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基于超薄型3轴力传感器的电动压缩机传递力测量

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摘要：汽车的电动压缩机在工作时，产生的机械振动通过发动机传递到车身从而产生车内噪声，噪声大小可以根据电动压缩机传递到发动机的传递力及其动力学特性进行推算。通常在电动压缩机与发动机连接处安装力传感器来测量传递力，然而，力传感器会干扰其他部件并使电动压缩机振动模式发生改变，从而在实际情况下可能无法实现传递力的测量。为此，基于石英晶体压电效应开发了新型超薄型3轴力传感器，实现了在接近实际情况下的电动压缩机传递力测量。

关键词：3轴力传感器；电动压缩机；车内噪声；传递力

中图分类号：U461；TB535　　**文献标志码**：A

Transfer Force Measurement of Electric Compressor with Low-Profile 3-Axis Force Sensor

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Abstract: An electric compressor generates a mechanical vibration that is transmitted from the engine to the vehicle body and then the vibration of the vehicle body creates a vehicle interior noise. The noise can be calculated by a transfer force from the electric compressor to the engine and transfer characteristics from the electric compressor to the vehicle cabin. The transfer force can be measured with a force sensor installed between the electric compressor and the engine. However, the force sensor interferes with other components and changes the vibration mode of the electric compressor. Therefore, the conventional force sensor cannot measure the transfer force of the actual phenomenon. In this paper, a new low-profile 3-axis force sensor was developed by use of piezoelectric quartz crystals, which achieved measuring the transfer force in as close to the actual phenomenon as possible.

Key words: 3-axis force sensor; electric compressor; vehicle interior noise; transfer force

In recent years, the market demands of the vehicle quietness are increased, therefore the reduction of the vibration and noise from an electric compressor is required[1-3]. The electric compressor generates a mechanical vibration that is transmitted from the engine to the vehicle body and then the vibration of the vehicle body creates a vehicle interior noise[4]. In general, the noise can be calculated by measuring transfer force by use of a 3-axis force sensor screwed with bolts between the electric compressor and the engine[5].

Then, the influence on vibration mode of the electric compressor is present in this paper by installing a 3-axis force sensor. Test pieces of different thickness are installed between an engine and the electric compressor, and a resonance frequency variation of the electric compressor is measured by shaking it up and down. The experimental system configuration is shown in Fig. 1 and the measurement results are shown in Figs. 2 and 3. As shown in Fig. 2, the resonance frequency variation of the electric compressor increases as the thickness of the force sensor rises, and the vibration mode differs from that of the actual equipment. The change in vibration mode is caused by the increased length between the engine and the electric compressor due to the installation of the force sensor, which increased the overhang of the electric compressor. Therefore, low-profile 3-axis force sensors are required to measure the force under actual situation.

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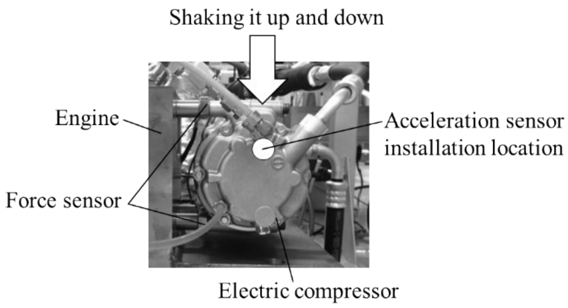


Fig.1 Experimental system configuration with 3-axis load sensor

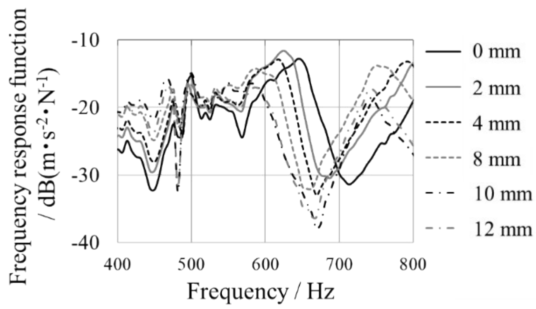


Fig.2 Resonance frequency between test pieces of different thickness

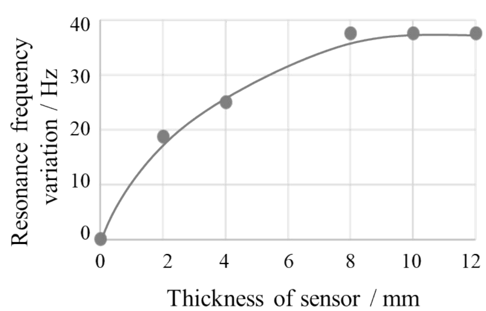


Fig.3 Resonance frequency variation

1 3-axis force sensor

1.1 Configuration of 3-axis force sensor

The low-profile 3-axis force sensor developed in this paper is shown in Fig. 4. The inner diameter of the force sensor is ϕ 12.6 mm, the outer diameter is ϕ 20.0 mm, and the thickness is 1.95 mm. The principle is piezoelectric effect with quartz crystals[6]. The crystal has an electrical axis, a machine axis, and an optical axis. An electrical charge is generated when a force is applied in the direction of the electrical axis. The piezoelectric quartz crystals to measure the force in the compression direction are cut out from the crystal to align the compression direction with the electrical axis while the piezoelectric quartz crystals to measure the force in the shearing direction are cut out from the crystal to align the shearing direction with the electrical axis. That is why the force sensor can measure the force in 3-axis direction.

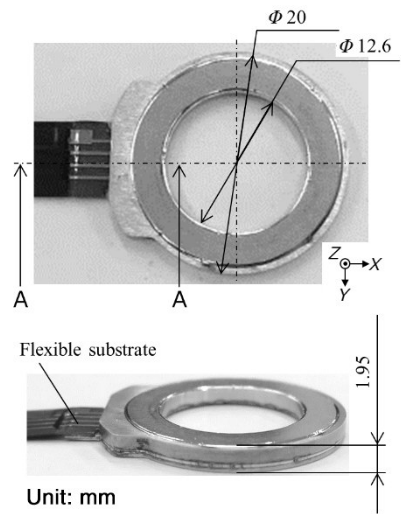


Fig. 4 3-axis force sensor

The internal structure of the 3-axis force sensor is shown in Fig. 5. The sensor laminates six pieces of piezoelectric quartz crystals which output the electric charge in the 3-axis direction and seven electrodes.

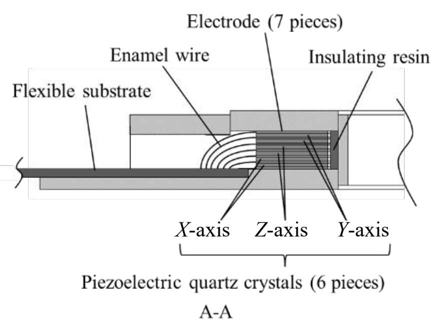
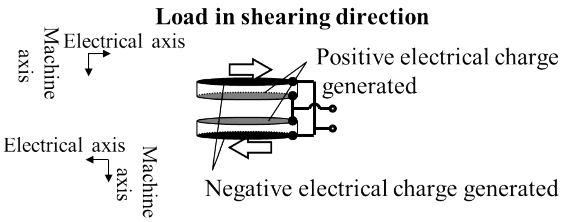


Fig. 5 Internal structure of 3-axis force sensor

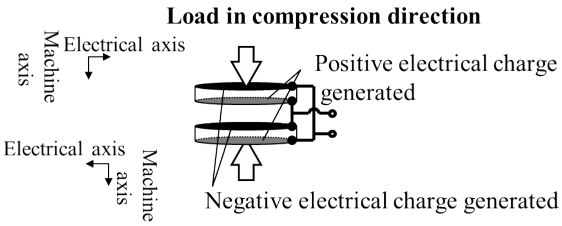
1.2 Piezoelectric quartz crystal

The principle of the piezoelectric quartz crystal to measure the force in the shearing direction is shown in Fig. 6 and the principle to measure the force in the compression direction is shown in Fig. 7.

The electrical axes of two crystals are aligned with the shearing direction, one crystal is placed in the opposite direction to another one, and machine axes of the crystals are aligned in the same direction as shown in Fig. 6. The electrical charge output is amplified twice on the load in the shearing direction; on the other hand, the electrical charge is canceled out on the load in the compression direction.



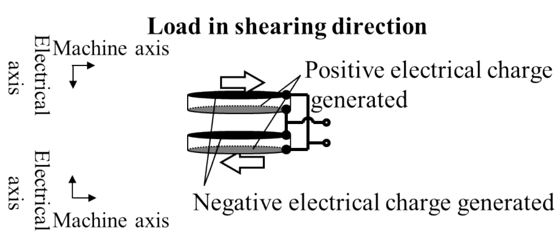
a The electrical charge output is amplified twice



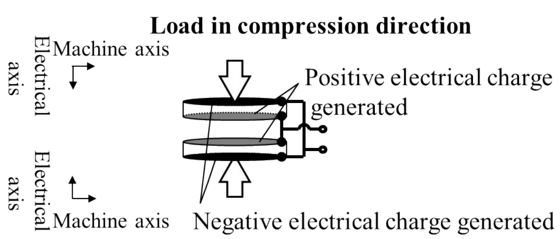
b The electrical charge is canceled out

Fig.6 Principle to measure shearing load

The electrical axes of two crystals are aligned with the compression direction, one crystal is placed in the opposite direction to another one, and machine axes of the crystals are aligned in the same direction as shown in Fig. 7. According to this configuration, the electrical charge output is amplified twice on the load in the compression direction; on the other hand, the electrical charge is canceled out on the load in the shearing direction.



a The electrical charge is canceled out



b The electrical charge output is amplified twice

Fig.7 Principle to measure compression load

1.3 Force division structure

The 16 kN load in the axis direction generates in the 3-axis force sensor at screwing bolt. In case that the piezoelectric quartz crystal incurs all load, it will be destroyed. The 3-axis force sensor developed divides the load into the crystal and the housing, whose safety factor ensures 2.3. The load distribution image is shown in Fig. 8.

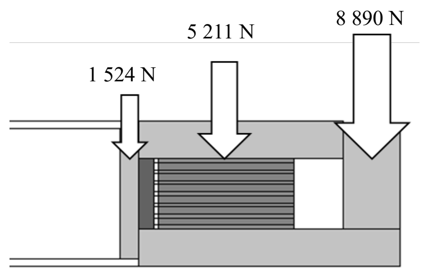


Fig.8 Load distribution image

1.4 3-axis force sensor accuracy

The calibration method of the 3-axis force sensor in the shearing direction is shown in Fig. 9, and the calibration method of the sensor in the compression direction is shown in Fig. 10. The sensor is installed on a surface plate and then a block where the load is applied is screwed together as shown in Fig. 9. The sensor in the shearing direction is calibrated by measuring electrical charge output when the load in the shearing direction, which applies to the block, is changed.

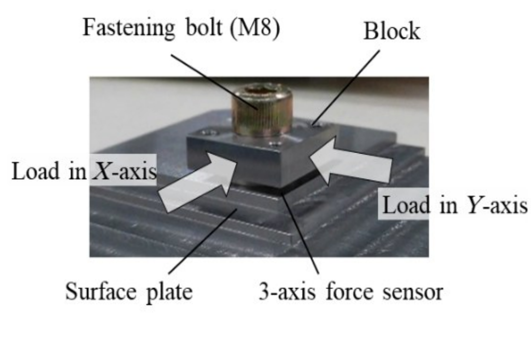


Fig. 9 Calibration for shearing direction

The calibration method for compression direction as shown in Fig. 10 is to add another block on the block shown in Fig. 9. The sensor in the compression direction is calibrated by measuring electrical charge output when the load in the compression direction, which applies to the block, is changed.

The calibration results are shown in Fig. 11. The electrical charge output bears a proportionate relationship to the load in each direction.

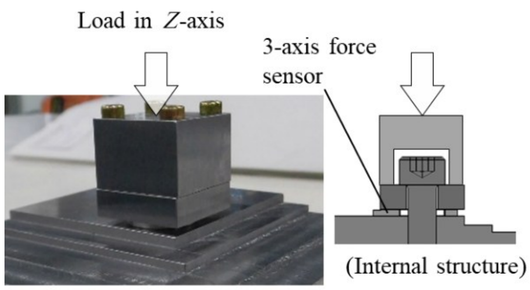


Fig.10 Calibration for compression direction

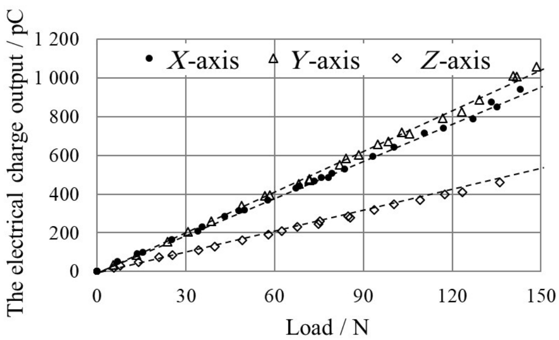


Fig.11 Calibration Results of 3-axis Force Sensor

2 Load of electric compressor

2.1 Measurement system configuration

The electric compressor is mounted on three places of stay that simulates the engine, and the load generates on the fastening places is measured when the electric compressor is operating. The 3-axis force sensor is installed between the electric compressor and stay and screwed together. The system configuration is shown in Fig. 12 and the picture of the sensor is shown in Fig. 13.

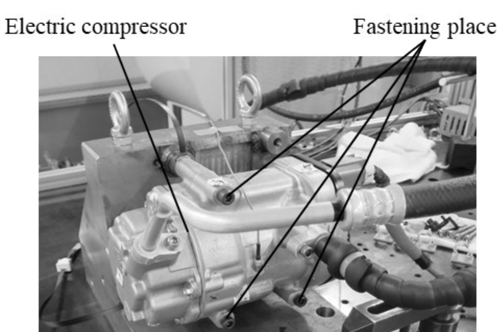


Fig.12 System configuration of load measurement

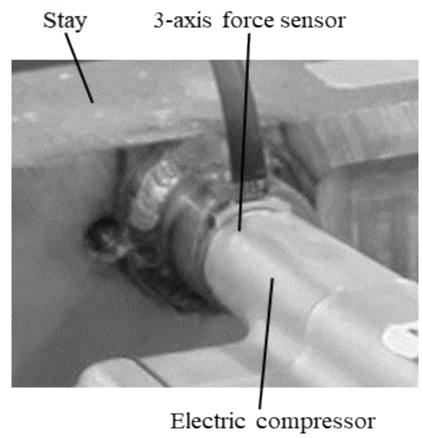


Fig.13 Picture of 3-axis force sensor

2.2 Test result

The measurement load in the axis direction when the electric compressor is operating is shown in the Fig. 14. The first-order load component of the electric compressor is measured not to be buried in the electromagnetic noise. Therefore, our developed low-profile 3-axis force sensor can be utilized to load measurement in a state close to the actual phenomenon.

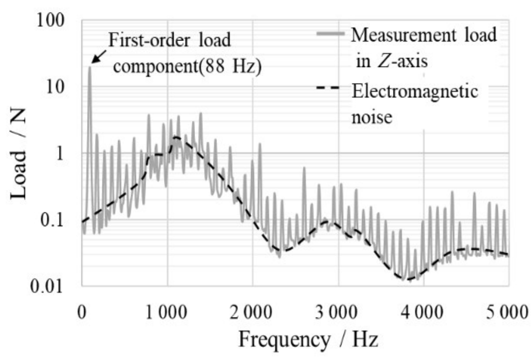


Fig.14 Load Test Result of electric compressor

3 Conclusions

A low-profile 3-axis force sensor was developed. The machine axes of the two piezoelectric quartz crystals were installed in parallel and the electrical axes were installed in opposite. Thus, the electrical charge output was amplified twice on the load of the measuring axis and canceled on the other axes. The load was divided with the piezoelectric quartz crystals and housing, then the safety rate of the crystals was ensured. The first-order load component of the electric compressor was measured not to be buried in the electromagnetic noise. An experiment was conducted to confirm that the developed sensor could measure the load transferred from the electric compressor to the engine in a state close to the actual phenomenon.

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