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Application News

No.V24M

High-Speed Video Camera

3D-DIC Analysis of CFRP Subjected to Collision with a High Speed Flying Object

Introduction

Off all composite materials, Carbon Fiber Reinforced Plastic (CFRP) is particularly superior in terms of specific strength and specific rigidity. As a result, it is used in aircraft and some transportation equipment in order to improve fuel efficiency by reducing weight. However, the exhibition of superior mechanical properties is limited by the orientation of the fibers in CFRP laminate boards. It is known that interlaminar strength is low, as is the strength in a direction orthogonal to the fibers. In considering its use in transportation equipment, an (interlaminar) impact load may be applied from the outer surface of the laminate board by hail and scattered stones. For this reason, collision tests with high-speed flying objects are a very important type of test. Even if external damage to the CFRP laminate board cannot be confirmed after the collision test, there may be internal damage since the interlaminar strength is low. Accordingly, in order to evaluate the impact properties of CFRP, it is necessary to check how the CFRP laminate board was deformed at the time of the impact, and what sort of internal damage was produced.
DIC analysis is effective for measuring the strain distribution of a specimen. Synchronized imaging is required from two directions in order to measure the 3D strain distribution. This article introduces an example of the evaluation of the deformation of CFRP due to collision with a high-speed flying object. 3D-DIC analysis is applied, using two high-speed video cameras.

Note: DIC Analysis
In this method, a random pattern on the surface of an object is compared before and after the object is deformed, in order to investigate the amount of pattern displacement. The random pattern in this case is created using a white spray.

Measurement System

Fig. 1 shows the imaging system, and Fig. 2 shows the interior of the vacuum chamber. A steel ball fired by a steel ball launcher collides with a CFRP specimen placed inside the vacuum chamber. Observation windows are positioned at the front of the vacuum chamber, on the left and right respectively. The collision with the steel ball is recorded through the observation windows by two HPV-X2 high-speed video cameras. The images obtained are subjected to 3D-DIC analysis utilizing VIC 3D (from Correlated Solutions), a DIC analysis program. The imaging equipment used is indicated in Table 1.

Table 1 Imaging Equipment

High speed video camera	: HPV-X2, 2 pc
Lenses	: 200 mm telephoto lens, 2 pc
Illumination	: Strobe, 2 pc
DIC analysis software	: VIC 3D

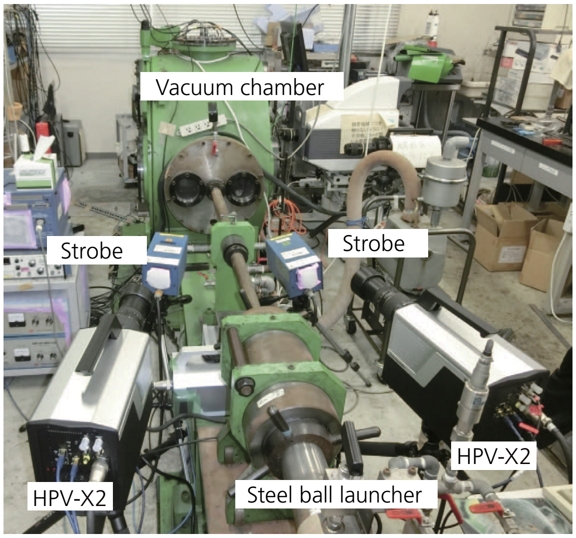

Fig. 1 Imaging System

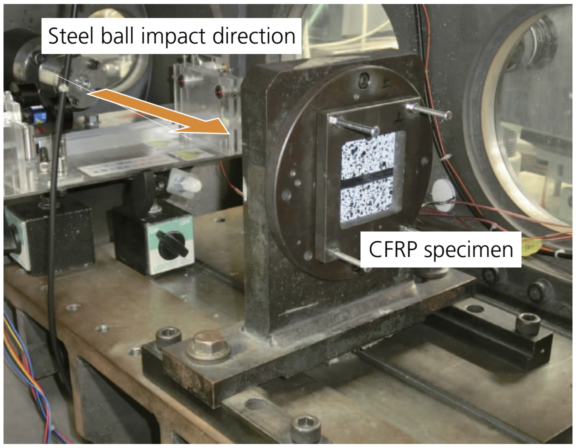

Fig. 2 Interior of the Vacuum Chamber

Table 2 Imaging Conditions

Imaging speed	: 500,000 frames/sec
Exposure time	: 500 ns
Collision speed	: 330 m/sec, 450 m/sec
Colliding object	: 4 mm dia. steel ball
Specimen	: CFRP suture material, t = 3.2 mm

Measurement Results

The collision speed for the steel balls was set to 330 m/sec and 450 m/sec, and imaging was performed. Fig. 3 shows the 3D-DIC analysis results (displacement in the direction of steel ball impact) at a collision speed of 330 m/sec. The steel ball does not penetrate the CFRP specimen. It can be confirmed in Fig. 3, Image 1 to 5 that the deformation region expands centered on the collision point, and that the amount of deformation is increasing in the direction of the steel ball impact. Afterwards, it can be confirmed in Image 10 that both the deformation range and the amount of deformation are decreasing. Fig. 4 shows the 3D-DIC analysis results (displacement in the direction of steel ball impact) at a collision speed of 450 m/sec. At a collision speed of 450 m/sec, the steel ball penetrates the CFRP specimen, and it can be confirmed as in Fig. 3 that the amount of deformation in the vicinity of the collision point is increasing. However, the deformation region is limited to the vicinity of the collision point, and is evidently smaller in comparison to the non-penetration case.

Conclusion

In this experiment, the amount of deformation caused by the collision of a steel ball with a CFRP board was measured by implementing 3D-DIC analysis utilizing two HPV-X2 high-speed video cameras. From the results, it is evident that in comparison to penetration by the steel ball, the deformation range is larger when there is no penetration, and the damage may be more extensive. Synchronized images from two directions are required in order to perform 3D-DIC analysis. Synchronized imaging is easily performed by the HPV-X2, so it can play a role in the evaluation of CFRP collision tests.

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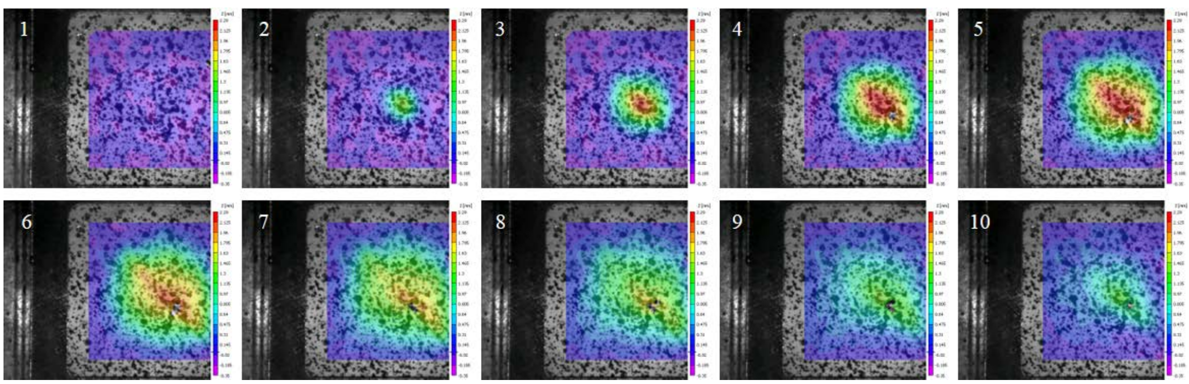

Fig. 3 Imaging Results (Collision Speed: 330 m/sec, Interval Between Images: 20 µm)

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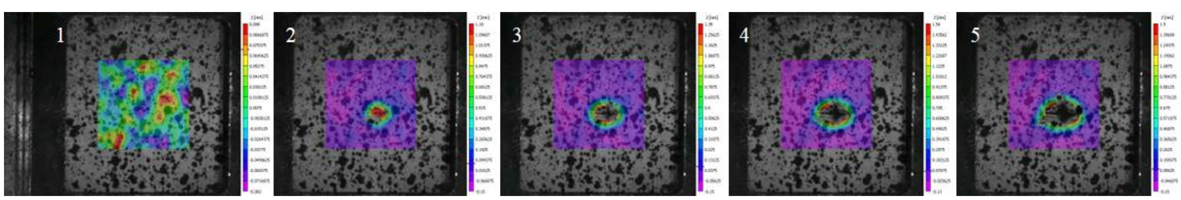

Fig. 4 Imaging Results (Collision Speed: 450 m/sec, Interval Between Images: 10 µm)

Data provided by the Tanabe Laboratory at Nagoya University,

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