda lime glass, respectively where (x = 0, 3, 6, 10, 14%). All the samples have prepared by hand layup process. In this study was investigated the thermal conductivity and some of the mechanical properties as a tensile strength impact strength, compressive strength, hardness and flexural strength. The factors of tensile strength, compressive strength and flexural strength appeared clear improvement at percent 2:6. The rest studied factors appeared different behaviors.

Key words: Unsaturated polystyrene, saw dust, soda lime glass, mechanical properties, thermal conductivity, polymerization

INTRODUCTION

Unsaturated polyester resin is a type of thermoplastic resin and is preparing from the reaction of monomer glycol with a non-saturated bipolar acid. One or both monomers must have a double bond in its composition. After forming the linear polymer mixing with an effective phenyl monomer such as styrene. In addition to the auxiliary factor breaks down into free cracks and thus, polymerization of phenyl monomer with double bonds along the polymer chain and thus, forming of polystyrene. The polyester resin has good thermal properties as it carries the high temperature (according to resins) up to 260°C but it has an automatic degradation at about 300°C even not having oxygen (Jesson, 2005).

It is also characterized by excellent electrical resistance and chemical resistance to solvents, acids, salts, anti-wear and environmental effects in addition to being low cost but weak and fragile. The polyester is reinforced for the manufacture of mold structures and components of aircraft bodies, automobiles and other industries (Ruban *et al*., 2014).

These days, natural materials reinforced composites show excellent thermal, electrical g and mechanical properties than made materials reinforced composites because of its majestic properties. The reinforced composites are biodegradable, renewable, lightweight, material and the environment-friendly according to synthetic materials (Garadimani *et al*., 2015; Murali and Mohana, 2007; Boopalan *et al*., 2013). The potential applications of these composites have increased quickly in many domains of engineering (Bledzki *et al*., 2007; Mukhopadhyay *et al*., 2008). Reinforced polymer composite materials are used extensively and increasingly in large numbers of industries including furniture, automotive, aerospace, marine, construction, sports equipment, electrical and domestic appliances (Yazdanbakhsh and Bank, 2014).

Waste management has long been known as one of the most important factors for achieving sustainable development. Scientific interest in the development and/or improvement of waste management has increased through several methods including reducing waste disposal and reuse to reducing processing costs (Varitis *et al*., 2015).

The wood filler for the sawdust is the most popular used to an unsaturated polyester resin as particles of various sizes which generated from graduated, generally which have a lower aspect ratio than wood and other natural fibers. Additives of wood contain a mixture of short chopped fibers and sawdust (Hafad, 2010).

The most common kind of glass is soda lime glass which used for glass containers, windowpanes and other uses (Hussain and Ali, 2010). Which often

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ends in the fracture, leading to an environmental problem that had to be disposed of by recycling and hence, the idea was to take advantage of them in the reinforcement of polymers.

This study has we focused on the investigation how the characteristics of soda lime glass and sawdust influence the mechanical and thermal properties of unsaturated polyester resin and on the other hand aims to eliminate the environmental problem of getting rid of the waste of glass and wood sawdust which is increasing day after day, so as to get useful and cheap materials at the same time.

MATERIALS AND METHODS

Experimental procedure

Raw materials: Unsaturated polyester (Saudi industrial resin limited, Saudi Arabia) and methyl ethyl ketone peroxide as a hardener, sawdust residues, glass residues (lime soda glass).

Reinforcement materials: In the beginning, the glass residue was washed from the dust and suspended dirt, then dried with 100°C heat oven for 2 h to dry it thoroughly and then grinded to a size 50 μm and then was stored until use.

Then the sawdust was taken and washed well and was dried in a 100°C oven for 2 h to completely remove the moisture, then grinded to 50 μm size and kept for use. This size was obtained by using standard sieves. The glass powder with the sawdust in an electric mixer for the purpose of full homogenization and for an hour each separately according to Table 1.

Preparation of samples: After that samples of the composite material were prepared to consist mainly of unsaturated polystyrene and the addition of the hardener by a fixed rate of 2% with sawdust and glass then mixed them together.

Lubricating the mold with vaseline to prevent adhesion between the substance of the sample and the mold. Pour the samples into the prepared mold and leave to dry for 1 day. After removing the samples from the mold, place them in a convection oven at 50°C and 1 h. Cut the samples by the dimensions required for each test according to ASTM D 790.

Measurements

Thermal conductivity: When there is a thermal difference between two surfaces, the heat will pass from the high-temperature surface to the surface low temperature and this phenomenon is known as thermal conductivity. On this basis can be defined the thermal conductivity is the rate of heat flow across the unit area during the time unit when there is a gradient thermal between two surfaces of 1°C. The thermal conductivity is different depending on the material (Solid, liquid, gaseous) through which the material is classified as a dielectric or heat conductor (Ibrahim, 2003).

Table 1: The proportions used for lime glass sawdust in prepared samples

Sample's code	Polyester (wt.%)	Wood (wt.%)	Soda lime (wt.%)
P2-0	98	2	0
P2-3	95	2	3
P2-6	92	2	6
P2-10	88	2	10
P2-14	84	2	14

Thermal conductivity in metallic materials on the transfer of free electrons whereas in composite materials it is adopted where the composite materials show a strong conductivity (Fiber Orientation) thermal conductivity on the fiber orientation. (Through the thickness) and a weaker conductivity in the longitudinal direction of the fiber. In general, the thermal conductivity of resins is increased after fiber reinforcement and this increase is expected due to the fiber capacity as a whole for thermal conductivity compared to the base material (Mallick, 2007). Coefficient of thermal conductivity is calculated by the following (Eq. 1) (Al-Saadi *et al*., 2018):

$$K\frac{(T_2\text{-}T_1)}{d_S} = e\left[T_1+\frac{2}{r}\left(d_1+\frac{d_s}{2}\right)T_1+\frac{d_s\text{-}T_2}{r}\right] \qquad (1)$$

where, the factor (e) can calculated by the following (Eq. 2) (Ibrahim, 2003):

$$IV = \pi r^2 e(T_1+T_3)+2\pi re[d_1\,T_1\,d_s\frac{(T_1+T_2)}{2}+ d_2T_1+d_3T_3] \qquad (2)$$

Where:

- K = The thermal conductivity coefficient measured in W/m.°C
- d_1, d_2 = Represent the thickness of the disk (mm)
- e = The quantity of heat passing by the unit of time
- d_s = The thickness of sample (mm)

Mechanical properties of composite materials: The general and engineering uses of composite materials depend largely on their mechanical and physical properties such as tensile strength, elasticity, elongation and resistance to heat and environmental conditions such as humidity, sunlight and other applied properties. All these properties depend heavily on the molecular structure of the resin and on its molecular weight and molecular forces. These properties also depend basically on reinforcing materials and on additives such as fillings and plasticizers (Amran *et al*., 2015). Among the characteristics discussed in this research are the following.

Impact strength: Impact strength expresses the material's ability to resist breakage under a sudden load and is a measure of the strength of the material. The impact strength can be expressed by the following (Eq. 3):

$$IS = \frac{U_f}{A}\left(\frac{KJ}{m^2}\right) \quad (3)$$

Where:

A = The sample's cross-sectional area (m^2)
U_f = The energy of fracture (KJ)

Tensile strength: Tensile strength is a measure of the material's ability to resist static forces that try to pull and break the material. The tensile strength can be expressed by the following (Eq. 4):

$$TS = \frac{F}{A}(MPa) \quad (4)$$

Where:

A = The cross-sectional area of the sample (mm^2)
F = The applied force (N)

Compressive strength: This resistance shows the extent to which the material is tolerated when it undergoes a static compression load before it is broken usually measured by MPa unit. The high values of tensile strength indicate the greater cohesion forces between the molecules of the material. The compressive strength can be expressed by the following (Eq. 5):

$$CS = \frac{F}{A} \quad (5)$$

Where:

A = The cross-sectional area of the sample (mm^2)
F = The applied force (N)

Flexural strength: This property is a measure of resistance to bending and can be defined as the maximum static load that can be affected on the test sample before being subjected or broken and measured in the unit of (Mpa). The flexural strength can be expressed by the following (Eq. 5):

$$FS = \frac{3Pl}{3bd^2}(MPa) \quad (6)$$

Where:

l = The distance between the two supports point, b and d are the sample's dimensions
P = The applied load

Hardness: Hardness is defined as material resistance to scratching or penetration. There are several different global standards for determining the hardness of plastic materials, the most common of which is the hardness of the Shore D. The penetration occurs at a slow rate on the surface of the sample during the affecting of force for the test, leading to a local creep. After the vanishing of the influencing force, a relatively slow recovery occurs in the test which changes the dimensions (De Medeiros *et al*., 2005). The hardness of all samples were examined according to the standard specification (TH 210) of Shore (D) device.

RESULTS AND DISCUSSION

X-ray diffraction: X-ray diffraction patterns of polyester with a different percent of glass-sawdust carried out by Shimadzu XRD-6000 using Cu $K\alpha_1$ radiation with wavelength of 0.15406 nm for five polyester samples which studied in the present work, they have similar patterns and it can notice that the peak is increased in height by increasing the wt.% of soda lime glass The general shape of this patterns is in agreement with the literature reported of patterns of polyester as shown in Fig. 1.

Thermal conductivity: Figure 2 shows the relationship between the thermal conductivity coefficient and the reinforcement materials (glass and sawdust) for different percent.

Increasing the sawdust in the polyester matrix reduces the thermal conductivity of the composite material due to the increase in the number of fine spaces in the compound due to the greater amount of bonding area between the sawdust and the polymer matrix, so, when the thermal energy moves through the matrix material by the vibration of the material.

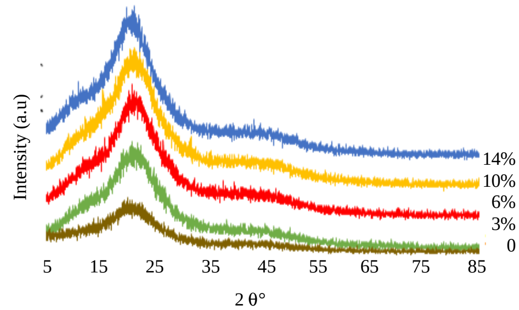

Fig. 1: X-ray diffraction pattern for of amorphous polyester/glass-sawdust composite system

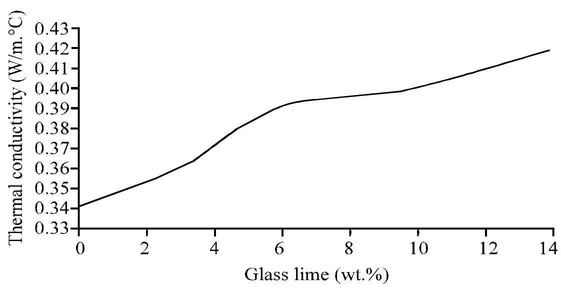

Fig. 2: The relationship between thermal conductivity and wt.% glass lime

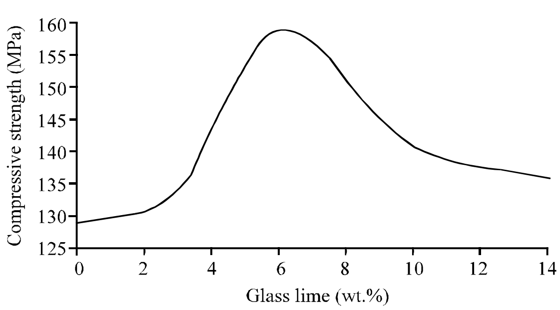

Fig. 3: The relationship between compressive strength and wt.% glass lime

The area of the interface will be different in which it will move which will block the transmission of heat energy and thus reduce the value of the transferred heat energy and will lead to lower thermal conductivity values (Alzuhairi *et al.*, 2016; Agarwal *et al.*, 2006).

On the other hand, the addition of glass to the polymer works to increase the thermal conductivity significantly. The reason for this is that the fine glass fills the gaps between the layers of the polymer in addition to the glass has a good adhesion to the polymer, unlike the sawdust (Muller *et al.*, 2017).

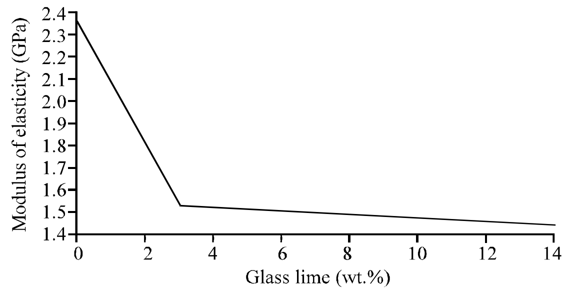

Fig. 4: The relationship between modulus of elasticity and wt.% glass lime

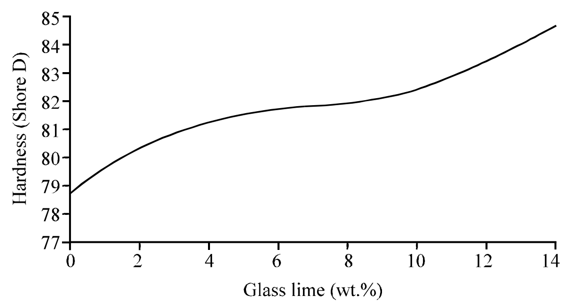

Fig. 5: The variation of hardness with wt.% glass lime

Compressive strength: Figure 3 exhibits the influence of the glass powder and sawdust at different percent loading on the compressive stress of the unsaturated polyester matrix. The figure display increasing in compressive strength when added the glass and sawdust to unsaturated polyester matrix this may be due to glass has high compressive strength also a good interface between the filler and matrix. The compression strength for composite gradually decreases when the filler beyond 6% wt. It indicates that the lower degree of particles-polymer interaction occurs at higher filler contents because of the agglomerated of the glass when the content of filler increased (Majeed and Ibrahim, 2017) Fig. 5.

Modulus of elasticity: Figure 4 exhibits we observe a clear decrease in modulus of elasticity from 2.37 to 1.44 GPa of the composites with the increasing volume fraction of glass. The greater the elasticity modulus, the stiffer the material (Aramide *et al.*, 2009; Callister, 2000). Figure 4, it appears that with the increase in glass volume in the composite samples, it becomes stiffer and reaches the maximum value at around 14% (Ali and Fahad, 2015). Generally, glass and sawdust have the same behavior but increased glass reinforcement has produced

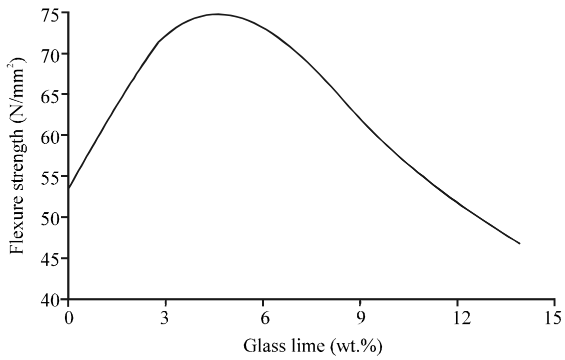

Fig. 6: The variation of flexure strength with wt.% glass lime

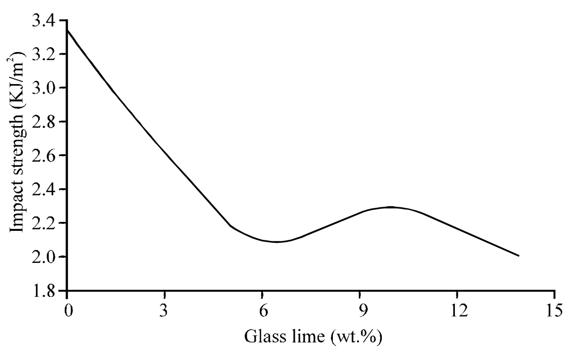

Fig. 7: The variation of impact strength with wt.% glass lime

better results that may be assigned to the truth that glass is described by their high strength (Abass *et al*., 2017).

Hardness (Shore D): Figure 5 shows the variation of hardness (Shore D) with different weight percentage addition of glass lime and sawdust to the composites. The hardness of the composite increased with increase in filler content of both sawdust and soda lime powder. From this figure it can be shown that the hardness increase with increasing the addition of the hardener composite P2-14 displayed highest hardness value compared to all other investigated samples as shown in Fig. 5. This observation may be due to better compaction between the reinforcing materials and possibly due to the inhomogeneity of the samples resulting from poor manual compaction of the sample. Generally, addition of fillers increases the hardness of composite materials, especially, if well compacted.

However, the presence of wood dust had been observed to significantly affect the hardness value.

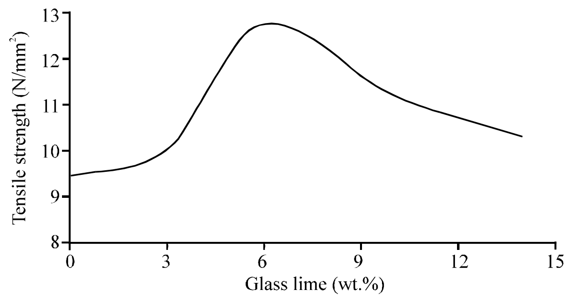

Fig. 8: The variation of tensile strength with wt.% glass lime

This observation is in agreement with the results of other studies (Omiwale *et al*., 2017; Oladele *et al*., 2013). Also, the saoda lime powder showed higher hardness compared to wood dust because of stronger bonding between polyester and glass and amorphous nature of glass powder. It can be deduced that hardness of a composite depends on the distribution of the reinforcing material in the matrix.

Flexural strength: The flexural strength of polyester composites relay certainly on composite's microstructure and the bonding of interfacial among the matrix and the reinforcement material (Oluwole and Oluwaseun, 2016). Flexural strength of the composites is presented in the from Fig. 5, it can observe that the addition of sawdust and soda lime glass increasing the flexural strength of the composites by about 73.5% for P2-6 sample. When compared the pure polymer with the reinforced, it can observe there is a change in the value of flexural strength from 53.5-73.5 N/mm^2 which is the highest value among all composites at 6 wt.%. That is because of the strong interfacial adhesion/bonding among the particles of the lime glass/sawdust and the matrix which enhances the transfer of load (Durowaye *et al*., 2014). The subsequence reduction in flexural strength is because of the agglomerate formation at advanced ratio of the reinforcement materials. The lowest value of flexural strength is 46.76 MPa which obtained from the composites with 14% soda lime glass filler as shown in Fig. 6.

Impact strength: Figure 7 explain the variation of impact strength and the percentage of filler content of soda lime glass and sawdust in reinforced polyester composites. For a sample which symbol is P2-0, we can notice it has a maximum value of

3.329 KJ/mm^2 at 0 wt.%. After the reinforcement process, the value of impact strength decreased. Accordingly, when the ratio of the soda lime glass increases, the poor interfacial adhesion appeared among the reinforcement material and the polyester matrix, so that, leading to the appearance of cracks in micro dimensions at the points of impact which reduces the impact strength. That happens because the insufficiency of the reinforcements to prevent the propagation of cracks resulting in the decrease of the impact strength (Durowaye *et al*., 2014). Above 6 wt.% the impact strength was increasing and then decrease again after 10 wt.% for sawdust sample. The excess in impact strength of the composites is because of an increase in elasticity of the composite, so that, way to increase the matrix's deformability (Thomas *et al*., 2012).

Tensile strength: The response of the materials to tensile strength is shown in Fig. 8. Treatments of polymer with fillers make them more hydrophobic resulting in improved bonding between the various constituents. Both soda lime and sawdust samples gave better tensile strength compared to low filler in P20 composite as shown in Fig. 6. Soda lime samples gave enhancement in tensile strength than sawdust samples. Highest tensile strength of 12.74 MPa was obtained for composites with 6 wt.% filler of soda lime which is an enhancement of about 35% over composites of lowest filler. Further addition of soda lime and sawdust to the composites resulted in reduction of tensile strength which is also observed in the flexure behavior. Above 6 wt.% for both filler loading, the tensile strength decreased possibly due to lack of good compaction between the reinforcements and the polymer matrix (Ibrahim, 2003).

It was observed in all investigated mechanical properties that similar behaviors were seen for the responses of soda lime and sawdust reinforced polyester composites. The properties tend to increases as the reinforcement content increases for soda lime than sawdust composites extremely to 6 wt.% filler. Since, the responses show a consistency in the tendencies of the behavior of the composites, it therefore, implies that both elemental constituents and weight fraction of these particles have influence on the mechanical properties of the developed polyester based composites.

CONCLUSION

The following conclusions were drawn from the results of the tests conducted. The soda lime and sawdust fillers are good alternatives to synthetic fibers as they are cost effective, abundantly available and environmentally friendly. The hardness of the composite increased with increasing the filler content of both soda lime glass.

The filler content containing 6 wt.% soda lime reinforcement increased the load carrying capacity of the material. The factors of tensile strength, compressive strength and flexural strength appeared clear improvement at percent 2:6. The rest studied factors appeared different behaviors.

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