LAAN-A-AG-E012

SHIMADZU
Excellence in Science

Application News

No.i247

Material Testing System

Material Testing by Strain Distribution Visualization – DIC Analysis –

Introduction

Strain distribution in samples is an increasingly important component of material testing.
As background to this trend, CAE (Computer Aided Engineering) is an analytical technology that is becoming widely used in the fields of science and industry due to the cost savings achieved through the reduced use of costly prototyping which is now being replaced by computerized product design simulation. A typical requirement is to conduct mechanical testing analysis of the region of a product in which strain is likely to occur, and to elucidate the correlation between the simulated analysis results and the strain distribution obtained in actual mechanical testing.
DIC (Digital Image Correlation) analysis is a technique used to compare the random patterns on the surface of a test sample before and after deformation to determine the degree of deformation of the sample. The advantages of this technique include the ability to measure displacement and strain distribution from a digital image without having to bring a sensor into contact with a test sample, and without requiring a complicated optical system. For these reasons, application development for DIC analysis is expanding into a wide range of fields in which measurement using existing technologies*1 has been difficult.

Here we introduce examples of DIC analysis of CFRP (Carbon Fiber Reinforced Plastic) and ABS resin high-speed tensile impact testing.

*1: Up to now, material strain distribution measurement has been conducted using various methods, including the direct attachment of large numbers of strain gauges to the test material. However, this method is not applicable for micro-sized samples to which strain gauges either cannot be attached, or attachment is difficult and complicated. These disadvantages also include the difficulty in measuring certain types of substances, such as films, that are easily affected by contact-type sensors.

Test Conditions

Fig. 1 shows the testing apparatus and software used in the high-speed tensile testing of CFRP. The test conditions are shown in Table 1, and information regarding the test specimens is shown in Table 2. For this experiment, special-shaped grips for composite materials were mounted to the HITS-T10 high-speed tensile testing machine, and the test specimen was affixed to the grips.
A high-speed HPV-2A video camera was mounted in front of the testing gap between the grips to collect video data of the specimen breaking, and the signal to start camera filming was a displacement signal from the high-speed tensile testing machine. The acquired video data was loaded into the StrainMaster (LaVision GmbH) DIC analysis software, and the strain distribution that occurred in the sample was analyzed.

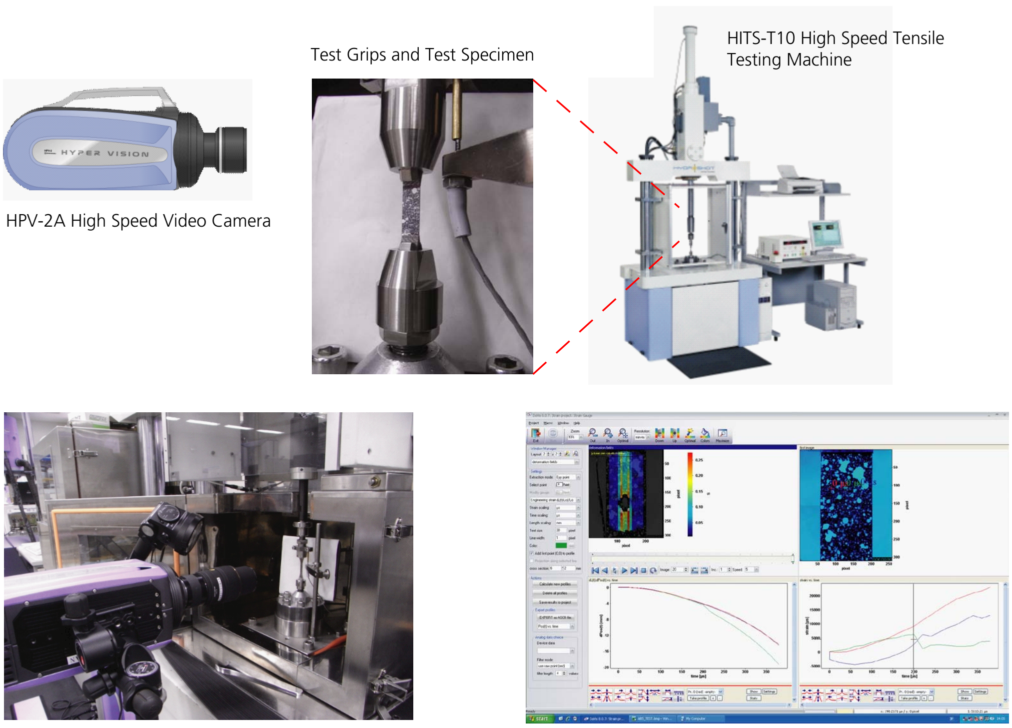


Fig. 1 Testing Apparatus

Table 1 Test Conditions

Instrumentation	HITS-T10 high-speed tensile testing machine HPV-2A high-speed video camera
Test Force Measurement	10 kN load cell
Test Speed	10 m/s
Grips	Special grips for composite materials
Sampling	250 kHz
Imaging Speed	500 kfps
Light Source	Strobe
DIC Analysis	StrainMaster (LaVision GmbH) With cooperation of MARUBUN CORPORATION

Table 2 Samples

Samples (dimensions)	CFRP-OH*2 Laminate method $[0/90]_{2s}$*3 (Hole diameter ϕ1 mm, W8 × t0.4 reed-shaped)
	ABS resin (ASTM L-shaped test specimen Total length 60 mm, Parallel part 3.2 (W) × 3.2 (T) mm)
Marking	CFRP-OH*2 : White random pattern ABS resin : Black random pattern

*2: OH: Abbreviation for Open Hole. Refers to a hole that is opened in a CFRP plate.

*3: The CFRP laminate used in this experiment is prepared by laminating prepreg fibers oriented in one direction. The $[0/90]_{2s}$ specified for "Laminate method" in the table represents two sets of prepreg layers stacked in the 0 ° direction and 90 ° direction.

In this test, the HITS-T10 high speed tensile testing machine and HPV-2A high speed video camera were synchronized to take video at the instant the sample fractured. The sample was prepared prior to the test by spraying paint onto its surface in a random pattern, and the strain distribution on the surface of the test specimen was visualized by DIC analysis based on the amount of shift of the random pattern.

Test Results

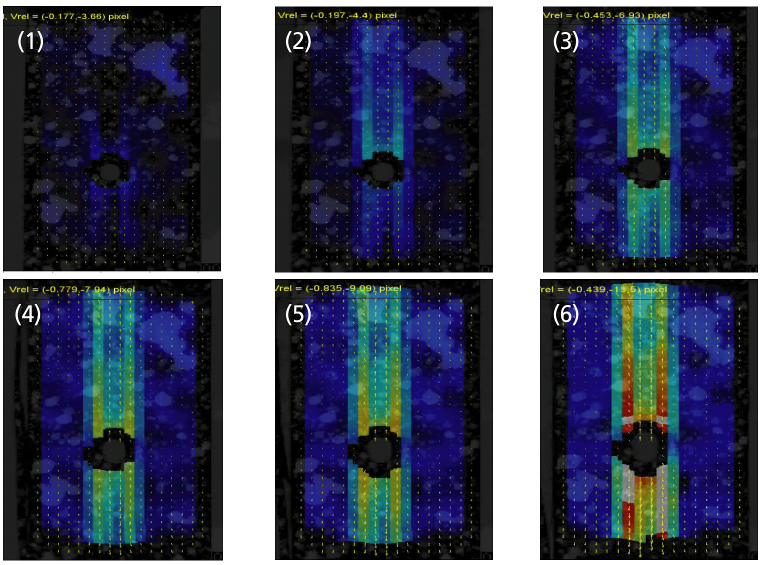
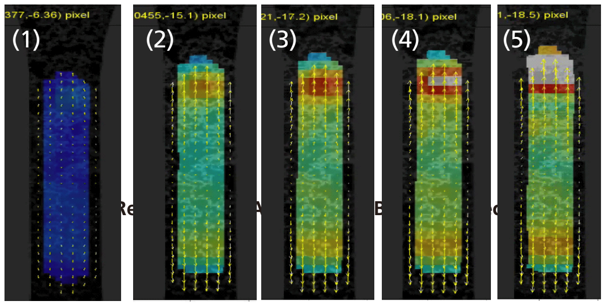


Fig. 2 Results of DIC Analysis of CFRP-OH Specimen

Fig. 2 and Fig. 3 show the DIC analysis results obtained in tensile testing of CFRP-OH and ABS resin test specimens, respectively. The images were extracted in the order of a typical time course analysis (image order corresponding to the numbers shown in images), from the start of the tensile test to the point that the specimen breaks. The appearance of coloring in the images corresponds to the strain distribution in the specimen. The amount of strain that occurs in the specimen corresponds to the degree of color warmth, with areas of darker color (such as blue-black) indicating low strain, and areas of brighter color (such as red-orange) indicating a greater degree of strain. It is clear that in Fig. 2, as the load is applied to the test specimen, the strain increases in the vicinity of the open hole. Because the test specimen is a $[0/90]_{2s}$ laminate material, it is believed that the fibers are aligned in the tensile direction in the test specimen surface layer which was subjected to random marking.



In Fig. 3, localized strain occurs from the edge of the parallel region of the test specimen, and as time progresses, localized strain is noticeable at the upper and lower edge of the parallel region.

Thus, by combining a high-speed tensile testing machine with a high-speed video camera, in addition to DIC analysis software, it has become possible to visualize the distribution of strain generated in a test specimen.

First Edition: Dce, 2012