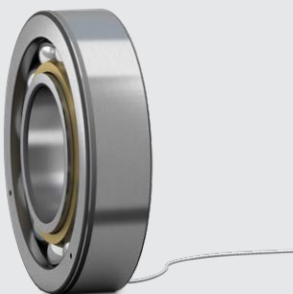
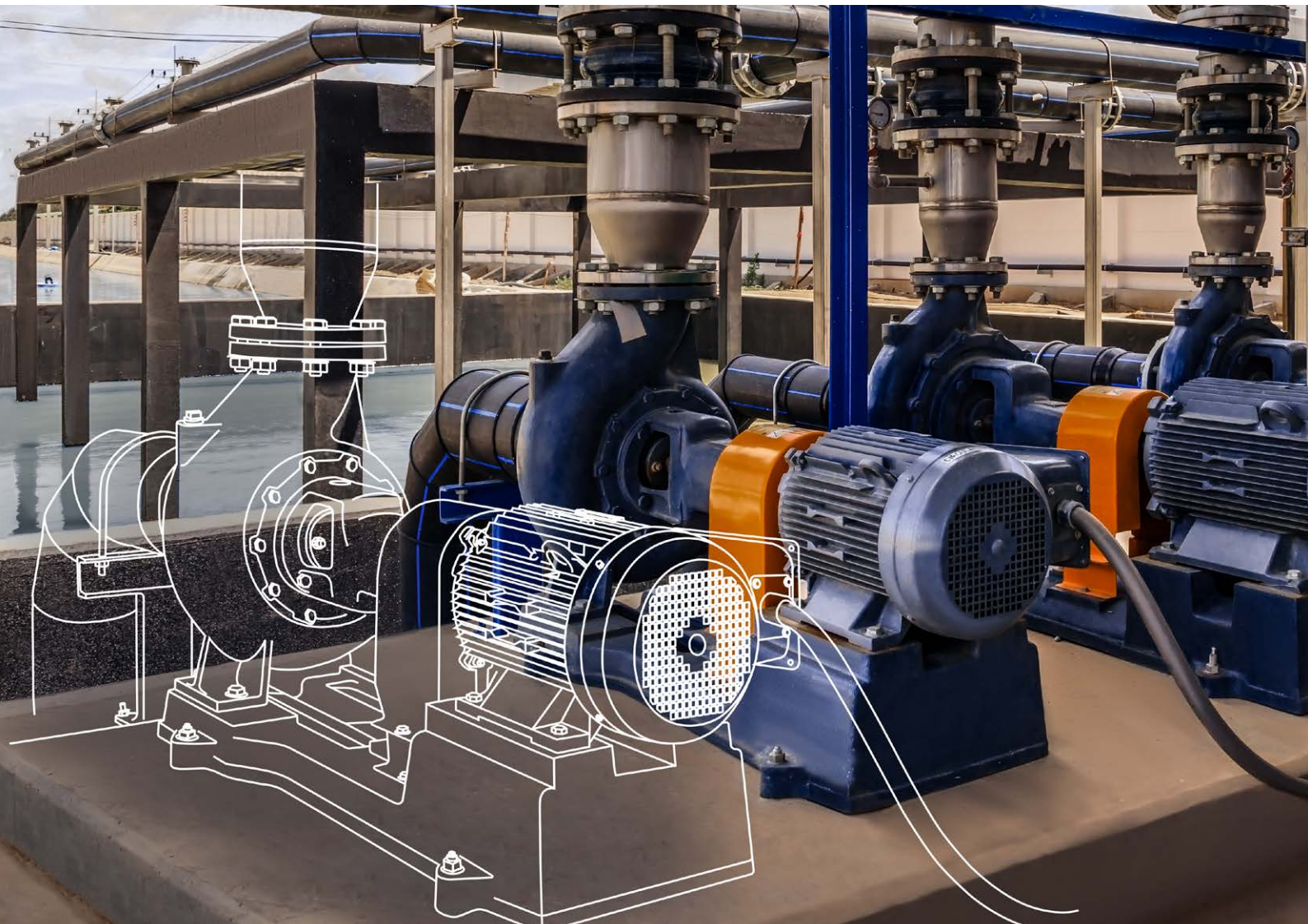
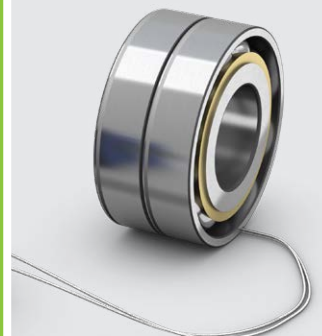


SKF Load Sensing Bearings – for pumps and compressors

Real-time load, speed and temperature sensing with fiber optics



Optimize pumps and
compressor design with
fiber optic load sensing
bearings



No guesswork. Shorter time to market.

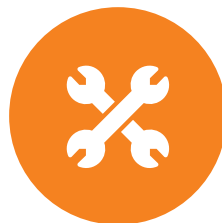
With the SKF Load Sensing Bearings – for pumps and compressors you get:



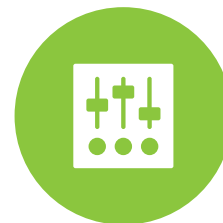
Lower cost for new products



Reduced time to market



Better product development decisions



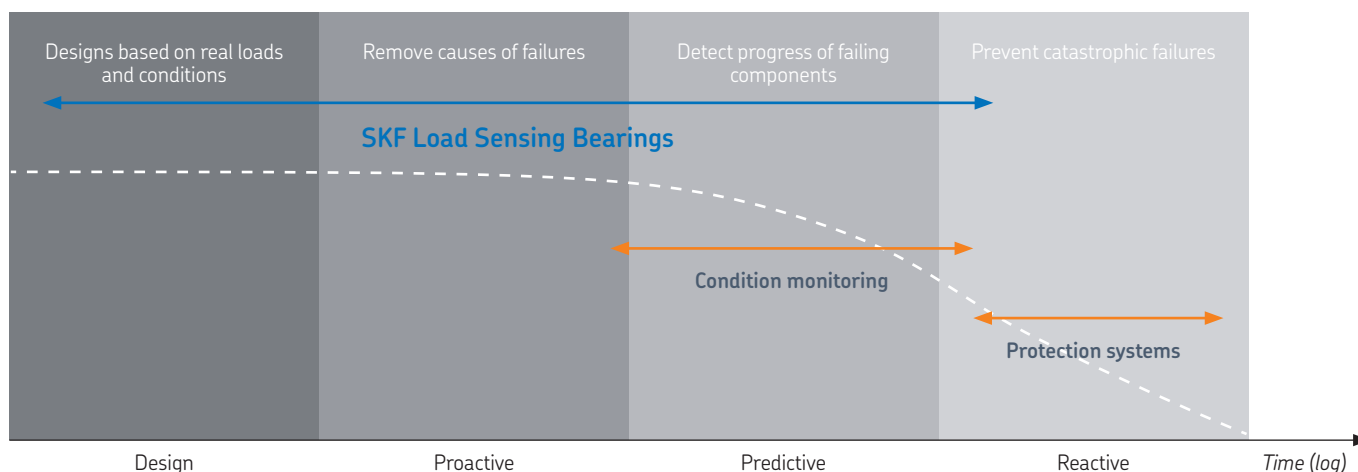
The possibility to digitalize your design, development and verification phases

Verify designs with load sensing

Shorter technology life cycles together with higher demands on throughput and sustainability can create a frustrating reality for engineers working with pumps and compressors. With the SKF Load Sensing Bearings – for pumps and compressors you can now limit guesswork and assumptions. It allows for verifying design and real time performance by creating a “digital twin”.

Since the bearing is the machine element that absorbs shaft loads, knowing bearing loads is essential in the design and development of rotating equipment such as pumps and compressors. By integrating a fiber optic sensorized bearing in the equipment being designed, the SKF Load Sensing Bearings – for pumps and compressors allows engineers to analyze bearing loads, strain spectra and load distribution, speeds (shaft and cage), temperatures, lubrication and more in real time.

SKF Load Sensing Bearings: Enabling online load analysis and closed-loop process control



This is how it works

The SKF Load Sensing Bearings system for pumps and compressors consists of a range of fiber optic sensorized bearings with fiber Bragg grating, an interrogator unit and a computer with the proprietary SKF Optomonia software for data collection and analysis, as well as data import and export.

The data collected can be refined, integrated and correlated with other test results and set-ups to draw quick and accurate conclusions about the performance of your design or prototype. By measuring real bearing loads (i.e. no assumptions or theoretical models), manufacturers of rotating equipment can design more optimized products, cut the testing, verification and product development cycle, and limit warranty and liability risks.

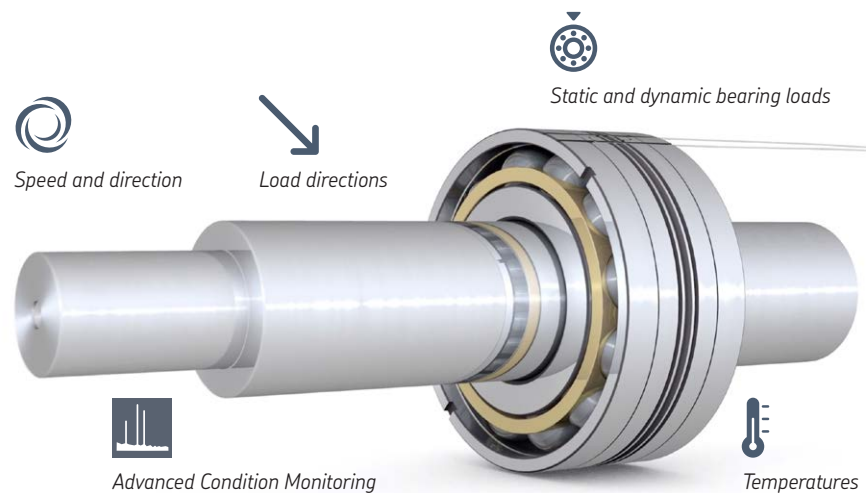
A wealth of information

The SKF System generates a wealth of new information about the tested equipment, which increases your understanding of the dynamic behaviour of the machine. In addition to supplying and supporting the SKF System, SKF can support you with advanced engineering services to assist data analysis and design process.

The system is initially made available for centrifugal pumps and oil flooded screw compressors with single row angular contact ball bearing designs according to API 610/ISO 13709 and 619/ISO 10440-1 (typical-shaft size 60 to 100 mm).



A direct link to the heart of the machine



The core of fiber optic sensing technology

SKF uses the fiber Bragg grating (FBG) method utilizing the precise reflective effect of a grating written in the core of an optical fiber. The grating is manufactured using direct writing by a special laser. This makes it possible to monitor the strain seen in the specific location caused by a local temperature or stress field.

An optical strain gauge

The FBG basically acts as an optical strain gauge. The sensing is done by sending in

light from a broadband light source into the fiber in which the FBG returns a specific wavelength via Bragg reflection. This reflection change in wavelength is according to how the strain changes the optical path length of the period within the FBG.

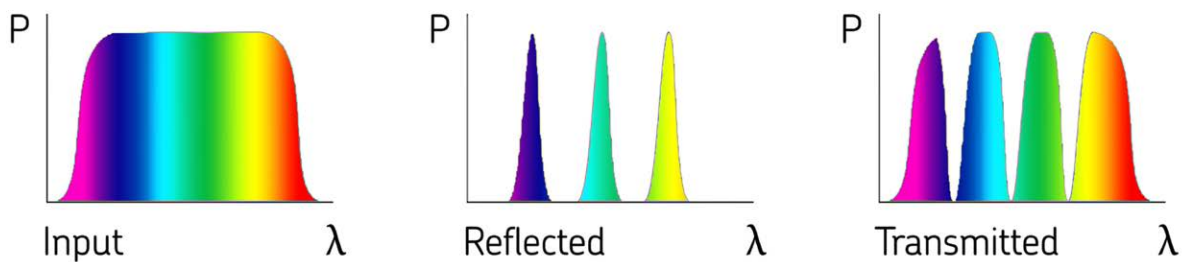
Simultaneous measurements

With a broad light source, it is possible to simultaneously measure a large number of FBGs in a fiber. These strain readings can be done at very long distances up to or above 10 km.

The FBG method is a well-established sensing technology. In practice it can measure most physical properties that can be transferred to strain. This has enabled for example force, temperature, vibration, pressure, viscosity, chemical, humidity, corrosion and current FBG sensors to be invented and demonstrated (contact SKF for a technical reference article if required).

Principle of fiber Bragg grating

Sensing: Strain, Load, Temperature



Benefits and features

The SKF Load Sensing Bearings – for pumps and compressors adds value in the laboratory, test and quality assurance environments. By basing designs on measured bearing loads and by verifying and clarifying assumptions and theoretical models, unnecessary costs relating to specifications, tolerances and material can be avoided.

By getting real-time bearing load feedback on a specific design or prototype under test the design cycle can be made shorter. The system can also help to further optimize the design and reduce the cost of product development. It can also play a significant part in the commissioning of new, upgraded and serviced products.

Data can be followed in real time in the SKF Optomnia software or exported to other software for further analysis, integration with other data sets using time stamps, etc.

High frequency strain spectra for advanced condition monitoring

In addition to acquiring and recording robust values of data, the system can also record high frequency strain spectra and polar plots using this data. High frequency strain spectra analysis basically uses the same fast Fourier transformation (FFT) methods as applied in conventional vibration analysis. However, the number of sensors is higher and positioned closer to the source. The sensors are also without interfaces as they are mounted in the outer ring of the bearing.

Powerful tools for new and unique insights

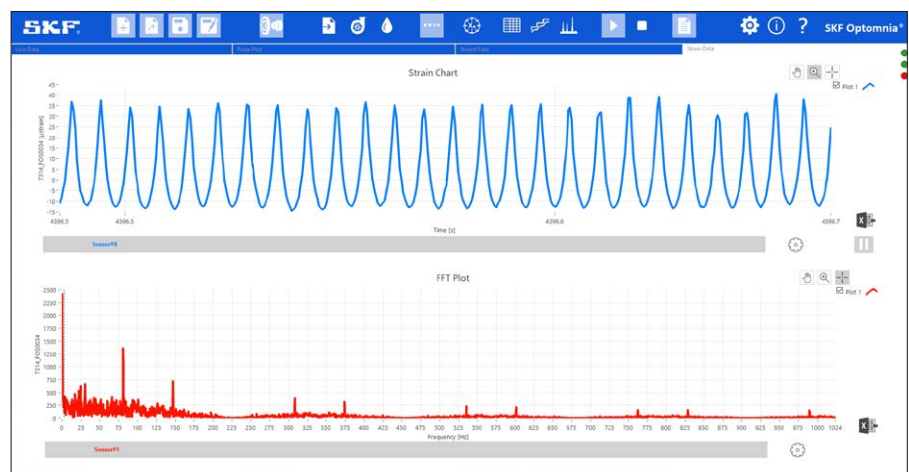
The high frequency strain spectra are recorded at 25 kHz from a selected FBG sensor one at the time. Any FBG sensor within the bearing can be selected. The data is typically plotted as strain pulse for individual rolling elements, FFT analyzed to strain spectra (similar to vibration spectra) or plotted in polar strain plots using the SKF Optomnia software program. High frequency

Parameter	Description
Axial load and direction	F_a (kN) and: 0° (drive direction) or 180° (hydraulic direction)
Radial load and direction	F_r (kN) and: $0^\circ \rightarrow 360^\circ$
Speeds	Load pulse generated: $r/\min_{\text{shaft}}$ FFT generated: $r/\min_{\text{cage}}$ RPM ratios (detection of bearing skidding)
Temperatures	Actual operating temperature ($^\circ\text{C}$)
Polar strain plots	Strains around the bearing ring for shaft alignment etc.
High frequency strain analysis	FFT spectral analysis on strain signals instead of vibrations
Estimated lubrication condition (ISO)	Viscosity ratio

strain spectra and strain polar plots are powerful tools and important complements to the recorded parameters for the advanced user. These data can provide new and unique insights into the behavior of the rotating equipment under test.

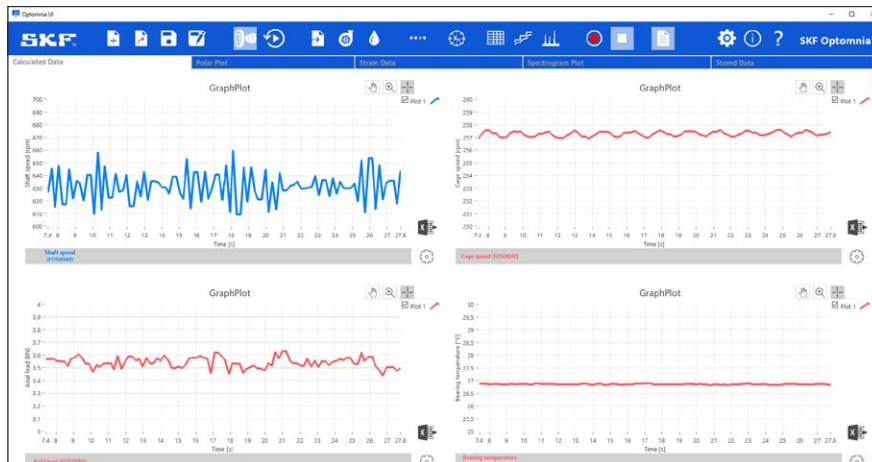
These unique methods may give significant contributions in the analysis of:

- Shaft deflection and misalignment at running conditions
- Cavitation
- Seal behavior and wear
- Poor lubrication conditions
- Dynamic loads e.g. unbalances

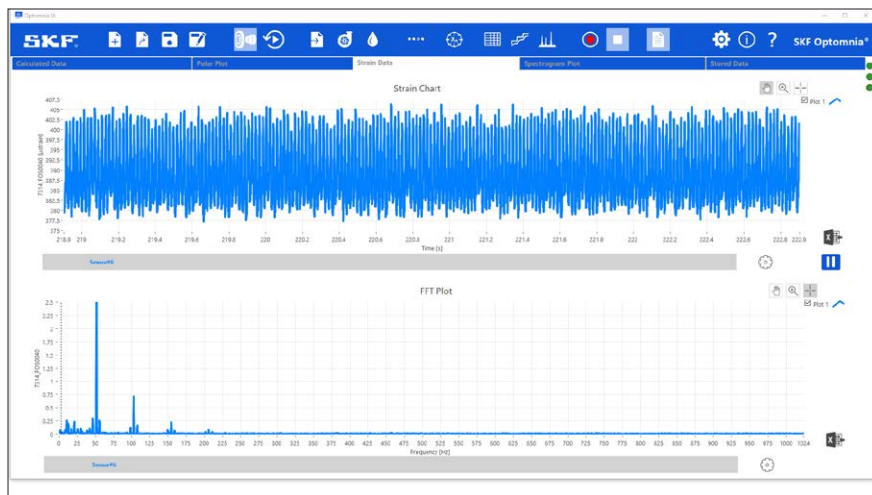


In-depth analysis

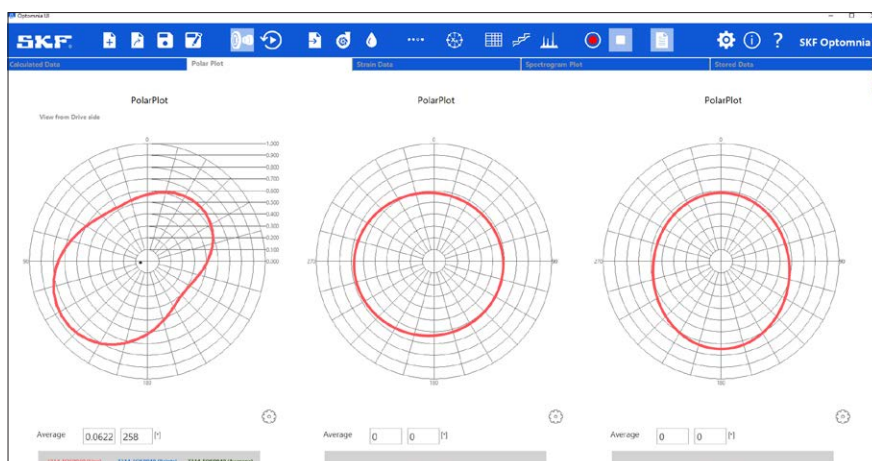
The SKF Optomنيا software gives extensive possibilities for in-depth post analysis within the software itself or in your own programs by using the results.



Follow live at 5 Hz your various forces, temperatures, lubrication and speed parameters, or by using post-processing, at up to 250 Hz. Find the main axial, radial and cyclic forces, such as unbalances, within your equipment.



Follow live how the strain patterns of the individual rolling elements develop in your tests vs. conditions by analyzing the strain pattern in itself, FFT processed or in FFT spectrograms.



See the strains develop within the bearing using the polar strain plots. It enables you to tune your design, optimize process settings and adjust the alignment of your machine when it is running.

SKF Optomnia Software

Setup of measurements

File handling:

Raw data files
CSV or TSV files

Documentation:

Test protocol
Equipment
Lubrication
Report generation

Setup support for:

Reference angle
1-4 SRACBBs
Single
Face-to-Face
Back-to-Back
Tandem
Check of fiber optic connections

Visualization:

5 Hz, real time
1 to 250 Hz post-processed

Strain measurements:

2.5 kHz, all FBGs
25 kHz, single selected FBG per bearing

Setup support for:

Dashboard data
Polar plots
Trend plotting
Ball pass strain plots
FFT strain and force plots
FFT spectrograms

Measurements

Axial load

Axial load, Standard deviation
Direction

Radial load

Radial load, Standard deviation
Radial load direction

Bearing temperature

Cage speed (ball passes)

Shaft speed (FFT speed)

FOS measured ambient temperature (to be introduced)

DeltaT (to be introduced)

Kappa conditions (derived)

Direction of rotation

Plotting

Live plots of variables (5 Hz)

Post plots of variables (1-250 Hz), or maximum at ball pass frequency.

Polar plots of FBG strain with bearing, real time

Plot
Off center angle direction
Off center value

Ball pass strain plot

Fast Fourier Transformation (FFT) plots

Strain
Strain spectrogram
Force
Force spectrogram

System overview

System description

The SKF Load Sensing Bearings system for pumps and compressors consists of bearings with fiber optical sensors, fiber optic cables and connectors, an Interrogator, and a computer with the pre-installed SKF Optomnia software.

Fiber optic sensor bearings

The system includes a range of load sensing bearings, i.e. sensorized angular contact ball bearings in so-called: back-to-back (API 610 centrifugal “pumps”); face-to-face (API 619 oil-flooded “compressors”) and tandem (“load sharing”) arrangements. A range of Load Sensing Bearing Angular Contact Ball Bearings from 7312 to 7320 are available.

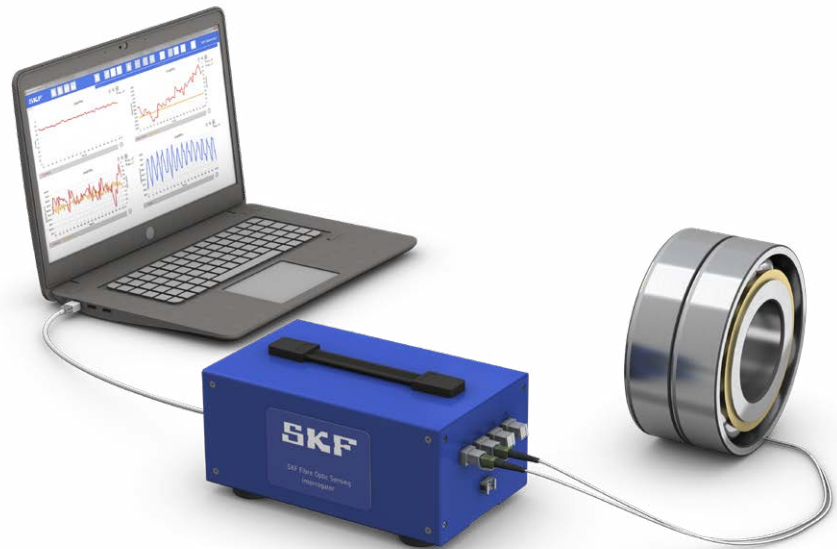
The SKF Load Sensing bearing comes with a fiber optic connecting cable and dowel pins for location.

Interrogator unit

The interrogator contains the optical transmitter/receiver and the computer control for steering and translating optical wavelength measurements to strain signals. It contains four ports for bearing signals. Communication ports for upgrades are well protected and can be accessed by sliding out the cards.

SKF Optomnia software and computer

The software is uploaded on a computer selected by SKF with the right performance for easy start-up and installation.



Fiber optic cables and connectors

The connecting cable from a SKF Load Sensing bearing is connected to the interrogator using a fiber optic connector and patch cord. The patch cord can virtually be of any length. The interrogator may therefore be placed in a controlled environment. The cabling requires feedthroughs for a non-pressurized casing (pumps), or through a pressurized casing (compressors) using gland type designs (not provided by SKF but advice can be given of suitable types).

The SKF System also includes a service kit for cleaning of fiber optic connectors and minor repairs.

System set-up and operation

Data extraction is tailor-made for each test set-up using a user-friendly software application. Examples from the preliminary set-up screen can be seen on page 6.

The SKF System can be used as a stand-alone program. Data can also be exported and used in other systems or software, to allow easy correlation and integration with other measured data sets. Recorded data is time stamped and saved as both raw data and processed data.

SKF services and support

System installation, commissioning and training

SKF will provide on-site support to assist the initial installation and commissioning of the system, as well as hands-on training. The training will be conducted by SKF subject matter experts with different training elements available for test rig operators, installers and advanced users.

The system installation, commissioning and training can be customized and normally include:

- First installation and mounting of hardware (SKF Load Sensing bearing, hardware, cables)
- Commissioning of installed system
- Start-up of system and setting of initial test parameters
- Training covering system operation, handling and maintenance

SKF Service Plan

The SKF Service Plan offered for the SKF Fiber Optic Sensing system includes access to SKF FOS online support service and software upgrades.

SKF advanced engineering services

The SKF System generates a wealth of new information about the tested equipment, which increases the user's understanding of the dynamic behavior of the machine.

The data provided by the SKF System frequently raises questions about the dynamic behavior of the tested equipment that require further analysis. SKF can support customers with advanced engineering services to assist data analysis and the design process.

Rotating Equipment Performance

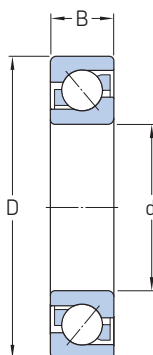
Whether you want to solve a specific rotating equipment problem, increase your plant and equipment performance, or improve your overall maintenance strategy and efficiency, SKF is your partner. With access to unique application insights, together with the right products, connected technologies and solutions, we can help you get the performance you want from your rotating equipment.

Speak to us and we can help identify your key areas for maximizing savings and improvements, and give you access to the latest connected technologies and services without the need for large capital investment. With different service levels to choose from, you can either maintain a product-based purchasing approach (for a fixed fee) while seeing the benefits of improved performance or evolve to a performance-based approach (for a fixed monthly fee) and remove many of the risks.

If you want to know more visit skf.com/REP

Single row angular contact ball bearings, Fiber optic load sensing bearings (basic range)

d 60-100 mm



Principal dimensions ¹⁾²⁾			Designation ³⁾ FOS Universally matchable bearing with universally routable connecting cable	Designation ³⁾ Universally matchable bearing with axial grooves for transfer of connecting cables (note: bearing not FOS equipped)
d	D	H		
mm			–	–
60	130	31	ZL 7312 BECBM/1	ZL 7312 BECBM/2
	130	31	ZL 7312 BEGAM/1	ZL 7312 BEGAM/2
65	140	33	ZL 7313 BECBM/1	ZL 7313 BECBM/2
	140	33	ZL 7313 BEGAM/1	ZL 7313 BEGAM/2
70	150	35	ZL 7314 BECBM/1	ZL 7314 BECBM/2
	150	35	ZL 7314 BEGAM/1	ZL 7314 BEGAM/2
75	160	37	ZL 7315 BECBM/1	ZL 7315 BECBM/2
	160	37	ZL 7315 BEGAM/1	ZL 7315 BEGAM/2
80	170	39	ZL 7316 BECBM/1	ZL 7316 BECBM/2
	170	39	ZL 7316 BEGAM/1	ZL 7316 BEGAM/2
85	180	41	ZL 7317 BECBM/1	ZL 7317 BECBM/2
	180	41	ZL 7317 BEGAM/1	ZL 7317 BEGAM/2
90	190	43	ZL 7318 BECBM/1	ZL 7318 BECBM/2
	190	43	ZL 7318 BEGAM/1	ZL 7318 BEGAM/2
95	200	45	ZL 7319 BECBM/1	ZL 7319 BECBM/2
	200	45	ZL 7319 BEGAM/1	ZL 7319 BEGAM/2
100	215	47	ZL 7320 BECBM/1	ZL 7320 BECBM/2
	215	47	ZL 7320 BEGAM/1	ZL 7320 BEGAM/2

FOS ACBBs of the ISO 73-series with larger bore size (d) than 100 mm may be requested, other ISO series, bearing designs and dimensions may be suitable for FOS (contact SKF for information).

1) The principal dimensions and tolerances of the base bearing (e.g. 7312 BECBM) and the FOS equipped bearing (ZL 7312 BECBM/1) are the same (see the base bearing in SKF Bearing Catalogue for details on dimensions and tolerances).

2) Request SKF proposal drawings for more details regarding design, locations and dimensions of:

- a. the connecting cable including the connectors;
- b. the egresses design of the universally routable fiber optic connecting cable of FOS bearing (.../1 design);
- c. the axial transfer grooves of an adjacent none FOS bearing (.../2 design);
- d. the locating pin with clamp; and
- e. the anti-rotational slot.

3) Designation details:

- ZL** Fiber optic sensing equipped bearing. Sensing with a fiber optic cable, "multi-purpose" sensor where the sensing variables depend on the analyzing software in use.
- BE** Single row angular contact ball bearing with a 40° contact angle. Optimized internal design.
- CB** Bearing for universal matching. Two bearings arranged back-to-back, face-to-face or tandem have normal axial internal clearance. Typical used in back-to-back centrifugal pump arrangement according to the standards API 610 and ISO 13709.
- GA** Bearing for universal matching. Two bearings arranged back-to-back, face-to-face or tandem have light preload. Typical used in face-to-face oil-flooded screw compressor arrangement according to the standards API 619 and ISO 10440-1

M Machined brass cage, ball centered

PH Glass fiber reinforced PEEK cage, ball centered (not in standard range, may be requested).

HC5 Rolling elements of silicon nitride ceramic (not in standard range, may be requested).

/1 Shortening suffix for ZL bearings and referring to the V-Number on the inner ring VU2901. FOS equipped bearing with universally routable connecting cable with a length of 1.5m.

/2 Shortening suffix for ZL bearings and referring to the V-Number on the inner ring VU2902. Bearing, without FOS sensing, capable of axially transferring two connecting cables from adjacent located FOS equipped bearings.

Other components and software:

Component	Designation / Order number	Comments
SKF Optomnia® software	FOSLX 00001/1	Version 01. Designed to work together with the SKF interrogator unit. New versions will be released when available.
Laptop PC	FOSLZ 0xxxx/yy	PC capable of running the SKF Optomnia® software and communicating with SKF interrogator unit at the required speeds. The software is normally pre-installed. Contact SKF for order details and location of use.
SKF standard ethernet cable	FOSLR 00001/2	Cable connecting PC with SKF interrogator unit.
SKF interrogator unit	FOSEP 00001/1	Designed to work together with the SKF Optomnia® software.
SKF standard patch cable (transport cable)	FOSLR 00001/1	5 m other lengths at request. Cable connecting SKF interrogator with SKF FO junction box. Lengths up to several km (miles) possible to be used and to be delivered. Contact SKF for advice.
SKF fiber optic junction box	FOSEE 00001/1	Box connecting and collecting the connecting cables of FOS bearings with the patch cable.
Assembly tool, arrangement and connecting cables carrier	FOSMV 0xxxx/yy	For more robust and secure mounting of FOS bearings. Contact SKF for order details of specific bearings and arrangements.
Dowel pin. Split pin.	FOSVD 0xxxx/yy	Contact SKF for order details of specific bearings and arrangements.
Clamp (connector)	FOSZJ 0xxxx/yy	To fixate the dowel pin.

The fiber routing and locking system

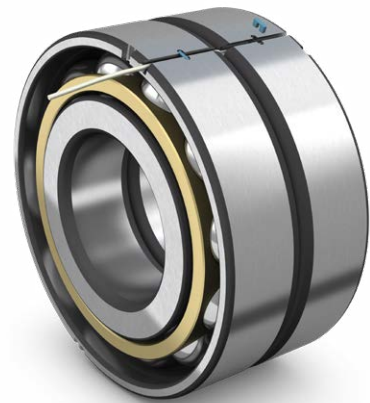
The connecting cable from the bearings may be placed in the groove system of the outer ring to enable transport, back-to-back, face-to-face, tandem arrangements. This design feature enable the bearings to be universal matchable. In addition the transport cable can be guide in the installation in both the face and back directions.



Single bearing in transport mode.



Back-to-back (example of arrangement of two adjacent located bearings)



Fixation of bearings with dowel pin and clamps

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