INFLUENCE OF FATIGUE AGING AND FIBER ORIENTATION ON THE HIGH VELOCITY IMPACT RESISTANCE OF GLASS WOVEN REINFORCED ELIUM ACRYLIC LAMINATES

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1. Abstract

Ballistic impact loading is one of the most critical conditions to which structures can be subjected. Therefore, the examination of a new material such as fully recyclable thermoplastic ELIUM Acrylic resin reinforced by glass fabric woven has a fundamental 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 and numerical work concerning an effect of damage due to fatigue aging on the process of perforation of thin (four layer) laminated composite plates using a hemispherical projectile.

2. Experimental work

Fatigue tests were carried out on two groups of specimens with 100 mm x 100 mm x 2 mm dimensions prepared by an infusion process at room temperature. The first group was cut out along the fiber, while the second one with a 45 degree angle, GFRE $[0°/90°]_4$ and $[45°/45°]_4$, respectively. Cyclic loading was executed under force control with a frequency of 2 Hz. The sinusoidal loading signal was characterized by $R = \sigma_{min}/\sigma_{max} = 0{,}1$. 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. The fatigue aging program did not led to a destruction of the laminated composites during cyclic loading, but to stiffness reduction of the tested specimens, only. Therefore, using an extensometer with the strain range of ±0.2, the Young's modulus variations were monitored as well as an evolution of the hysteresis loop width [2]. The fatigue aging program was stopped before the specimen failure. Subsequently, the aged specimens were dismounted from the testing machine and subjected to perforation tests using a gas gun testing stand. The projectile for impact tests had a hemispherical shape with a diameter of 12 mm, and total mass of 29,1 g, approximately. It was made of maraging steel and subsequently heat treated to reach a yield stress over 2 GPa. Therefore, the projectile had no visible permanent deformation during the penetration. All perforation tests were carried out at room temperature for an impact velocities up to 180 m/s. During experiments an initial and residual values of projectile velocity were measured. The following formula proposed by Recht and Ipson [3] for ballistic impact was used:

$$V_R = (V_0^K - V_B^K)^{1/K} \quad (1)$$

where V_0 is the initial velocity, V_B is ballistic limit velocity and K is a shape coefficient. The parameters of Eq.(1) were calculated using the least squares method based on experimental results.

The energy absorbed by a target *Ed* were estimated using the following equation:

$$E_D = \frac{m_p}{2}(V_0^2 - V_R^2) \quad (2)$$

where m_p is the projectile mass.

Having these results a ballistic curve of the tested plates as well as absorbed energy vs initial impact velocity were established. In order to obtain comparison of numerical and experimental results, simulations were carried out using 3D solid element meshes within Abaqus software.

3. Conclusions

The experimental results show that all groups of specimens after fatigue loading exhibited a clear strain-softening effect and a lower impact resistance in comparison with the non-aged specimens. It is clearly visible for the specimens cut out at 45 degree angle, $[45°/45°]^4$. Examination of images captured using the scanning electron microscope and microtomography showed that the fatigue aging deteriorates the interface between matrix and glass fibres due to an appearance of cracks in the transverse yarns. This leads to the inter-yarn decohesion between longitudinal and transverse yarns (meta-delamination), and as a consequence, induces the softening of the reinforcing phase responsible for the stiffness of the composite and its impact resistance.

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5. References

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