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Application News

Fatigue/Endurance Testing Machine Servopulser™

Endurance Test and Dynamic Three-Dimensional DIC Analysis of Outer Case of Electric Vehicle Motors

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User Benefits

- It is possible to analyze the actual strain distribution of modules and automotive parts without processing test specimens.
- Graphs and color mapping display are possible by synchronizing the testing machine signal (test force and stroke) and DIC analysis results.
- Strain (longitudinal, transverse, shear, principal) and displacement can be measured at any point.

■ Introduction

In recent years, the trend toward decarbonization has accelerated to reduce greenhouse gas emissions. In particular, the shift to electric vehicles (EVs) in the automobile industry is playing a major role in realizing a decarbonized society.

To reduce the weight of EVs, major automobile parts are manufactured with aluminum die castings, which are light and durable. The aluminum alloys used in die casting have low viscosity and tend to have internal defects, so they need to be designed with cracking in mind. These parts are molded into thinner and more complex shapes to further reduce weight, and are subjected to continuous high-speed rotation and vibration during actual driving. Therefore, durability is required, and it is important to observe the dynamic deformation state.

In this article, an example of an endurance test and a dynamic three-dimensional DIC analysis*1 of a motor outer case (motor housing) used in EVs is introduced.

*1 What is DIC analysis?

DIC analysis is a method to compare a random pattern on the surface of an object before and after deformation to determine how much the pattern moves. In this case, the random pattern was applied to the surface of the test piece using a spray.

■ Specimen Information

Fig. 1 shows a photograph of the specimen and Table 1 shows the specimen information. This specimen was donated by Hamamatsu Next-Generation Automobile Center, Hamamatsu Regional Innovation Promotion Organization. For DIC analysis, a random pattern was sprayed onto the entire surface of the loaded part, and strain gauges were attached to the back of the loaded part to compare strain values.

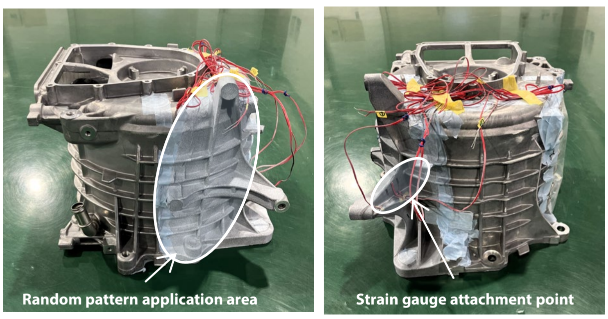

Fig. 1 Photograph of the Specimen
(Left) Front (Right) Side

Table 1 Specimen Information

Parts:	Outer Case of Electric Vehicle Motors
Material:	Aluminum alloy
Processing Method:	Aluminum die casting

■ Testing Equipment

For the endurance test, the fatigue testing machine EHF-UV (Fig. 2), which has a T-groove surface plate at the lower part of the frame and an upper mount actuator, was used to test the specimen. The wide test space of EHF-UV is suitable for dynamic evaluation of various specimens, real objects and structures.

The configurations of the testing machine and measurement system are shown in Tables 2 and 3, respectively. Two DIC analysis cameras we are used for the three-dimensional analysis.

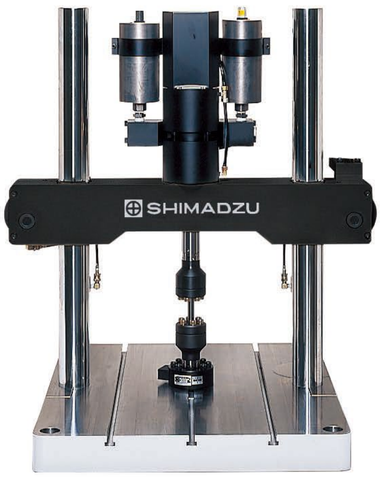

Fig. 2 Photograph of Fatigue Testing Machine EHF-UV

Table 2 Testing Machine Information

Testing Machine Main Body Type:	EHF-UV020KNA-040
Jig:	Dedicated grip
Load Cell:	10kN
Testing Software:	Windows software for 4830

Table 3 Measuring Systems

DIC Analysis Software:	VIC-3D by Correlated Solutions (Photographed using a Vic-snap10)
DIC Analysis Camera:	boA5328-100cc (Pixels 5328 × 4608) By BASLER × 2PC
Strain Gage:	KFGS-5-120-C1-11L1M2R (GL = 5 mm)
Bridge Box:	DBT-120A-1 For 120 Ω Gauge
Dynamic Strain Amplifier:	DC-97A

■ Endurance Test

The endurance test is shown in Fig. 3. In the endurance test, a load cell and a universal joint were attached to the piston tip of the upper actuator of the testing machine and connected to the protrusion of the specimen to apply a load vertically to the protrusion of the specimen. The lower part of the specimen was bolted using a step clamp and a T-type nut attached to the T-groove surface plate of the testing machine body.

The test conditions are shown in Table 4.

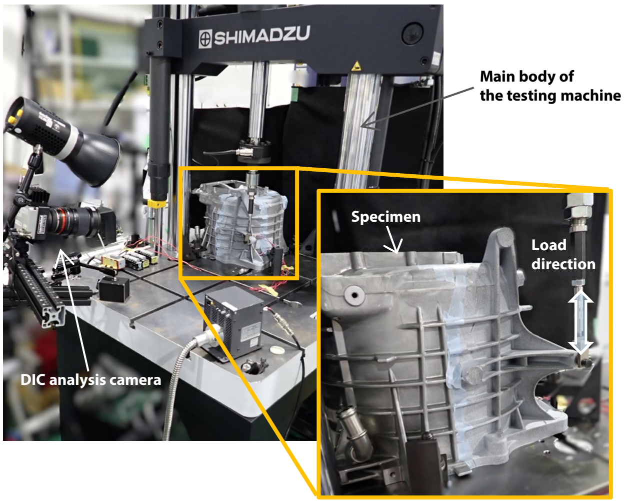

Fig. 3 Endurance Test

Table 4 Test Conditions

Waveform:	Harver-sine wave
Control Mode:	Force
Maximum:	1000 N (Tensile direction as seen from testing machine)
Minimum:	0 N
Test Frequency:	0.5 Hz

■ Comparison of Machine Stroke and Analyzed Displacement

The stroke value measured by the testing machine was compared with the vertical displacement value (Y) calculated by DIC analysis. Fig. 4 shows the displacement color mapping. The displacement values were measured at two points, Point R0 and Point R1 shown in Fig. 4.

In Fig. 4, the left shows the minimum load (0 N) and the right shows the maximum load (1000 N). When comparing the left and right sides, it can be seen that the deformation is small over the whole area under the minimum load, but the distribution is such that the deformation is large toward the tip of the protrusion under the maximum load.

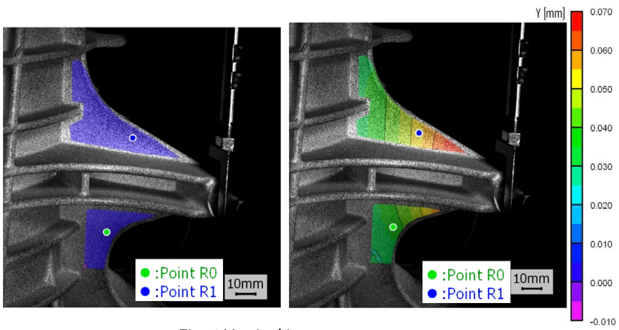

Fig. 4 Vertical Displacement Map
(Left) Under Minimum Load (Right) Under Maximum Load

Fig. 5 shows a graph of displacement-image frame number and a graph of test force-image frame number. The image frame rate is 5 fps, which means 0.2 seconds per frame. The horizontal axes of the displacement-image frame number graph and the test force-image frame number graph have the same dimension. The horizontal axis of the graph below shows the same condition. It can be seen that the displacement values (DIC displacement R0 and R1) calculated by DIC analysis of Point R0 and Point R1 are in phase with the test force (Force) and stroke (Stroke) without delay.

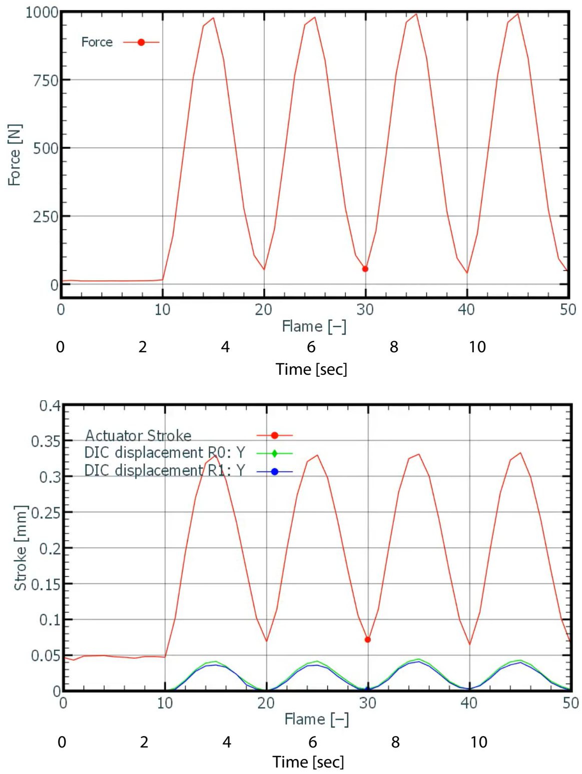

Fig. 5 (Top) Test Force - Image Frame Number Graph
(Bottom) Displacement - Image Frame Number Graph

■ Comparison of Strain Gauge Results and Analyzed Strains

The strain values measured by the strain gauges were compared with the longitudinal strain values (eyy) calculated by DIC analysis. Fig. 6 shows the color mapping of the longitudinal strain. Strain gauge 4 was attached to the back of the position Point R2 as shown in Fig. 6.

In Fig. 6, at maximum load, the upper part of the protrusion is strained in the negative (compressive) direction, while the lower part is strained in the positive (tensile) direction, and the direction of deformation is opposite in the top and bottom.

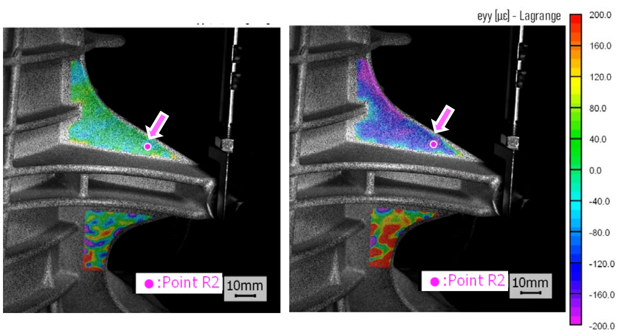

Fig. 6 Longitudinal Strain Color Mapping
(Left) Under Minimum Load (Right) Under Maximum Load

Fig. 7 shows the strain-image frame number graph and the test force-image frame number graph. Notice that the phase of the test force and each strain value is reversed by 180 degrees. It can be seen that there is no delay in either strain as well as or displacement.

Comparing Point R2 and Strain gauge 4, which measure the strain at the same point, we can see that they overlap in phase, and the strain value obtained by DIC analysis is close to the value measured by the strain gauge. Using DIC analysis, strain values can be estimated at any location without using multiple strain gauges.

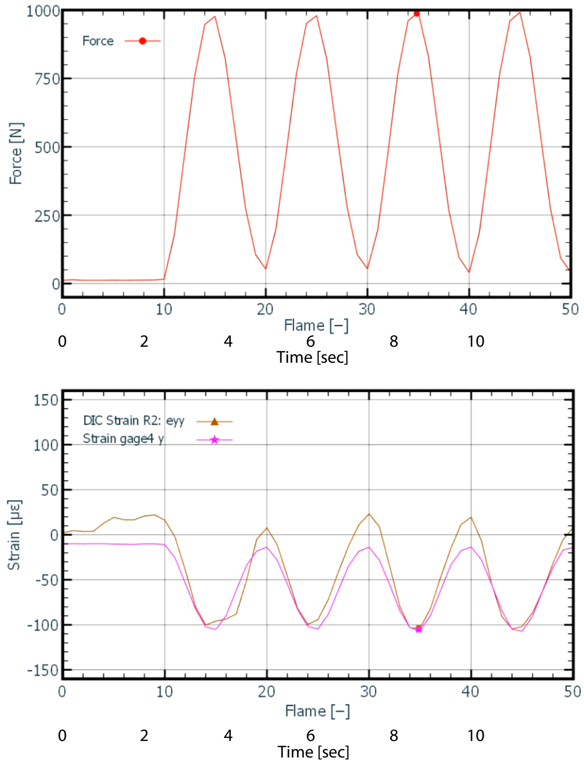

Fig. 7 (Top) Test Force - Image Frame Number Graph
(Bottom) Strain - Image Frame Number Graph

Fig. 8 shows the color mapping of the lateral strain values (exx).

It can be seen that there is little change in the distribution between the minimum load on the left and the maximum load on the right.

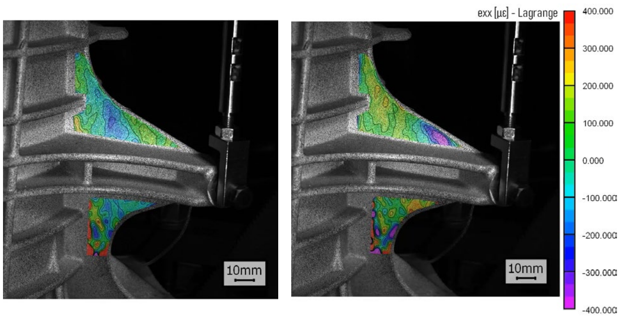

Fig. 8 Lateral Strain Color Mapping
(Left) Under Minimum Load (Right) Under Maximum Load

■ Vector Display of Principal Strains

Color mapping and vector display of the principal strain direction strain value (e1) calculated by DIC analysis were performed. The results are shown in Fig. 9.

Notice that the principal strain rotates counterclockwise from the bottom to the top, although the load is applied vertically to the protrusion. This is because the specimen is cantilevered and is subject to bending moment.

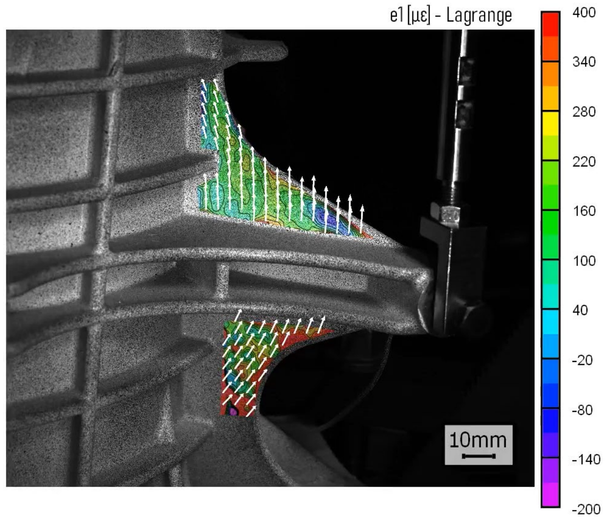

Fig. 9 Principal Strain Color Mapping and Vector Display

■ Conclusion

Endurance tests were conducted on an EV motor outer case using a fatigue testing machine and evaluated by three-dimensional DIC analysis.

The displacements and strains calculated by the DIC analysis were compared with the stroke of the testing machine and the strain gauge results, and it was found that the measurements were in phase. In the DIC analysis, it was found that strain values can be calculated at any specified point, and the value obtained were close to those measured on a strain gauge at the same point.

It is also possible to create a color mapping of the strain values in the principal strain direction and display vectors in the principal strain direction. With this function, it was possible to observe the bending moment applied to the specimen.

Dynamic three-dimensional DIC analysis in the endurance test using the fatigue testing machine enables the analysis of strain distribution as it is. This is expected to contribute to the development of electric vehicles (EVs) in the future.

<Acknowledgments>

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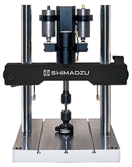

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