Design and Basic Technology for Watertight, Dust-Resistant Brushless Motors

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Oriental Motor has expanded the product lineup of the **BMU** and **BLE2** brushless motor series to now include dust and water resistant specifications. Compared to the conventional brushless motors in the **BMU** and **BLE2** Series, the joints of exposed components are reduced and an O-ring is used for the seal. Adopting high corrosion-resistant coating and shapes that water easily flows across, this product can be adopted for any food machinery required to use under a hygienic condition. In addition, we have established our own evaluation standard taking aging degradation into consideration to ensure that water resistant performance is maintained. Oriental Motor has sold the watertight and dust-resistant induction motors **FPW** Series, and projects the requirements for dust and water resistant performances are also increasing in brushless motors because they are compact and offer high output power compared to induction motors. This new brushless motor is expected to play an active role in the market.

1. Introduction

Automation in factories is growing due to a decrease in the labor force population and other factors, and motors are increasingly used in applications exposed to dust and water. Induction motors are widely used in food machinery. Recently, motors that are compact and offer high output power in addition to improvement of speed controllability are desired. Food machinery may require regular cleaning from a viewpoint of hygienic control, but motors that can be used in an environment where water is splashed are currently limited.

Oriental Motor has developed the **BMU** and **BLE2** Series watertight, dust-resistant brushless motors (hereinafter referred to as "IP66/IP67 brushless motor") that can be washed with water. Motors of output power 200 W, 300 W, and 400 W are available.

Adopting the IP66/IP67 brushless motor can improve speed controllability while achieving compact size and high output power, allowing for the design and manufacturing of equipment at a higher level.

This article introduces the design and basic technology of the IP66/IP67 brushless motor.

2. Features of Watertight, Dust-Resistant Brushless Motor

2.1 High Dust and Water Resistant Performances

The IP66/IP67 brushless motor is a product of structural design with high sealing property, and conforms to the IEC 60034-5 IP66 and IP67 degrees of protection. In addition, Oriental Motor has established unique test conditions for water resistant performance considering aging degradation, and also has conducted tests. Details are described in the chapter 3.

2.2 Compact Size and High Output Power

Brushless motors achieves downsizing (shorter in length) relative to induction motors by using permanent magnets with maximum energy product. The motor length of the maximum output power 90 W for the **FPW** Series is 222 mm, while the motor length of 143 mm has been achieved for the IP66/IP67 brushless motor of 400 W (see Figure 1. and Figure 2.).

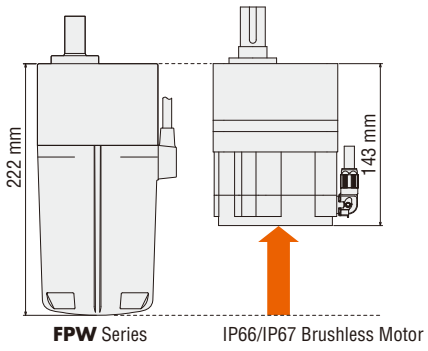


Figure 1. Overall Length Comparison with **FPW** Series (Gear ratio 5)

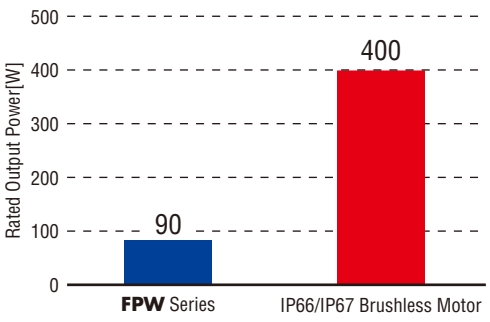


Figure 2. Rated Output Power Comparison

2.3. Low Heat Generation

Brushless motors have higher energy conversion efficiency than induction motors. This enables the brushless motor to be designed with low heat generation. The motor case temperature of the **FPW** Series of 90 W rises by 52 °C during operation. In the case of the IP66/IP67 brushless motor of 400 W, although the output power is more than four times, the motor case temperature rise is 31 °C, which is reduced by 21 °C (see Figure 3.). Brushless motors are suitable for applications such as food machinery where temperature rise of a load is desired to be suppressed.

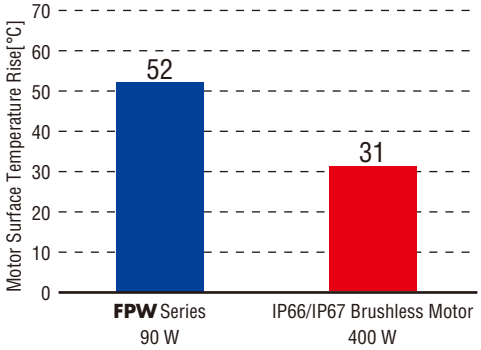


Figure 3. Motor Case Temperature Rise Comparison with **FPW** Series

3. Design for Dust and Water Resistant Specifications

3.1 Motor Structure

Conventional motors of the **BMU** and **BLE2** Series (hereinafter referred to as "conventional model") have a structure in which a stator is exposed(1), but the IP66/IP67 brushless motor adopts a structure in which a stator is covered with a case to achieve higher dust and water resistant performances (see Figure 4. and Figure 5.).

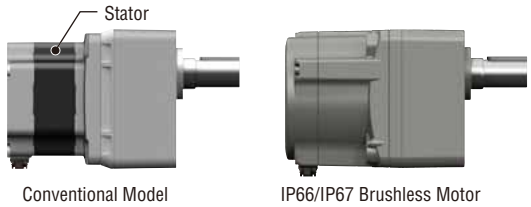


Figure 4. Appearance Comparison with Conventional Model

Figure 5. Structure of IP66/IP67 Brushless Motor

As shown in Figure 6., the conventional model needed to seal three places in the motor. The IP66/IP67 brushless motor has been redesigned to have a structure that seals only one place, ensuring higher dust and water resistant performances.

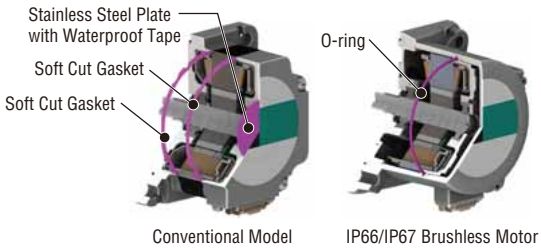


Figure 6. Structures Comparison with Conventional Model

3.2. O-ring

The conventional model uses soft cut gaskets for seal, but the IP66/IP67 brushless motor uses an O-ring. The O-ring, which obtains water resistant performance by deformation, has a proportional relationship to water pressure at which the repulsive force when pressed can be sealed. In addition, the repulsive force increases when water pressure is applied (self-sealing). This achieves higher water resistant performance than the soft cut gaskets (see Figure 7.).

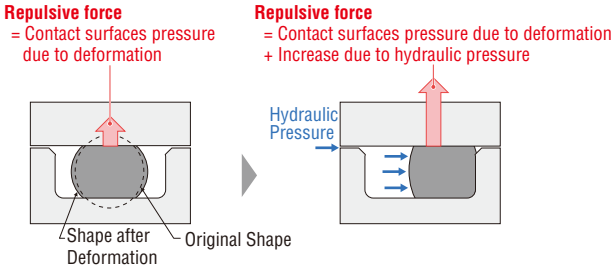


Figure 7. Principle of Self-Sealing

3.3. Waterproof Connector

The waterproof connector which degree of protection conforms to IP66 and IP67 is used for the IP66/IP67 brushless motor in the same way as the conventional model. This connector is jointly developed with Hirose Electric Co., Ltd. and allows easy connection using a locking structure with lever. It is a waterproof connector compatible with a composite cable of motor power line and signal line (see Figure 8.).

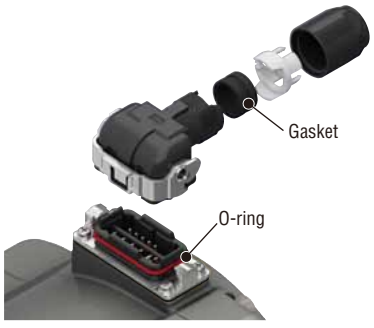


Figure 8. Structure of Waterproof Connector

Cables are available in 0.5 m to 20 m lengths*1 and can be connected to the driver directly without extension connections. It is not necessary to connect the lead wires with a terminal box and provide waterproof treatment (see Figure 9.). The cable outlet direction can also be selected from the following three directions (see Figure 10.).

Figure 9. Wiring of Cable with Waterproof Connector

Figure 10. Cable Outlet Direction

3.4. Degree of Protection

Dust and water resistant performances are indicated using the IP code based on the degree of protection. The IP codes are specified by IEC 60529 and indicated as follows. IEC 60034-5 that specifies dedicated test conditions is applied to motors.

[Example of IP Code]

IP67
- 7: Second characteristic numeral: Degree of protection against harmful ingress of water
- 6: First characteristic numeral: Degree of protection against ingress of solid foreign objects and access to hazardous parts

If one of the numerals for degree of protection is not specified, the digit is indicated by X as shown in IP6X and IPX7.

The degree of protection against water is tested by local water jet for IPX1 to IPX6. For IPX7, a test for immersion in water is performed at a depth of 1 m. Test conditions*2 for IPX6 and IPX7 are different. Therefore, both tests have been conducted and passed.

3.5. "Water-Washing Resistant Test" Considering Aging Degradation

The previously mentioned tests for the degree of protection based on IEC 60529 and IEC 60034-5 do not take into account aging degradation due to long-term use. There is a concern that the seal will deteriorate while the motor is used and the initial water resistant performance will not be able to be maintained. Therefore, Oriental Motor has established a unique evaluation standard called "water-washing resistant test" that aging degradation is taken into account. The IP66/IP67 brushless motor satisfies this evaluation standard. We have confirmed that the **FPW** Series also satisfies the evaluation standard.

The test flow is as follows.

1) Test for Rapid Change of Temperature
Set Temperature: Low temperature −24 °C, high temperature 100 °C
Leaving Time: Low temperature 85 minutes, high temperature 75 minutes
Number of Cycles: 110 cycles
(IEC 60068-2-14 Conditions are for IP66/IP67 brushless motor)

▼

2) Vibration Test
Frequency Range: 10 to 150 Hz
10 to 60 Hz: Double amplitudes 0.7 mm
60 to 150 Hz: Acceleration 50 m/s²
Axes of Vibration: 3 axes (X, Y, Z)
Number of Sweep Cycles: 20 times in each direction
(IEC 60068-2-6 Annex C)

▼

3) Water Jet Test
Water jet of water pressure 100 kPa and flow 100 L/min (see Figure 11.)

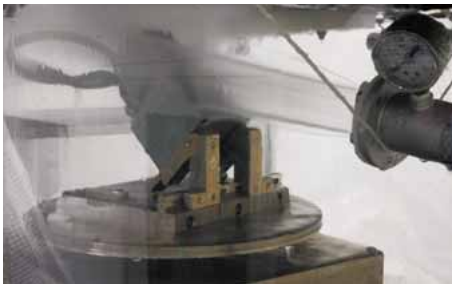


Figure 11. Water Jet Test

▼

4) Judgment
No water intrusion into the motor.

First, thermal degradation equivalent to five years is applied to the seal by 1) test for rapid change of temperature. The concept of accelerated degradation by the test for rapid change of temperature is as follows.

$$\frac{L_2}{L_1}=\left(\frac{\Delta T_2}{\Delta T_1}\right)^{-4} \quad \cdots\cdots (1)$$

L_1 : Expected number of cycles
L_2 : Number of test cycles
ΔT_1 : Temperature difference of operating conditions [°C]
ΔT_2 : Temperature difference of test conditions [°C]

In equation (1), the expected number of cycles L_1 is the number of temperature changes, and the daily temperature change is counted as one cycle. Therefore, the expected number of cycles for the assumed five years is 1825. The temperature difference of operating conditions ΔT_1 represents the difference between the motor case temperature when used under the upper limit of the operating ambient temperature and that when used at the lower limit of the operating ambient temperature. The temperature difference

*1 When combined with a driver of the **BLE2** Series. Up to 10 m when combined with a driver of the **BMU** Series.
*2 IPX6 Water projected in powerful jets from any direction shall have no harmful effects.
IPX7 Ingress of water in harmful quantity shall not be possible when immersed in water under defined conditions of pressure and time.

of test conditions ΔT_2 is determined according to the range in which the usable temperature of the O-ring is not exceeded. The number of test cycles L_2 is determined by these conditions.

In addition, considering that the seal is displaced due to vibration, vibration is applied with 2) vibration test.

The IP66/IP67 brushless motor is assumed that it is washed with water pressure of 100 kPa (approximately to pinch the end of the hose connected to the faucet), and this is applied to 3) water jet test.

4. Design Considering Corrosion Resistance

4.1 Coating

In an environment exposed to water, it is assumed that the components of the motor will be corroded. Scratches on the coating will expose the substrate of aluminum and cause corrosion starting from there. If the corrosion progresses continues, the coating may peel off, which may affect the equipment.

Therefore, two types of coatings having different functions are applied to the IP66/IP67 brushless motor to improve the corrosion resistance (see Figure 12.).

The first layer of coating is made of acrylic resin coating, which forms the coating film while dipping in the paint. This coats the inside of the through holes to suppress the exposure of the substrate of aluminum. This coating also has excellent adhesion to the substrate of aluminum.

The second layer of coating is made of polyester coating, which is generally used outdoors. This coating is resistant to scratches since it forms a thick coating film of about 200 μm.

In addition, using a double-layer coating is effective against pinholes (fine holes) since even if the pinholes are generated in the first layer, the second layer can block them.

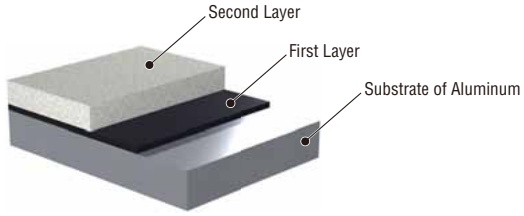


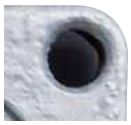
Figure 12. Double-Layer Coating

In order to verify the corrosion resistance of this coating, a salt spray test was conducted under the following conditions (ISO 9227).

Saltwater Concentration: 50±5 g/L
Spray Pressure: 98±10 kPa
Temperature in Facility: 35±2 °C

This test uses 5 % saltwater, compared to a typical sodium chloride concentration of about 3.4 % in seawater. Assuming that the coating has been scratched, the evaluation samples having scratches as to reach the substrate of aluminum were provided. Table 1 shows pictures after 200 hours have passed since the test was conducted.

Table 1. Coating Surfaces after 200 Hours of Salt Spray Test

	Entire Picture	Enlarged Picture
Single-Layer Coating		
		
Double-Layer Coating Adopted for IP66/IP67 Brushless Motor		
		

As shown in Table 1, the blistering of coating has spread over the entire surface from the scratched area on the single-layer coating, but it has hardly occurred on the double-layer coating.

The blistering of coating has also occurred on the single-layer coating even from the place where scratches are not provided, but it has not occurred on the double-layer coating.

4.2. Galvanic Corrosion (Bimetallic Corrosion)

Many people have experienced an experiment in which two different metals are placed in electrolyte and a miniature bulb is lit when it is connected to the metals.

This is the principle of the battery. As shown in Figure 13., a metal (zinc) with a large ionization tendency becomes the negative electrode, while a metal (copper) with a small one becomes the positive electrode, and electrons flow from the metal with a large ionization tendency, causing the miniature bulb to light. At this time, the zinc atom, which has lost its electrons, ionizes and elutes into the electrolyte. Corrosion of metal generated based on this principle is called galvanic corrosion.

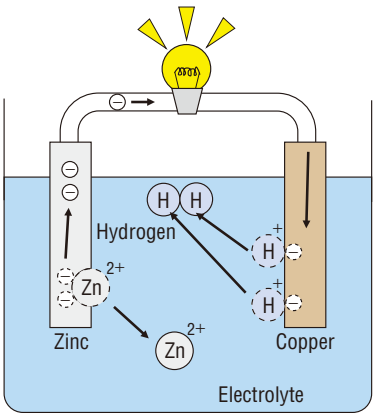


Figure 13. Principle of Battery (Voltaic Cell)

There is a concern that this phenomenon may also occur when a motor is installed in equipment. It occurs if two types of metals with different ionization tendencies adhere electrolyte that conducts electricity.

As an example, suppose that a motor made of aluminum is installed to equipment having frames made of stainless steel and the equipment is washed with water (see Figure 14.). Then, the stainless steel acts as a small ionization tendency, the aluminum acts as a large ionization tendency, and the water used in washing acts as electrolyte. This causes the aluminum that has a large ionization tendency to corrode.

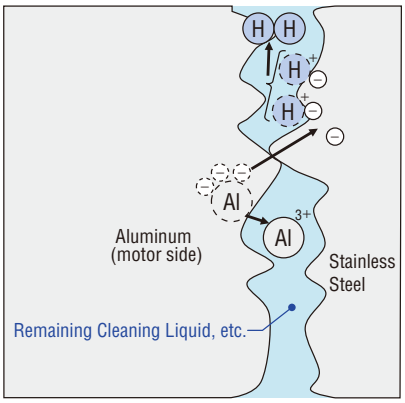


Figure 14. Contact of Motor Mounting Surface and Stainless Steel Frame

The mounting surface of the IP66/IP67 brushless motor is also coated so that galvanic corrosion does not occur (see Figure 15.). Insulating between metals by coating suppresses occurrence of corrosion.

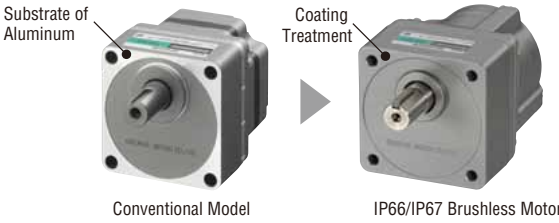


Figure 15. Mounting Surface Comparison with Conventional Model

4.3. Use of Parts Made of Stainless Steel

Screws and the shaft are made of stainless steel (see Figure 16.). Stainless steel screws are applied with adhesive to prevent fluid from entering the areas in contact with aluminum, making galvanic corrosion less likely to occur.

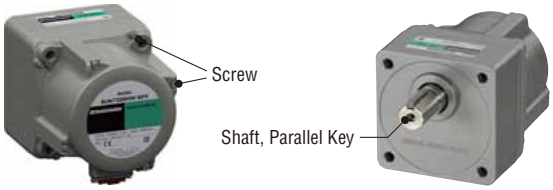


Figure 16. Parts Made of Stainless Steel

5. Motor Shape

Assuming that the IP66/IP67 brushless motor is used in an environment exposed to water, it is designed to have inclined shapes so that the water can flow easily even if installed in any direction shown in Figure 17.

Figure 17. Shape with Many Inclinations

We also received feedback stating that it is undesirable for dirt to accumulate in the holes of hexagonal socket head screws to maintain hygiene in food machinery. In order to satisfy these customers, we have designed the product so that commonly used hexagon head bolts*3 can be used for the mounting screws that are the largest size for this product (see Figure 18.).

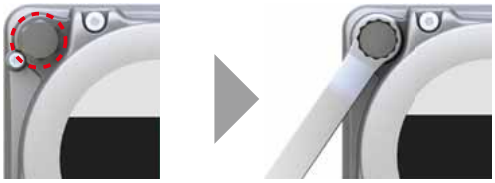


Figure 18. Shape Possible to Use Hexagon Head Bolts

6. Summary

Following the recent expansion of environments where motors are used, we have developed watertight and dust-resistant brushless motors. A new structure was introduced to improve dust and water resistant performances, and a unique "water-washing resistant test" considering aging degradation of the product was established to be applied to this product. In addition, the coating and the shape in consideration of hygiene is adopted.

This design concept was recognized and the Good Design Award could be given. We plan to expand the product lineup such as addition of models of other output powers and frame sizes, and those with an electromagnetic brake.

Oriental Motor will continue to develop products and provide customer services to meet changing customers' needs in the future as well.

*3 Hexagon head bolts are required separately due to not including with the product.

References

(1)Shinya Kuwata and Ayuka Hori: "Features of Brushless Motor NexBL **BMU** Series" RENGA, No. 179, (2014), pp.4-6

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AC/BL Motor Development Dept.