are somewhat higher in the case of the preloaded plates. Nevertheless, the differences between the residual-velocity curves for the non-preloaded and preloaded plates do not seem to be very high.

Also, the ballistic limit was determined from result of the analytic and numerical models (Table 1). The experimental ballistic limit was determined by the following equation [22,23]:

$$v_{\mathrm{r}} = \begin{cases} 0, & 0 < v_o \leqslant v_{\mathrm{L}} \\ B \cdot (v_o^p - v_{\mathrm{L}}^p)^{1/p} & , v_o > v_{\mathrm{L}} \end{cases} \tag{24}$$

where v_r is the residual velocity, v_o the impact velocity, v_L the ballistic limit, and p and B are two empirical adjusting parameters.

It was observed that the preloading of the composite plates increased the ballistic limit. A good correlation was found between experimental, analytical and numerical results (Table 1), which demonstrate that the models used in this study faithfully reproduce the material behaviour.

7. Conclusions

The influence of the preload conditions (biaxial) on the behaviour of plates made of woven glass/polyester composite laminate materials under impact loading has been studied to determine the residual velocity and the ballistic limit.

In the biaxially preloaded plates, the ballistic limit for the projectile used proved approximately 11% higher. Both the analytic model and the numerical one reproduce this behaviour and can predict the ballistic limit for the non-preloaded plates with a precision of 2% and with 8% in the case of the preloaded plates.

For velocities lower than the ballistic limit, the contribution of the total energy of failure of the secondary fibres was the greatest, while, for velocities far above the ballistic limit the greatest contribution was the formation of the cone. The existence of preload did not affect the contributions of each energy term.

The energy absorbed due to tensile failure of primary yarns and due to matrix cracking did not contribute significantly to the reduction of the kinetic energy of the projectile.

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