

Experimental and numerical investigation of the effect of adding silica nanoparticles on the behavior of composite polyester resin

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Abstract

This study examines the behavior of the composite composition of polyester resin containing silica nanoparticles and compares some of its mechanical properties, including the maximum permissible toughness and fracture toughness with the corresponding values of pure resin polyester. In other words, the present paper examines the effect of adding silica nanoparticles to polyester resins and forming a resistant nanocomposite. Silica nanoparticles are one of the important additives for polymer resins, and they promote some of their mechanical properties. The experiments were carried out by the arcan device and on the butterfly arcan specimen. These specimens were loaded at seven different angles and the magnitude of maximum deflection was obtained. These angles produced pure tensile fashion, pure shear fashion, and five different modes of composite fashion, and the values of stress intensity coefficients and strain energy relaxation rates were obtained for each of the states.

Keywords: Nanocomposite; Silica nanoparticles; Polyester resin; Fracture toughness; Arcan specimen.

1. Introduction

Fracture is one of the most important and common failures that occur for different materials. Human beings have always been looking for a better and less risky life to prevent a sudden and unfulfilled failure in materials. One of these ways is to strengthen the material of the piece by combining it with other materials. A material that is a macroscopic composition of the raw material is a composite material (composite). Silica particles, also known as "igneous silicon", contain fine particles of silicon oxide ($2SiO$). These particles have an initial diameter of about 7 to 94 nm. One of the most common uses of silica particles is its use as a reinforcing, thickening agent and thixotropic agent of resins. This substance in Iran is often known by the name of Aerosil, which is the brand name of the German Uonik Company for this product. The representation of fine silica particles is shown in Fig. 1.

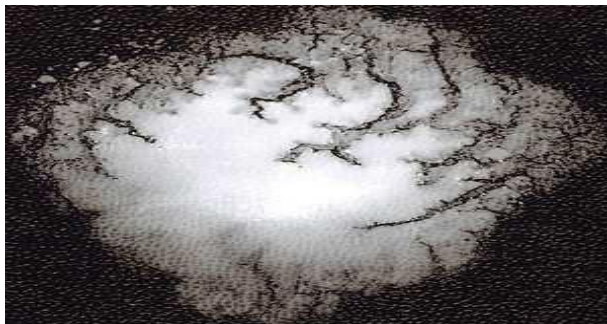


Fig. 1: Silica nanoparticles.

2. Experimental section

As stated, in this study, arcan was used to obtain fracture toughness values. This device, which is characterized by a sample holder and specimen in Figure (2), covers a wide range of composite modes. By loading three samples at each particular angle and averaging the results, the critical loading rate was found to be tolerable. These numbers are grouped in Table (1).

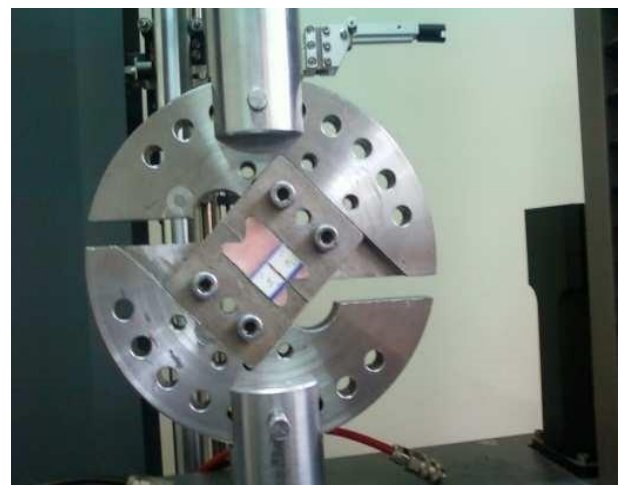


Fig. 2: Arcan Device and Sample.

Table 1: The Critical Failure Force for the Two Materials Studied

Loading angle	Maximum residual net failure force (N)	Maximum resistivity of nanoparticle resin (N)
0 degrees	2372.03	2601.263
15 degrees	1415.29	1810.3386
30 degrees	1371.54	1423.7937
45 degrees	1992.96	2290.0675
60 degrees	2399.49	3369.3996
75 degrees	2621.26	3498.59244
90 degrees	3309.6	4744.9262

Using the critical loads of failure and the dimensionless geometric correction obtained from numerical studies, according to (1), we can calculate the intensity coefficients of the first and second modes of stress. In the same way, the relaxation rate of the strain energy of the modes is also calculated by relations (2) to (4) [1-5]. $f(a/w)$

$$K_Q = \frac{PQ}{wt} \sqrt{\pi a}$$

$$G_I = (1-\nu) \frac{K_I^2}{E}$$

$$G_{II} = (1-\nu) \frac{K_{II}^2}{E}$$

$$G_T = G_I + G_{II}$$

In this case, K is the coefficient of stress, G is the strain energy release rate, P is the critical force (the choice is in the relevant standard [5]), w is the sample length, t is the thickness of the sample, a primary crack length, and f is the geometric correction factor. Also, ν and E, which refer to the Poisson coefficient and the modulus of elasticity of materials and their mechanical properties, were obtained by tensile test using the ASTM-D638 standard. These values for the two items in Table (2) are observable [6-8]

Table 2: Mechanical Properties of the Materials Under Study

Features	Polystyrene resin	Polyester resin containing silica nanoparticles
E (GPa)	4.2	5.31
ν	0.4	0.4

3. Results and discussion

The values of the critical stress intensity coefficients of the first and second modes for the present nanocomposite and at each particular angle are classified in Table (3). Also, the graphs of (3) and (4) show the comparison of the critical stresses and stresses of the strain energy of two materials (resin polyester and its combined state with silica nanoparticles) while changing the loading angle. It is clear from the diagrams that the fracture toughness and the energy required for failure of the nanocomposite significantly increased at some angles relative to their pure matrix, which is indicative of the good nano-silica enhancement nature.

Table 3: Strength Coefficients of the First and Second Modes of Nanocomposite Fashion

Loading angle	KI (MPa.m ^{1/2})	KII (MPa.m ^{1/2})
0 degrees	4.40	-
15 degrees	2.95	0.18
30 degrees	2.08	0.27
45 degrees	2.73	0.62
60 degrees	2.84	1.10
75 degrees	1.53	1.28
90 degrees	-	1.79

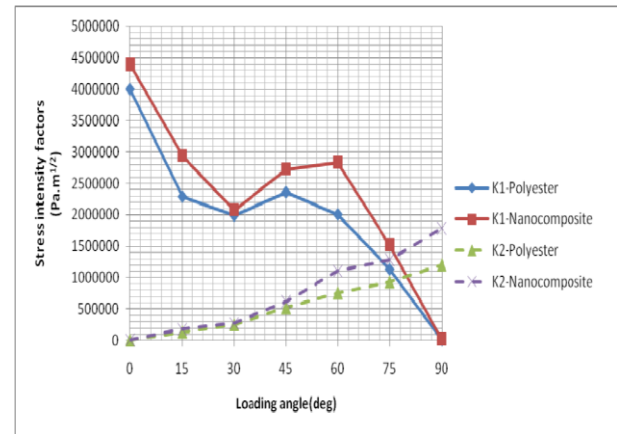


Fig. 3: Changes in the Intensity of Stresses of Two Materials with Angular Variation.

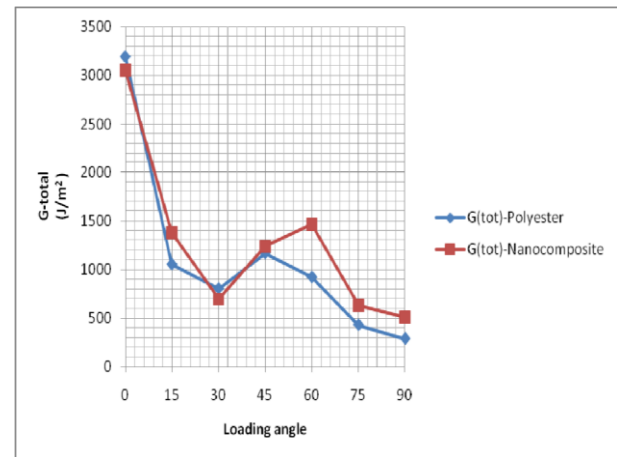


Fig. 4: Changes in the Total Rate of Release of the Strain Energy of the Two Materials by Changing the Loading Angle.

4. Conclusion

As expected, the nanoparticles used at some angles had a positive effect on the critical failure strength, stress intensity coefficients and strain energy release rates, as well as a significant increase in the concentration of resin polyester.

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