SHEAR STRENGTH CHARACTERISTICS IN AGED POLYESTER-GLASS FIBRE COMPOSITES

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SUMMARY: Researches on the effects produced by the sun light upon polymeric matrix composites have been increased on the last ten years. It is commonly to find literature about mechanical characteristics degradation due to different environment effects. But a few ones are related to the shear behaviour. Moreover a limited studies are related to glass fibre polyester, even that are the composites most commonly used, due to its easily elaboration process and to its good cost-performance ratio. Thus, this paper will deal with the study the degradation on the shear behaviour of glass fibre polyester composites exposed to an accelerated simulation with an UV-visible light source. The influence on kind of resin and cured temperature were analysed. The shear degradation fits really close to the mathematical model proposed. Some relations have been found on the shear degradation due to the kind of resin and to the cured temperature.

KEYWORDS: Shear strength, sun light ageing, polyester composites, and degradation's model.

Introduction

The study of the environmental effects upon polymeric composite's mechanical properties had been grown on the last ten years. Day by day we could find new literature about degradation on composite's static or dynamic mechanical behaviour exposed to different environmental effects, but a few ones are focussed on shear behaviour (Adams, Castaing, Davis), or with overload combined effect (Fujii, Karama). Some studies on loss of fracture toughness (Hooper, Lucas, Selzer), or microbiological degradation (Puh, Tucker). All of them had been studied the effect of liquid substances on the degradation behaviour of polymeric composites such as graphite/epoxy, glass fibre/epoxy and in some cases glass fibre/vinilester. Generally, these studies are on unidirectionally reinforced composites and advanced or sophisticated conformation process.

Glass fibre/polyester is one of the most spread composites, due to its low cost, reasonable mechanical properties and easily conformation techniques (Hand lay up, spray, resin transfer and reactive injection moulding). In the last years becomes to be important the studies related to degradation on mechanical behaviour. We found in the bibliographical revue some works related to the behavior of glass fibre-epoxy (Evans) or carbon-epoxy (Pintado) to the high-energy radiation behavior. It is commonly to find bibliography related to the harmful effect of sun light radiation to thermoplastics. But in the other hand there are so little works on mechanical properties degradation due to sun light exposition on thermosetting matrix composites (Segovia).

The aim of this work is to determinate the influence of the artificial sunlight ageing on shear mechanical characteristics, and to establish the mathematical ageing model even considering the influences of the selected resins and cure temperature.

Materials

Hand lay up laminates were done, employing as matrix two orthophtalic unsaturated polyester resins with different reactivity level, medium (A) and high (B). The most important resin properties are summarised on table 1.

The reinforcement consist on 8 layers of 2D equilibrated glass fibre fabric, each layer consists on two fibre sheets at +45º and the other at –45º. The 2D-fabric density is 440 gr/m^2.

Laminates were cured at room temperature of 18ºC and controlled temperature of 40ºC uncasing them after 24 hours.

The composites physical properties were:

- Density: 1.57 ~ 1.61 gr/cm^3
- Fibre content: 32.5% ~ 33.6% (vol.),
- Porosity: 5.9% ~ 9.2% (vol.).

Table 1: Resins characteristics.

Resin	Tensile σ (MPa)	Tensile strain (%)	Flexural. σ (MPa)	Flex modulus (GPa)	Toughness (J/m^2)	HDT (°C)	T_G (°C)
A	80	2.3	110	4000	14	70	95
B	65	2.0	115	4500	20	105	121

Ageing

The ageing essay has been done applying UV light to the prepared samples. The samples were positioned in a closed chamber equipped with three sun light radiation adjusted lamps of 300 W each one, the average luminic density was 0,17 W/cm^2. Chamber's temperature was of 50 °C. Mechanical characterisations were done after 500, 1000, 2000 and 7000 hours of exposition.

The hypothetical real exposition time referred to the data obtained from the lamp manufacturer and from the "Centro Meteorológico de Levante" (Weather forecast centre of Valencia, Spain) is that 1000 h of this artificial ageing test corresponds to 3000 h (600 days) of real sun light exposition.

Sample preparation

Samples were cut from the laminate with a refrigerated diamond radial saw to the specific width and length. A couple of protectors were bonded to each end of the samples, to prevent the occasionally damage produced by the testing machine grips. The sample dimensions were: total length 205 mm, width 25 mm and length between marks of 127 mm.

Testing

Axial tests were developed accordingly to ASTM D3039-76 on an INSTRON 4202 Universal Testing machine. The essay was developed using an extensometer and the displacement speed was 2 mm/min.

Experimental results

The mechanical characteristics evaluated were Young Modulus (**E**) and tensile stress (σ_u), The shear modulus (**G**) and the shear stress (τ) could be calculated employing the following equations (1) and (2) respectively. The hypothetical value of the Poisson ratio ν is 0.14

$$G = \frac{E}{2(1+\upsilon)} \quad (1)$$

$$\tau = \frac{\sigma_u}{2} \quad (2)$$

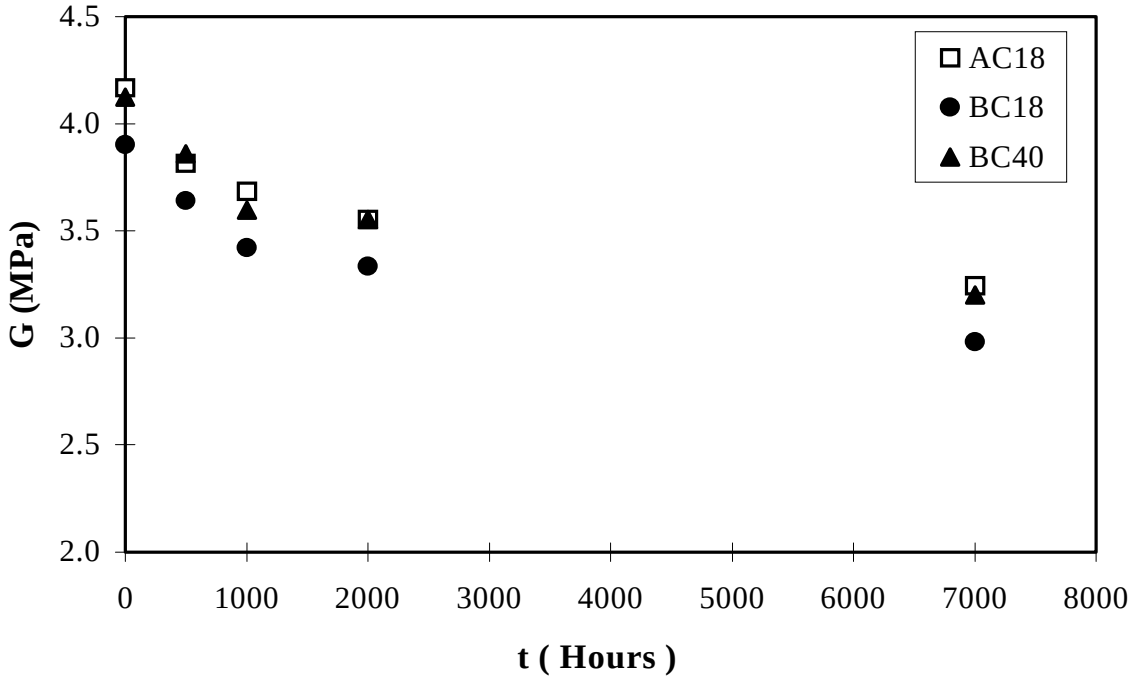

Fig.1: Evolution of shear modulus versus ageing time.

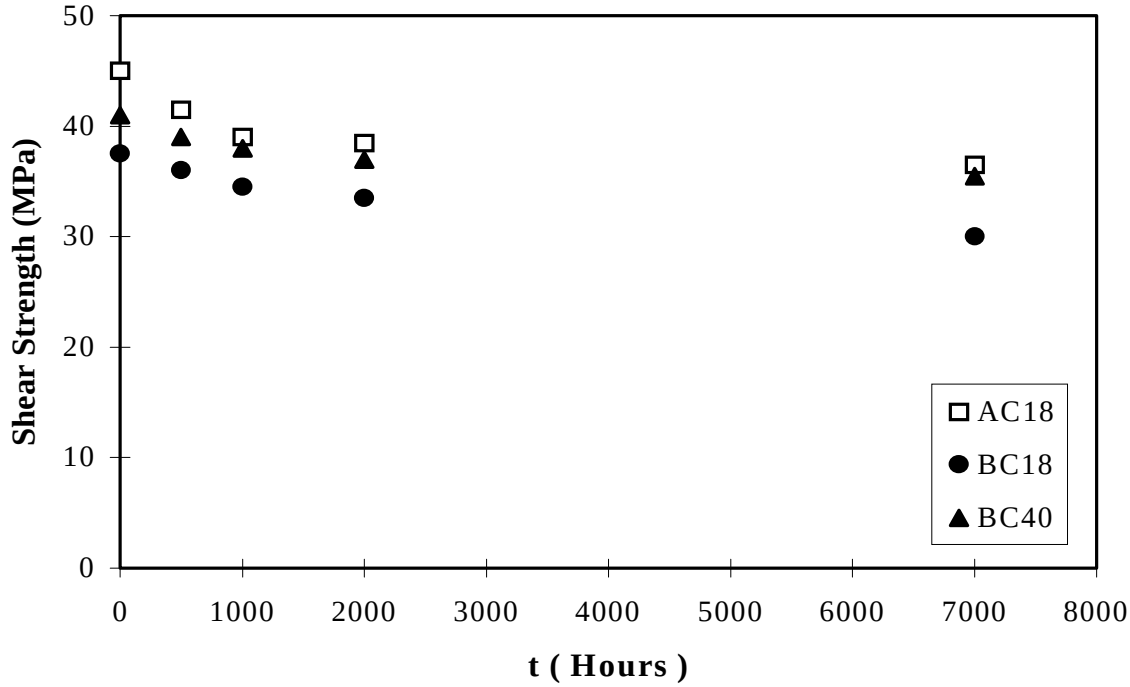

Fig. 2: Evolution of shear strength versus ageing time.

The behaviour of shear modulus as a function of time could be observed on figure 1 where could be noted that the degradation follows a damped exponential model, in correspondence to the following equation.

$$Y = \alpha + \beta\, e^{-kt} \tag{3}$$

Where α is the asymptotic value, β is the difference between the initial and the asymptotic value, k is the extinction constant (h^{-1}), and t is the time of accelerated exposition (h). Equally the shear stress has a similar behaviour as could be seen on figure 2, but in this case both parameters B and k are sensitive to the kind of resin and to the cured temperature. On table 2 are gathered the calculated ageing model's parameters, which represent the modelled behaviour to the different kind of resin and cured temperature.

Table 2. Ageing's model coefficients.

	Laminate	α (MPa)	β (MPa)	k 10^{-4} (h^{-1})	R^2	$\alpha+\beta$ (MPa)	$\beta/\alpha+\beta$ (%)
Shear	AC18	3200	900	5	0.93	4100	22
Modulus	BC18	3000	800	5	0.92	3800	21
G	BC40	3200	800	5	0.85	4000	20
Shear	AC18	37	7.0	8	0.89	44	16
stress	BC18	30	7.0	4	0.97	37	19
τ	BC40	36	5.0	8	0.98	41	12

Discussion.

A comparative study must be done to have a better behaviour comprehension and to observe the mechanical characteristic loss. To evaluate this phenomena, the model's parameters, such as $\alpha+\beta$ and α must be studied. These parameters represent the value of the mechanical property at 0 and 7000 h respectively. Equally $\beta/\alpha+\beta$ which represents the loss of them. In the case of the shear modulus loss due to light exposition is nearly the same in the three cases but is the most deteriorated characteristic as could be noted on the following values: 22% (AC18), 21% (BC18) and 20% for (BC40).

The shear stress shows another behaviour, it behaves in different way depending on the cured temperature and the losses are higher. If the cured temperature is higher (40ºC) its shear stress shows a little degradation just 12%. On the other hand the worst comportment was the laminates done with the same resin (high reactivity BC18) but cured at lower temperature 18ºC which exhibits a 19% of loss. The laminate with medium reactivity (AC18) shows an intermediate degradation of 16%.

The pattern of degradation are lower in the case of the shear stress than in the case of modulus, but the stress is really susceptible to kind of resin and cured temperature.

All explained before could be summarised in:

- The photoxidation degradation mechanism affect in higher grade to the medium reactivity resin than high reactivity one.

- The sunlight affects either the matrix-fibre interface.

Laminates AC18 and BC18 were used to study the effect of kind of resin upon the mechanical properties. Such laminates are identically in reinforcement composition, time of cured and temperature of cured, but AC18 had a medium reactivity resin and BC18 a high reactivity resin.
Could be observed that the Shear modulus (G) is higher on laminate made with medium reactivity resin, showing an increment on this characteristic equal to 8% and 7% at 0 and 7000 hours respectively. In the same way the shear strength (τ) experiments a remarkable improving that in this case are equal to 19% at 0 hours and 23% at 7000 hours. Both characteristics are really influenced by the kind of resin employed.
The influence of temperature cure was studied on laminates BC18 and BC40. Both laminates were made with the same resin and characteristics differing only on its temperature of cured which are 18ºC and 40ºC respectively. Could be noted an improvement on the shear modulus of 5% for such laminate cured at 40 °C at 0 h of exposition and at 7000 hours of exposition the increase of the modulus is 7%. The shear strength shows a stronger improvement. The shear strength for BC40samples improved its behaviour up to 11% at 0 hours, but this difference grows up to 22%, at 7000 hours, twice the initial difference. The temperature of cured in composites of high reactivity is really important to improve the mechanical properties. In fact could be noted that the properties of the BC40 are nearly the properties of AC18.

Conclusions

The plain shear test is a good way to abroad the study the degradation process on polymeric composites degradation due to an exposition of an artificial sunlight radiation. Because it is easily to compare and evaluate the loss of mechanical properties.

The behaviour of the mechanical properties as a function of time of exposition to the sun light source fits really closed to the mathematical model proposed, which follows a decreasing damped exponential pattern.

The degradation's effect is stronger to the shear modulus than in the case of the strength. The Degradability was less energetic in resins of medium reactivity or in the case of higher curing temperature.

The kind of resin and the cure temperature have a real significance on shear characteristics, in higher grade to strength than to the modulus.

Composites made of resins with reactivity high but cured at 40ºC become as good as composites done with medium reactivity resin but cured at 18ºC.

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