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Behaviour of glass woven reinforced thermoplastic laminates under uniaxial cyclic loading

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Abstract:

During the last decades the usage of organic matrix composites in the transportation industry has increased considerably. In addition to weight reduction they offer, a simple adaptation to the complex structural elements that are difficult to achieve with commercial metals and alloys. Due to the current recycling requirements, especially new laminates with thermoplastic acrylic resin become to be the most widely used. The contemporary investigations of their thermo-mechanical properties indicate that thermoplastic based laminate composites have better impact resistance and damage tolerance [1]. However, it is necessary to verify how these properties may change under fatigue aging conditions. The work reported herein aims at broadening knowledge regarding the behaviour of glass woven reinforcing the thermoplastic laminates under low and high uniaxial cyclic loading.

The fatigue tests were carried out on specimens composed of acrylic matrix and four plies of woven provided in the form suitable to the impact tests. Dimensions of the measurement part of the specimens were equal to 100 mm x 100 mm x 2mm. Cyclic loading was performed under force control with the frequency of 2 Hz. The sinusoidal loading regime was characterized by $R = \sigma_{min}/\sigma_{max} = 0{,}1$. Boundary conditions were set in the loading controller to limit maximum and minimum of force during cycling. Six stress levels were taken into, Fig. 1a. For the first three tests, the stress level of loading cycles was planned to be below the yield point. In the second group, a similar program was arranged, however, with the value of maximum force giving a stress above the yield point. All tests were carried out using an extensometer with the strain range of ±0.2. The loading cell was calibrated in the range of ±250 kN.

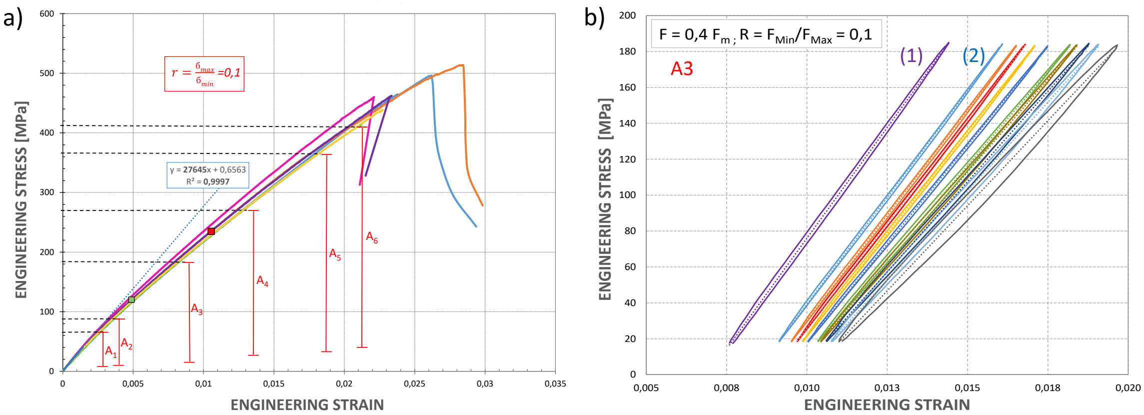

Fig. 1. Tensile characteristics of GFRP [90°]₄ (a), the hysteresis loops identifying ratcheting effect (b).

The results of tests carried out on the GFRP $[90°]_4$ under stress amplitudes lower than the yield point are presented in Fig. 1b. The first cycle is illustrated by the line denoted as (1). The second hysteresis loop registered after 500 cycles denoted as (2), moved with respect to first one (1) identifying effect of ratcheting. It was observed during the rest of subsequent cycles. As it shown in Fig. 1b, the strain increments for maximum stress were significantly greater than those for minimum stress obtained. In the experimental program the Young's modulus variations were monitored. Figure 2a. presents its evolution during fatigue. As it is shown, almost 25% reduction of the initial stiffness was obtained for the material in question (the purple dotted line, denoted as E_N). This value corresponds to stable hysteresis loop [2], and it was subsequently applied to predict fatigue life using the Manson–Coffin–Basquin curve presented in Fig. 2b.

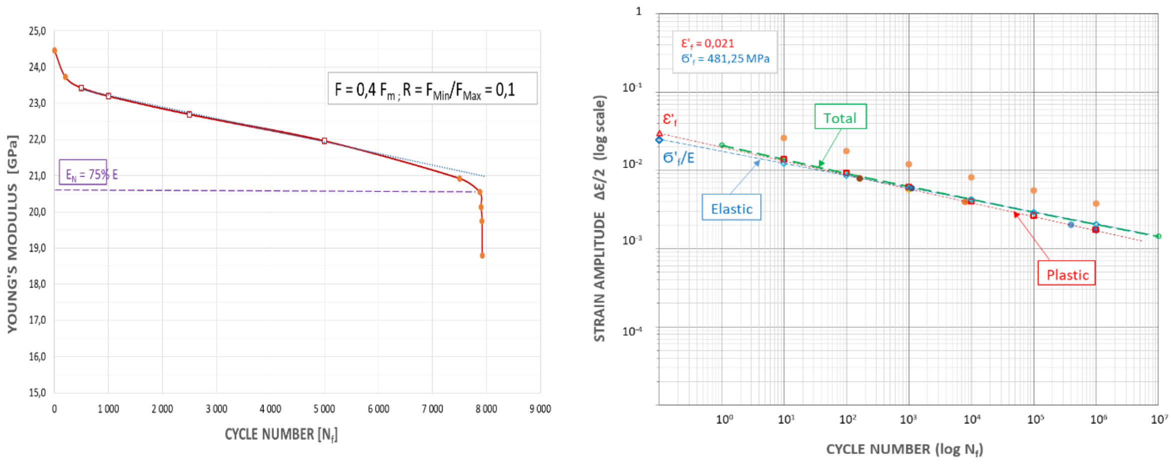

Fig. 2. a) Young's modulus evolution; b) Manson-Coffin-Basquin curve for GFRE [90°]$_4$

In conclusion, it has to be emphasised that the GFRE [90°]$_4$ exhibited the visible effect of strain-softening observed during fatigue, especially in the case of several last cycles. The specific structure of glass woven (formed by interlacing the longitudinal and transverse yarns (warp and weft, respectively) reinforcing acrylic thermoplastic resin, is presumably responsible for such behaviour during fatigue. It produces four types of failures in 2D woven laminates: intra-yarn cracks in the yarns oriented transversely to the loading direction (1), inter-yarn decohesion between longitudinal and transverse yarns (meta-delamination) (2), fiber failure in longitudinal yarns (3) and yarn failure (4).

References

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