Mechatronics

Sensor-Bearing Units .......................................................... 957

Steer-By-Wire Modules ......................................................... 967

Mast Height Control units .................................................... 969

Other sensorized units .......................................................... 971
Sensor-Bearing Units

SKF Sensor-Bearing Units ................................................................. 958
SKF Explorer class deep groove ball bearings....................................... 959
SKF active sensor units ..................................................................... 959

Unit data – general ............................................................................. 960
Design ............................................................................................... 960
Dimensions ....................................................................................... 960
Bearing tolerances ............................................................................ 961
Bearing internal clearance .................................................................. 961
Permissible speeds ............................................................................ 961
Temperature range ............................................................................ 961
Electrical interface data ..................................................................... 961
Electro-magnetic compatibility .......................................................... 961

Selection of Sensor-Bearing size ....................................................... 962

Application of Sensor-Bearing units ..................................................... 962
Radial location .................................................................................. 962
Axial location ................................................................................... 962

Mounting ........................................................................................... 963

Lubrication and maintenance .............................................................. 963

Product table ..................................................................................... 964
Exact information on the motion status of rotating or axially travelling components is decisive in many fields of engineering. Exact motion control becomes all the more important with the increasing necessity of automation of all kinds of processes. In addition, the demand to design more light-weight and simpler constructions calls for integral system solutions (→ fig. 1), e.g. for sensor bearing units to record:

1. the number of revolutions.
2. the speed.
3. the direction of rotation.
4. the relative position/counting.
5. the acceleration or deceleration.

**SKF Sensor-Bearing Units**

SKF Sensor-Bearing Units (→ fig. 2) are mechatronic machine components covering the fields of both sensor and bearing engineering. They are virtually an ideal combination of a versatile ball bearing with a sensor unit shielded from external influences. The sensor body, impulse ring and bearing are mechanically attached to each other, forming an integral ready-to-mount unit.

The SKF designed and patented Sensor-Bearing Units are simple, robust and consist of

- an SKF Explorer class deep groove ball bearing and
- an SKF active sensor unit.

The SKF Sensor-Bearing Units are specially designed to perform as incremental encoders for motor and/or machine control. They are specially adapted to fit asynchronous motors, and provide compact and reliable encoding for their most demanding control. They are intended for applications with rotating inner ring and stationary outer ring. SKF Sensor-Bearing Units for applications with stationary inner ring and rotating outer ring, e.g. for the use in conveyor systems, can be manufactured on request, please contact the SKF application engineering service.
SKF Explorer class deep groove ball bearings
The single row SKF Explorer deep groove ball bearings are suitable for high speeds and robust in operation. They can accommodate not only rather heavy radial loads, but also axial loads and serve as locating bearings guiding the shaft axially in both directions. Furthermore they are noted for their high manufacturing accuracy, their low noise and friction levels. The efficient sealing and the grease filling provide maintenance-free operation for life.

SKF active sensor units
The SKF Sensor-Bearing Unit incorporates an active sensor designed to be compact and robust, very close to an incremental encoder function. It provides accurate measuring down to zero speed. Its main components are the impulse ring, the sensor body with the sensors and the connecting cable.

The composite magnetized impulse ring is attached to the bearing inner ring. Depending on the bearing size, it is divided into a certain number of north and south poles. The number of pulses per revolution normally ranges between 32 and 80.

The sensor body is attached to the bearing outer ring by an SKF patented solution. The sensor body has two cells, enabling the direction of rotation to be determined. The two sensors are offset to each other in the sensor body. In a small integrated circuit they contain not only the Hall generator as an active element but also the electronics for signal amplification and conversion. The analogue sinusoidal signal generated by the Hall cell is amplified and converted into a square-wave signal by a Schmitt trigger (→ fig. 3). The leading signal determines the direction of rotation.

Furthermore two sensors provide double the number of pulses, e.g. 128 pulses per revolution compared with 64 for a standard bearing. When counting the rising and falling edges of the pulses a maximum accuracy of 256 pulses per revolution can be attained, which corresponds to a resolution of 1.4 angular degrees.

The sensor requires an external voltage supply. The signal output is fed via an open collector circuit.

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Fig. 3

[Diagram showing the principle of operation of the active sensor unit, including an impulse ring, sensor body with sensors, and connecting cable, with labels for clockwise and anticlockwise rotation.]
Unit data – general

Design
SKF Sensor-Bearing Units (fig. 4) consist of

- an SKF Explorer deep groove ball bearing with a RS1 contact seal and a snap ring groove in the outside surface of the outer ring (a)
- a magnetized impulse ring (b)
- a sensor body (c)
- a connecting cable (d).

At the side opposite to the seal, the impulse and sensor body form an effective labyrinth seal.

The impulse ring is a composite magnetized ring. The number of north and south poles (between 32 and 80) depends on the bearing size. The impulse ring is attached to the inner ring.

The sensor body protecting two embedded Hall cells is attached to the outer ring – a patented SKF solution. The multi-wire cable extends in the radial direction, connecting the SKF Sensor-Bearing Unit and the signal processing electronics and has a standard length of approximately 500 mm. To account for the different interface requirements between the Sensor-Bearing Unit and the customized electronic unit, SKF Sensor-Bearing Units (fig. 5) provide the choice of three versions:

- Version 1: Free cable end.

Dimensions
SKF Sensor-Bearing Units are based on SKF Explorer class deep groove ball bearings in the 62 series, which dimensionally comply with ISO 15: 1998 as regards diameter. However, the unit is slightly wider due to the integral sensor.
Bearing tolerances
The bearings used for SKF Sensor-Bearing Units are manufactured to P5 tolerances (d ≤ 25 mm) or P6 tolerances (d ≥ 30 mm) as standard, which conform to ISO 492:2002 and are listed in the tables 7 and 8 on pages 129 and 130.

Bearing internal clearance
SKF Sensor-Bearing Units have C3 radial internal clearance as specified for deep groove ball bearings in ISO 5753:1991. The values are listed in the product table and are valid for unmounted units under zero measuring load.

Permissible speeds
SKF Sensor-Bearing units are designed to suit the limiting speed of the appropriate sealed bearing. If Sensor-Bearing Units are to be operated at higher speeds than indicated in the product table, please contact the SKF application engineering service.

Temperature range
SKF Sensor-Bearing Units have a temperature range from –40 to +120 °C, as extensive long-term testing has proved. For temperatures constantly exceeding +120 °C and up to +150 °C, please contact the SKF application engineering service.

Electrical interface data
Active sensor operation requires a regulated supply voltage of 5 to 24 V. Signal output is effected via an open collector (fig. 6). Resistors inserted between the conductor connected to the voltage supply and the conductors for the output signals limit the output current to 20 mA (table 1, page 962). The signal output features are shown in table 2, page 962.

Electromagnetic compatibility
SKF Sensor-Bearing Units can be used in systems functioning under most arduous electromagnetic environment such as described in the European Standard EN 50082-2.
## Application of
Sensor-Bearing Units

Two bearings are normally required to support a shaft – a locating and a non-locating bearing. Since the SKF Sensor-Bearing Unit is mainly used as a locating bearing, the opposite shaft end may be supported by a non-locating bearing. If heavy axial loads act on the SKF Sensor-Bearing Unit in both directions, it should be mounted in such a way that the heavier axial load acts on the bearing outer ring side face opposite the sensor unit.

### Radial location

In accordance with the general recommendations, the inner ring has a tight fit on the shaft and the outer ring a loose fit in the housing bore. The sensor unit connection cable emerging radially from the bearing determines the position of the outer ring relative to the housing. A sufficiently dimensioned cable duct must be provided in the housing or housing cover (→ fig. 7). It is recommended that the cable protruding from the sensor body be protected against excessive rotation by a radial notch in the housing, having a circumferential width of 9 to 15 mm.

### Axial location

The inner ring with tight fit is normally located in the axial direction on both sides, e.g. by a shaft shoulder, a distance sleeve or a snap ring. The axial location of the outer ring depends on the bearing size.

For bearings up to and including 25 mm bore diameter the outer ring is located axially on the side opposite to the sensor unit by a shoulder in the housing bore:

- If the bearing is only subjected to light loads or not loaded at all in the opposite direction, a snap ring engaging a groove in the housing bore is sufficient for axial location on the sensor side (→ fig. 7).
- In case of heavier axial loads SKF recommends to locate the bearing with an end cover bolted to the housing via a snap ring in the groove of the outer ring.

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### Selection of Sensor-Bearing size

As far as the bearing function is concerned, the selection of the required size of the SKF Sensor-Bearing Unit is made by using the same factors and normal methods as for standard deep groove ball bearings (→ section “Selection of bearing size”, starting on page 49).
Larger bearings should abut a housing shoulder with the side face opposite the sensor unit. At the outer ring side face with the sensor the bearing can be axially located either with

- a thin-walled slotted distance sleeve, which abuts the bearing on one side and a snap ring at the other (→ Fig. 8) or
- an end cover bolted to the housing.

The abutment dimensions can be found in the product table. For detailed information please refer to the product brochure “SKF Sensor-Bearing Units – concentrate intelligence in your motion control” or contact the SKF application engineering service.

**Mounting**

During mounting SKF Sensor-Bearing Units must be handled with great care in order to avoid damage to the sensor unit and the connection cable. On request SKF can provide customized assistance in optimizing the process of mounting and connection; please contact the SKF application engineering service.

**Lubrication and maintenance**

SKF Sensor-Bearing Units are supplied as sealed ready-to-mount and ready-to-operate bearing units. They are filled with a polyurea grease for the entire bearing life and suitable for the temperature range of the sensor unit – between –40 and +120 °C. The grease fill is adapted to the bearing size. Thus SKF Sensor-Bearing Units are maintenance-free.
### Sensor-Bearing Units

**d 15 – 45 mm**

<table>
<thead>
<tr>
<th>Bearing</th>
<th>Principal dimensions d</th>
<th>Basic load ratings</th>
<th>Fatigue load limit</th>
<th>Limiting speed r/min</th>
<th>Sensor unit No. of pulses</th>
<th>Sensor unit Phase accuracy</th>
<th>Mass kg</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>kN</td>
<td>kN</td>
<td>–</td>
<td>%</td>
<td>degrees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>35 11</td>
<td>8,06</td>
<td>3,75</td>
<td>0,16</td>
<td>13 000</td>
<td>32 ± 3</td>
<td>0,060</td>
<td>BMB-6202/032S2/EA002A</td>
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<tr>
<td>20</td>
<td>47 14</td>
<td>13,5</td>
<td>6,55</td>
<td>0,28</td>
<td>10 000</td>
<td>48 ± 3</td>
<td>0,15</td>
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<tr>
<td>25</td>
<td>52 15</td>
<td>14,8</td>
<td>7,8</td>
<td>0,34</td>
<td>8 500</td>
<td>48 ± 3</td>
<td>0,18</td>
<td>BMB-6205/048S2/EA002A</td>
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<tr>
<td>30</td>
<td>62 16</td>
<td>20,3</td>
<td>11,2</td>
<td>0,48</td>
<td>7 500</td>
<td>64 ± 4</td>
<td>0,22</td>
<td>BMB-6206/064S2/EA002A</td>
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<tr>
<td>40</td>
<td>80 18</td>
<td>32,5</td>
<td>19</td>
<td>0,8</td>
<td>5 600</td>
<td>80 ± 5</td>
<td>0,40</td>
<td>BMB-6208/080S2/EB002A</td>
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<tr>
<td>45</td>
<td>85 19</td>
<td>35,1</td>
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<td>5 000</td>
<td>80 ± 5</td>
<td>0,44</td>
<td>BMB-6209/080S2/EB002A</td>
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Bore diameter of end cover
≥ D2 + 1 mm

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Abutment and fillet dimensions</th>
<th>Radial internal clearance</th>
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</thead>
<tbody>
<tr>
<td>d</td>
<td>d1</td>
<td>d2</td>
</tr>
<tr>
<td>mm</td>
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<td>20</td>
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<td>48</td>
</tr>
<tr>
<td>45</td>
<td>57,6</td>
<td>53</td>
</tr>
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</table>
SKF Steer-By-Wire Modules are plug-and-play mechatronic components that combine intelligent sensing technology with operational functionality. The module provides an electronic signal that gives information on:

1. the speed and acceleration of steering.
2. the direction of steering.
3. the relative position of the steering wheel.

The plug and play module includes

- an SKF Explorer deep groove ball bearing
- an active sensor
- a steering shaft

which are compactly integrated into a strong steel housing. The exterior surfaces are galvanically coated for protection against corrosion for severe environments. The modules have a temperature range from −40 to +70 °C. They are sealed and greased for life and maintenance-free, thus relubrication and steering torque adjustments are never needed.

Active sensor design
The SKF Steer-By-Wire Module incorporates a compact, robust active sensor, which provides the incremental encoder function. Its main components are the magnetic impulse ring and four sensor cells embedded in a body with connecting cables.

The composite magnetized impulse ring, divided into a certain number of north and south poles, is linked to the rotating inner ring of the bearing. The sensor body is attached to the bearing outer ring and equipped with four Hall cells and the connecting cable. An analogue sinusoidal signal generated by the Hall cells is amplified and converted into a square-wave signal by a Schmitt trigger. The leading signal determines the direction of rotation.

The digital output signals transmitted to the electronic processing control unit, equal to the number of pole pairs on the impulse ring, provide information about

- the shaft’s angular position
- direction of rotation
- speed or acceleration of the rotating shaft.

The Steer-By-Wire module electronic output is redundant, containing an identical set of sensors that operate independently. If one set of sensors fails, the other set continues working. The active sensor requires external voltage supply. The signal output is fed via an open collector circuit.

Designed for demanding applications
SKF Steer-By-Wire Modules are designed to reduce OEM costs while providing more flexibility in cabin design, enhancing operator comfort and ultimately productivity.

SKF Steer-By-Wire Modules can provide the manufacturers of off-road vehicles, including forklift trucks, agricultural, mining, construction and forestry equipment, watercraft or electric carts with more cost effective solutions.

For detailed information about the SKF Steer-By-Wire Modules please contact the SKF application engineering service.
SKF Mast Height Control units (MHC) are plug and play mechatronic components that combine intelligent sensing technology with operational functionality. They are used e.g. in forklift trucks for control of the height position of the fork unit. The MHC unit provides an electronic signal that gives information on:

1. the relative position of the mast.
2. the direction the mast is moving.
3. the speed and acceleration of the mast.

The MHC unit includes an SKF Explorer class deep groove ball bearing with active sensors integrated in either a pulley or cam roller arrangement. These units interface directly with the vehicle controller to provide useful information to the operator.

SKF MHC units are currently available in two designs:

- A spring-loaded cam arrangement, using spring force to press the sensorized bearing against the moving part of the mast. The mechanical interface of the cam roller unit, which can be customized to meet the OEM requirements, is directly driven by the moving counter surface.
- A pulley arrangement, driven either by a wire or belt that has been incorporated into the design of the mast height positioning system.

**Active sensor design**

The SKF cam control unit incorporates a compact, robust active sensor, which provides the incremental encoder function. Its main components are the magnetic impulse ring and sensor cells embedded in a body with connecting cables.

The digital output signal is equal to the number of pole pairs on the impulse ring. This is transmitted to the electronic processing control unit, and provides information about the length over which the unit has moved, speed and acceleration of the counter surface, for example that of a forklift mast. This enables accurate mast height control, which is particularly important to those operations that demand speed and accuracy from the operator or the need of preprogrammed operating cycles. The MHC unit output signals may also be used for simple digital readout systems or to trigger other safety systems.

**Designed for demanding applications**

The concept of the SKF Mast Height Control units primarily aims at increased operator efficiency. MHC also has applications well beyond forklift trucks. They can be adapted to agricultural, forestry, mining and construction equipment and a variety of other applications.

Additional designs of MHC units can be developed based on specific requirements. For detailed information about the SKF cam control units please contact the SKF application engineering service.
Other sensorized units

The SKF range of sensorized units is not limited to deep groove ball bearings and the units described on the previous pages. In the course of the development, the sensor concept was implemented many years ago with other bearing types as well.

Several SKF publications are available with detailed information on these sensorized bearing units and can be supplied by request.

Sensorized units for road vehicles

Pioneering developments in engineering often start in vehicle construction. For reasons of both weight reduction and safety, more and more vehicles are being equipped with speed sensing devices. The optimum wheel speed sensor solution is however unique for each individual application. Depending on requirements the sensor can be either non-integrated or integrated to improve reliability, save weight and ease assembly. The sensor may also be either of

- the passive type, which is capable of providing signals down to a speed of a few km/h sufficient for ABS or of
- the active type, which can provide signals down to zero speed, necessary for systems such as traction control or navigation.

Whatever the solution, SKF can help to take advantage of these opportunities by offering a wide range of existing solutions for both car as well as truck hub units.

Sensorized bearing units for rail vehicles

Operating conditions in rail vehicles are especially arduous. The units must not only tolerate vibration, impact loads, heavy loads and extreme temperatures, but must provide high operational reliability over great distances and with long maintenance intervals. The same is true for the integral sensors, which control the braking system, provide optimum frictional engagement of the driving wheels on starting-up and detect the direction of rotation.

The SKF sensorized tapered bearing units (TBU) for rail vehicles are compact, ready-to-mount and easy-to-install solutions, having a taper roller bearing as the basic bearing.

Apart from these bearing units with speed sensors, bearing units with temperature sensors are also available from SKF. They enable immediate and permanent monitoring of bearing temperature, detecting hot-running axle-boxes and bearing damage in operation.

Sensorized bearing units for traction motors

Sensorized bearing units with integral speed and temperature sensors for railway drive systems, the traction motor bearing units (TMBU), are another speciality from SKF. Two standard basic versions are available

- for the locating position, a deep groove ball bearing unit with a flanged outer ring for attachment to the motor shield
- for the non-locating position, a cylindrical roller bearing unit.

The SKF TMBU concept combines in one unit all the functions important for the bearing arrangement, also including the insulation, if required.