Motorized Linear Module for Tracking System of Solar Light / Solar Heat Power Generation

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NTN is engaged on product development in the renewable energy sector. This article introduces motorized linear modules, which possess the features of low cost, high performance, and easy maintenance for solar tracking systems.

1. Introduction

Expectation for renewable energy is increasing, daily, due to growing interest in the reduction of greenhouse gases and the review of electrical power supply. Particularly, solar energy utilization, such as photovoltaic and solar thermal power generation, has attracted attention. However, the reduction of overall cost, including simplified associated equipment, easy maintenance, and reduced running cost, is required, since the investment in facilities reflects the power generation cost.

NTN has developed several motorized cylindrical linear modules with high environmental resistance, thrust power, and resolution.

In this paper, the structure and specifications of these modules are introduced.

2. Solar tracking system for solar thermal power generation

As a measure to efficiently utilize solar energy, a mechanism is implemented to ensure that an irradiated surface, such as the mirror in Fig. 1, faces the sun at all times (heliostat). The mechanism consists of a reflective mirror, a linear motion actuator for tracking the solar angle of elevation, and a rotating driver for tracking the horizontal angle.

The sunlight reflected by the heliostat is collected by the solar collector at the central tower, as shown in Fig. 2. The medium inside the heat collector is heated to 500 – 1000°C by the collection of light and used as the heat source for steam-power generation.

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So far, pneumatic and hydraulic cylinders are used for actuators to control the angle of elevation for tracking the height of the sun, because their structures are simple and suited for mass production. However, since they require ancillary equipment, air and oil may leak from inside the cylinder or hose. Therefore, the use of motors is attracting attention.

3. Structure and characteristics of the motorized linear module

Fig. 3 and Fig. 4 show the structure and outer view of the motorized linear module for tracking solar light, respectively.

3.1 Feed screw

To emphasize maximum thrust, long-lasting reliability, and position reproducibility for both forward and backward directions (accuracy of repeatability), ball screws were adopted.

3.2 Linear motion guide

As shown in Fig. 5, a trunnion structure was adopted with bearings installed at the tips of 4 shafts which extended radially from the outer surface of the nuts for the ball screws. The trunnion bearings are in contact with 4 raceway surfaces inside the housing of the body to obtain a smooth linear guide, as well as to receive uneven load applied to the slide shaft tips in the vertical and horizontal directions.

3.3 Motor, reducer

A 2-phase stepping motor and worm gear reducer were adopted.

3.4 Installation to the body

Rod ends were installed at both ends of the fixed side (motor side) and floating side (slide shaft side) so that the mirror is freely movable within a certain range.

3.5 Other structure

A dust control seal is provided at the inlet/outlet of the slide shaft to prevent dust and foreign objects from entering. In addition, a stainless steel cover is installed for the motor. The sensor areas and wiring are also protected by ultraviolet-resistant and heat-resistant tubes. Finally, a weather-resistant mold agent is used at the connection of exterior components to provide a dustproof and drip-proof property.
4. Application of motorized linear module for tracking solar light

4.1 Operating conditions

Table 1 shows the operating condition of the motorized linear module. This condition assumes operation in severe environments, such as a desert. Reliability was emphasized for developing this product.

Usually, the reflective mirror changes the direction gradually so that it is precisely synchronized to the orbit of the sun; however, with strong wind, the reflective mirror withdraws at the maximum speed to the horizontal position for protection from danger. The load applied to the tip of the module is considered in this operation.

4.2 Product specification and measurement results

Table 2 shows the measurement results of the motorized linear module product (n = 2). This confirmed that the results sufficiently satisfy the overall specifications.

Table 1  Service condition of motorized linear module

<table>
<thead>
<tr>
<th>Item</th>
<th>Operating condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>-10℃～+45℃</td>
</tr>
<tr>
<td>Ambient humidity</td>
<td>40％～100％</td>
</tr>
<tr>
<td>Condition for maximum thrust as needed</td>
<td>Wind speed 40m/s</td>
</tr>
</tbody>
</table>

4.2.1 Accuracy of positioning

The accuracy of positioning reproducibility was 1/10 or less than the specification.

Also, the accuracy of positioning in the entire stroke range was very high; with 0.10 mm or less as shown in Fig. 6.

4.2.2 Verification of thrust performance

The thrust performance required for withdrawal operation under strong wind was evaluated with the measurement equipment shown in Fig. 7. From this test result, the maximum thrust was verified to be adequate.

5. Solar tracking system for photovoltaic power generation

There are mainly three different methods for light-collection-type photovoltaic power generation: the fresnel lens method, which utilizes concentrically arranged annular sections of regular lenses which are made thinner than regular lenses but have a jagged cross section (Fig. 8); the reflective mirror method, which collects light at the central focal point by reflecting the sunlight with a concave mirror, and then again with a convex mirror placed above at the center (Fig. 9); and the cassegrain lens method, which collects light at the central point of the bottom part of concave mirror by reflecting the sunlight with the concave part of the bottom of the lens, and then again...

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Table 2  Specifications and validation result

<table>
<thead>
<tr>
<th>No.</th>
<th>Measured Item</th>
<th>Specification</th>
<th>Developed product No.1</th>
<th>Developed product No.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Resolution</td>
<td>1μm/p</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Maximum speed</td>
<td>2.5mm/s or more</td>
<td>Complied</td>
<td>Complied</td>
</tr>
<tr>
<td>3</td>
<td>Accuracy of repeatability of positioning</td>
<td>Less than ±0.1mm or more</td>
<td>≤0.004</td>
<td>≤0.004</td>
</tr>
<tr>
<td>4</td>
<td>Thrust output</td>
<td>40m/s of wind speed equivalent</td>
<td>Complied</td>
<td>Complied</td>
</tr>
<tr>
<td>5</td>
<td>Verification of loss of steps of stepping motor</td>
<td>40m/s of wind speed</td>
<td>No loss of steps</td>
<td>No loss of steps</td>
</tr>
<tr>
<td>6</td>
<td>Accuracy of positioning</td>
<td>Reference</td>
<td>0.096mm</td>
<td>0.093mm</td>
</tr>
<tr>
<td>7</td>
<td>Backlash</td>
<td>Reference</td>
<td>0.002mm</td>
<td>0.016mm</td>
</tr>
<tr>
<td>8</td>
<td>Power consumption</td>
<td>Reference</td>
<td>29W</td>
<td>24W</td>
</tr>
</tbody>
</table>
with the convex part of the top of the lens (Fig. 10). All of these types require accurate tracking. NTN has developed both a high-accuracy and high-rigidity type motorised linear module so that they can be selected depending on the size and structure of the solar panels. Both of these specifications are currently under evaluation with no problems in continuous operation.

Fig. 11 High precision spec linear module

Fig. 12 High stiffness spec linear module

5.1 High-accuracy specification

Fig. 11 shows a motorized linear module aiming for moving small panels with high accuracy. The body of the module is fixed to the base using pins for supporting the body at both sides of the housing; then, the reflective mirror is installed to the clevis at the tip of the slide shaft. The stroke is about 200 mm and a ball screw is used in the actuator for high accuracy, similar to the one for solar thermal power generation. A trunnion structure is adopted for the linear motion guide.

5.2 High-rigidity specification

Fig. 12 shows the high-rigidity type solar tracking system for accurate tracking of sunlight while strongly supporting medium to large panels. A trunnion structure is adopted, the same as the other types, for the linear motion guide to cope with uneven loads and high rigidity. The stroke is 500 mm and an accurate trapezoidal screw is used.

In addition, the slide shaft is equipped with bellows for preventing dust and drips from entering.

6. Conclusion

It is expected that demand for renewable energy will continue to increase.

We have developed motorized linear modules for tracking systems that suit the properties of solar thermal power generation and photovoltaic power generation, respectively.

While they are currently under empirical evaluation, improvement in durability and maintainability is being addressed for product commercialization that meets market demand.

Photo of authors

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