# Molding process and experimental research on a circular composite fragile cover

Deng'an Cai, Guangming Zhou, Xiaopei Wang & Honghao Yu
State Key Laboratory of Mechanics and Control of Mechanical Structures, Nanjing University of Aeronautics and Astronautics, Nanjing, 210016, China

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**Abstract.** The overall structure and the weak zone of a new circular composite fragile cover have been presented. In fabrication of the fragile cover, a particular hand lay-up molding process is proposed. The deflection and failure pressure of the circular composite fragile cover have been experimentally investigated. The results show that the deflections of cover center will grow nonlinearly along with the increasing gas pressure and have less distinction with different height of weak zone. The failure pressure of the cover first increases and then decreases with the increasing height of the weak zone, which obtains the maximum value of 0.79 MPa at the weak zone height of 18 mm.

## Introduction

Missile launch canister cover is an important part of missile storage and launch system. Before missile is launched, the cover is seen as a storage lid of missile to protect the warhead to avoid damage and to prevent inert gas leak. At the moment of missile launch, the cover can be opened timely, and will not affect the normal missile launch. In the past, the missile launch canister cover was often metal and was opened by mechanical methods [1] or burst [2] [3], which increased the weight of the launch system and extended the time of the launch, resulting in slower operations.

With the increasing use of composite materials replacing metals in aerospace applications, the increasing canister covers of missile launch system are manufactured by composites. Doane [4] designed a bursting type of composite film cover with simple structure using glass fibre composite materials. The cover could improve the speed of reaction of the launch system markedly, but the warhead might be damaged while bursting. On account of this, Kam [5] and Wu [6] developed a kind of frangible canister cover by making full use of the superior designability of composites, which used missile gas flow to break the cover out of canister in four parts. Zhou and Qian [7] [8] investigated the structure and properties of integrated frangible composite cover. In these works, effect of weak zone structure on performances of fragile cover were discussed and the strength of the cover could be changed by different composite material layers labelled on two sides of weak zone. Afterwards, a failure analysis of a fly through frangible canister cover was studied based on transient dynamics via the finite element method [9]. The result shows that the failure pressure and the corresponding time rise as the length of bonding layer increases.

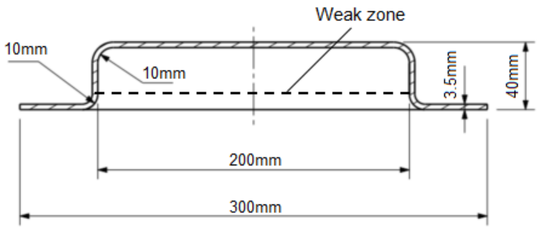
In this paper, a new composite fragile cover used to simulate launch test is studied. The molding process and the failure properties of the cover are also presented.

## Structure of composite fragile cover

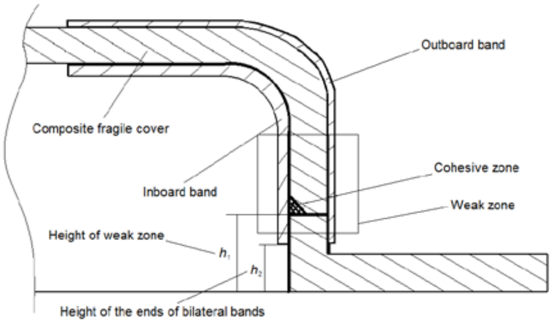
The shape of the proposed composite fragile cover are designed as convex structure like round cap, which is fabricated with the weak zone set circumferentially between top and bottom. The dimensions of the fragile cover are shown in Fig. 1a. The two fluctuation parts of the cover are adhesively bonded together along with their edges in forming the weak zone, which is lapped by fiber layers inside and outside (Fig. 1b) to improve the bonding strength of the cover, namely called inboard band and outboard band, respectively. The height of lapped fiber layers h = h1 - h2 = 5 mm. The canister cover is designed in such a way that when subjected to an impulsive gas pressure, the adhesive bond between the two components will be broken and the severed cap-like composite part is blown away from the opening of the frame.

In the structure of weak zone, a right triangle groove (the width of the groove is half of the wall thickness of the fragile cover, Fig. 1b) is designed to improve the bonding strength and the pressuretightness of the fragile cover.

The material of fragile cover under consideration is glass fabric/epoxy composites, the fabric with a nominal ply thickness of 0.4 mm. A number of fragile cover with a quasi-isotropic stacking sequence of [(0/90)/(±45)]2s are fabricated. The inboard band and outboard band are lapped by fiber layers with a ply thickness of 0.1 mm, where two plies are prepared for inside and one for outside.




(a) Dimensions of the fragile cover




(b) Details of the weak zone

Fig.1. Structure of circular composite fragile cover

## Molding process

The matrix material of the fragile cover is epoxy resin (E51 system, Brand 618). The composite fragile cover is manufactured by hand lay-up molding and the specific steps are as follows.

(1) Under the condition of room temperature, clean up the mold and daub the low temperature grease on it. According to the mold shape, cut the polyester brittle plastic films and post them on the mold.

(2) Cut 8 pieces of bidirectional fabric of 0.4 mm with 400 mm long and 400 mm wide. Then, make up adhesive solution of epoxy resin.

(3) Spread the first layer of fabric on the mold along 0°/90° direction. Then scrape and soak the glue.

(4) According to the stacking sequence, pave the rest of the layers.

(5) Scrape the glue evenly and then keep it at the room temperature for 24 h.

(6) Put the mold in the incubator for 2 h at 50 °C.

(7) Take out the mold from the incubator. After cooling, demold and remove burrs.

(8) On account of the definite height of weak zone, divide the fragile cover into two parts of the cover body and the frame.

(9) Grind out a 45°chamfer on the inside edge of the cover body, and the width is half of the wall thickness of the cover.

(10) Put the frame and the cover body together with prime seam according to its original position, and use AB glue to fix position for 30 min.

(11) Inject the AB glue in the triangle groove and keep it at room temperature for 12 h.

(12) After curing, burnish the inside surface and keep it smooth.

(13) Paste two fiber layers of 0.1mm glass fabric with 50 mm width on inside surface of the fragile cover and one fiber layer on outside, and then keep it at room temperature for 24 h.
(14) Put the cover in the incubator for 2 h at 50 °C. According to test device, punch holes in the frame of the fragile cover before experiment.

## Test details

Based on the dimensions of the fragile cover, simulating launch test device is developed (Fig. 2). The device consists of test tank, gas pump, pressure gage, clamp ring, seal ring and bolt. The flange of the launch canister and the frame of the fragile cover are matched, through the bolt connection. The rubber rings are put among the clamp ring, the frame of the fragile cover and the flange of the launch canister, which have a function of sealing and protect outside surface of the cover to effectively avoid unwanted damage during the installation. The pressure loading on the composite fragile cover can be applied via a gas pump. The pressure data in the launch canister can be monitored real-timely by the barometer.

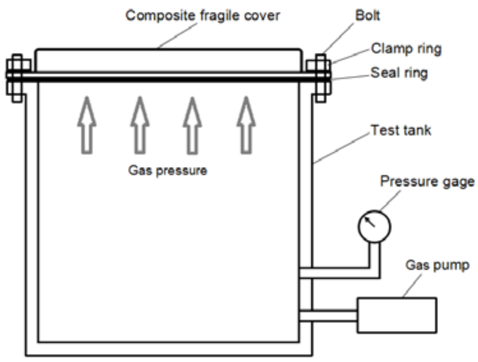


Fig.2. Test device

The experimental process are shown in Fig. 3. Five different heights of the weak zone (h1 = 12 mm, 15 mm, 18 mm, 21 mm and 24 mm) are used to give different properties of the fragile cover. The center deflections of the cover along with the changes of pressure load can be measured by vernier caliper (Fig. 3b). The pressure load are applied at a rate of 0.002 MPa/s. Note that record the deformation of the cover center every 0.05 MPa and stop to do that when the pressure load is up to 0.30 MPa for safety.

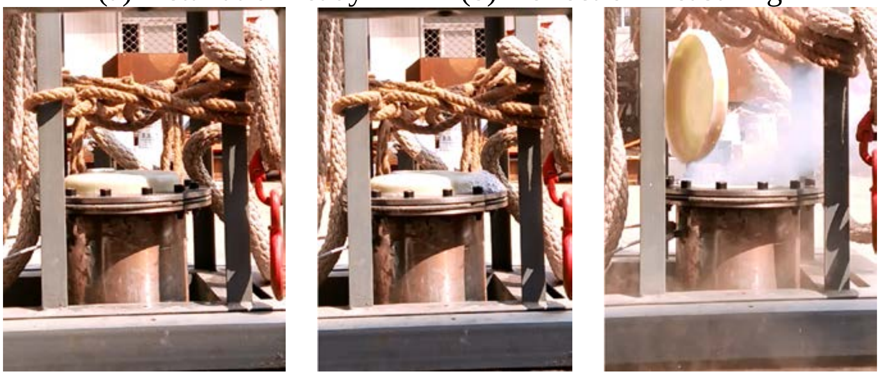
After the test of deformation measuring finished, failure test (Fig. 3c, Fig. 3d and Fig. 3e) can be carried out at a loading rate of 0.02 MPa/s. The fragile cover is loaded by gas pump until catastrophic failure. During the failure test, there is elastic rope intertwined on the steel test frame due to the risk factors. Bubble water will be blotted out around the fragile cover, which is used to show the local damage of the cover (Fig. 3d).

## Results and discussion

To every height of weak zone, three test fragile covers are used for the deformation test and failure test. Failure test follows deformation test closely. In the experiment, all composite fragile covers are well manufactured with stable performance. The test results obtained are shown in Fig. 4. The nonlinear increasing trend of the deflection of the fragile cover is observed along with the increasing gas pressure (Fig. 4a). Also, the deflection of the cover center grows slightly with the rise of the height of weak zone h1. At the gas pressure of 0.30 MPa, the deflection of the cover center goes up to the maximum value 6.47 mm at h1 = 24 mm, while the deflection gets 6.02 mm at h1 = 12 mm. The ultimate strength (namely, failure gas pressure) of the fragile cover with different heights of the weak zone is shown in Fig. 4b. The error bars show the standard deviation of measured strengths calculated from the three tests. The failure pressure first increases and then decreases along with the increasing height of the weak zone, which is smallest (0.54 MPa) at h1 =

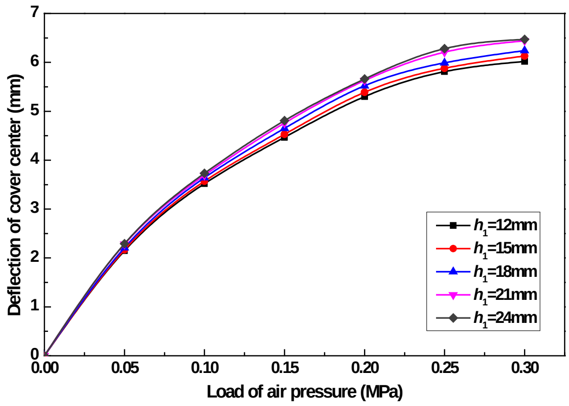
12 mm and is up to the peak of 0.79 MPa at h1 = 18 mm. That is, the fragile cover studied in this work with the weak zone height of 18 mm obtains the maximum ultimate strength.

(a) Installation ready (b) Deflection measuring

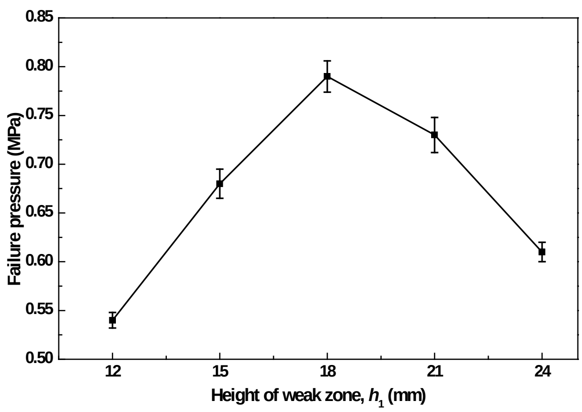


(c) Destructive test ready (d) Localized flaw (e) Ultimate failure

Fig.3. Experimental process




(a) Deflection curves of the cover center under different pressure




(b) Ultimate strength of the fragile cover with different heights of the weak zone

Fig.4. Experimental results

## Conclusions

This study has set out to present the hand lay-up molding process of a circular composite fragile cover and quantify the interaction between failure pressure and height of the weak zone of the fragile cover. The covers with different heights of weak zone have different failure pressure. The deflection of the cover center under diverse gas pressure is also discussed. A full range of height of weak zone under gas pressure load has been investigated. The results of experiment indicate that the deflection of the cover center with different heights of weak zone is adjacent and grows nonlinearly along with the increasing gas pressure. And the fragile cover with the weak zone height of 18 mm obtains the maximum failure pressure.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