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Application News

Fatigue/Endurance Testing Machine Servopulser™

Endurance Testing of Bus Bar for Electric Vehicles

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User Benefits

- It is possible to perform endurance testing of bus bars against cyclic loads in practical loading directions.
- The high frequency response of the EMT series enables rapid test results at high test frequencies.
- By observing the fracture surface, it is possible to determine from which direction the load was applied.

■ Introduction

Bus bars are rod-shaped or plate-shaped conductors used to connect and distribute power in distribution panels and control panels. They are very useful as power electronics components because they can conduct large currents. They can conduct large currents because they have the following advantages compared with conventional cables.

• Bus bars are made of high-purity materials and have low electrical resistance, so they can conduct large currents compared with cables. Cables are usually alloyed to provide ductility and malleability.

• Since bus bars have a large surface area, they can dissipate heat more efficiently than cables.

Because of these advantages, in recent years bus bars have been widely used not only for distribution boards and control boards, but also for connecting automotive batteries, motors, inverters, etc., due to the introduction of EVs.

When bus bars are installed in automobiles, unlike in distribution boards and control boards, they may be subjected to external loads due to vibration or impact. It is important to evaluate their durability under such conditions. In this article, durability tests were conducted on bus bars in different load directions to evaluate their durability.

■ Specimen Information

In EVs, the motor is driven by alternating current (AC), but the battery outputs direct current (DC). Therefore, an inverter is essential to convert DC to AC. A bus bar is generally used to connect the inverter to the motor because of the large current flow. Fig. 1 shows a schematic diagram of the bus bar used to connect the inverter to the motor. It is expected that the bus bar will be subjected to loads from all directions due to road conditions and vibrations from the motor.

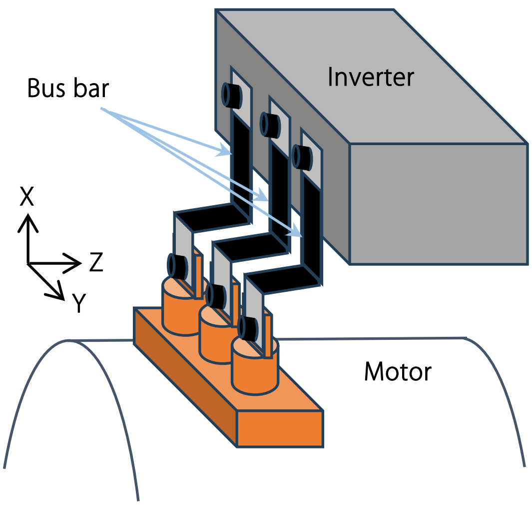

Fig. 1 Schematic Diagram of the Bus Bar Used to Connect the Inverter to the Motor

Bus bars that were envisaged to be connected as shown in Fig. 1 were produced as test specimens. Fig. 2 shows a photograph of a specimen, and Table 1 shows the specimen information. The shape was formed by bending. The material is tough-pitch copper with excellent conductivity. The surface was plated with nickel for rust prevention, and nylon coated for insulation.

A real EV would have an output of 100 to 150 kW and a large current of about 500 A, so a large bus bar would be required. In this case, a relatively small output of several kW such as those used in electric motorcycles was assumed, and the dimensions were set to 9 mm wide and 2 mm thick with a rated current of 50 A.

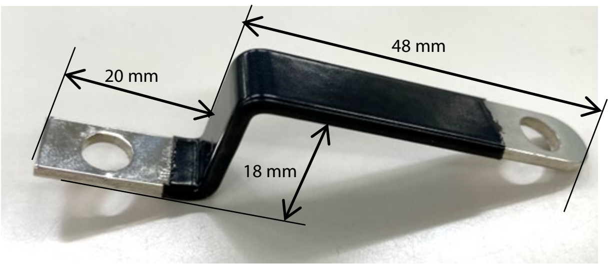

Fig. 2 Photograph of a Specimen

Table 1 Specimen Information

Material:	Tough-pitch copper
Size:	Width 9 mm, thickness 2 mm
Plating:	Nickel plating
Covering:	Nylon coating

■ Testing Equipment

The EMT-1kNV-50 electromagnetic dynamic and fatigue tester was used in these tests. Fig. 3 shows a photograph of the tester. An electromagnetic actuator with extremely high frequency response enables high-precision dynamic testing. In these tests, the maximum test frequency was 50 Hz. The EMT series is ideal for such high-frequency testing.

Specialized jigs were manufactured to apply in-plane and out-of-plane loads to the specimen. The test force transmission section had a trunnion mechanism to accommodate the deflection angle of the specimen.

Fig. 3 Fatigue Testing Machine EMT-1kNV-50

Table 2 Testing Machine Information

Type of Testing Machine:	EMT-1kNV-50
Jig:	Dedicated grip
Loadcell:	1 kN
Software:	Windows Software for 4830

■ Endurance Tests

Durability tests were conducted with two different load directions: an in-plane test in which linear cyclic loading was applied in the Z-axis direction shown in Fig. 1, and an out-of-plane test in which linear cyclic loading was applied in the Y-axis direction. The load reversed between positive and negative with 0 as the average. The control mode was test force, and the test force applied was based on the weight of the inverter. The weight of an inverter of about 5 kW was assumed to be about 3 kg (30 N).

Table 3 shows the in-plane test conditions. In the in-plane test, the fatigue strength was expected to be low due to the load in the thickness direction of the specimen, so the test amplitudes were 10 N, which was 1/3 of the weight of the inverter, and 30 N. The test frequency was started at 10 Hz and gradually changed to 20 Hz after 1 million cycles.

Fig. 4 shows the in-plane test photographs.

Table 3 In-plane Test Conditions

Load Direction:	In-plane (Z-axis)
Waveform:	Sine wave
Control Mode:	Force
Amplitude:	10 N, 30 N
Average:	0 N
Stress Ratio:	-1
Test Frequency:	10 Hz - 20 Hz

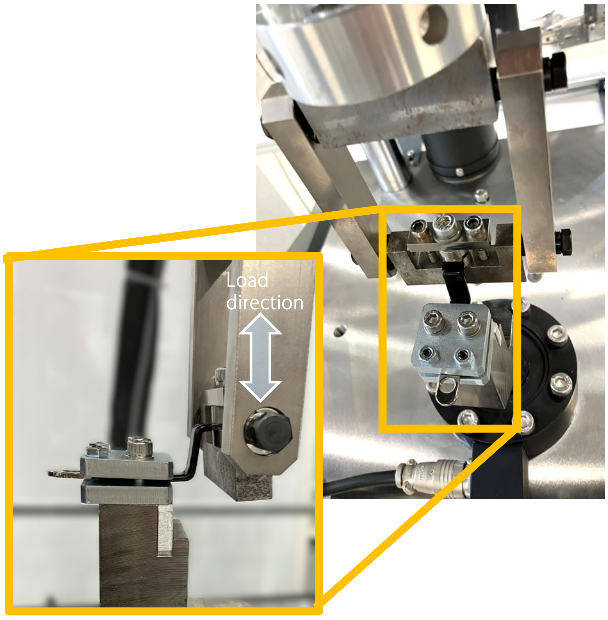

Fig. 4 In-plane Test

Table 4 shows the out-of-plane test conditions. In the out-of-plane test, the fatigue strength is expected to be higher than in the in-plane test because the load is applied in the width direction of the specimen. The test amplitude was 30 N and two times the weight of the inverter, 60 N. The test frequency was started at 20 Hz and gradually changed to 50 Hz after 1 million cycles.

Fig. 5 shows the out-of-plane test photograph.

Table 4 Out-of-plane Test Conditions

Load Direction:	Out-of-plane (Y-axis)
Waveform:	Sine wave
Control Mode:	Test force
Amplitude:	30 N, 60 N
Average:	0 N
Stress Ratio:	-1
Test Frequency:	20 Hz - 50 Hz

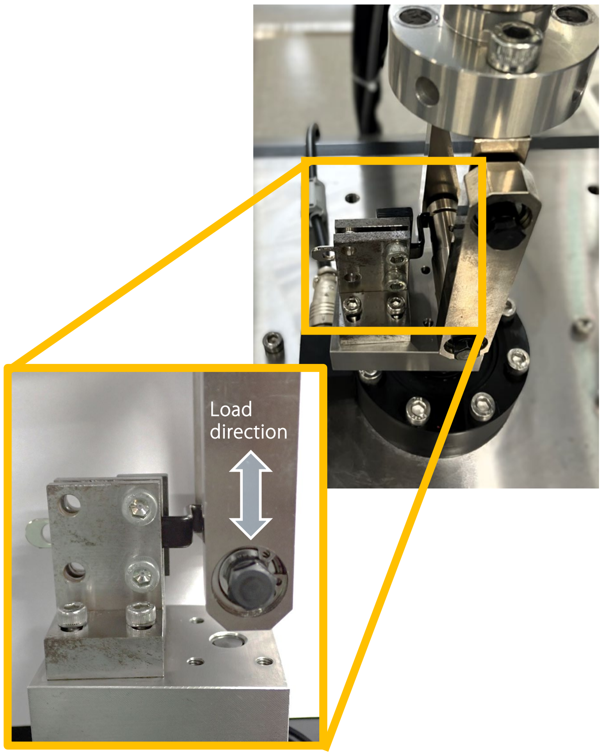

Fig. 5 Out-of-plane Test

■ Test Result

Fig. 6 shows the time waveforms of test force and displacement during 1.1 million cycles under the test conditions of 30 N test amplitude and 20 Hz test frequency. The displacement was measured using the machine stroke. The sine wave is well formed, and it is clear that stable control without disturbance was achieved.

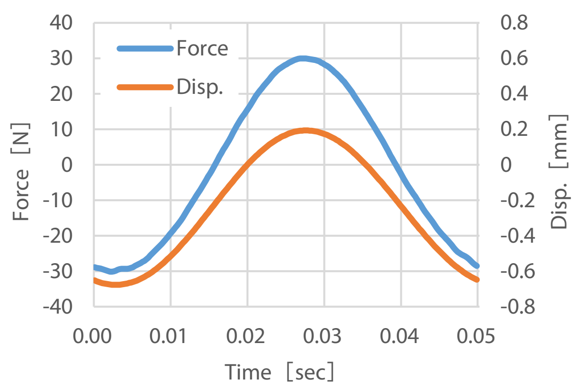

Fig. 6 In-plane 30 N Test Frequency 20 Hz Time Waveform

Fig. 7 shows the test force-displacement diagram for the same in-plane test as Fig. 6 under the test conditions of 30 N test amplitude and 20 Hz test frequency during 1.1 million cycles. It can be seen that there is no disturbance even at the 0 cross point.

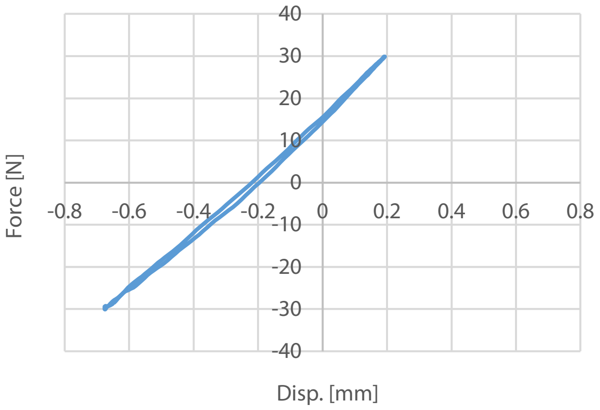

Fig. 7 In-plane 30 N Test Frequency 20 Hz Force-Disp. Diagram

Fig. 8 shows the time waveforms of the test force and displacement during 10 million cycles under the test conditions of 30 N test amplitude and 50 Hz test frequency in the out-of-plane test. Similar to the in-plane test, the sine waves in the out-of-plane test are well formed and stable control without disturbance was achieved.

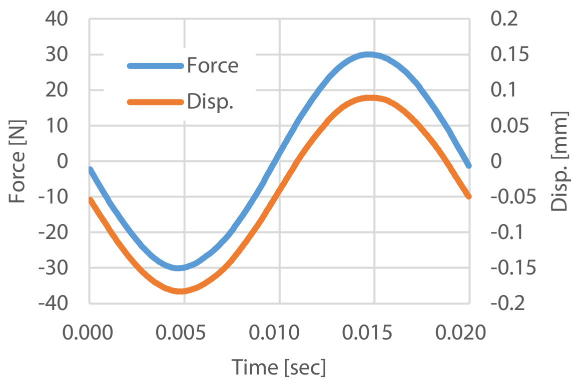

Fig. 8 Out-of-plane 30 N Test Frequency 50 Hz Time Waveform

Fig. 9 shows the test force-displacement diagram for 10 million cycles under the same out-of-plane test conditions as Fig. 8, with a test amplitude of 30 N and a test frequency of 50 Hz. It can be seen that there is no disturbance even at the 0 cross point.

Therefore, the EMT series exhibits excellent response even at a frequency of 50 Hz. If the test is conducted at a high frequency, the test time can be shortened and the test can proceed efficiently.

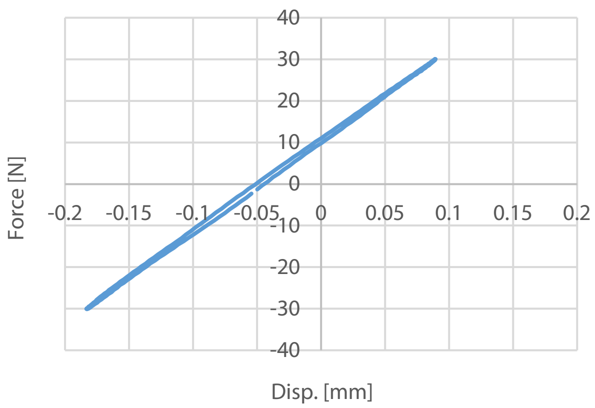

Fig. 9 Out-of-plane 30 N Test Frequency 50 Hz Force-Disp. Diagram

Fig. 10 shows the displacement peak value vs. number of cycles graph. The in-plane test of 10 N and the out-of-plane test of 30 N were stopped because the test specimens did not break at 2.5 million and 10 million cycles, respectively. The transition of the displacement peak value of 10 N in-plane test is almost the same as that of the 30 N out-of-plane test.

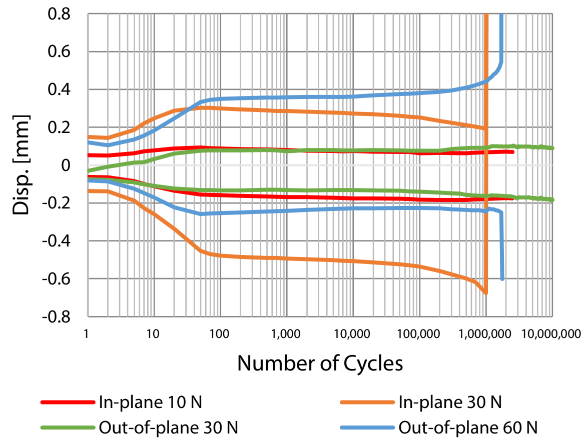

Fig. 10 Disp. Peak Value - Number of Cycles Graph

Fig. 11 shows the test force-rupture cycle diagram. At a test force of 30 N, which is equal to the weight of the inverter, the fracture occurred after about 1.4 million cycles in the in-plane test, but the fracture did not occur even after 10 million cycles in the out-of-plane test. At a test force of 60 N, which is equal to two times the weight of the inverter, the fracture occurred after about 1.7 million cycles in the out-of-plane test, and the fatigue strength was found to be two times that of the in-plane test.

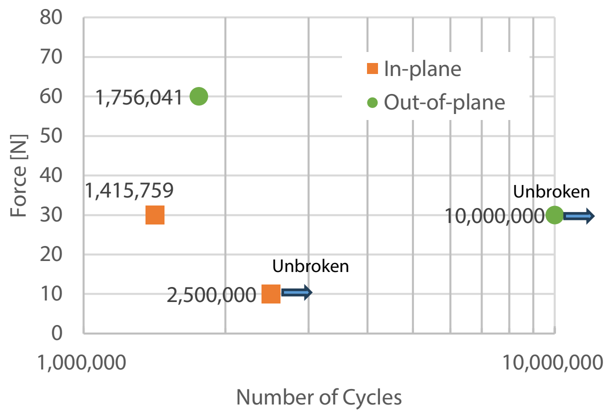

Fig. 11 Breaking Force - Number of Cycle Diagram

■ Comparison of the Fracture Surfaces of the Specimens

Figs. 12 and 13 show photographs of the fracture surfaces of the in-plane 30 N test and the out-of-plane 60 N test specimens, respectively. In both cases, the failure location was at the same bend. In both cases, the failure location was at the same bend. On the fracture surface of the in-plane test, beach marks can be seen where the crack propagated in the in-plane direction. On the other hand, on the fracture surface of the out-of-plane test, beach marks can be seen where the crack propagated as if twisting from both sides.

In the displacement peak value - number of cycles graph shown in Fig. 10, the peak width of the in-plane 30 N graph is constant and the average gradually changes. This is probably because the crack is growing in one direction. On the other hand, the peak width of the out-of-plane 60 N graph gradually widens. This is probably because the crack continues to grow evenly in both directions and ruptured at the center.

Fig. 12 Fracture Surface Photograph of In-plane 30 N Test

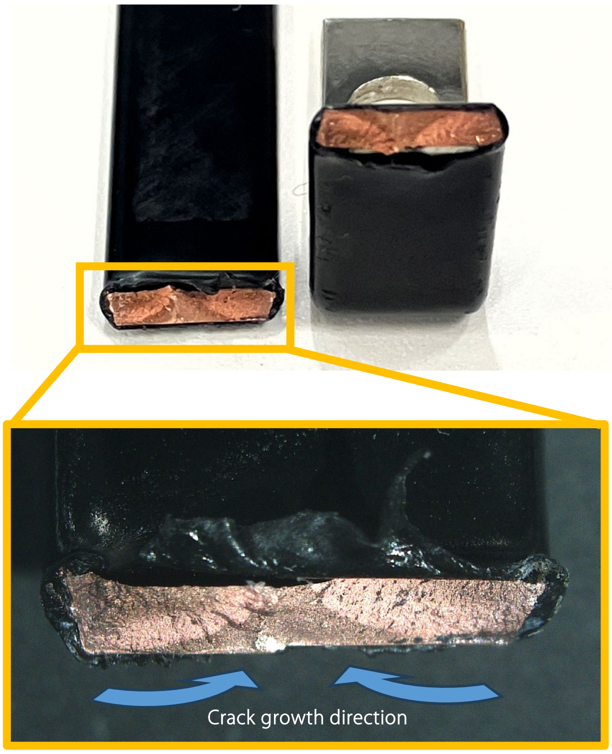

Fig. 13 Fracture Surface Photograph of Out-of-plane 60 N Test

■ Conclusion

A fatigue testing machine was used to test the durability of a small bus bar in two different directions. As a result, the fatigue strength in each direction of loading was clarified. In addition, when the fracture surfaces of the specimens in each direction of loading were observed, the beach marks indicating the direction of crack propagation were confirmed.

Depending on the combination of options, the fatigue testing machine can test the durability of actual specimens. If combined with a constant temperature bath, it is possible to test the bus bar at the same temperature as when Joule heat is generated through the current. By using a testing machine with a larger test capacity, it is possible to test full-scale bus bars of larger EVs.

It is useful for the development and quality control of various parts.

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