EFFECT OF UNIAXIAL FATIGUE AGING AND FABRIC ORIENTATION ON LOW VELOCITY IMPACT OF COMPOSITE LAMINATES

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1. Introduction

Impact resistance belongs to the most important features that manufacturers of automobile parts are considering. It determines the lifetime of an element, product liability and its safety as well. Therefore, an examination of a new material such as fully recyclable thermoplastic ELIUM Acrylic resin reinforced by glass fabric woven has a great importance. Its high strength and lightweight as well as low production cost contribute to its wide application in the automotive industry as a replacement of the thermoset-based laminates [1].

The study presents an experimental work concerning an effect of damage due to fatigue aging on the process of perforation of thin (four layer) laminated composite plates subjected to the low impact velocity tests.

2. Experimental work

Fatigue tests were carried out on the specimens cut out along the fibre direction GFRE $[0°/90°]_4$ and $[45°/45°]_4$ with 100 mm x 100 mm x 2 mm dimensions prepared by the infusion process at room temperature. Cyclic loading was carried out under force control and frequency of 2 Hz. The sinusoidal loading mode was characterized by $R = F_{min}/F_{max} = 0.1$. The fatigue program was divided into two types of blocks distinguished by blue and red colors, Fig.1. In the first type blocks, the elastic modulus was determined based on the simple tensile test. In the second type of loading blocks, a given number of uniaxial tensile cycles n_i was applied.

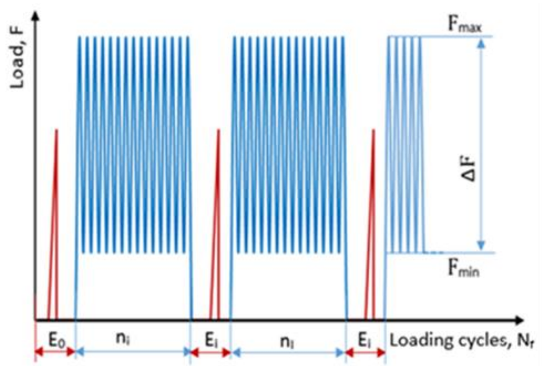

Fig. 1. Schematic illustration of the loading sequences.

In order to more thoroughly described an influence of the fatigue aging on the impact resistance, two stress levels were taken into account. The first one was planned to be below the yield point. In the second, a similar program was arranged, however, the maximum force was chosen, so that the stress level exceeded the yield point.

Based on the elastic modulus evolution recorded during all fatigue conditions, a damage parameter D_E was defined. By analogy to the damage definition introduced by Kachanov, the loss of material stiffness was taken as a damage indicator. Based on the residual stiffness E_i, and damage parameter D_E evolution, the pre-critical states were established for all groups of the composite laminates tested. As a result, the cyclic loading process was interrupted prior to the total failure of specimen at the damage state assumed. It has to be mentioned here, that all the aged specimens acquired the same level of degradation (similar stiffness loss). The aged specimens were subsequently subjected to low impact velocity tests on the drop weight tower.

The low impact velocity tests were performed on an Instron DYNATUP 9250HV drop weight tower. Experiments were carried out using an impactor with the hemispherical shape with a diameter of 16 mm for the impact energies of 5 J, 10 J, 30 J and 50 J, which corresponded to the impact velocity equal to 1.32 m/s, 1.86 m/s, 3.23 m/s and 4.16 m/s, respectively.

3. Results and discussion

In the present work, the energy absorbed by the specimen (Ea) is used as an indicator of damage degree. Therefore, the curves representing an energy variation versus time were elaborated and plotted. The results in Fig.2. enable to assess a significant loss of stiffness caused by matrix cracking and interface debonding between the fibres and the matrix. The results for GFRE [45°/45°]$_4$ tested under low velocity impact at 10 J exhibit that it was a less prone to delamination than GFRE[0°/90°]$_4$, and moreover, kept better impact resistance after fatigue aging.

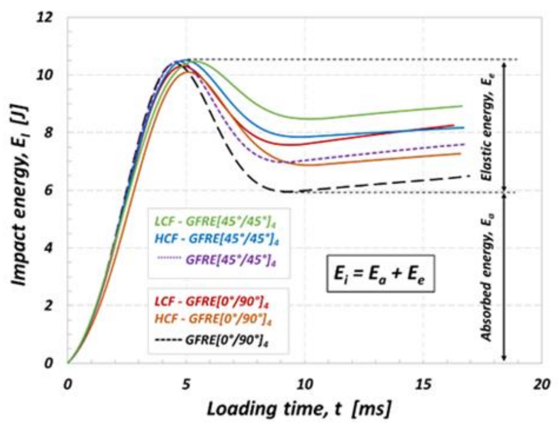

Fig. 2. Effect of fatigue aging on the E_a of the non-aged and aged GFRE for impact energy equal to 10 J.

Subsequently, an energy profile diagram (EPD) for all tested laminates was elaborated, Fig.3. The penetration threshold was defined as the point where the absorbed energy (E_a) is equal to the impact energy (E_i).

The results for the impact energy of 10 J and 30 J clearly show how the difference in energy absorption ability may change due to a type of reinforcement orientation and fatigue aging conditions. The prior aged laminates under LCF loading conditions attained practically the impact resistance limit regardless of the woven fabric orientation. It means that the absorbed energy attained the maximum possible amount of the impact energy applied. The highest values of absorbed energy were obtained for the GFRE [45°/45°]$_4$ after ageing due to LCF tests. It means, that in comparison to the other considered material configurations such oriented material is the least suitable for applications where the impact loading is dominant. Contrary to that case, the lowest values of absorbed energy were achieved after ageing due to HCF tests for GFRE [0°/90°]$_4$. In order to illustrate damage occurred on the opposite side of the impacted specimens, their damage images are also presented in Fig.3. They represent stages of damage for the GFRE [0°/90°]$_4$ in the as-received state subjected to impact under energy equal to 5 J, 10 J and 30 J.

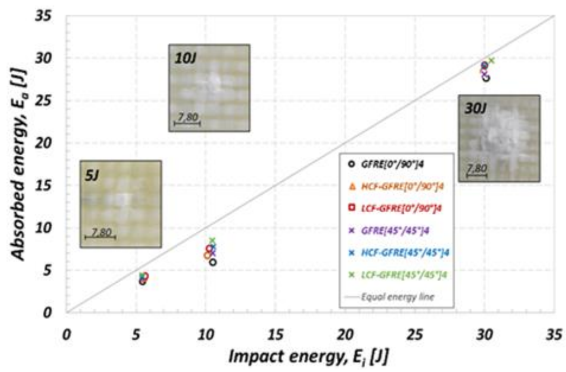

Fig. 3. EPD used in analysis of the effect of fatigue aging on the penetration threshold of the all tested GFRE.

4. Conclusions

The analysis of the absorbed energy during impact tests, confirmed that the aged materials containing the woven fabric oriented at the angle of 45° exhibited the weakest impact resistance. Therefore, one can conclude that the fibres orientation, fatigue aging, and glass fibres concentration significantly affect the elastic properties and lead to decrease of the stiffness reduction and increase of the energy absorbed.

References

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