Wheel-end solutions for optimal performance

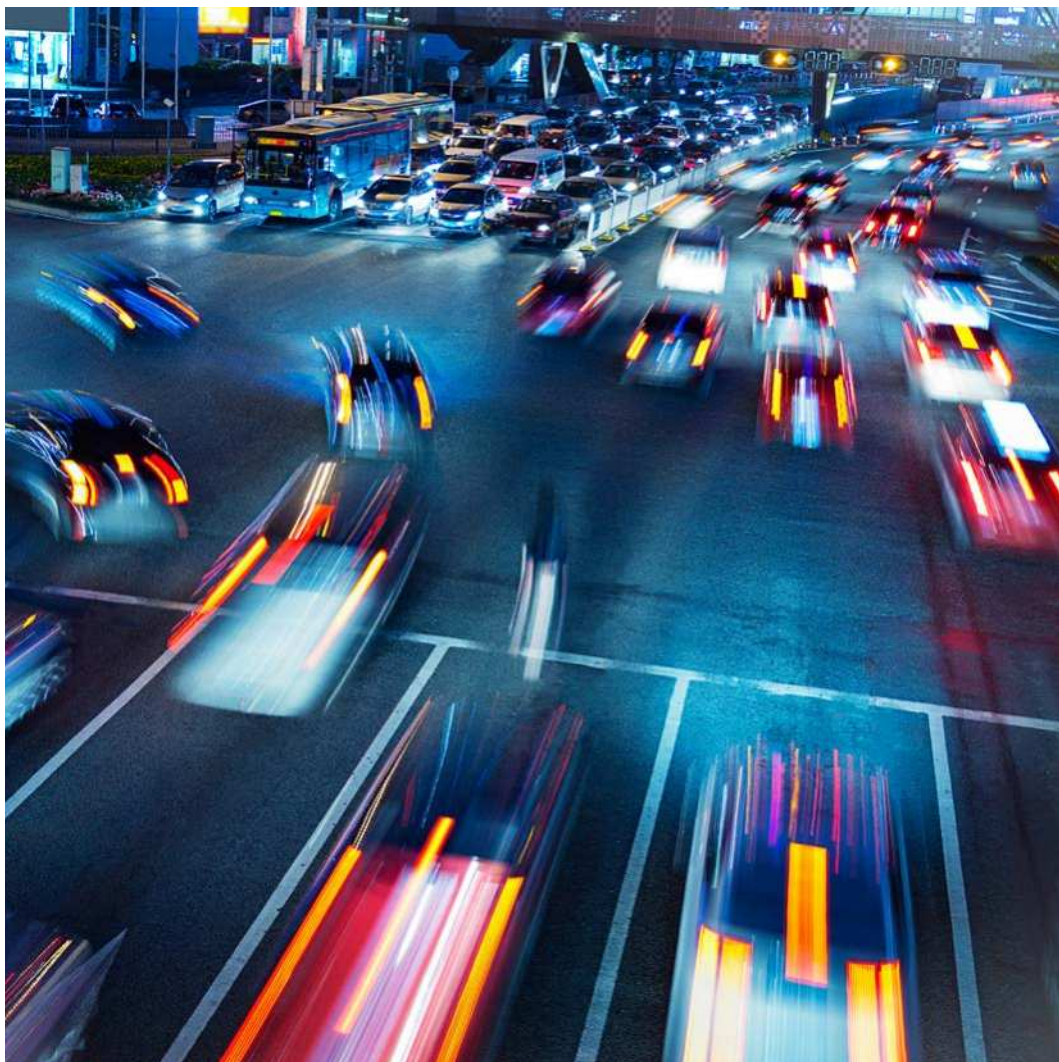
Hub bearing units engineered to address future market challenges

RIDING ON SKF WHEEL BEARINGS

15

MILLION NEW VEHICLES

PER ANNUM



Thriving in an era of rapid change

Changing consumer preferences, tightening regulatory pressures, diverging markets, and technology breakthroughs have ushered in an era of uncertainty and transformation for original equipment manufacturers (OEMs).

New technologies and features are quickly moving from the drawing board to the streets. And while automakers focus on getting in front of these trends, stricter environmental regulations are closing in. To satisfy these changing standards and demands, OEMs must engineer better vehicle performance by smartly investing in new technologies, from infotainment and connectivity to lightweight and friction-reducing drivetrain components, such as hub bearing units (HBU).

At the same time, market share continues to shift to emerging regions, forcing automakers to prioritize growth in Asia and other developing areas. In doing so, OEMs must ensure that their production footprints can support future market demand and reach.

When tackling these challenges, cementing healthy and collaborative relationships with suppliers is key. To survive and thrive in this era of unprecedented change, automakers must partner with a supplier equally focused on innovation and growth as they are. SKF is that partner.

Hub bearing units: Key components of fuel efficiency, reduced emissions, and performance

The primary application of the HBU is in the wheel end, where the task of the bearing is to allow wheel rotation – conveying either the axle's power or enabling as much free wheel rotation as possible. This double function is key in minimizing the friction generated by the vehicle and reducing fuel consumption and emissions. In addition, the HBU must provide the right stiffness and low un-sprung masses to ensure desired vehicle handling. Other applications for HBUs include transmissions and engine fans.

Driving innovation: World-class hub bearing units from SKF

Today, the world's top vehicle manufacturers rely on SKF for wheel-end components and integrated systems. Every year, 15 million new vehicles ride on SKF wheel bearings. The SKF family of wheel-end products now includes a wide-ranging, highly sophisticated set of solutions. Combined, they are helping to improve wheel-end functionality, reliability, efficiency, and safety.

But SKF's wealth of experience and wide range of capabilities extend beyond just designing high-quality HBUs. We also have a long history of testing our HBUs per unique customer specifications (e.g., safety, life, sealability, corrosion, friction) and providing world-class manufacturing in factories around the world.

Building on these traditions, SKF is continuously working to improve its HBU products as goals such as weight and friction reduction, as well as higher performance and reliability, represent continuous challenges for automakers.

The SKF Difference

A focus on innovation: SKF has pioneered every major advancement in wheel-end technology since the invention of the automobile. And today, the tradition continues. Through continuous research in HBU engineering, SKF continues to cut weight and reduce friction without compromising quality or bearing life.

A custom approach: SKF provides engineering assistance and calculation support to meet the exact specifications of today's carmakers.

A commitment to excellence: SKF combine world-class laboratory facilities with engineering expertise to perform product and subsystem validation testing.

A global presence: SKF has established HBU solution factories all over the world, providing local access to global SKF knowledge.

A focus on innovation

Generations of innovation

SKF hub bearing units are greased for life, compact units providing defined and pre-adjusted clearance or preload, plus integrated sealing solutions. SKF has developed three generations of SKF hub bearing units with dedicated designs to meet specific application requirements. Each of them can be tailored to add functionalities and optimize performance.

First generation: HBU1 and HBU1T

First generation designs – HBU1 and HBU1T – are based on ball and tapered roller bearings respectively, with cylindrical external diameters. HBU1 and HBU1T both have a two-piece inner ring.

Boundary dimensions, including chamfers, are optimized to deliver superior application and cost/performance ratio with each specific shaft and housing arrangement. Internal clearance is tailored for the specific application requirements.

Second generation: HBU2/2T/2R/2TR

The second generation of SKF hub bearing units – HBU2 and HBU2T – are also based on ball and tapered roller bearings respectively. The outer ring of each unit integrates a flange with threaded holes or studs and a spigot to center and mount surrounding parts; all dimensions are engineered to specific customer requirements.

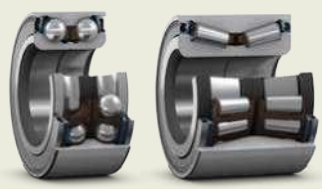
While HBU2/2T units are generally used for outer ring rotating applications, a variant is also available for applications with inner ring rotation – HBU2R and HBU2TR.

Third generation: HBU3/3.2T

HBU3 based on ball and HBU3.2 tapered roller bearing designs, are the third generation of SKF hub bearing units. The dynamic load carrying capacity of HBU3/3.2T is maximized by SKF's unique design. HBU3 integrates the flange on the inner and outer rings. HBU3.2T integrates the flange on the outer ring.

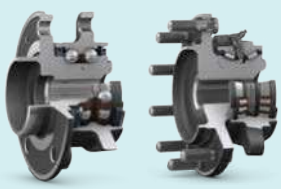
The flanged outer ring makes possible to bolt the unit to the suspension, while the rotating inner ring with its flange, spigot and threaded holes or studs, is designed for the assembly of brake disk and wheel rim.

First generation



Second generation

Third generation



SKF HBU features

Internal geometry and influence of fit on final clearance

Internal geometry is adjusted to achieve the desired value of preload once the unit is assembled in the car corner, considering the influence of mounting conditions. This depends on the corner architecture and HBU generation used. In first and second generation HBUs, the two-piece inner rings are axially clamped with a nut, and tightly fit on the spindle. First generation HBUs also require a tight fit, between outer ring and knuckle. In third generation HBUs, roll formed versions, the clearance reduction is ensured by the components' internal design. For all vehicle applications, specific calculations for clearance reduction under actual mounting conditions are carried out to ensure HBU compliance with desired customer performance.

Lubrication

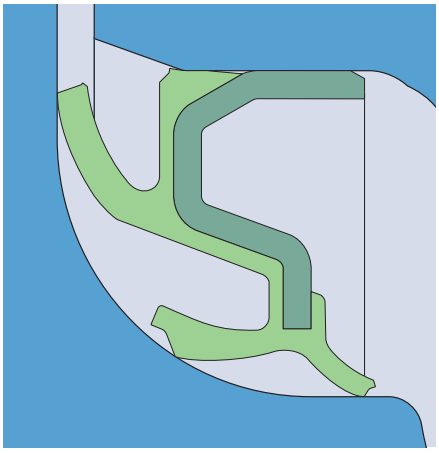
All HBUs are greased for life. The greases used in SKF hub bearing units are extensively tested to typical wheel end application conditions. These include both extreme loads to check grease compliance to thermomechanical stresses and alternating loads to verify fretting wear performance.

Cage

Hub bearing units are usually equipped with two cages made of polyamide with fiberglass reinforcement. Material properties make these cages suitable for continuous operating temperatures of up to 120 °C. Polyamide-based cages could operate in somewhat higher temperatures, but specific validation tests are recommended to determine the potential impact on cage life. Specific, and otherwise challenging, application requirements can be met with cage material options that include high temperature-resistant polymers such as PEEK, as well as metal-pressed cages.

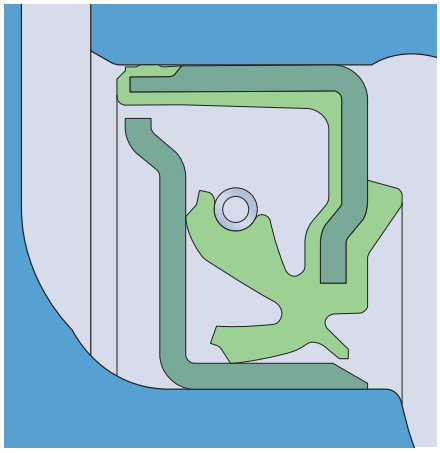
Sealing

Hub bearing units may be equipped with various sealing solutions, all made of material selected to tolerate application operating temperatures. The most common rubber mix used for HBU seals is NBR (Nitrile Butadiene Rubber). Seal lip designs, in terms of shapes and contact forces, are customized based on performance requirements. The seal designs can be grouped into three main types: mono component seals, cassette seals and special seals.



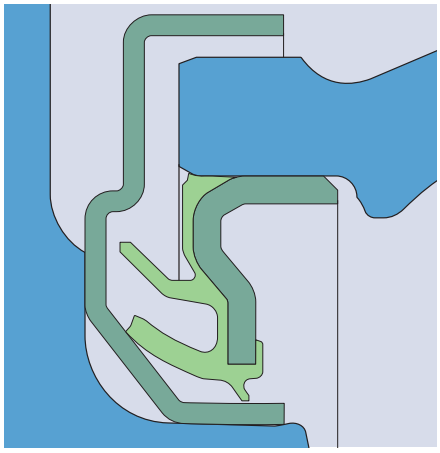
Mono component seal solutions

These consist of a single component seal that is essentially an insert seal with lips riding directly on the ring, which works as a counter face. While the simplicity of the design offers some benefits, the choice needs to be evaluated carefully, especially in highly corrosive environments and in applications without additional protection from water ingress.



Cassette seal solutions

These consist of two components: a mono component seal plus a metal insert as a seal counter face (commonly referred to as “flinger” or “slinger”). The insert seal consists of a metal insert with rubberized lips, of which there can be one or more situated in the radial and/or axial direction. Some designs also include a spring to maintain a high and constant contact force over the bearing lifetime. The flinger is fit on the inner ring shoulder, protecting the seal lips against direct water flow. In cases of rotating inner ring applications, the flinger’s centrifugal effect prevents dust, mud and water from entering the unit. Thanks to the materials used, this design prevents any seal corrosion that would result in seal failure caused by excessive seal lip wear. Today, most cassette seal designs on HBU inboard (vehicle) side integrate a magnetic ABS encoder into the flinger.



Special seals

The designs of special seals – including both internal and external features – are tailored specifically to customer requirements. These seals may include an additional labyrinth against water ingress, designed in combination with the HBU outer ring features and corner protection devices. Similarly, inboard (vehicle) side seals can be used with additional protection features to further prevent contaminant ingress if necessary.

Custom designs and special features

SKF HBUs can be equipped with:

- Sensors (for ABS)

- Sensor carriers (for ABS sensor)

- Caps (for replacing the vehicle side seal and maintaining ABS encoder feature)

SKF provides engineering assistance and calculation support to meet the exact specifications of today's carmakers.

Dimensions and tolerances

Since hub bearing units are customized products, dimensions and tolerances are defined per customer application requirements. SKF proposal drawings for customers include all mating surfaces dimensions, tolerances and information to ensure proper integration and assembly into surrounding parts.

Internal clearance

Product drawings will note internal axial clearance; values are valid for bearings before mounting and under specified measuring load.

Low friction grease

Available upon request for all SKF HBUs, low friction grease reduces hub friction by approximately 9%, while maintaining all other attributes of HBU performance. The low friction grease for hub bearing units contributes to lower CO_2 emissions and to improving total vehicle efficiency. In fact, the grease reduces the absorbed energy by up to 9,5%, compared to standard grease. Using the SKF Vehicle Environmental Performance Simulator (VEPS), and based on the New European Driving Cycle (NEDC), it has been calculated that a car with four hub bearing units using low friction grease saves 0,15 g CO_2 per km. Results are based on a reference case and may vary from application to application.

Reduced preload range

The preload range reduction for third generation hub bearing units provides 10% lower friction, while maintaining the same bearing performance. The car wheel hub bearing unit's friction torque reduction has been achieved by combining design and process improvements based on special preload controls. The emission benefit is achieved through this reduction in friction torque. The SKF Vehicle Environmental Performance Simulator (VEPS), based on the New European Driving Cycle (NEDC), calculated CO_2 emissions savings of up to 0,2 g CO_2 per km.

* In-house tests based on SKF specifications with rolled HBU3 in both loaded and unloaded conditions. Friction benefit is subject to bearing size, type and application conditions.

Anti-corrosion coating

Many car manufactures request solutions to protect the wheel bearings against corrosion. The anti-corrosion coating for hub bearing units developed by SKF provides easier post-sale serviceability. By preventing corrosion, the task of detaching surrounding parts (e.g., knuckle, brake disc, rim) is much easier.

This feature also improves the aesthetics of the bearing during vehicle life and prevents rusty surfaces from coming into contact with the seals, thus maintaining their effectiveness. The anti-corrosion coating has been designed to achieve extremely long life in salt-spray tests as defined by DIN EN ISO 9227 NSS and to provide required geometric tolerances of mating surfaces. This solution can be applied to all second and third-generation, flanged hub bearing units. Anti-corrosion coating layer thickness can be adjusted according on customer requirements, such as low thickness tolerance. The coating has a working temperature above 200 °C and does not require organic solvents.

Optimized hub bearing units

SKF hub bearing unit internal geometry can be optimized per required performance targets by using specific calculation tools. By using an optimizer tool and SKF SimPro Expert to perform the bearing calculation, ball-set geometry can be designed to provide the best balance between life, friction and stiffness for the given geometric constraints. By using a similar approach, ring shape can be optimized to minimize the hub weight while maintaining required structural life and stiffness performance.

Front and rear wheel applications

Wheel ends refer to the components connecting the wheel rim to vehicle. These components include the drive shaft, steering knuckle, suspension arm, braking devices (either disc or drum), hub and bearing. The design and arrangement of wheel ends depend on the vehicle's axle architecture and are usually classified as driven or non-driven and can be in either front or rear position of the vehicle (→ **fig. 1**). The wheel bearing assembly is called hub bearing unit (HBU) because it integrates some of the wheel end components.

In the driven wheel configuration, hub bearing units are fitted between the rotating drive shaft and the stationary housing, e.g., the steering knuckle for the front position, and the hub carrier for the rear position. An example of the arrangement for a driven front wheel is shown in **fig. 2**.

Benefits of integrating wheel end components into the hub bearing unit:

- Smaller number of components
- Saves space and weight
- Pre-adjustment of preload provides higher reliability
- Reduced assembly

Fig. 1

Car wheel classification

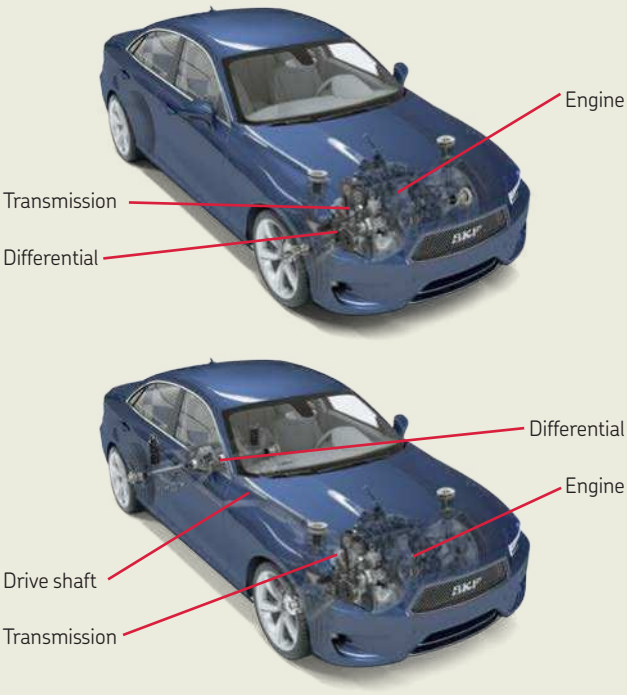
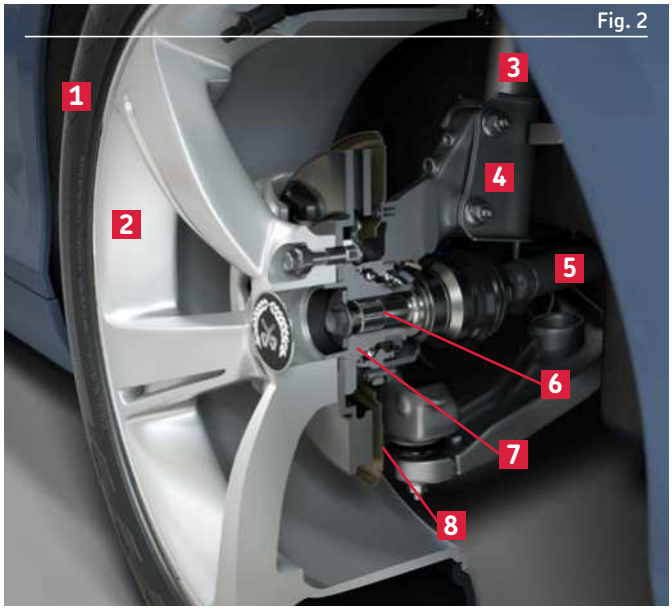


Fig. 2



Example of driven front wheel arrangement

1 *Tyre*
2 *Wheel rim*
3 *Suspension arm*
4 *Steering knuckle*
5 *Drive shaft*
6 *Bearing*
7 *Wheel hub*
8 *Brake disc*

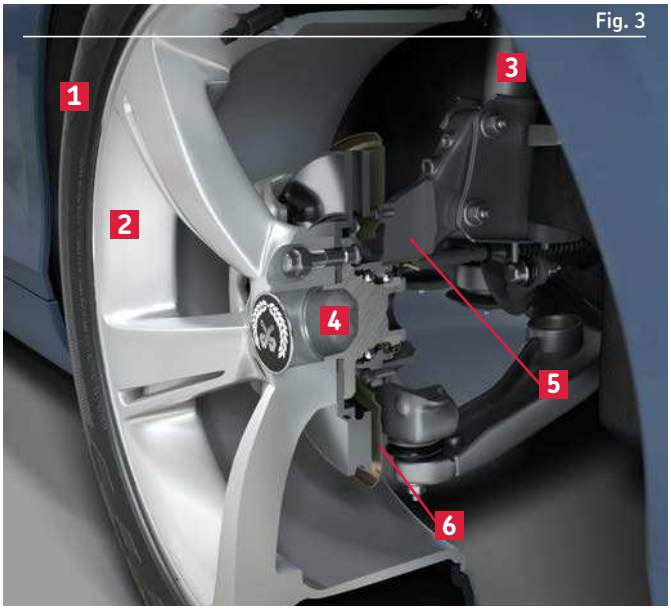
In a non-driven wheel configuration, wheel ends are fitted on the knuckle (or spindle) linked to suspension. An example of an arrangement for a non-driven rear wheel is shown in **fig. 3**. The system including wheel, wheel end, suspension and shaft is also called "corner" as illustrated by **fig. 4**.

The forces acting on the wheel include:
- Gravitational force perpendicular to the road that results from the vehicle weight
- Acceleration force between the tire and road in the driving direction
- Braking force between the tire and road opposite the driving direction
- Cornering force between the tire and road due to the lateral acceleration of the vehicle (expressed in g) during cornering

Operating conditions of wheel end applications include:
- High loading, especially in cornering conditions (up to 1,2 g for sport cars)
- Moderate rotational speed (below 2 000 r/min)
- Moderate to high temperatures, due to heat generated by braking
- Severe contamination (e.g., water, mud, dust, salt)

In addition to handling these forces and operating conditions, hub bearing units must fulfill general requirements such as:
- Reliability
- Low weight
- Low friction
- High sealability
- High stiffness
- Compactness
- Maintenance-free
- Easy assembly

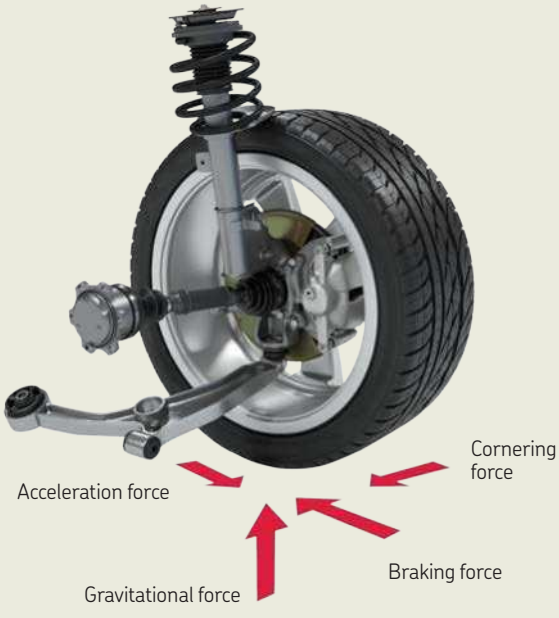
Fig. 3



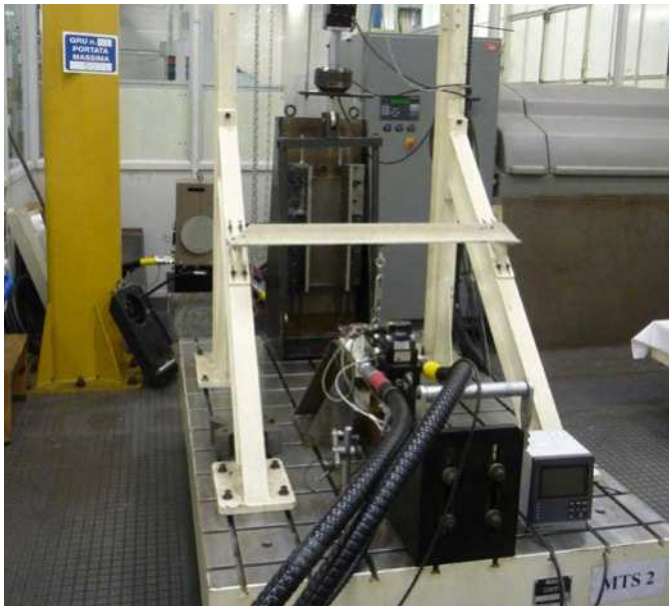
Example of non-driven rear wheel arrangement
1 *Tyre*
2 *Wheel rim*
3 *Suspension arm*
4 *Hub bearing unit*
5 *Knuckle*
6 *Brake disc*

Fig. 4

Car corner and wheel forces



SKF testing and capabilities



SKF combine world class laboratory facilities with engineering expertise to perform automotive product and subsystem validation testing for passenger cars, trucks, commercial vehicles, and high-performance sports cars.

Certified to ISO/TS 16949 quality standards, harmonization of equipment, competence, and capabilities ensure that services are consistently provided at a high-quality level. Performed per either SKF proprietary or to customer specifications, homologation tests evaluate product performance under a wide range of simulated field conditions including the following:

- **Endurance:** fatigue tests with variable speed, temperature, and load conditions
- **Seal performance:** slurry tests with variable temperatures, contaminants, speed, and loads
- **Stiffness:** deflection measurements with increasing tilting loads
- **Fretting wear resistance:** transportation simulation with oscillating loads
- **Strength:** curb impact, maximum load, and brinell resistance
- **Friction torque:** variable speed and load

With a laboratory network located in ten countries across three continents, global alignment is combined with a local presence to provide maximum customer value.

Investigation

SKF offers a variety of in-depth inspection services in three areas of expertise:

Metallurgy

- Evaluation of all types of heat treatment
- Testing for micro and macro inclusions, microstructure anomalies, carbide network and segregations, grain size, fibre flow, surface defects, hardenability and other metallurgical parameters
- Hardness testing, determining tensile strength, yield strength and elongation, component testing and other technical parameters
- Metallurgical examinations
- Support in the development of specifications for materials, testing and heat treatment
- Ultrasonic immersion testing service (e.g., complete rings, rollers)

Field performance analysis

- Bearings performance assessment and other components (e.g., housings, camshafts) from production, rig tests or field returns
- Metallography and material testing
- Microanalysis of particles and bearing contamination, reaction layers and coatings
- X-ray diffraction (XRD) based material response analysis of bearings from rig tests or the field to identify the mechanism and progress of material loading
- XRD to measure levels of retained austenite
- Material and technology consultancy

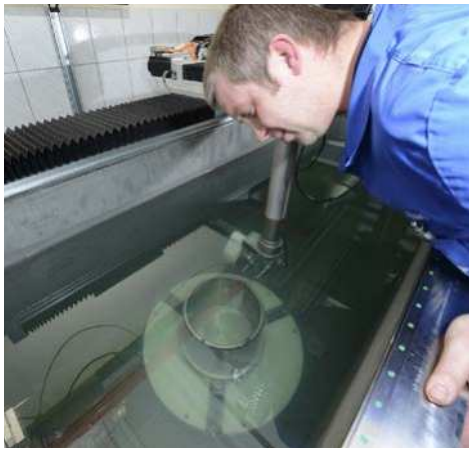
Chemistry

- Evaluation of physical and chemical properties of lubricants, polymers and seal materials
- Grease and oil testing to determine remaining grease life and levels and types of contamination
- Elemental analysis of materials
- Testing the chemical composition of metals by optical emission spectrometry, inert gas fusion or combustion methods
- Evaluation of preservatives and coatings
- Compatibility testing of lubricants, polymers and seal materials
- Cleanliness assessment of lubricants and bearings, including particle counting and gravimetric investigation

Scanning electron microscope

Material samples preparation

X-ray diffraction aparatus



Ultrasonic testing

Innovation and Research & Development: moving towards the future of mobility

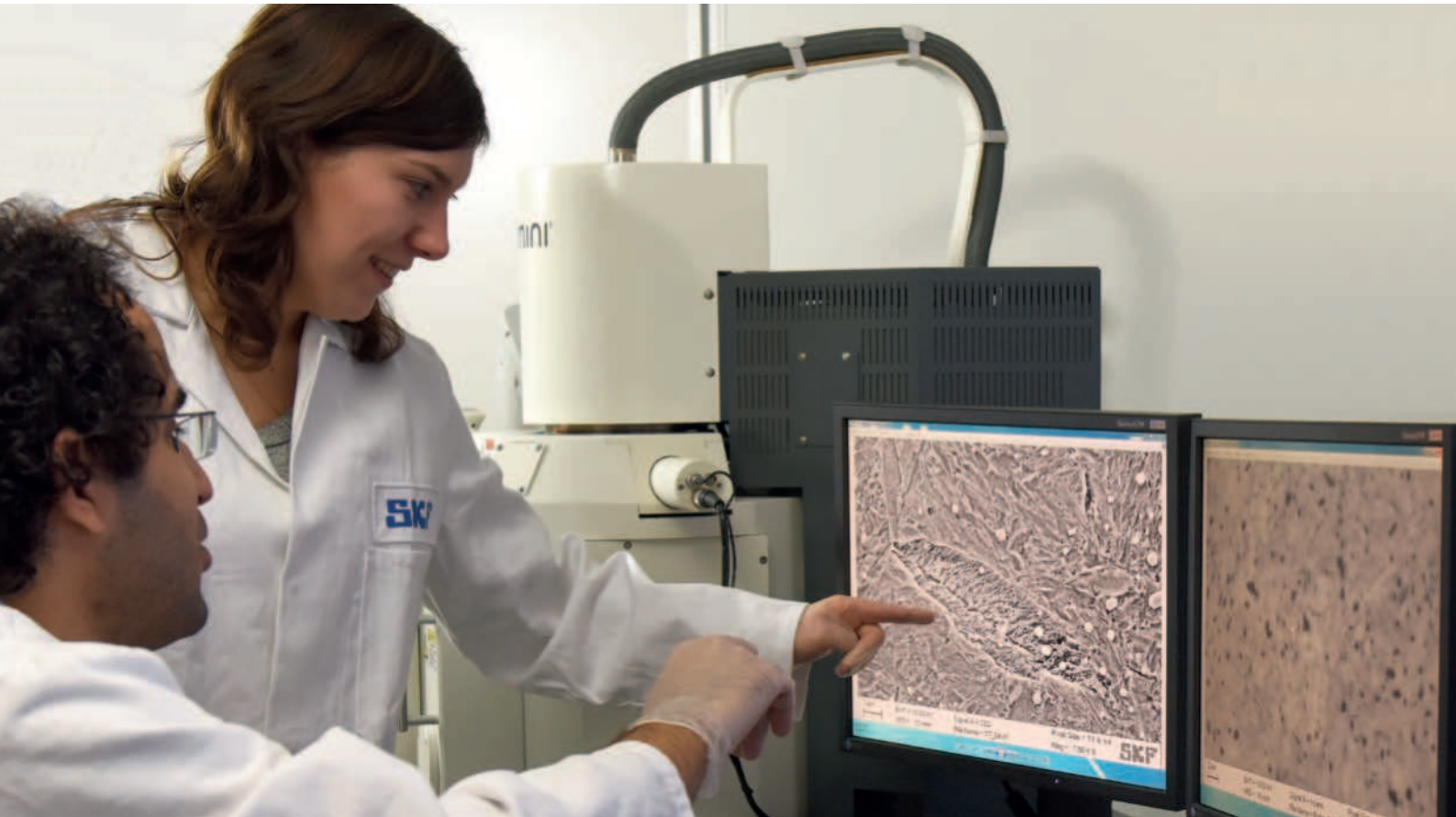
Innovation in product design has been an important driving force behind SKF's leadership in this field. SKF has pioneered every major advancement in wheel bearing technology. Traditional drivers such as life, stiffness and cost remain as important as ever. In addition, an increasing focus is placed on the reduction of weight and friction. Both are important to reduce the fuel consumption of conventional vehicles as well as to increase the range of battery electric vehicles. The silent operation of electric vehicles also means an increasing attention to bearing noises and this is an area where SKF is strong with its in-house developed modelling and simulation as well as testing capabilities.

Our Research & Development (R&D) efforts continue to look for ways to reduce weight and friction by incremental measures such as the optimization of flange geometry, raceway profiles and the application of low friction coatings. At the same time, we look for more radical ways to address future needs, for example by the application of advanced materials such as aluminium and polymer composites.

Load sensing capability of bearings is an area of special interest for SKF. An intelligent wheel bearing provides the data that is used for an accurate real-time estimation of the road/tyre friction. This information in turn can be utilized by the vehicle control unit for increasing vehicle performance or for enhancing safety in braking and cornering manouvers.

Automonous vehicles present their own unique requirements. One example is the need for high definition encoders that enable a very precise and accurate measurement of the wheel angle position at low speeds to improve vehicle positioning during low speed manouvres, such as parking. Autonomous vehicles in a car-sharing environment may lead to a substantial acceleration of the vehicle's mileage accumulation and this presents the need for improved life performance.

Our R&D teams continue to bring innovation to our wheel bearing products and keep SKF at the forefront of this field.



Product and Application Engineering

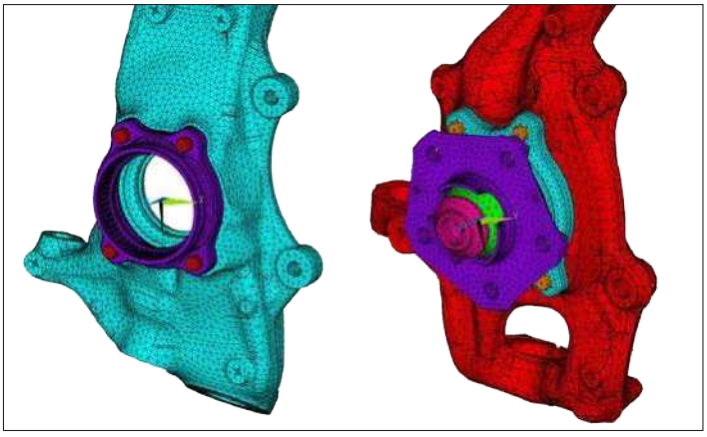
SKF provides engineering support throughout the entire HBU development process using advanced calculation and design tools. Our HBU calculation tools and methodologies have been developed to help predict bearing performance and behavior without the need to build prototypes and carry out expensive tests.

These tools are used to:

- Verify compliance of the HBU design to customer requirements
- Support the decision making process during design changes

Our primary calculation software includes:

- SimPro Expert: SKF developed software for bearing life calculation
- Ansys: for stress analysis by FEM
- PC-hub: SKF developed software for clearance reduction



CAD models of HBUs are developed internally using CAD/CAE software and can be exported to any required 3D format. SKF engineers also make use of the complete Design for Six Sigma toolbox, including Kano analysis, DFMEA, Design of Experiment and Basic Statistics.

We recommend contacting the SKF Application Engineering Department for any support and further information.

World-class hub bearing units manufactured worldwide

At SKF, we meet the individual needs of our customers with an optimal combination of standardized processes and set-ups for increased flexibility. Our lean manufacturing offers high efficiency with reduced waste, and we provide great flexibility in volume and bearing type per channel.

The SKF wheel end HBU manufacturing footprint includes eight production sites worldwide that produce the full range of SKF HBU solutions. Facilities are located in:

- Puebla, Mexico
- Cajamar, Brazil
- Tudela, Spain
- Airasca, Italy
- Pune, India
- Jakarta, Indonesia
- Shanghai, China
- Busan, South Korea

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