Offering Japanese quality with prestigious development and manufacturing techniques

In recent years, the output capacity of wind turbine generators has continued to increase. However, growth in terms of the size of wind turbines has reached its limits. The current demand is for smaller and lighter wind turbines with equivalent or better power-generating capability, higher reliability, and maintenance-free systems. With this background, the performance requirements demanded from bearings have become increasingly diverse. Other important issues include consideration for characteristics such as energy efficiency, safety, high product quality that is compliant with global standards, and more competitive pricing.

Utilising its development expertise, JTEKT is introducing cutting-edge technologies to resolve such issues. To support this, basic technologies applied in various fields, such as tribology, nano technology, materials development, precision machining and heat treatment processes, are included as well. We have established a worldwide network to further deepen the use of these basic technologies and expand our technology development capabilities even further. High evaluations are received not only from our customers, but also from other markets. In terms of manufacturing, we integrate mass production technologies acquired through automobile bearing production and large-scale product production technologies acquired through bearing production for the steel-making industry and tunnel boring machines to create manufacturing lines never before imagined. Product management systems such as “KAIZEN” and “MIERUKA” are also implemented to ensure world-class Japanese quality.

Wind turbine generator operating environment

The wind energy moving wind turbine blades is changed into rotational energy at the rotor. This energy is then transferred through the main shaft and gearbox, and finally transformed into electricity by the generator. This is the main flow of the power train in a wind turbine generator. The load on the wind turbine generator varies widely from light to heavy according to the wind speed and direction, which changes every 0.1sec, and this affects rotational speed as well. Additionally, the operating temperatures can range from -30 to 100°C. Even under such severe conditions, the designed service life for bearings is over 20 years, a strict requirement in order to ensure high reliability.
Main shaft bearings

After the wind load is transferred through the rotor, this important component transmits the rotational torque to the gearbox. Spherical roller bearings (Fig.1) are mainly utilised for the main shaft bearings because of their superior aligning characteristics and load durability. At JTEKT, compact and highly reliable bearings are selected taking into account thorough analyses of complicated rotor rotational speeds, appropriate loads, the shaft, housing rigidity and lubrication. An example of the main shaft configuration is shown in Fig. 2, and Fig. 3 shows an FEM analysis example for the main shaft housing. Both larger and hybrid wind turbine generators are likely to be keys in order to improve power efficiency and reliability. Consequently, not only bearing sizes are increasing but also the types of bearings are diversifying from conventional spherical roller bearings to cylindrical roller and tapered roller bearings. JTEKT are supplying all types of bearings depending on wind turbine sizes.

Fig. 1 Main shaft bearings (spherical roller bearings)

Fig. 2 Example of the main shaft configuration

Fig. 3 Example of a FEM analysis for the main shaft housing

Main shaft oil seal

- Full-rubber Seal (MS type)
  - Full-rubber material simplifies installation
  - Can be manufactured with a cut-type in one location
- Pressure-resistant seal (MHSA type)
  - Reduction of lip deformation due to pressure
  - Excellent sealing performance under high-pressure conditions

Gearbox bearings

The gearbox is the device that increases the rotational speed transmitted via the main shaft up to the speed where power can be converted into electricity, which consists of some planetary drives (a set of a sun gear, planet gears and a ring gear) and parallel shafts. Fig. 4 shows a major configuration, which includes one-stage planetary gear and two-stage parallel shafts (an intermediate and a high speed shafts). In many cases, double-row cylindrical roller bearings are used for the planet gear section, but recently the utilization of an integral type bearing (Fig. 5) is on the increase. It is also important to investigate the proper bearings implemented to the gearbox using an analysis program considering shaft stiffness, shaft inclination, lubricating condition and bearing internal design (clearance and rolling contact profile) since the operating condition of the gearbox is severe. An example of analysis result for the planet gear section is shown in Fig. 6. If the rigidity of the planet is low, the ring gear deforms, which may have an influence on the inner components and shorten the service life of the bearings. Another example of analysis result for the contact stress distribution on the contact area is shown in Fig. 7. If the contact stress concentrates at the contact area, the shaft where the bearing sits deforms, which makes the service life of the bearing short. Fig. 8 and 9 also show shaft deformation of each shaft and load distribution of each rolling element on each shaft. Consequently, it is important to select appropriate bearings using an analysis program considering shaft deformation and load distribution on a roller.

Fig. 4 Example of a gearbox configuration

Fig. 5 Example of a bearing arrangement for a planet gear section on a low-speed shaft

Fig. 6 Planet gear rigidity study results

Fig. 7 Contact stress considering the rolling element profile

Fig. 8 Deformation of each shaft

Fig. 9 Load distribution on rolling elements of each bearing
Hybrid ceramic bearings for generators

Bearings used in generators are subject to electric pitting, a phenomenon where the surface melts locally because sparks are generated as electricity passes through the ultra-thin oil layer and into the bearing while it is rotating. This is one of the factors that can lead to damage and reduce bearing service life. As a measure to prevent this, a ceramic ball with excellent insulation performance is used for the rolling elements, creating a hybrid ceramic bearing with good efficiency. Furthermore, compared to common bearings, the hybrid ceramic bearing does not reach high temperatures when rotating (Fig. 10), which improve the life of the lubrication and the duration of preventive maintenance. The further advantages of ceramics are shown in Table 1. The lower density contributes to lighter weight, and excellent anti-seizure is to be expected.

<table>
<thead>
<tr>
<th>Item</th>
<th>Silicon Nitride</th>
<th>High carbon Chromium ( Bearing steel )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat resistance (°C)</td>
<td>1,200</td>
<td>800</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>3.2</td>
<td>7.8</td>
</tr>
<tr>
<td>Linear expansion coefficient (°C)</td>
<td>3.2 x 10⁻⁶</td>
<td>12.5 x 10⁻⁶</td>
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<tr>
<td>Vicker's hardness (HV)</td>
<td>1,300 to 2,000</td>
<td>700 to 800</td>
</tr>
<tr>
<td>Longitudinal elastic modulus (GPa)</td>
<td>310</td>
<td>210</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>0.25</td>
<td>0.3</td>
</tr>
<tr>
<td>Magnetic property</td>
<td>Nonmagnetism</td>
<td>Magnetism</td>
</tr>
<tr>
<td>Electric property</td>
<td>Insulator</td>
<td>Conductor</td>
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<tr>
<td>State of material bonding</td>
<td>Covalent bond</td>
<td>Metallic bond</td>
</tr>
</tbody>
</table>

Fig. 10  KE bearing life characteristics

KE bearings for yaw-driven reduction gears

The bearings utilised in reduction gears can be subjected to contamination of metallic particles resulting from exposure to abrasive microscopic particulates, and this can influence the bearing service life. Koyo KE taper roller bearings have the best results when subjected to such severe conditions. KE bearings have an extremely hard raceway surface, and the volume of the retained austenite has been optimised, resulting in bearings that have dramatically improved performance in contaminated lubricants. The service life characteristics for these bearings are shown in Fig. 11.

JTEKT Products Utilised in Wind Turbine Generator Production and Control

Machine tools

Machine Tools with Wider Machining Ranges and Higher Productivity
Big, Fast and Powerful for Even Higher Efficiency Machining of Large Parts.

FH1250SX
Large-scale Horizontal Machining Center

This advanced machining center leads its class in both maximum workpiece size machining capability and fastest rapid-feed rate.

- Maximum workpiece size: Ø 2,400 x 1,800mm
- Maximum load on pallet: 5,000kg
- Pallet size: 1,250 x 1,250mm
- Rapid-feed rate: 42m/min
- High-torque spindle speed: 8,000min⁻¹
- Maximum spindle torque: 1,099Nm

Select G7
Large-scale Combination Grinder

This multiuse grinder is equipped with a grinding-wheel swivel function that enables switching between straight and angular grinding.

- Swing over table (mm): Ø660
- Load between centers (kg): 1,500
- Distance between centers (mm): 1,000, 2,500, 3,200, 4,000
- Grinding wheel size (mm): Ø760, Ø915, Ø1,065
- Grinding wheel width (mm): 200, 300
- Grinding wheel speed (r/min): 30, 45

Pitch brake hydraulic pumps

Utilised as the power pack for pitch brakes. Power packs reduce the rotor speed using a disc in a way similar to that of the disc brakes used in automobiles. For safety, the brake is equipped with an independent hydraulic system.