An investigation of failure scenario of the metallic insert in sandwich structures

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Abstract

This paper addresses an experimental study of the metallic insert in composite sandwich structures, which simulates an insert application on to a fuselage of a helicopter under pull-out failure load test. Nomex® honeycomb core and carbon epoxy composite face skins were used for specimen fabrication. The molded-in type should always be used to this application because of its ability to bond the insert, core and face skins into one rigid unit with the selected resin potting medium. Observation of the response of the specimens during testing showed that first failure occurred by buckling of the honeycomb cell wall that attributed to a transverse shear failure adjacent to the potting mass. However, the strength and stiffness of the sandwich structures containing a potting/lower face skin bond decreased substantially with increasing debonded size until interfacial failure and followed by rapid rip of the honeycomb core that attributed to a tension failure at the ultimate load test.

Keywords*:* Sandwich structures, junction, Metallic insert, Insert failure behavior.

1. Introduction

The sandwich structures consist of top and bottom face skins attached to an inner core with adhesive material (Fig. 1). The face skins are made of sheet material, by generally used as high stiffness to the sheeting plane. It can be

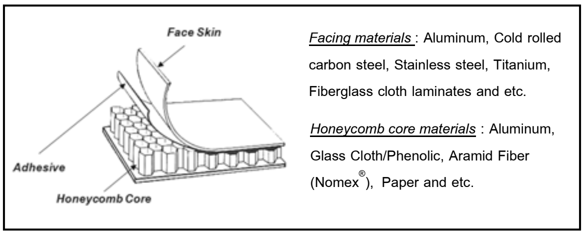

Fig. 1 Typical honeycomb panel construction and materials were used [1,2]

compared to the flanges of an I-beam, as they resistance the flexural moment to which the beam is subjected. The thick core is continuous support to the face skins to produce a uniformly stiffened panel. The honeycomb core is widely used in the aviation and aerospace industries, where light weight plus high strength and stiffness (comparison and shear) are compared to the other materials as density. [1,3]

Stiff honeycombs can be considered to be orthotropic materials which possess different properties depending on how stress is applied to the individual hexagonal cells that its made sheets and bonded together with glue as shown in Fig. 2. The resistance to shearing on Nomex® honeycomb plane W get values less than 2 times approximately of the plane L which is intersects the area where cells are glued so one another so that the thickness is doubled. [4]

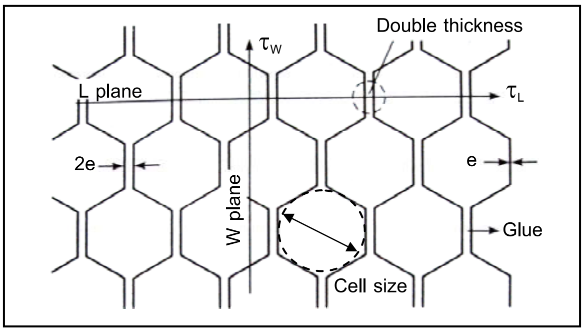

Fig. 2 Shearing of the honeycomb core [4]

By its very nature, sandwich structures are not used to be a junction with the other structures as the core can not carry concentrated unit loading. Especially, the out-of-plane loading is the leading to damages on the weakness core that has low shear resistance. [1]

Fig. 3 shows several types of inserts. It is generally recognized, that 'through-the-thickness' inserts are superior to 'fully-potted' inserts with respect to load carrying capability. Because of the both face skin in sandwich panel with 'through-the-thickness' inserts are forced to deflect together, where as this is not the case for sandwich panel with 'fully-potted' inserts. In excess of this, the insert's head can be help transfer stress concentration occurred on to components in sandwich structure [5,6].

However, the insert should not be allowed to touch the inner surface of the lower face skin due to assure a bond between the inside surface of the lower face skin and the insert. So, the 'molded-in' fastener can be used to relieve stress concentration occurred in the vicinity of the junction of the sandwich panel [1]

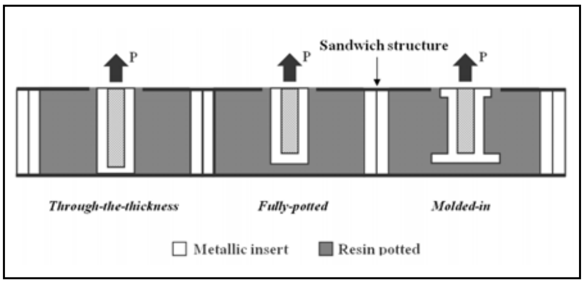

Fig. 3 Types of inserts

This research intends to gain insight into the complexity of their mechanical behavior, particularly when loading is produced out-of-plane. In addition, the results can be used to design insert in sandwich structures with investigation of the damage mechanism and the failure modes of the metallic insert under pull-out experiment.

2. Pull-out test descriptions

2.1 Materials and specimen fabrications

The specimen is fabricated by honeycomb sandwich panel with metallic, threaded insert used in the fuselage of a

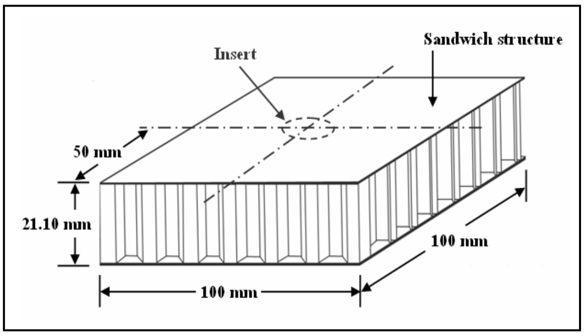

Fig. 4 Specimen and dimension

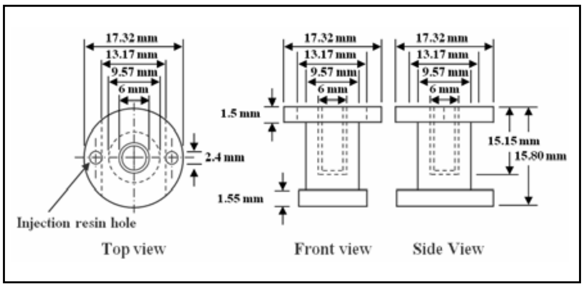

Fig. 5 Insert geometry

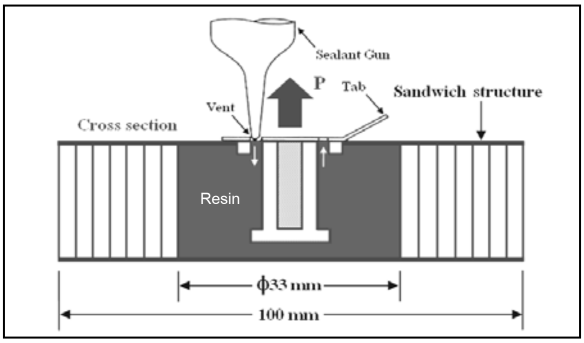

Fig. 6 Potting operation for molded-in insert

helicopter. The sandwich structures in size of 100 x 100 x 21.1 $mm.^3$ consists of two identical carbon face sheet (G939/145.8) with [0/90] layups and Nomex® honeycomb core 3.2-mm cell size, 48-kg/m^3 density and 20-mm thickness (see Fig. 4,5). The sample was drilled at the center and the core was undercut of 33-mm diameter for putting a commercial metallic insert, which intend to adjust the position of the insert by a tab (see Fig. 6). To fill the hole inside, Araldite AV121B resin epoxy composed of EA 9396 STRUCTIL® adhesive resin parts A and B is mixed with phenolic micro-balloon epoxy about 10% of overall weight. Then it is injected through one of the potting holes with a sealant gun, or equivalent, which permits venting through the other hole thus insuring a completely uniform fill shown in Fig. 6 [1].

2.2 Experimental procedures

The pull-out test's fixtures consist of four rigid steel plates (Fig. 7). The support plate was drilled with a circular hole of 60-mm diameter for pulling the insert through. The bottom plate is fixed with the base of apparatus to be reference. The specimen was gradually loaded by Instron 4206 50 kN Universal Testing Machine with speed of 1 mm/min. During the test, the force versus displacement curves was measured. In every test, force is measured by the load cells of the machine and displacements at the top of insert head are measured by laser displacement sensor. Both results are connected through a Yokogawa DL708E digital oscilloscope for investigating their relation simultaneously (Fig. 8).

There were 4 identical samples in the experiment. Every sample was test until the failure occurs except the last sample called "sample 4". The sample 4 was tested by stop at 1.9-mm which is observed by three previous samples to be seriously failed from the reading results.

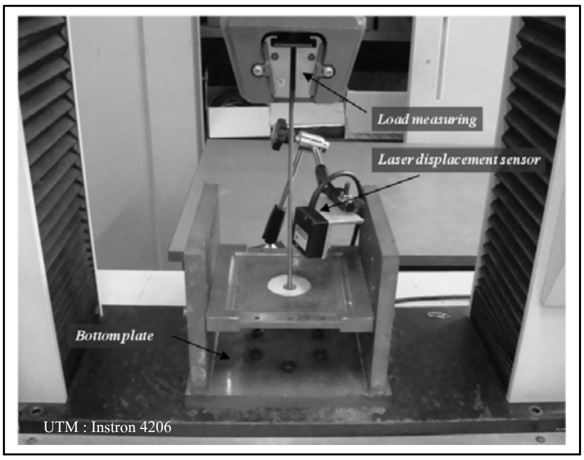

Fig. 7 Pull-out test set-up

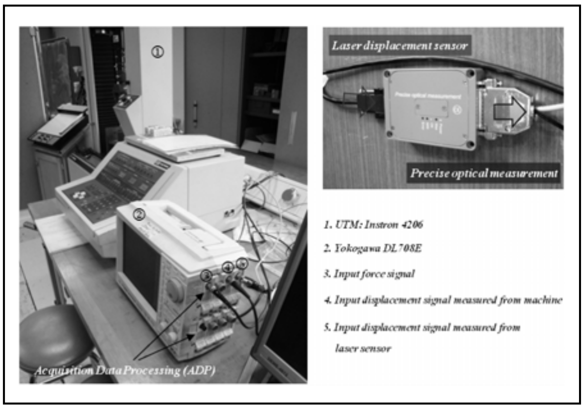

Fig. 8 Acquisition data-processing system

2.3 Experimental results and failure process

The pull-out test results of each insert in sandwich specimens shown reproducibility, representative curve (see Fig. 9). In general, four distinct points can be identified,

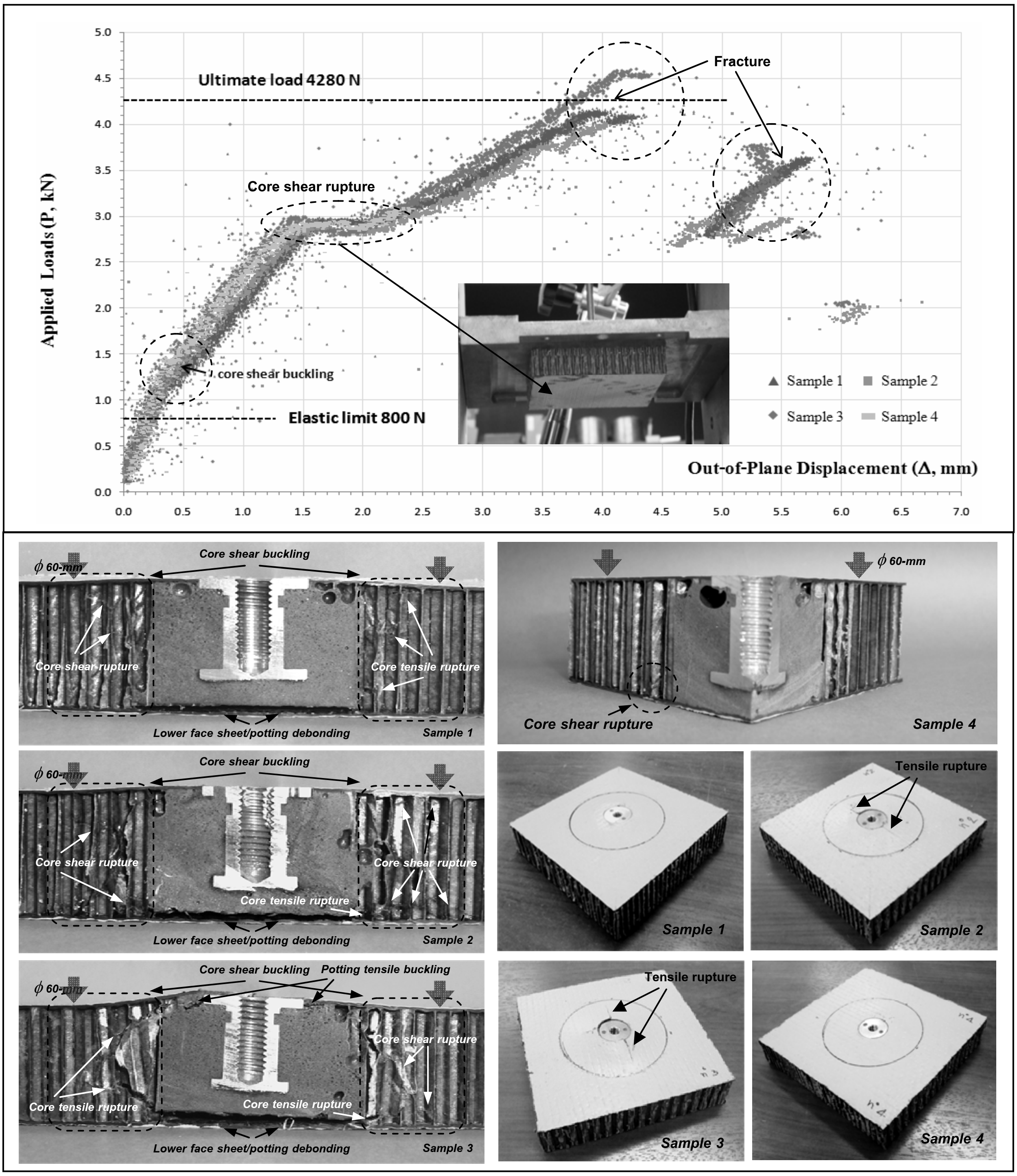

Fig. 9 Load-displacement results under pull-out test and post-failure of specimens

Characterized the failure scenarios under out-of-plane loading. Initially, the metallic insert behaves linearly, with a load-displacement slope equal to the original molded-in insert sandwich modulus up to a load about 800-N at which cell wall honeycomb core start to buckle in W plane.

The cell wall is progressively buckled when the applied force reaches about at 2900-N with slightly reduced stiffness shown in every tests. At this point, we observe a horizontal load-displacement which corresponds to completely crushing of the cell wall as observation from the surface of cut-through the center of the sample 4 (see Fig.10). The observation on lower surface of the specimen during experiment shows circular crushing form of the whole potted area which is possible to be a large shear degradation of the core.

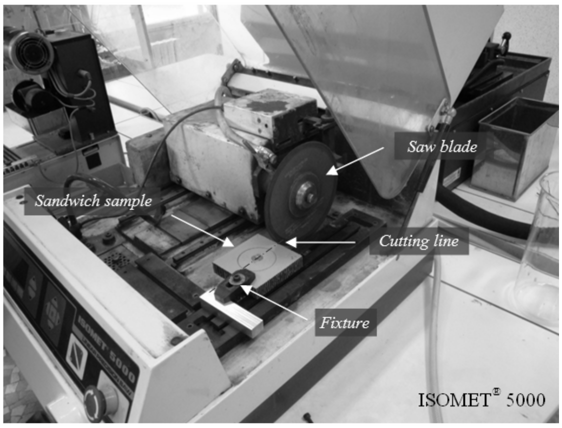

Fig. 10 Cut-through the center operation

After undergoing the deformation without an increasing load is finished at 1.9-mm deformations, force starts to regain which can be observed by the curve. This behavior is obtained by the whole potted area, potting/lower surface interface bond and partially honeycomb core (L-plane), exhibits an out-of-plane load with respect to the rest of the panel. Then the failure growth again up to a load at 4300-N approximately, where it drops because of a peeling/debonding of the resin potted and lower surface combined with a shear failure at the honeycomb core, which can be seen by cut-through the center surface of total damage sample. After ultimate load test at 4300-N the post damage behaviors are mainly characterized by a tensile failure of the honeycomb core and a tensile rupture of the upper face skin until specimen completely failure at 3650-N approximately.

3. Conclusion

In this paper, the failure scenario of the metallic insert in sandwich structure was investigated experimentally. Insert pull-out tests show a core shear buckling is occurred first in the weakest plane, and then the crushing of cell wall is observed by constant force as indicated by the load-displacement relation. The following failure mechanism is then the debonding of the potting with the bottom skin identified by stop-test specimen with the combination of core shear rupture and followed by rapid rip of a core tensile rupture combined with a tensile rupture of the upper face skin at the ultimate load test.

4. Acknowledgement

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