Application News

Fatigue/Endurance Testing Machine Servo Pulser™
Axial Torsion Testing Machine EHF-EV/TV

Evaluation of EV Motor Shaft Produced by Radial Forging —Torsional Fatigue Test of Hollow Shaft—

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User Benefits

- By using the combined axial force and torsion tester, the axial and torsional loads can be applied simultaneously to the test specimen.
- Static torsion tests can be performed on hollow shafts.
- Torsional fatigue tests can be performed on hollow shafts.

■ Introduction

In recent years, the trend toward decarbonization has accelerated to reduce greenhouse gas emissions. The shift to electric vehicles (EVs) in the automotive industry plays a major role in realizing a low-carbon society. In order to promote the use of EVs, there is a need to improve the range of the vehicle, so a development theme is to reduce the weight of the vehicle body. In particular, reduction of shaft weight is an important development theme because it is expected to improve not only the driving range but also the responsiveness of the motor by reducing the inertia force. Radial forging is a new forging technology for hollow shafts. While applying force from the radial direction of a hollow shaft or shaft with a hammer (mold), the inner and outer diameters can be formed simultaneously by inserting a core metal and transferring the inner diameter shape[1]. Hollow shafts manufactured by the radial forging method are attracting attention as a manufacturing method for next-generation shafts because they can achieve both strength and weight reduction. Since hollow shafts are used for motor shafts and cranks, they are often subjected to torsional loads. In addition to simple tension and compression, evaluation using torsional fatigue tests are also important.

In the previous report[2)-4)], in order to evaluate the change in mechanical properties during radial forging, specimens were cut from actual products and a multi-faceted evaluation was conducted. As a result, it became clear that the product exhibits excellent characteristics in the radial forging processed area. In this study, torsional fatigue tests were conducted on three types of real products (hollow shaft shapes), radial forging, forging, and blank, and their fatigue characteristics were evaluated.

■ Specimen Information

Fig. 1 shows a photograph of a specimen. Specimens are splined. Hollow processing was applied from the tip to the center of the spline. There were three types of specimen: radial forging (RF), forging (F), and blank (N). Table 1 shows the specimen information.

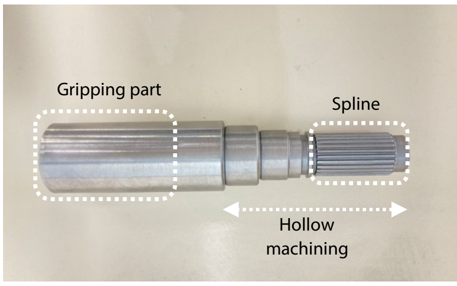

Fig. 1 Photograph of a Specimen

Table 1 Specimen Information

Shape of the Specimen:	Real product (hollow shaft: see Fig. 1)
Type of Specimen:	Radial forging (RF) Forging (F) Blank (N)

■ Testing Equipment

The torsion test was carried out using an EHF-EV/TV Axial Torsion Testing Machine. Table 2 and Fig. 2 show the configuration of the equipment and the test results. The round bar shaped part of the specimen (Fig. 1, left side) was directly gripped by a hydraulic collet grip for a round specimen. On the other hand, the spline side was fixed by a spline fitting jig. The spline fitting jig was machined with grooves that matched the uneven shape of the spline part, and can be fixed in the torsional direction by inserting the spline part of the specimen. Fig. 3 shows the spline fitting jig. The machine can control not only the torsion but also the axial force at the same time, and the tests were performed with the axial force direction controlled by position holding.

Table 2 Testing Equipment

Testing Equipment:	Axial Torsion Testing machine EHF-EV100 kN/TV1kNm
Grips:	Hydraulic collet grips for round specimen Spline fitting jig (Made by Tsuzuki Manufacturing Co. Ltd.)
Software:	Windows® Software for 4830

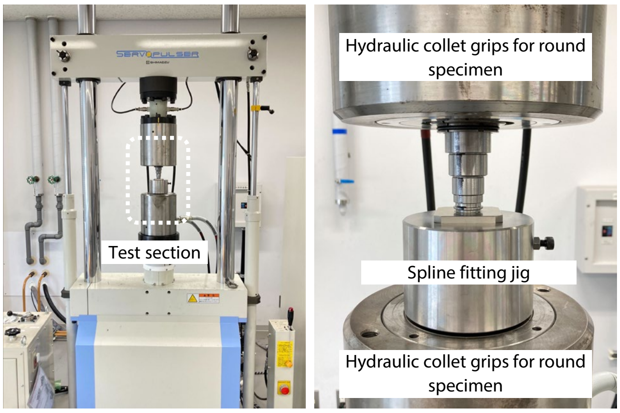

Fig. 2 Test (Left: Entire Test Machine, Right: Test Section)

Fig. 3 Spline Fitting Jig

■ Static Torsion Test

To determine the torque level of the torsional fatigue tests, a static torsional test was conducted first. The test conditions for the static torsion test are shown in Table 3. An example of a torque-angle diagram is shown in Fig. 4. Radial forging (RF) and forging (F) have similar torque-angle diagram trends, but the maximum torque, yield point torque, and so on for blank (N) are smaller than those for radial forging (RF) and forging (F), and the trends are different. Table 4 shows the results of the static torsion tests. Based on these results, torsional fatigue test torque conditions were set to approximately 85 %, 75 %, 65 %, and 55 % for each yield point torque.

Table 3 Static Torsion Test Conditions

Control TD:	Angle control
Test Speed:	10 deg/min
Number of Tests:	n = 2

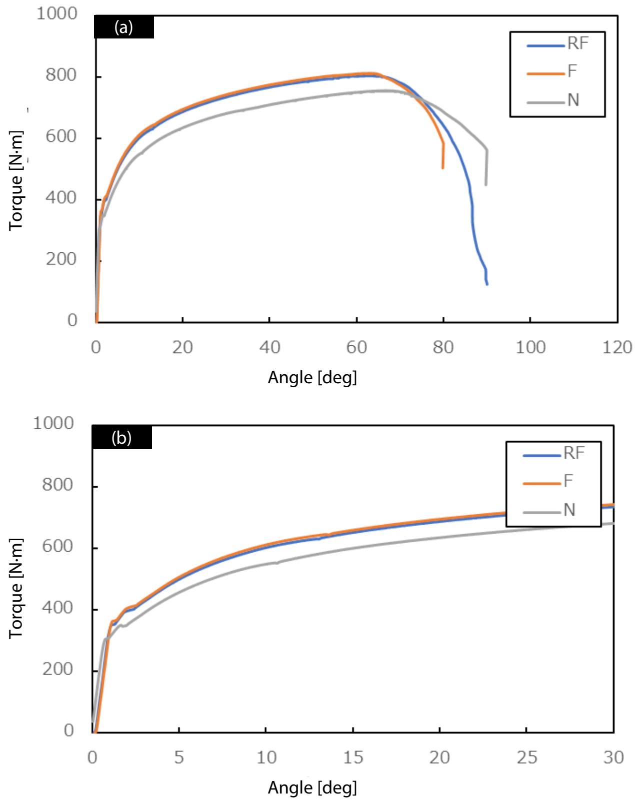

Fig. 4 Example of Torque-Angle Diagram
(a) Overall Tests (b) Initial Test

Table 4 Results of Static Torsion Tests

Specimen Type	Maximum Torque [N·m]	Yield Point [N·m]
RF	802.5	352.5
F	801.5	362.5
N	751.5	310.0

■ Torsional Fatigue Test

Table 5 shows the torsional fatigue test conditions. The maximum load cycle was 1 million, and the test stopped after reaching 1 million even if the load was not broken. Fig. 5 shows the S-N diagram. Radial forging (RF) and forging (F) were unbroken at 1 million times at 200 N · m. Fig. 5 shows that the fatigue strength of the forging (F) and blank (N) are almost equal. The fatigue strength of radial forging (RF) with a torque of 270 N · m or more is superior to that of forgings (F) and blank (N), but the fatigue strength of 230 N·m or less is almost equivalent on the S-N diagram.

Table 5 Torsional Fatigue Test Conditions

Control TD:	Torque control
Test Frequency [Hz]:	8
Maximum Load Torque [N·m]:	300, 270, 230, 200 (RF, F) 290, 265, 230, 200 (N)
Number of Tests:	n = 2 (n = 1 for maximum load torque of 200 N·m)
Stress Ratio:	-1
Maximum No. of Cycles:	1,000,000 cycles

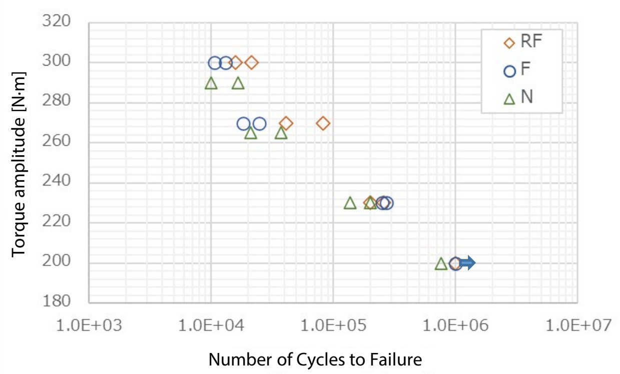

Fig. 5 S-N Diagram

■ Conclusion

Static torsion and torsional fatigue tests on shafts subjected to radial forging and forging and on blanks were carried out using a combined axial force torsion tester. It was found that the maximum torque and yield torque were improved in radial forging and forging products compared with blanks, and the torsional fatigue test results revealed that the durability of the radial forging was equal to or greater than that of the forging.

<References>

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