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A Theoretical Study on the Mechanical Behavior of E-Glass Reinforced Polyester Composites

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ABSTRACT: This investigation evaluated the mechanical properties of polyester resin reinforced with different weight fractions of E-glass fiber (10%,20%, 30%, 40%) by using mathematical and simulation approach. The standard specification (ASTM D638-I) was used to calculate the mechanical properties of glass fiber reinforced polyester composites with different weight fractions (10%, 20%, 30%, 40%) respectively. The results obtained using mathematical approach is compared with simulation results. The obtained result shows that increase in fiber content results in enhancement of mechanical properties of pure polyester resin.

KEYWORDS: Polyester resin, glass fiber, mechanical properties, mathematical and simulation approach

I. Introduction

A composite material is combination of one or two materials with different physical and mechanical properties combined together to form a parent material. The composite materials generally possess special characteristics like high stiffness, high strength, low weight, high corrosion resistance and high hardness compared to the individual components. The composite materials are classified into three categories namely laminar composites, particular composites and fiber reinforced composites [2, 4]. This investigation evaluation of mechanical properties comes under fiber reinforced composites. The manufacturing of fiber reinforced materials involves incorupting high strength fiber into the matrix material. The high strength fibers are glass, carbon and aramid [12].

Generally, the composites have two elements namely matrix material and reinforcing material. Matrix material is called continuous phase which may contain metal, ceramic or polymer matrix. Polymer Matrix materials posses better mechanical and thermal properties when compared to metal and ceramic matrix. Polymer matrix is low cost and easy to fabricate. Commonly used polymer resins are polyester, vinyl ester and epoxy resin [2, 3]. The reinforcing materials is called as distributed phase and are available in variety of forms like continuous fibers, short fibers, whiskers, particles etc..The reinforcements include synthetic fibers or natural fibers[2, 10]. The synthetic fibers are glass, carbon, aramid, kevlar etc...And some of naturalfibers are banana, bamboo, flax, abaca, hemp, sisal etc… [1]

Ali I. Al-Mosawi et al (2012) investigated the mechanical properties of araldite resin reinforced glass fiber with different weight fractions for manufacturing electrical circular plates using simulation approach [5]. Abbas and Al-Jeebory et al (2010) studied the effect of hybrid composites (carbon-kevlar) on the mechanical properties of araldite resin with different weight fraction of fibers[7]. The increase in fiber content results in enhancement of mechanical properties. Mahmoud A. Hassan (2012) investigated the physical and thermal properties of S-glass fibers reinforced with araldite resin by changing the fiber reinforcement percentage [8]. Ali I.Al-Mosawi et al (2013) investigated the mechanical properties polypropylene resin reinforced glass fiber with different weight fractions using simulation approach and also Ali I. Al-Mosawi et al (2102) studied the mechanical properties vinyl ester resin reinforced glass fiber with different weight fractions using theoretical approach [2, 6]. The mechanical properties of E-glass fiber and polyester resin are listed in Table 1 and 2.

Table: 1 Properties of E-glass fiber[1, 9]

Property	E-glass fiber
Density (g/cm^3)	2.6
Elastic modulus (GPa)	3400
Tensile strength (MPa)	72
Poisson ratio	0.22

Table:2 Properties of polyester resin [12]

Property	Polyester resin
Density (g/cm^3)	1.2-1.5
Elastic modulus (GPa)	2-4.5
Tensile strength (MPa)	40-90
Elongation (%)	2
Poisson ratio	0.4

II.MECHANICAL PROPERTIES

TENSILE STRENGTH

Ultimate Tensile strength (UTS) is the ability of a material to withstand a pulling force (ie.. tensile force). It is obtained by plotting stress versus strain. UTS is the peak point in the stress-strain curve. The tensile strength is expressed in terms of MPa. The factors which affect tensile strength are preparation of the specimen, presence of surface defects and the temperature of the test environment and material.
The tensile strength of a material is given by,

$$\sigma = \frac{P}{A} [6]$$

Where,

σ- Tensile strength (N/m^2)
P- Test load (N)
Cross section area of sample (mm^2)

TENSILE MODULUS

Tensile modulus is the ability of the material to resist deformation under load.Tensile modulus is also known as young's modulus. It is a measure of a stiffness of an elastic material. Tensile modulus is the ratio of stress to strain.
Tensile modulus of a material is given by,

$$E_c = \frac{\sigma}{\varepsilon} \quad [11]$$

Where,

E_c- Tensile modulus (N/m^2)
σ- Tensile strength (N/m^2)
ε- Strain of a material

TOUGHNESS

Toughness is the amount of energy that a material can absorb before rupturing. The toughness may be evaluated using charpy and izod tests. Toughness can be determined by integrating the stress-strain curve.
The toughness of a material is given by,

$$U_T = \sigma \times \varepsilon \quad [13]$$

Where,

U_T- Tensile toughness (J/m^3)
σ- Tensile strength (N/m^2)
ε- Strain of a material

IMPACT STRENGTH

Impact strength is the ability of the material to absorb shock without breaking. It is expressed in terms of energy. The factors which influence the impact strength are volume of the material, elastic modulus, force distribution and yield strength.

The toughness of a material is given by,

$$G_C = \frac{Uc}{A} \qquad [14]$$

Where,

G_C - Impact strength (J/m^2)
U_C - Absorbed energy (J)
A - Cross section area of sample (mm^2)

III. METHODOLOGY

MATHEMATICAL APPROACH

In this research, the orientation of fiber is assumed to be unidirectional. In unidirectional composite structures, the fibers carry most of the load as the tensile force acts along in which fibers are oriented. The standard specification (ASTM D638-I) with dimensions 165 × 19 × 3 mm was used with dumb bell section.

For unidirectional continuous fiber composite [15, 16]

1. Ultimate tensile strength of composite $(\sigma_c)^T = (\sigma_f)_{ult} V_f + (\sigma_m)_{ult} V_m$
2. Ultimate strain of fiber $(\varepsilon_f)_{ult} = \frac{(\sigma f)ult}{Ef}$
3. Ultimate strain of matrix $(\varepsilon_m)_{ult} = \frac{(\sigma m)ult}{Ef}$
4. Tensile modulus of composite $E_c = E_f V_f + E_m V_m$
5. Cross section of the composite $A_c = t_c h$

Where,

$(\sigma_f)_{ult}$- Ultimate tensile strength of fiber (MPa)$(\sigma_m)_{ult}$- Ultimate tensile strength of matrix (MPa)
V_f- Volume fraction of fiber V_m- Volume fraction of matrix
E_f - Tensile modulus of fiber (GPa) E_m- Tensile modulus of matrix (GPa)
t_c- Thickness of the specimen (mm) h - Height of the specimen (mm)

Using above formulas the ultimate tensile strength of composite, ultimate strain of fiber, matrix and composite were calculated for E- glass fiber reinforced polyester composite with different weight fraction of fibers (10%, 20%, 30% and 40%) and alternatively mechanical properties of the prepared composites were calculated.

SIMULATION

In this research, ANSYS program version (14) was used to calculate the mechanical properties of E-glass fiber reinforced polyester composite materials. Specific properties for both resin and fibers had imported in database of ANSYS program and then draw the obtained stress and strain value after applied the loads.Specifications used to draw the samples are listed in Table 4. The von-mises stress and strain values obtained for E-glass fiber reinforced polyester composite at 40% weight of fiber is shown in Figure. 1 & 2

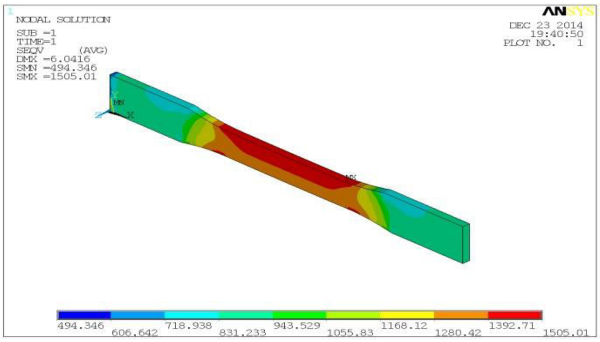

Figure.1 Stress value of E-Glass fiber polyester reinforced composite with 40% weight fraction

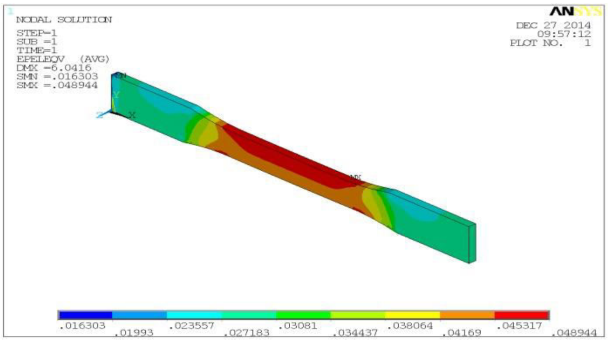

Figure.2 Strain value of E-Glass fiber polyester reinforced composite with 40% weight fraction

IV. RESULT AND DISCUSSION

From results obtained it is found that mathematical approach and ANSYS simulation have better correlation. Mechanical properties of E-glass reinforced polyester composite for different volume fractions (10%, 20%, 30% and 40%) obtained using mathematical approach and ANSYS simulations are illustrated in the Figure. 3 to 6. Incorporation of E-glass fibers (10%, 20%, 30% and 40%) in polyester resin leads to enhancement in tensile strength, modulus, toughness and impact strength compared to control.

The tensile strength of E-glass reinforced polyester composite with different weight fractions using mathematical approach and ANSYS simulation is depicted in Figure. 3. If the modelling is done mathematically, addition of E-glass fiber 10%, 20%, 30% and 40% in polyester resin shows 513.076%, 1026.153%, 1539.230% and 2052.307% enhancement in tensile strength compared to pure polyester. Alternatively, if is simulated by ANSYS, then the addition of E-glass fiber 10%, 20%, 30% and 40% results in enhancement of 429.50MPa, 788.42MPa, 1146.91MPa and 1505.01MPa tensile strength respectively.

The tensile modulus of E-glass reinforced polyester composite with different weight fractions using mathematical approach and ANSYS simulation is depicted in Figure. 4. Using mathematical approach, incorporation of 10%, 20%, 30% and 40% volume fraction of E-glass fiber leads to 211.538%, 423.076%, 634.615% and 846.153% increase in modulus of elasticity compared to pure polyester. But in ANSYS simulation, the addition of E-glass fiber 10%, 20%, 30% and 40% results in 30.75GPa, 23.87GPa, and 16.99GPa and 10.12GPa enhancement of tensile modulus compared to control.

The toughness and impact strength of E-glass reinforced polyester composite with different weight fractions using mathematical approach and ANSYS simulation is depicted in Figure. 5&6.

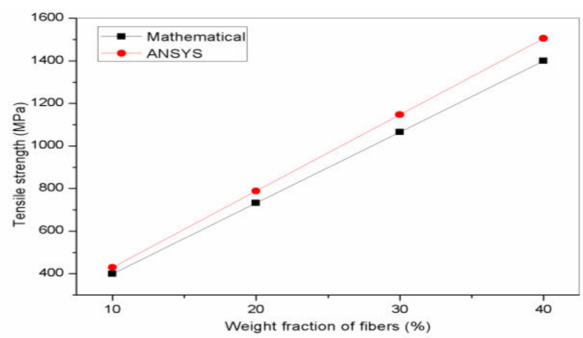

Figure.3 Tensile strength for 10%, 20%, 30% and 40% addition of E-glass fiber reinforced polyester composites using mathematical and simulation approach

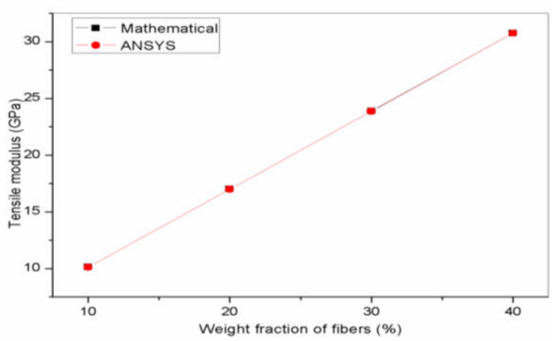

Figure.4 Tensile modulus for 10%, 20%, 30% and 40% addition of E-glass fiber reinforced polyester composites using mathematical and simulation approach

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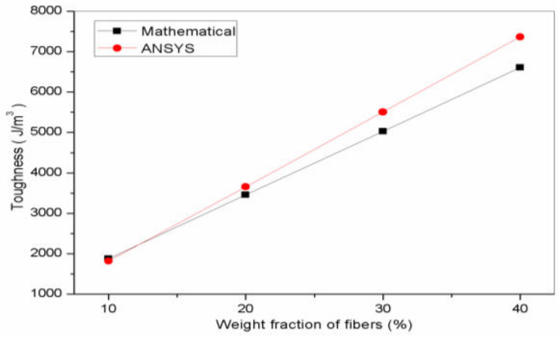

Figure.5 Toughness for 10%, 20%, 30% and 40% addition of E-glass fiber reinforced polyester composites using mathematical and simulation approach

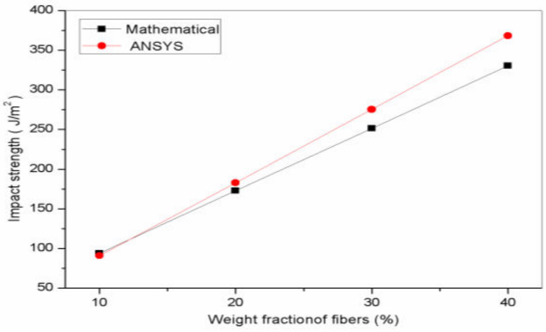

Figure.6 Impact strength for 10%, 20%, 30% and 40% addition of E-glass fiber reinforced polyester composites using mathematical and simulation approach

The toughness and impact strength of E-glass reinforced polyester composites with different weight fraction is presented in Table 3.

Table 3: Toughness and Impact strength of E-Glass fiber reinforced with polyester resin

Fiber	Weight Fraction	Toughness (J/m^3)		Impact Strength (J/m^2)	
		Mathematical	ANSYS	Mathematical	ANSYS
E-Glass	10%	1881.717	1821.986	94.08	91.10
	20%	3456.504	3656.543	172.83	182.83
	30%	5031.291	5509.640	251.56	275.48
	40%	6606.078	7366.120	330.30	368.31

V. CONCLUSION

The theoretical evaluation proves that addition of increasing volume fraction of fiber content in polyester matrix results in enhancing the mechanical properties of the composite compared to pure polyester. In mathematical approach, at higher weight fraction of fiber (40%) in polyester resin, it results in higher tensile strength of 1399MPa (2052% enhancement compared to pure) and with respect to ANSYS simulation we obtain tensile strength of about 1505.01MPa (2215% enhancement compared to pure). When tensile modulus is considered using mathematical approach, incorporating higher weight fraction (40%) of fiber content in matrix results in enhanced tensile modulus of 30.75GPa (1018% increase compared to pure matrix) where as in ANSYS simulation the result obtained is similar to mathematical approach. Similarly for toughness and impact strength , incorporation of 40% fiber content in polyester matrix shows maximum toughness of 6606.078 J/m^3 and impact strength 330.30 J/m^2 which shows similar results to that of simulation where we attain toughness of 7366.120 J/m^3 and impact strength of 368.31 J/m^2 respectively.

REFERENCES

[1]. NabiSaheb, D., Jog, J.P.: Natural fiber polymer composites: a review. Advanced Polymer Technology 18, 351-363(1999)

[2]. Ali, I. Al-Mosawi., Abdul Razaq Mohammed., Ali, R. Yousif.,: Theoretical approach to mechanical properties of resinous composite. Academic Research International 4, 96-10 (2013)

[3]. Dobrzanski, L A., Ziebowicz, B., Dark, M.: Mechanical properties and the structure of magnetic composite materials. Journal of Achievements in Materials and Manufacturing Engineering 18(1-2), 79-82 (2006)

[4]. DeGarmo, E P., Black, J., Kosher, R A.: Material and Processes in Manufacruring (10th edition). John Wiley & Sons (2008)

[5]. Ali, I. Al-Mosawi., Muslim M. Ali., Ali R. Yousis.: Theoretical estimation of flexular strength of araldite composite used for manufacturing electrical plates. Academic Research International 3, 34-37 (2012)

[6]. Ali, I. Al-Mosawi., Moslen, M. Ali., Salim, J. Abhas.: Using of ANSYS program to calculate the mechanical properties of advanced fibre reinforced composite. The Iraqi Journal of Mechanical and Material Engineering 12, 673-679(2012)

[7]. Abbas A. Al-Jeebory., Ali I. Mosawi.: Mechanical properties of araldite matrix composites reinforced with Hybrid Carbon-Kevlar fibers. Al-Qadisiya Journal for Engineering Sciences 3, 44-50 (2010)

[8]. Mohmoud A. Hassan.: Physical and Thermal properties of fiber (S-type) – Reinforced Composite Araldite Resin (GY 260). Al-Qadisiya Journal for Engineering Sciences 5, 341-346 (2012)

[9]. Brannan R T.: Futher Evidence against the orientation of structure in Glass fibers. Journal of the American Ceramic Society 36, 230-231 (1953)

[10]. Ali, I. Al-Mosawi., Hatif A H.: Reinforcing by Palm-Kevlar hybrid fibers and effected on Mechanical properties of Polymeric Composite Material. Journal of Babylon University 20, 188-193 (2012)

[11]. Ku, H., Wang, H., Pattarachaiyakoop, N., Trada M.: A review on tensile properties of natural polymer composites. Composite structure. Part B, 42, 856–873(2011)

[12]. Balkan, O., Demiver, H.: Mechanical properties of glass bead and wollastonite-filled isotactic-polyopropylene composites modified with thermoplastic elastomers. Polymer Composites 31, 1285-1308(2010)

[13]. Najim, A., Hamzah, S., Ahmed F.: Experimental and numerical simulation of Impact Fracture Toughness of polyphenylene Sulphide Basis Composite Material (2014)

[14]. Autar, K. Kaw.: Mechanics of composite materials, 2nd ed. Taylor and Francis Group, Inc (2006)

[15]. Malik, P K.: Fiber reinforced composites materials, manufacturing and design, 3rd ed. Taylor and Francis Group, Inc (2008)