BALLISTIC BEHAVIOR OF PRELOADING CFRPs PANELS

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In this paper the effect of static biaxial preloading of CFRPs plates under high velocity impact is investigated experimentally. Results are compared with those obtained when no static loads are applied to the specimens. Two magnitudes were measured from the tests: the residual velocity of the impacting projectile and the extension of the damage area in the laminate.

INTRODUCTION

Structural elements may be subjected to impact loads along their service life. Particularly, CFRPs panels are especially sensible to these kinds of loads, their residual mechanical properties diminishing although the damage may not be visually detectable.

From the structural point of view, some aeronautical or aerospace structures, such as those of aircraft fuselage or reservoirs of launching vehicles, may be considered as plates subjected to in-plane static loads. Because these components may suffer the impact of foreign bodies, to study their behavior under in-plane loading in combination with impact is interesting in order to guarantee their structural integrity.

Many researchers have studied the behavior of composite material plates subjected to impact at low and high velocities without considering static loads acting along the specimen edges. However, less research has been done regarding the behavior of specimens subjected to in-plane axial preloading and impact loads [1].

Experimental evidences of impact tests carried out for light aluminum alloys have shown that, for in-plane static pre-stressed (50% of the yield stress) specimens, catastrophic failure of them appears [2], due to unstable cracks generated in the neighborhood of the stagnation point. Also, for glass fiber reinforced plastics subjected to in-plane stresses less than 50% of the ultimate tensile strength, an increase of the damage area has been observed [2].

In this paper, the effect of biaxial preloading on the impact behavior of plates made of carbon fiber reinforced-plastic is considered. Results of the tests carried out in such conditions are compared with those obtained from specimens free of loads at their edges, for the same kind of projectile and impact velocities. The biaxial stress state in the specimens was chosen because it is representative of internal structural loads of many composite material structural elements and also because, after scientific literature revision about this topic, a lack of knowledge was detected specially for high velocity impact (100-300 m/s) conditions [3].

MATERIAL AND TESTING

The selected composite material in our study was a quasi-isotropic laminate of carbon fiber in epoxy matrix (AS4-8552). This kind of material is widely used in the aeronautical industry. The laminate was 3 mm thick and it had 16 plies with the following stacking sequence: $[\pm 45,0,90]_{2s}$.

Two specimen shapes were used in the experiments. For tests in which the coupons were free of stresses at their borders, the specimen geometry was rectangular (140 x 200 mm), while cross-shaped specimens (200 x 200 mm) were used for the biaxial static preloaded tests. This last specimen shape was chosen to guarantee a pure biaxial stress state in the area of the specimens receiving the impact load. The static preload applied to the specimens was 51 kN in each direction.

The shape of the impacting projectile was spherical with 12.5 mm in diameter. Its mass was 8.33 g and the impact velocities ranged from 100 up to 350 m/s. A gas gun was utilized to launch the projectiles. In all the tests, the impact occurred orthogonally to the specimen surface. The impact and residual velocities of the projectiles were measured by means of high speed video camera technique. After the tests, specimens damage areas were obtained from C-Scan inspection.

EXPERIMENTAL RESULTS AND DISCUSION

From the tests results, the impact and residual velocities in each experiment were drawn (Figures 1 and 2), both for non pre-stressed specimens and for those biaxial pre-loaded. Then, a curve was fulfilled to the results according to [4]:

$$V_r = \begin{cases} 0.0, \quad V_i \le V_l \\ A \cdot (V_i{}^p - V_l{}^p)^{1/p}, \; V_i > V_l \end{cases}$$

where: V_r is the residual velocity, V_i the impact velocity, V_l the ballistic limit, and p and A are two empirical adjusting parameters that should be obtained experimentally.

From those curves, the ballistic limits were estimated. No significant influence of the two pre-loading conditions herein considered on the ballistic limit was observed (the ballistic limits were: 114 m/s for the specimen unloading case, and 102 m/s for the specimens biaxial pre-stressed.

There is small influence of the pre-stressed condition on the damage area extension (Figures 3 and 4), in contrast with the behavior of GFRPs tested for the same impact conditions and the same level of pre-stress (120 MPa) [2]. Perhaps the higher mechanical strength of CFRP (632 MPa), and the consequent lower preloading level (20%) regarding those corresponding to GFRP, may explain this fact.

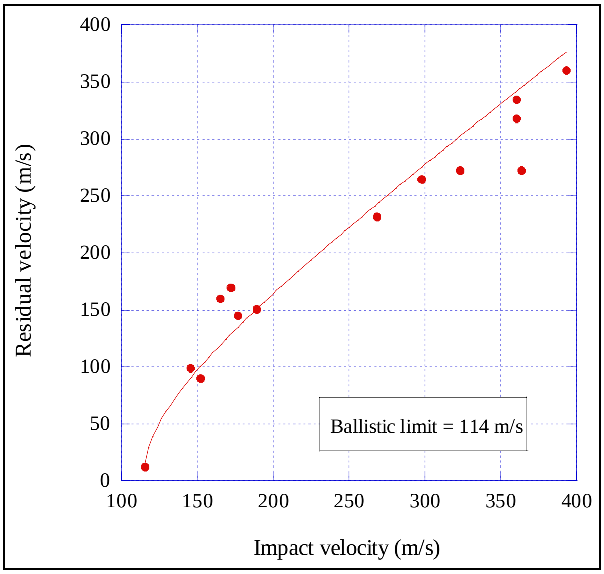


*Figure 1.- **Residual velocity versus impact velocity for unloading laminate***

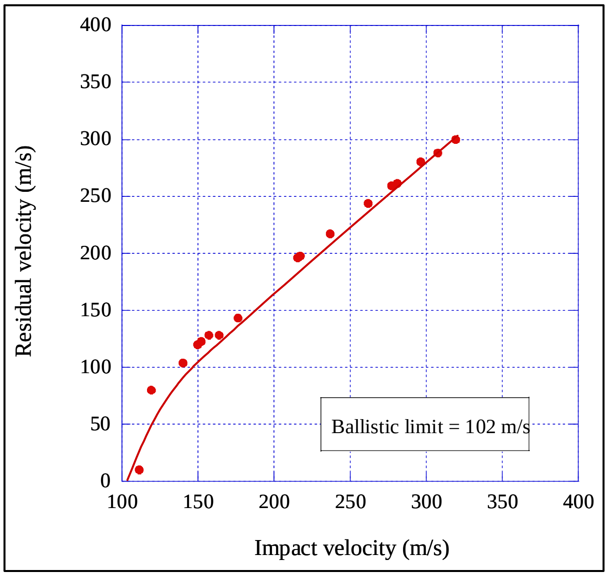
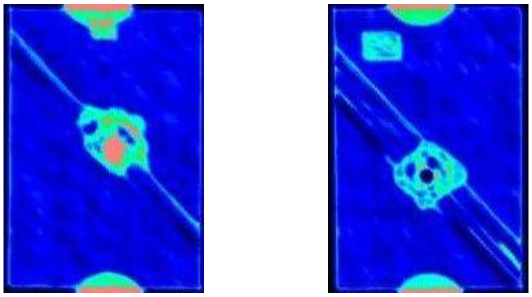


*Figure 2.- **Residual velocity versus impact velocity in biaxial preloaded laminate***

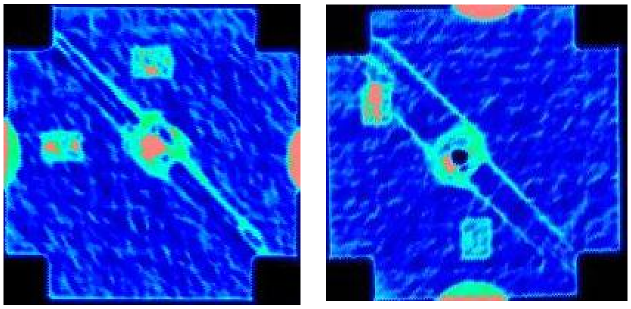
CONCLUSIONS

For pre-stressed levels less than 20% of the ultimate tensile strength, no changes in the ballistic limit have been observed for the material herein considered (AS4-8552). Also, for the projectile velocities range considered in this work, damage extensions in the specimens seem not to be dependent on the pre-loading conditions of the specimens.



Impact velocity = 152 m/s Impact velocity = 324 m/s

*Figure 3.- **C-Scanning inspection images of the quasi-isotropic non-preloaded laminate***



Impact velocity = 152 m/s Impact velocity = 319 m/s

*Figure 4.- **C-Scanning inspection images of the quasi-isotropic laminate biaxial pre-stressed***

ACKNOWLEDGMENTS

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