EFFECTS OF REPLACEMENT OF A DYNAMIC CRASH TEST WITH A QUASI DYNAMIC ONE. TEST OF PW-5 WORLD CLASS GLIDER

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Abstract

This paper presents the results of a comparative studies carried out to investigate a possibility of replacing a dynamic crash test with quasi dynamic one in a case of glass-epoxy structure. In a case of gliders, general practice is that the fuselage is subjected to the required static load and the extend of the damage in the longitudinal direction is judged. Such procedure is relatively simple and inexpensive and for these reasons often applied however the relationship between the amount of energy absorbed in dynamic crash and that absorbed in a quasi dynamic one is not well known. To obtain necessary information preliminary investigations with the use of coupons and sub-components were carried out. The results showed that in the both cases the failure modes in macro scale were similar, (the same deformation modes) but in micro scale a pronounced difference occurred with the respect to the damage modes and the energy absorption mechanisms. The quasi dynamic loading resulted in the damage caused by the local bending of the laminar composite structure. The dynamic loading resulted in the local bending as well but in addition it produced the extensive delamination being the main mechanism of energy absorption. The results of the tests suggest that the quasi dynamic test will produce conservative results with the respect to the amount of the energy absorbed.

Introduction

The analysis concerned the relationship between the amounts of energy absorbed in dynamic and quasi dynamic damage of GFRP structure only. Other aspects of replacement of a dynamic crash test with quasi dynamic one were out of the scope of this analysis. The JAR 22.561,(b),(2) requirement stands that a glider structure must be designed to give each occupant a every reasonable chance of escaping serious injury in a crash........., if an ultimate load of six times the weight of the glider acting rearwards and upwards at an angle of 45° to the longitudinal axis of the glider is applied to the most forward part of the fuselage at the foremost point(s) suitable for the application of such a load. The most common way to show a compliance with this requirement is to apply the required static load to the fuselage and judge the extend of the damage zone, Fig.1.

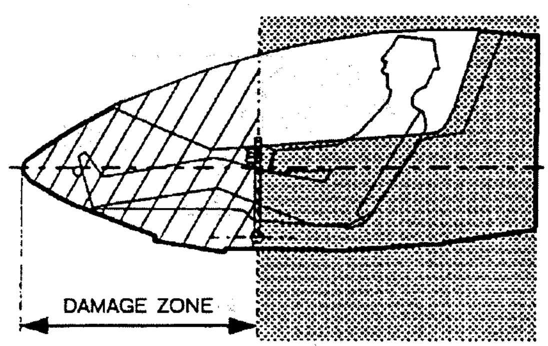

Fig.1. Allowed damage zone.

The procedure is relatively simple and inexpensive and for these reasons often applied. One of the unknowns in such a procedure is the relationship between the amount of energy absorbed in dynamic crash and that absorbed in a quasi dynamic one. To investigate this relationship tests with the use of coupons and sub-components of the front part of the fuselage of the PW-5 were carried out. The coupons and sub-components were damaged by static and dynamic loadings and modes of failure and amounts of the energy absorbed were compared.

Tests

Coupons and sub-components design. The geometry of the tested coupons is shown in Fig.2. The coupons were made from the same components as the structure of the glider and represented the reinforced region of the cockpit. Figure 3 shows sub component representing the most foreword part of the fuselage.

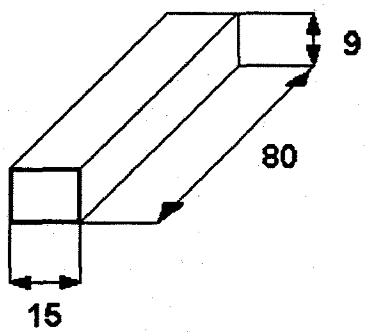

Fig.2. The test piece representing the structure of the reinforced regions of the cockpit

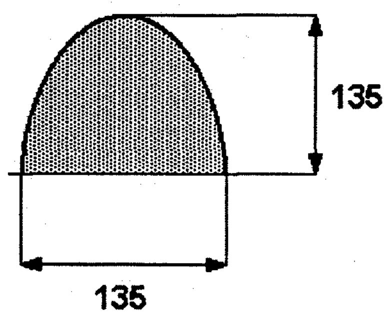

Fig.3. The test piece representing the front part of the fuselage structure.

Its structure was identical with that of the corresponding part of the glider.

Test procedure. The coupons were damaged in a static manner in three point bending with two cross head speeds: 1.67 mm/s and 10 mm/s. For the dynamic testing the Charpy pendulum was used. The estimated contact velocity was about 5000 mm/s and the corresponding initial strain rate was about 1.2 1/s.

The sub-components were loaded in compression with the cross head speed of 1.5 mm/s until a size of the damage zone reached 80 mm. The dynamic loading was produced by dropping a weight of 8.8 kg, Fig.4. The estimated contact velocity was about 11.3 m/s.

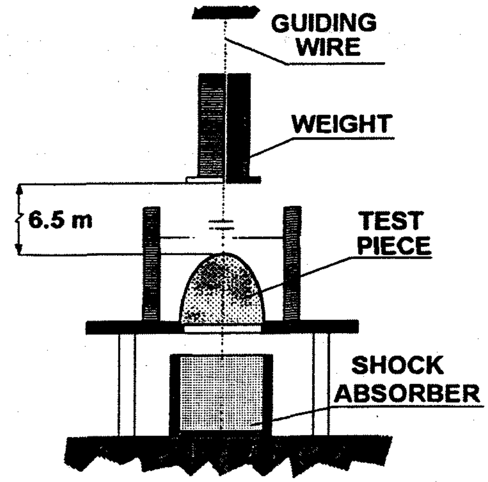

Fig.4. Dynamic test of the sub component.

Results

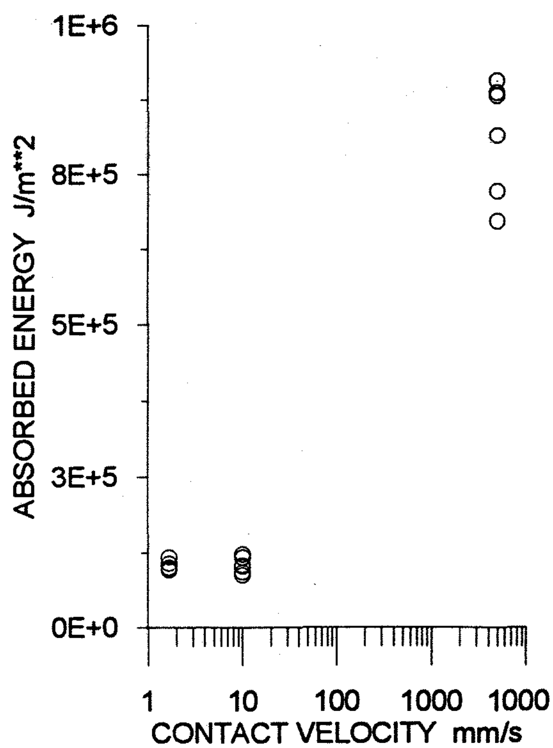

Fig.5. Damage of coupons. Absorbed energy vs. contact velocity.

Diagram in Fig.5. shows the amount of energy absorbed vs. contact velocity for the coupons for three contact velocities 1.67 mm/s, 10 mm/s and 5000 mm/s. The amount of energy absorbed by each coupon was normalised with the respect to the coupon lateral cross section.

Figure 6 shows load vs. displacement curves obtained for sub-components subjected to the static and dynamic loadings. In the cases of the static loading the amount of the absorbed energy was calculated from load vs. displacement curves. The amount of the energy absorbed in the drop test was calculated on the basis of the deceleration and displacement of the weight.

Pictures in Figs. 7 and 8 show the modes of damage of the coupons resulting from the static and dynamic loadings respectively. Picture in Fig.9 shows the damage mode of the sub components destroyed by static loading and Fig.10 shows the sub components destroyed by dynamic loading.

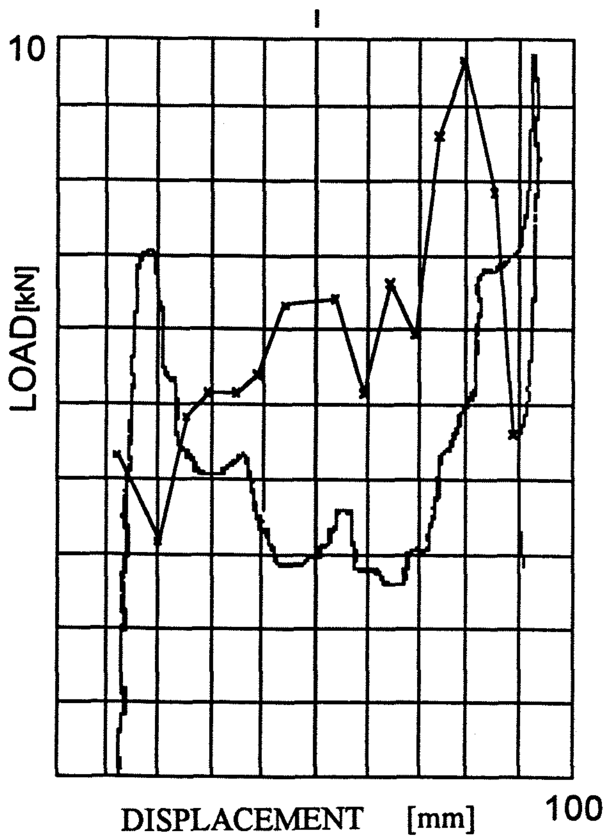

Fig.6. Damage of the sub components. Load vs. displacement curves for static loading (—) and dynamic loading (-x-).

Discussion.

The diagram in Fig.5 indicates that the amount of energy absorbed during low velocity loading (1.67 mm/s and 10 mm/s) is about eight times lower than that absorbed during high velocity loading (5000 mm/s). The coupons failed under static loading display relatively small damage zone, Fig. 7. It is localised in the close vicinity of the fracture and is restricted to fibers and matrix broken in tension or compression. In this case the main mechanism of energy absorption is rupture of fibers and matrix, and pull out of fibers. Contribution of delamination is small. The damage caused by the dynamic loading is more complex. The picture in Fig.8. suggest that the observed extensive delamination is the main mechanism of energy absorption. The reason for which almost no delamination is produced by static loading is not well known and further material investigations are needed.

In the case of the sub components the observed modes of failure in a macro scale are similar. In the both cases initially the shell locally buckled then collapsed inward. The amount of the absorbed energy corresponding to the static loading was about 40% lower than that corresponding to the dynamic one. Inspection of the damaged test pieces suggests that the static loading produces branched, throughout cracks resulting from local bending. The damage of the composite shell is restricted to the areas in the nearest vicinity of the cracks, Fig.9. Under dynamic loading, cracks are less extensive but accompanied with extensive delaminations, Fig.10. Probably, the splitting of layers reduces stiffness of the shell and the value of the normal stresses resulting from the local bending is not high enough to break the fibers and the delamination is the main mechanism of the energy absorption.

On the basis of the above results one can conclude that the absorbed energy increases with the deformation rate in the observed range and that the quasi dynamic loading will produce conservative results with the respect to the energy absorption capacity of glass-epoxy laminar structures. The main mechanism of energy absorption is delamination. The result also suggest that impairment of the interface may result in higher energy absorption capacity of the laminar structure.

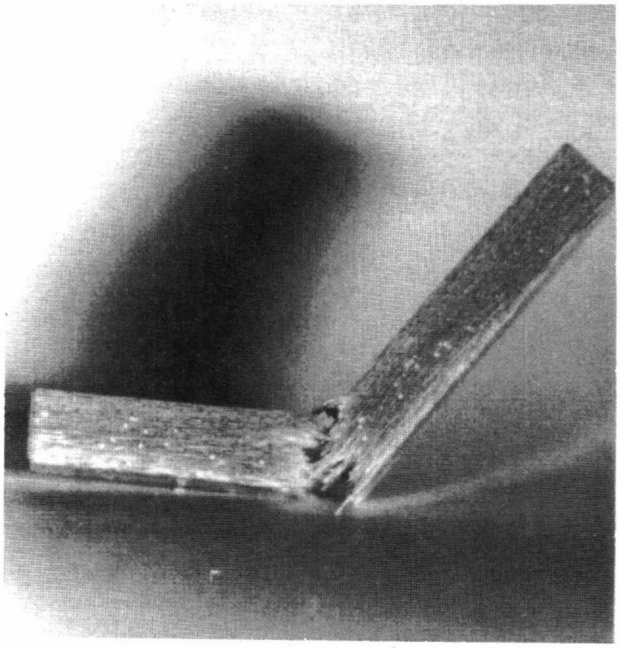

Fig.7. Damage caused by static loading. Contact velocity 1.67 mm/s

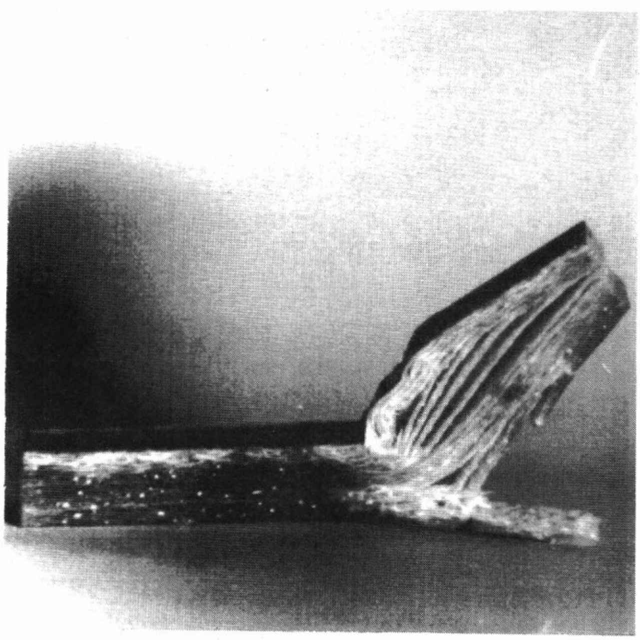

Fig.8. Damage caused by dynamic loading. Contact velocity 5000 mm/s

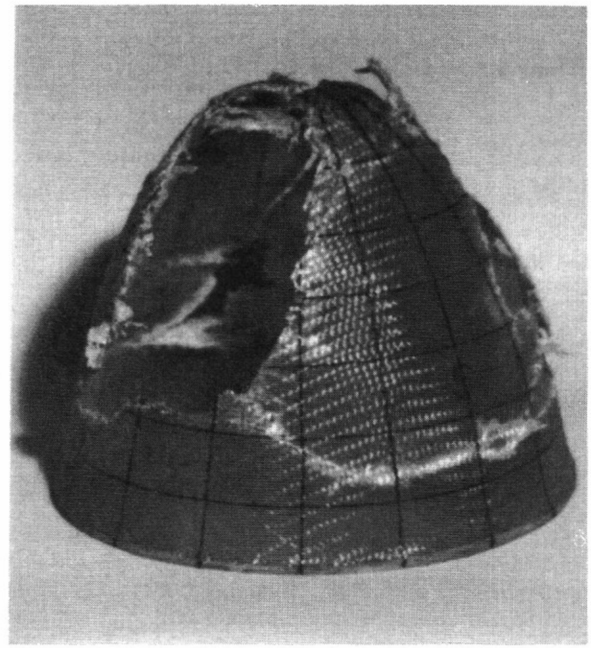

Fig.9. Damage caused by static loading. Contact velocity 1.5 mm/s

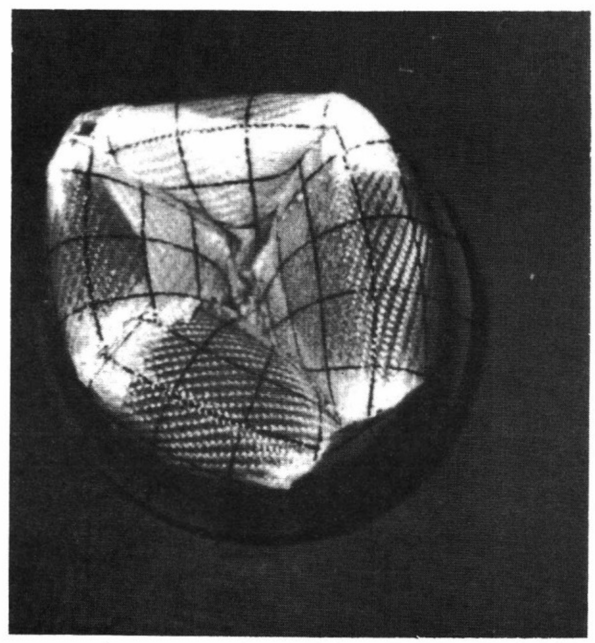

Fig.10. Damage caused by dynamic loading. Contact velocity 11.3 m/s