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RESEARCH ARTICLE

New Composite Material of Thermoset Base Reinforced by Micro-hyper-woven Fiber Resistance for Petroleum Derivatives

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Abstract

A new composite of polyester reinforced by micro-hyper-woven glass and carbon fibers has been prepared to obtain unique mechanical and thermal properties and physicochemical activity such as high specific strength, stiffness and corrosive resistance to different hydrocarbon derivatives. In this experimental work, an attempt has been made to test the aging of new hyper composites in terms of their thermo mechanical properties by changing the weight percent, C_w/g_w, of the additive woven mixed fiber in the range of (1, 2, 3). This new composite is fabricated by manually layering the base polyester matrix and reinforced hyper woven fibers 200/20 (gm/gm) from the base matrix, and a hardener is applied for each cast with 1 gm of micro-zirconium. Different aging results of the thermo mechanical properties (thermal conductivity, thermal expansion, impact strength, flexural strength, tensile strength, elongation, hardness, and compression resistance) are obtained according to the American Society for Testing and Materials (ASTM) standards. The results for these aging thermo mechanical properties after one month show that the specimens reinforced by hyper woven g_w/C_w with three percentage mixing ratios (1, 2, 3 wt.%) have excellent aging thermo mechanical properties.

Keywords: *Hyper woven fiber, Polyester composite, Aging characteristic properties.*

Introduction

Composite materials are used in oil-resistant constructions such as floor grates, footpaths of platforms, and staircase railings. The thermoset resins are corrosion-resistant with high insulation property against aging in severe conditions. Then, this resistance is increased with reinforcing fibers such as glass or carbon fibers. The main challenge in this field of application for composite materials is the development of new construction materials that operate under severe temperature and pressure conditions [1].

Further development of this technology has resulted in the manufacture of hybrid composites: thermoplastic structures reinforced with glass-reinforced plastic composite and thermoplastic reinforced with glass, aramid or carbon fibers. The advantages of hybrid composite systems are higher flexibility and better chemical and thermal resistance.

Therefore, hybrid composite systems can be applied in transferring systems for wastewater or oil derivatives and in drilling operations [2]. Depending on their purpose, hybrid composite systems are commonly produced of epoxy, vinyl-ester or phenolic matrix with glass fibers. Phenolic matrices are characterized by good heat resistance with a small emission of toxic vapors when they are in contact with fire. The use of composite materials for those purposes is reasonable because those structures have high corrosion resistance [3, 4, 5].

This study aims to manufacture new high-efficiency composites with high thermo mechanical aging and physicochemical activity properties from thermoset polyester reinforced with micro-hyper-woven fibers to resist severe conditions, including severe temperature and time that these structures are in contact with petroleum derivatives (kerosene and benzene) during transferring operations.

Materials

The base resin polyester is a commercial polyester. Societe Anonyme Omanaise Generale (SAOG) in Oman. The commercial glass fiber is a white, woven commercial fiber supplied by Societe Anonyme Omanaise Generale (SAOG) in Oman. The carbon fiber is a black, woven commercial fiber form supplied by Societe Anonyme Omanaise Generale (SAOG) in Oman. The zirconia used was less than 250 µm of a white, powdered chemical supplied by Societe Anonyme Omanaise Generale (SAOG) in Oman.

Methods

Preparation of the New Hyperwoven Microcomposite

First, 200 gm of polyester was continuously mixed with 20 gm of hardener at 100/2 w/w weight ratios, according to the standard specification of the manufacturing company, and 1 gm of micro zirconia material for 15 min until the reaction temperature was 40°C to obtain a homogenous solution. Different weight ratios of woven glass and carbon fiber were applied (1, 2, and 3) to the coated glass molder of fixed dimension (15x15 cm^2) with Vaseline gel to prevent the composite structure from adhering. Then, the weighted fibers were layered by gradual addition of polyester resin by continuously brushing the resin with fibers for 20 min to obtain good adhesion to the composite material. Then, the fibers and base resin were compressed using a roller machine, which evenly distributed the resin and removed air pockets. Multiple layers of fibers were deposited until the desired weight and thickness were achieved.

The composites were left under atmospheric pressure and temperature for 24 hrs; then, they were cured in an oven for 2 hrs at 170°C to obtain a new homogeneous cured composite material. An open mold was used to obtain parts of different shapes with a cutting machine depending on the test to be performed [6]. Table (1) shows the mixing ratio and conditions for different prepared specimens.

Table 1: The mixing ratio and conditions for different prepared specimens

Sample no.	Base PE/H	C_w/g_w wt. ratio	g_w/C_w wt. ratio
1	200/20	1	-
2	200/20	2	-
3	200/20	3	-
4	200/20	-	1
5	200/20	-	2
6	200/20	-	3

Methodology

Different instruments to characterize a new hybrid micro composite were used for both thermal mechanical and chemical properties. The impact strength was determined using a Charpy impact instrument., tensile and compressive strength were determined using a universal machine. The flexural strength was determined using PHYWE, which is a three-point bending tester, according to ASTM D790. The hardness was determined using a Western Amsler, Harkeprufer DIN 53505, Shore D. The thermal conductivity and thermal expansion tests were conducted using Lee's disk instrument (Koeyigit Electronic, UK). The thermal conductivity and thermal expansion were calculated as follows:

$$e = P / \pi r [r (T_1 + T_3) + 2 (d_1 T_1 + 0.5 ds (T_1 + T_2) + d_2 T_2 + d_3 T_3] \ldots. (1)$$

$$K = e\, ds [T1 + 2 T_1 (d1 + 0.5 ds) / r + T_2 ds / r] / (T_2 - T_1) \ldots. (2)$$

Where: ***e*** = loss in heat per unit area in (w /cm^2. C°). ***P*** = supplied power in (w). ***r*** = radius of disk in (cm).***d_1, d_2, d_3*** = thickness of disks in (cm).***ds*** = thickness of specimen in (cm). ***T_1, T_2, T_3*** = measured temperatures of disks no., 1, 2, and 3 in (C°).***K*** = thermal conductivity in (w / cm .C°).

Aging Characterization of the New Hyper Woven Micro Composite

Different characterization properties were obtained using standard methods in ASTM before and after aging in contact with petroleum derivatives at 50°C for 21 days. Fig. 1 shows the tensile strength, impact strength, compression strength, flexural strength, elongation, thermal conductivity, thermal expansion, and chemical resistance of the prepared specimens before testing [4].

Fig. 1: Molds for new hyper- woven – micro composite material at different weight ratios from woven glass and carbon fibers

Results and Discussion

Fig. 2 shows the effect of different additive weight ratios of hyper glass and carbon fibers on the impact strength of the new hyper composite. The hyper composite reinforced by glass/carbon fibers has higher strength than that of composites reinforced by higher carbon/glass ratios because glass fibers have higher strength than that of carbon fibers [7].

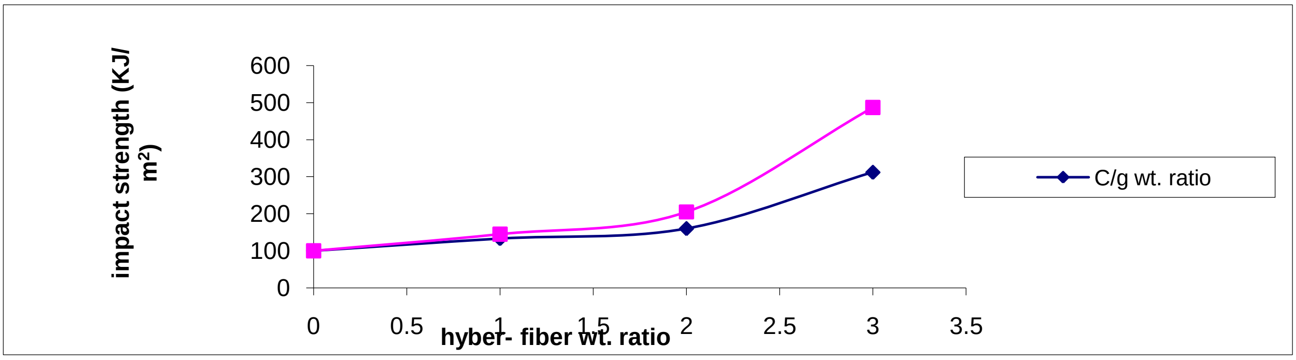

Fig. 2: Show the effect of different additive weight ratios of hyper glass and carbon fiber on the values of impact strength for the new hyper composite

Fig. 3 shows the effect of different additive weight ratios of hyper glass and carbon fibers on the elongation of the new hyper composite. The hyper composite reinforced by glass/carbon fibers has a higher modulus than that of composites reinforced by carbon to glass ratios because glass fibers have higher moduli than those of carbon fibers [8].

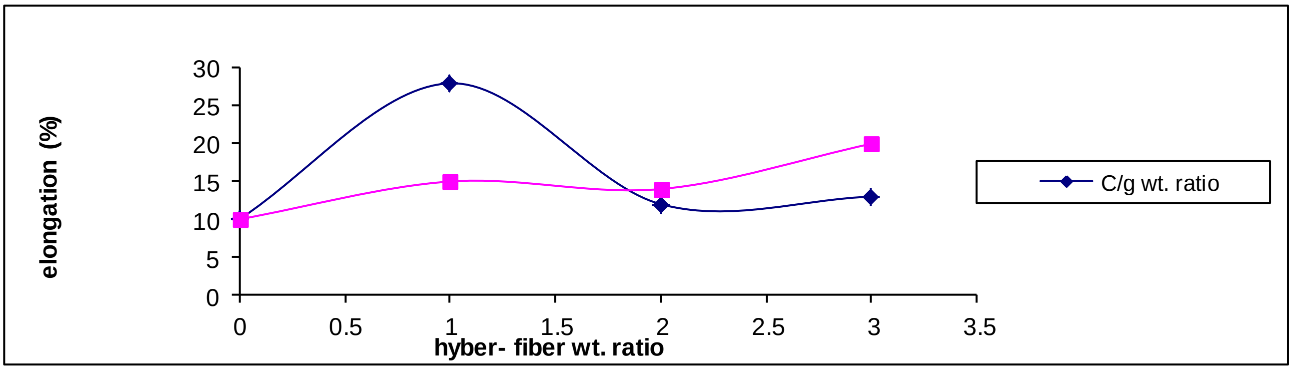

Fig. 3: Shows the effect of different additive weight ratios of hyper glass and carbon fiber on the values of elongation for the new hyper composite

Fig. 4 shows the effect of different additive weight ratios of hyper glass and carbon fibers on the tensile strength of the new hyper composite. The hyper composite reinforced by glass/carbon fibers has a higher modulus than that of composites reinforced by carbon to glass ratios because glass fibers have higher moduli than those of carbon fibers [8].

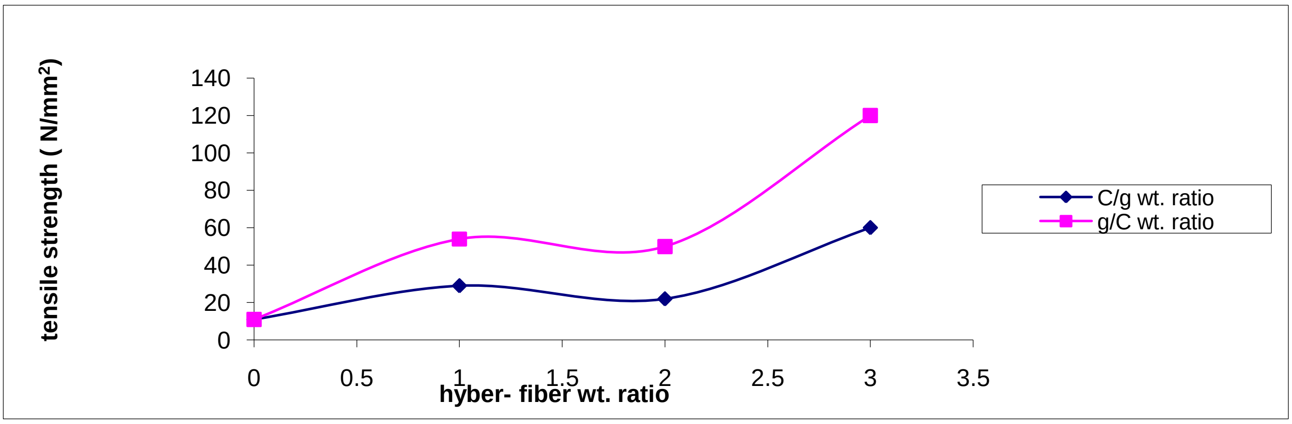

Fig. 4: Shows the effect of different additive weight ratios of hyper glass and carbon fiber on the values of tensile strength for the new hyper composite

Fig. 5 shows the effect of different additive weight ratios of hyper glass and carbon fibers on the flexural strength for the new hyper composite. The hyper composite reinforced by glass/carbon fibers has a higher modulus than that of composites reinforced by carbon to glass ratios because glass fibers have higher moduli than those of carbon fibers [9].

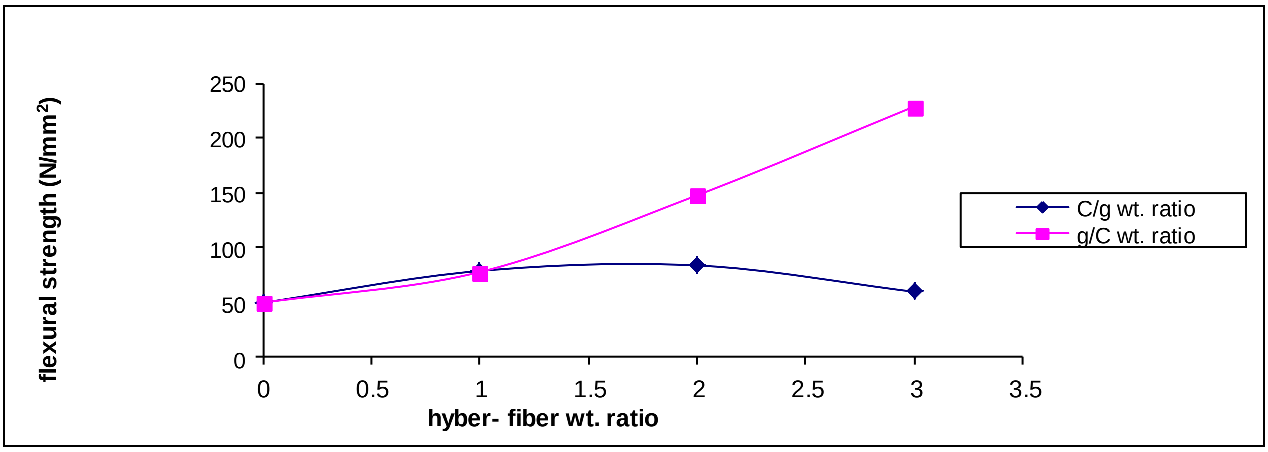

Fig. 5: Shows the effect of different additive weight ratios of hyper glass and carbon fiber on the values of tensile strength for the new hyper composite

Fig. 6 shows the effect of different additive weight ratios of hyper glass and carbon fibers on the compression strength of the new hyper composite. The hyper composite reinforced by glass/carbon fibers has a higher modulus than that of composites reinforced by carbon to glass ratios because glass fibers have higher moduli than those of carbon fibers [6]. Fig. 7 shows the effect of different additive weight ratios of hyper glass and carbon fibers on the hardness of the new hyper composite. The hyper composite reinforced by glass/carbon fibers has a higher modulus than that of composites reinforced by carbon to glass ratios because glass fibers have higher moduli than those of carbon fibers [10].

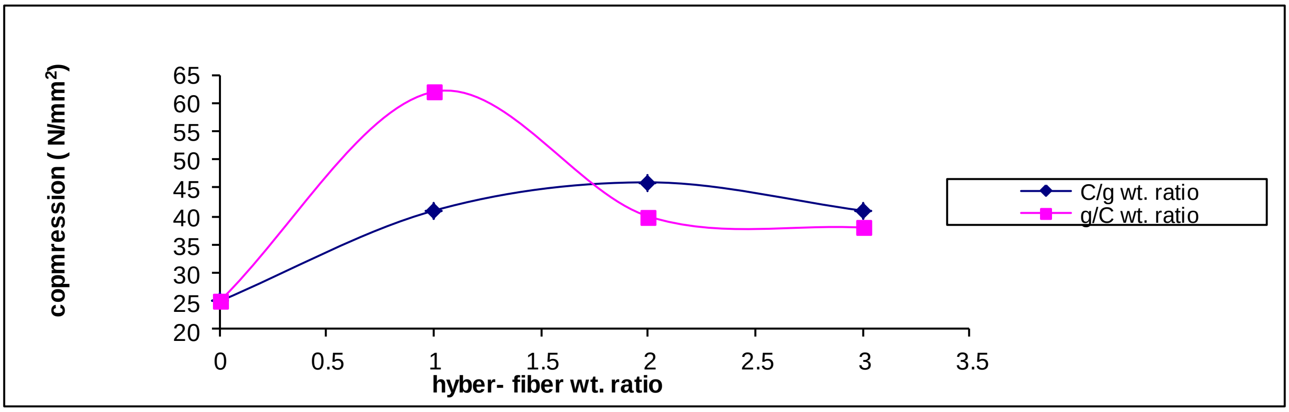

Fig. 6. Shows the effect of different additive weight ratios of hyper glass and carbon fiber on the values of tensile strength for the new hyper composite

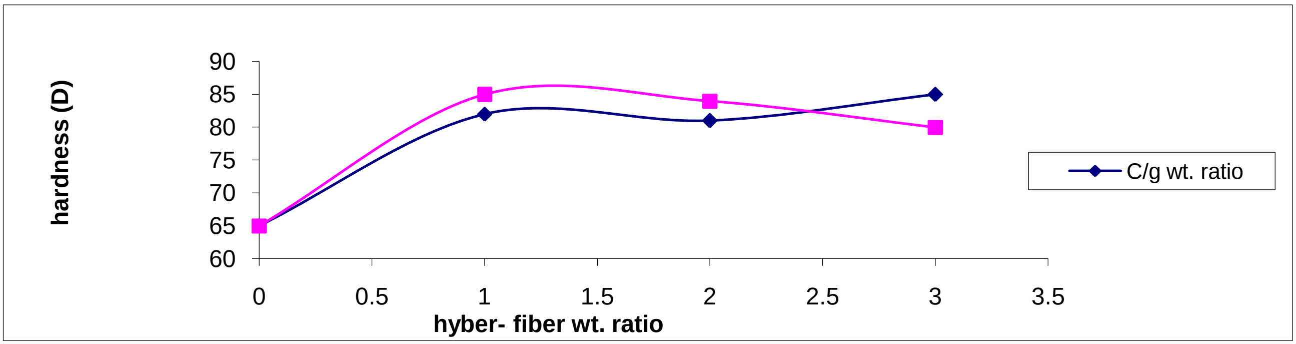

Fig. 7: Shows the effect of different additive weight ratios of hyper glass and carbon fiber on the values of tensile strength for the new hyper composite

Fig. 8 shows the aging resistance of the impact strength at 50ºc after 21 days for different additive weight ratios of hyper glass and carbon fibers for the new hyper composite. The hyper composites of large weight ratio (3) of both reinforced carbon/glass and glass/carbon fibers have higher impact strength under severe conditions than that of other reinforced specimens due to the high chemical and thermal resistance of carbon fibers and high strength and mechanical properties of glass fibers [11]. Fig. 9 shows the aging resistance of elongation at 50°C after 21 days for different additive weight ratios of hyper glass and carbon fiber for the new hyper composite. The hyper composites of weight ratio 3 of reinforced glass/carbon and weight ratio 1 of carbon/glass fiber have larger elongation values under severe conditions than that of other reinforced specimens due to the high chemical and thermal resistance of carbon fibers and high strength and mechanical properties of glass fibers [12].

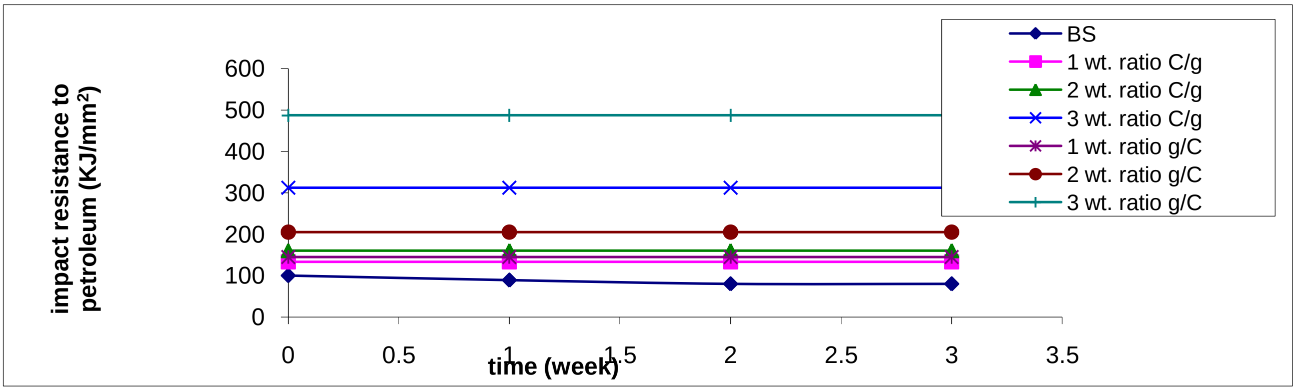

Fig. 8: Shows the aging resistance (50ºc and 21 day) of different additive weight ratio of hyper glass and carbon fiber on values of impact strength for the new hyper composite

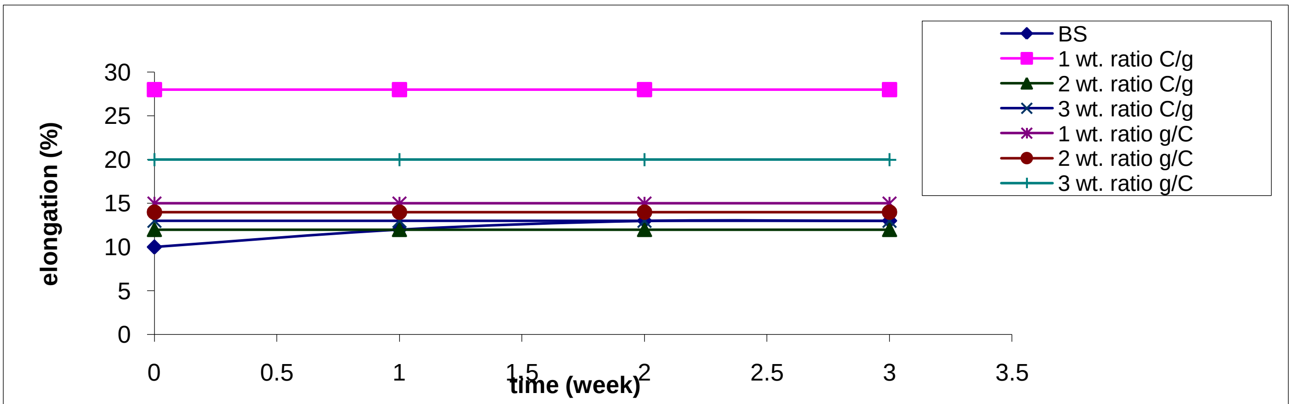

Fig. 9: Shows the aging resistance (50ºc and 21 day) of different additive weight ratio of hyper glass and carbon fiber on values of elongation for the new hyper composite

Fig. 10 shows the aging resistance of the tensile strength at 50ºc after 21 days for different additive weight ratios of hyper glass and carbon fibers for the new hyper composite. The hyper composite of weight ratio 3 of reinforced glass/carbon fibers has higher tensile strength under severe conditions than that of other reinforced specimens due to the high chemical and thermal resistance of carbon fibers and high strength and mechanical properties of glass fibers [13]. Fig. 11 shows the aging resistance of the flexural strength at 50°C after 21 days at different additive weight ratios of hyper glass and carbon fibers for the new hyper composite. The hyper composites of large weight ratios (2 and 3) of reinforced glass/carbon fibers have higher flexural strength under severe conditions than that of other reinforced specimens due to the high chemical and thermal resistance of carbon fibers and high strength and mechanical properties of glass fibers [7].

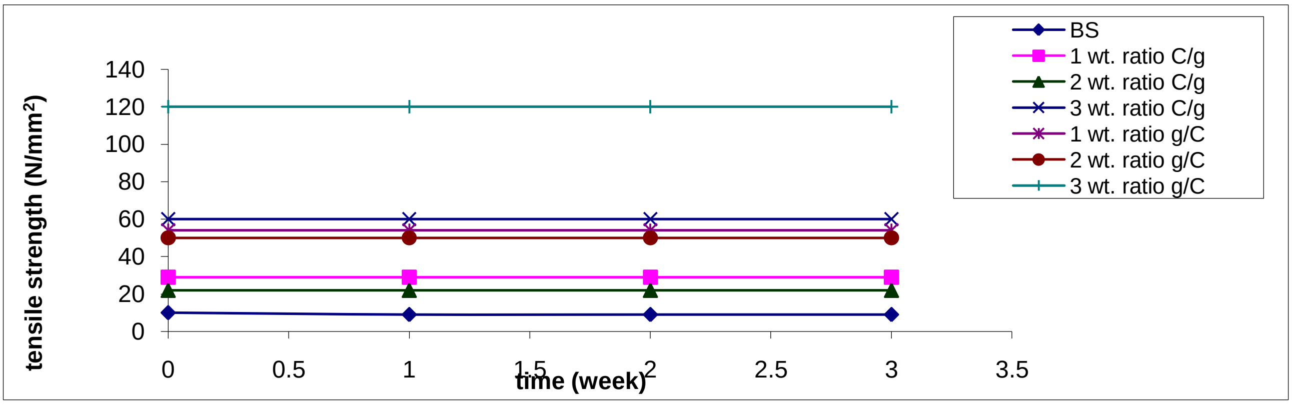

Fig. 10: Shows the aging resistance (50ºc and 21 day) of different additive weight ratio of hyper glass and carbon fiber on values of tensile strength for the new hyper composite

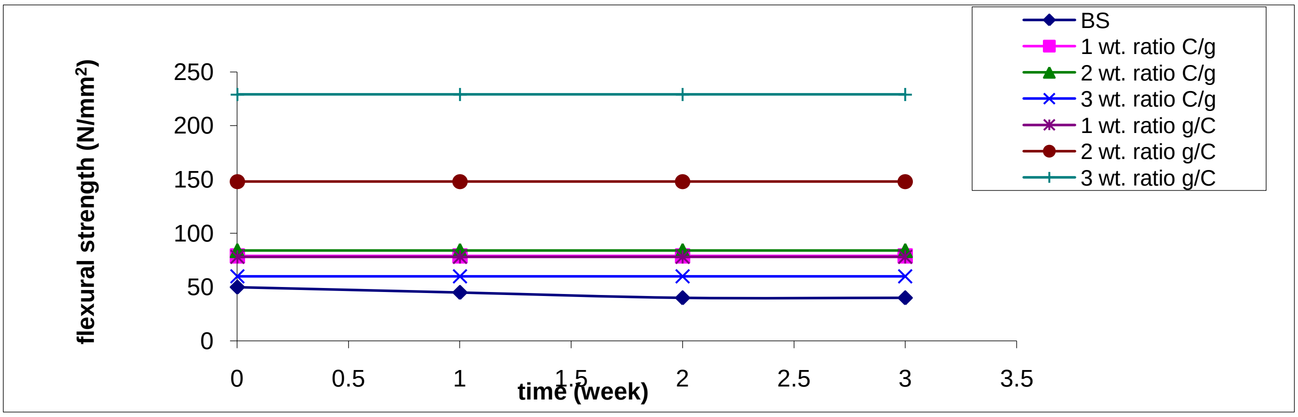

Fig.11: Shows the aging resistance (50ºc and 21 day) of different additive weight ratio of hyper glass and carbon fiber on values of flexural strength for the new hyper composite

Fig. 12 shows the aging resistance of the compression resistance at 50°C after 21 days for different additive weight ratios of hyper glass and carbon fibers for the new hyper composite. The hyper composite of large weight ratios of reinforced carbon/glass fiber (2 and 3) and weight ratio of glass/carbon of 1 have higher compression resistance under severe conditions than that of other reinforced specimens due to the high chemical and thermal resistance of carbon fibers and high strength and mechanical properties of glass fibers [14].

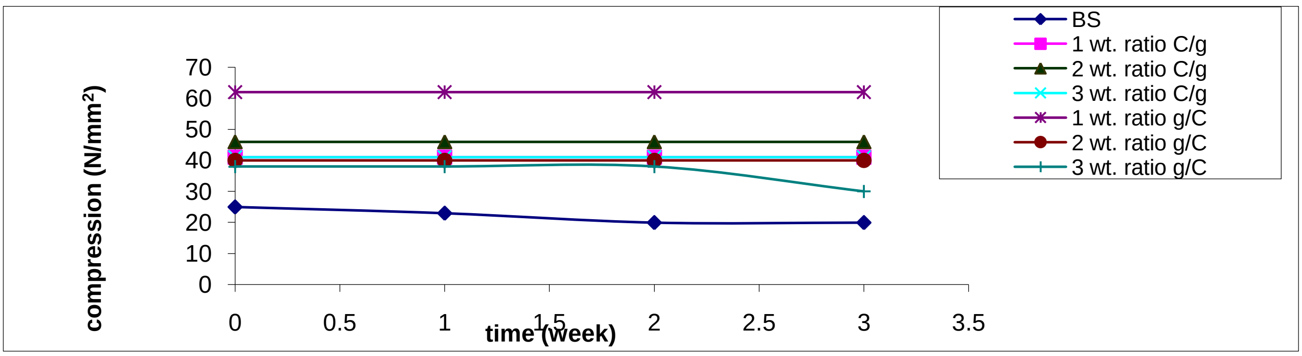

Fig.12: Shows the aging resistance (50ºc and 21 day) of different additive weight ratio of hyper glass and carbon fiber on values of compression resistance for the new hyper composite

Fig. 13 shows the aging resistance of the hardness at 50°C after 21 days for different additive weight ratios of hyper glass and carbon fiber for the new hyper composite. All hyper composites reinforced by carbon/glass and glass/carbon fibers have higher hardness than that of other base materials under severe conditions due to the high chemical and thermal resistance of carbon fibers and high strength and mechanical properties of glass fibers [13].

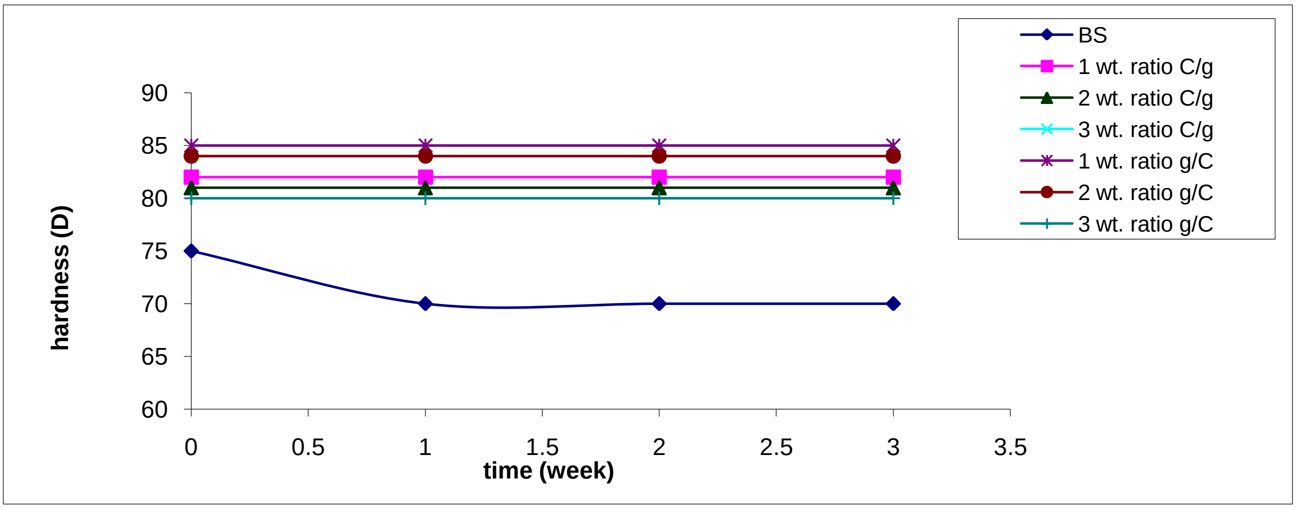

Fig.13: Shows the aging resistance (50ºc and 21 day) of different additive weight ratio of hyper glass and carbon fiber on values of hardness for the new hyper composite

Physicochemical Activity

Fig. 14 shows the aging resistance of the physic-chemical activity at 50ºc after 21 days for different additive weight ratios of hyper glass and carbon fiber for the new hyper composite. The hyper composite reinforced by glass/carbon fibers with a weight ratio of 3 has higher physic-chemical activity than that of other base materials under severe conditions due to the high chemical and thermal resistance of carbon fibers and high strength and mechanical properties of glass fibers [12].

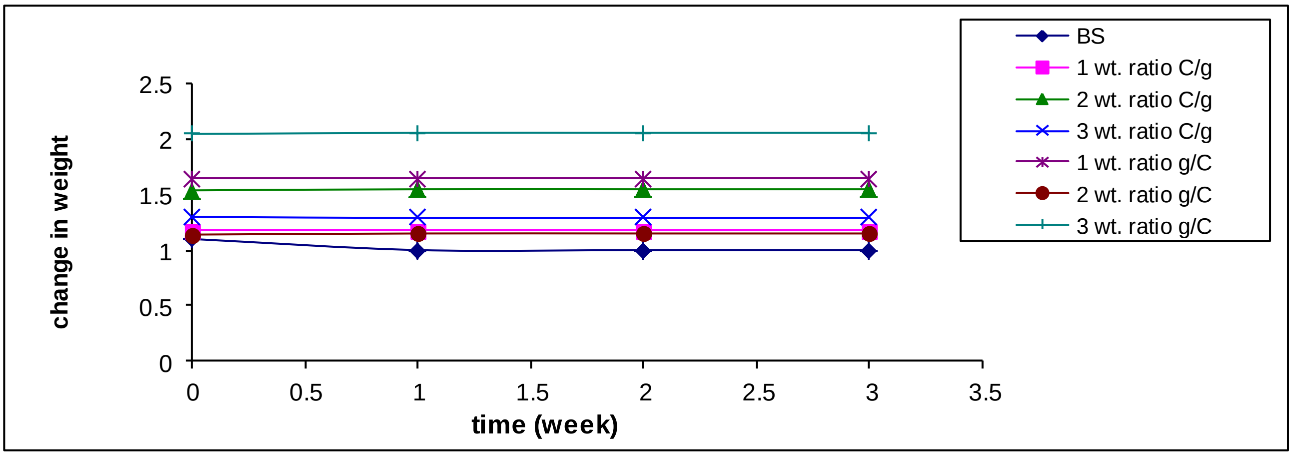

Fig.14: Shows the aging resistance (50ºc and 21 day) of different additive weight ratio of hyper glass and carbon fiber on values of physic-chemical activity for the new hyper composite

Thermal Properties

Fig. 15 shows the thermal conductivity at different additive weight ratios of hyper glass and carbon fiber for the new hyper composite. The hyper composite reinforced by carbon/glass fibers has better thermal insulation than that of other hyper composites reinforced by glass/carbon due to the high chemical and thermal resistance of carbon fibers and high strength and mechanical properties of glass fibers [11]. Fig. 16 shows the thermal expansion at different additive weight ratios of hyper glass and carbon fiber for the new hyper composite. The hyper composite reinforced by carbon/glass fiber has better thermal insulation than that of other hyper composites reinforced by glass/carbon due to the high chemical and thermal resistance of carbon fibers and high strength and mechanical properties of glass fibers [9].

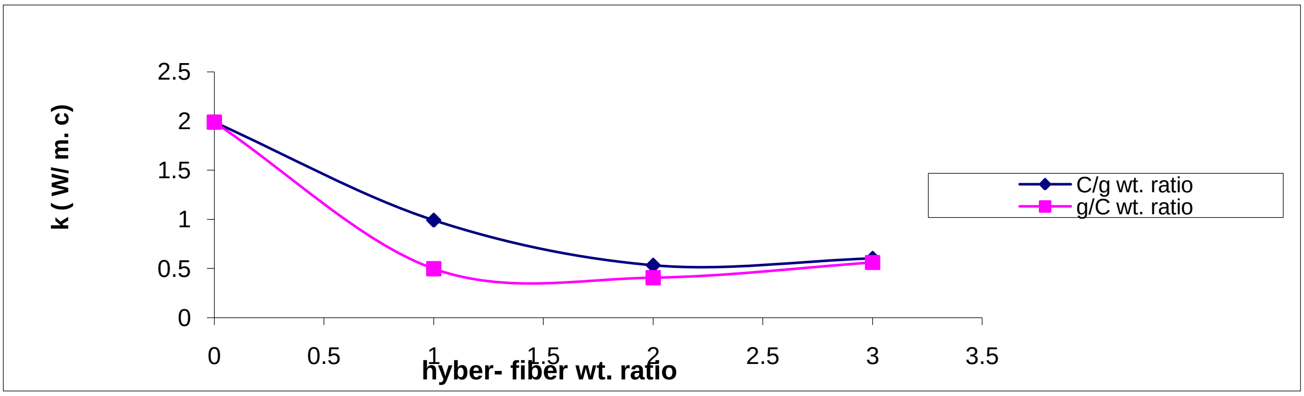

Fig.15: Shows the thermal conductivity of different additive weight ratio of hyper glass and carbon fiber on values of thermal conductivity for the new hyper composite

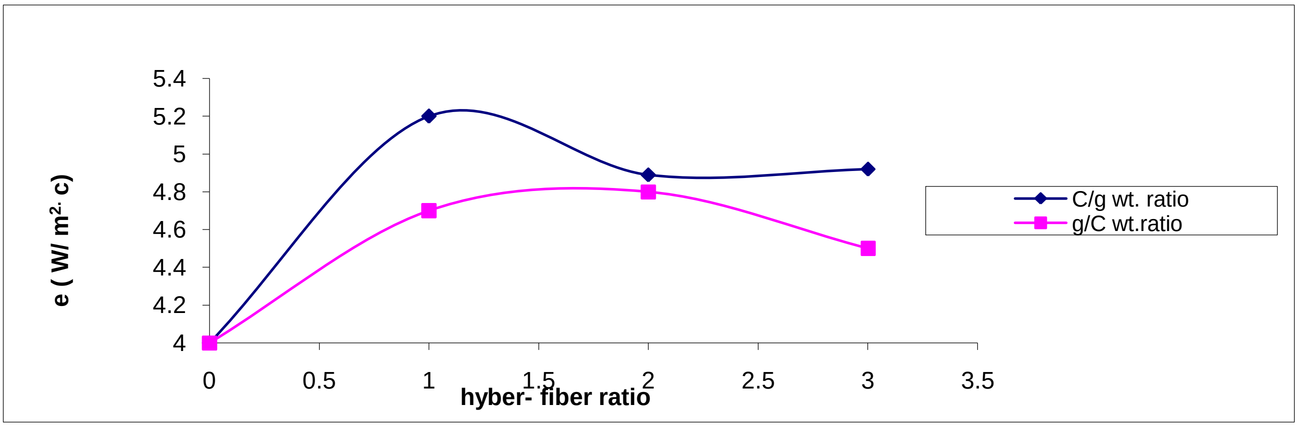

Fig.16: Shows the thermal expansion of different additive weight ratio of hyper glass and carbon fiber on values of thermal expansion for the new hyper composite

Conclusions

From the above results, the following can be concluded:

- The optimum mixing ratio to obtain a high mechanical strength is the weight ratio of glass/carbon fibers of 3.
- The optimum mixing ratio to obtain high physicochemical resistance is a weight ratio of glass/carbon fibers of 3.
- The optimum mixing ratio to obtain high insulation and thermal change resistance is a weight ratio of glass/carbon fibers of 3.
- The optimum mixing ratio to obtain high aging under severe conditions (50°C and 21 days of mechanical strength) is a weight ratio of glass/carbon fibers of 3.

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