SCHAEFFLER

We pioneer motion

Caba3D

An Insight into Rolling Bearing Dynamics

Bearinx Simulation Suite – The perfect tools for systems with rolling bearings

Thanks to its state-of-the-art simulation programs, Schaeffler offers the best possible support in the product development process – from the dynamic simulation of an entire drive train, through to the detailed simulation of contact conditions inside rolling bearings. The Bearinx Simulation Suite includes CAE tools that are perfectly suited to the specific requirements of the design.

Simpla

Simpla – system simulation with rolling bearing expertise

As part of the Bearinx Simulation Suite, Simpla provides support in the creation, control, and analysis of complex mechanical system simulations, e. g. wind turbines, in order to help analyze and optimize their dynamic behavior. The focus here is on the interactions between our products and the customer's design. Simpla uses numerous interfaces to combine expertise from software developed inhouse such as Bearinx and commercial programs such as Abaqus, Simpack, and Samcef.
This enables a wide range of simulation methods to be combined with each other.

Bearinx

Bearinx – bearing design with an understanding of systems

Bearinx allows complete gearboxes and linear guidance systems to be modeled and calculated with all the relevant data regarding elasticity, contact rigidity,and environmental influences. The results provided also include loads and the displacement and deformation of all the components. Additional parameters such as rating life, safety factors, pressure curves, and friction vaues are calculated for bearings. Gear teeth are also analyzed with a high level of detail. Data records and calculation models can be easily exchanged with other programs via different interfaces.

Caba3D

Caba3D – a dynamic view inside the bearing

As part of the Bearinx Simulation Suite, the Caba3D MBS software allows a view inside rolling bearings. It enables a precise analysis of the dynamic processes that take place inside a rolling bearing. This means that the movement patterns of the bearing components, the forces acting between them, and the frictional power that is generated can be determined. These results allow statements to be made regarding the minimum load, the risk of smearing, and surface-induced damage. Stresses and damage can be predicted by analyzing the elasticity of cages.

Telos

Telos – where the focus is on contact

The Telos program is the detailed contact simulation within the Bearinx Simulation Suite. Telos considers the lubrication conditions in individual contacts, for example between the rolling elements and the raceway in detail. The effects of surface damage and coatings can thus be analyzed as well. Furthermore, it is possible to specify different input values with a time curve. The input data from a Bearinx simulation model can also be automatically transferred using a special interface.

Caba3D gives us an insight into the dynamic inner world of rolling bearings. The name stands for "Computer Aided Bearing Analyzer 3 Dimensional". Caba3D allows us to analyze and understand the processes that take place inside a bearing. This understanding is fundamental for the development of reliable and energy-efficient rolling bearings.

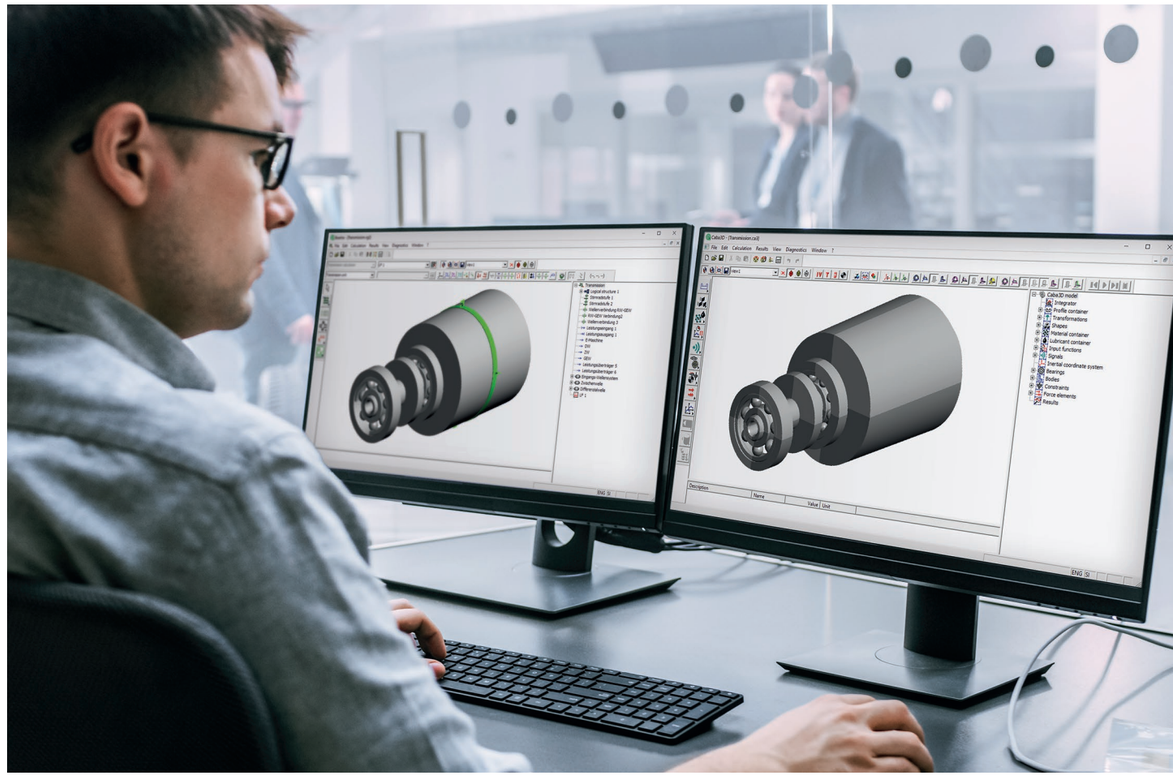
There are no static loads in a bearing

The interior of a rolling bearing is subjected to highly dynamic loads even under a static external load. This is because the location and magnitude of the internal forces constantly change due to the motion of the rolling elements. If external dynamic loads such as vibration, shocks or speed ramps also occur, a quasistatic design according to our Bearinx program, for example, is often no longer sufficient. In this case, dynamic simulation programs with a higher performance capability must be used. In short, a program like Caba3D is required!

A program that grows with the task

Caba3D was specially created for investigating the dynamic processes in the interior of bearings – taking account of complex, time-dependent boundary conditions and the deformation of the adjacent construction.

This simulation program was presented for the first time in 1999 and has been continuously developed by Schaeffler in close collaboration with users. Caba3D thus defines the state of the art in the dynamic simulation of rolling bearings.



Interfaces between Bearinx and Caba3D enable an efficient simulation process

The virtual bearing test rig

Software with rolling bearing expertise

Caba3D is a rolling bearing multi-body simulation program (MBS), which allows a realistic dynamic simulation of all rolling bearings. A decisive special feature of rolling bearings is that the individual rolling elements are only connected to each other via frictionally engaged connections. This means that the kinematics cannot be specified as is the case with gear teeth, for example. In addition, most bearings have a cage for guiding the rolling elements, which does not play an active role in force transmission but is subjected to loads.

In order to map these effects correctly, Caba3D contains – in contrast to conventional MBS programs – a hydrodynamic friction and contact model that has been specially developed for rolling bearings and is based on Schaeffler's technological expertise.

Put to the test on the virtual bearing test rig

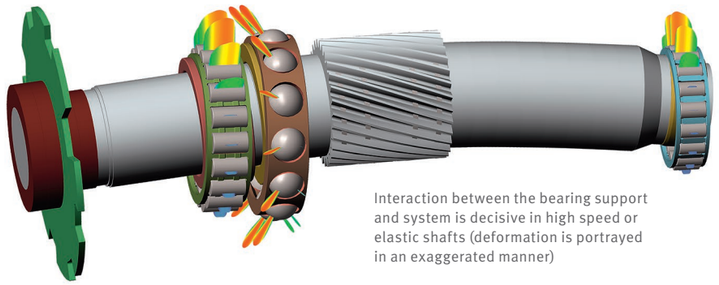
Caba3D is our virtual bearing test rig, which we use to make a quick and precise assessment of targeted modifications at the very beginning of the product development process. This is an economical way to develop the best possible bearing for your application.

Caba3D takes all six special degrees of freedom of each bearing component (rolling elements, rings, cage) into account in the simulation. Guidance functions allow the definition of constraint conditions, which map the motion of a planetary gear bearing or connecting rod bearing, for example. The forces and moments, which act on the bearing and components, can be specified as a constant or time-dependent function.

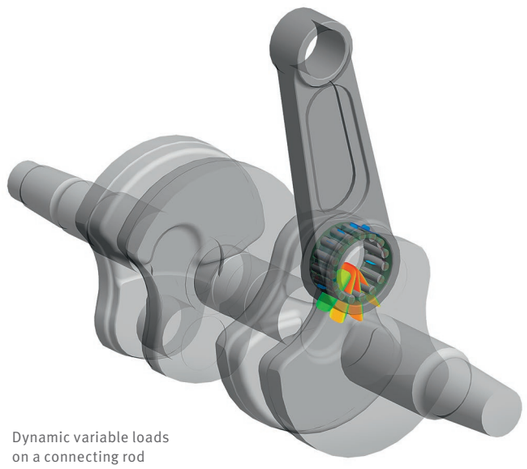
Modeling of rigid or elastic systems

Caba3D can not only be used for simulating individual bearings, but also systems with a number of bearings. This plays an important role if the bearing support and system interact dynamically as in high speed shafts, for example.

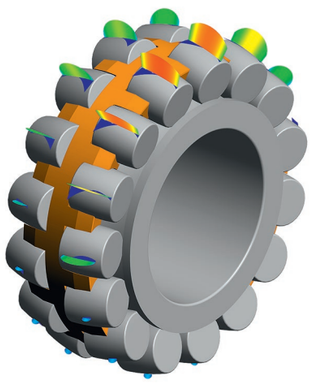
Bearing elements and other bodies can be modeled on a rigid or elastic basis. In the case of shafts and bearing cages in particular, it is important to take their deformation into account for the purposes of the system behavior. The contacts between all the bodies are always regarded as elastic in Caba3D.



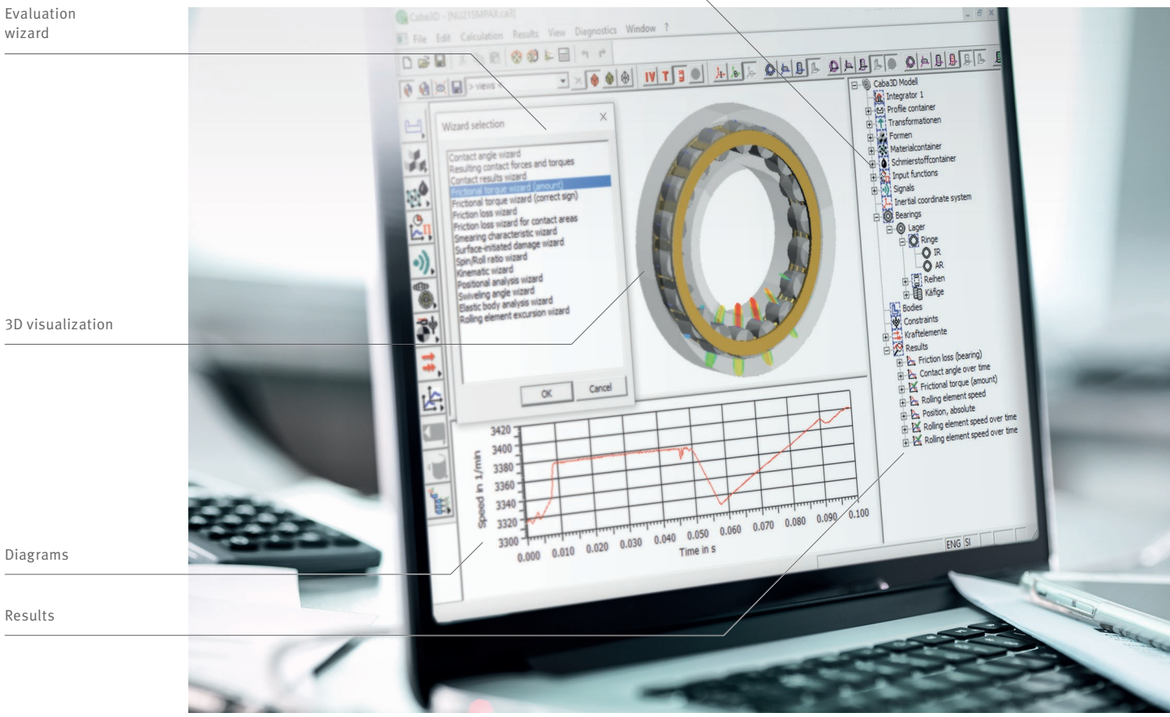
Interaction between the bearing support and system is decisive in high speed or elastic shafts (deformation is portrayed in an exaggerated manner)



Dynamic variable loads on a connecting rod



Spherical roller bearing showing progression of contact pressure and slippage



The graphic Caba3D user interface

Detailed results

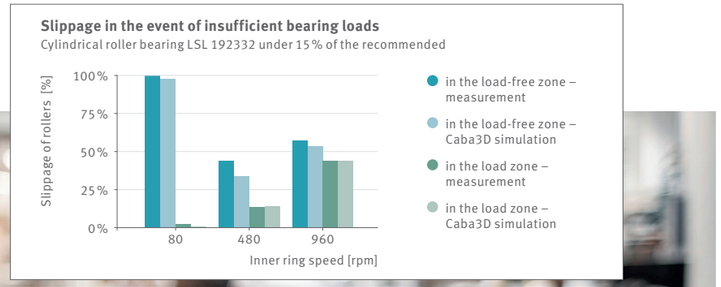
In addition to the kinematics of all bodies, the results of a Caba3D simulation provide us with all the forces and moments, which act on these bodies. Detailed information is also available on the contacts and the conditions in the lubrication gap, such as:

- Pressure distribution
- Lubricant film thicknesses
- Slippage and mixed friction conditions
- Contact power losses
- Failure characteristics

User-friendly interface

There are two options for creating models in Caba3D: Either via a graphic user interface or through an import from other programs such as Bearinx or CAD tools. The Caba3D user interface also offers a wide range of tools for post processing. This allows the results to be displayed as a 2D or 3D diagram. For frequent evaluations, wizards can be used to simplify the creation of diagrams. The results can also be animated in the 3D view and saved as a video. In this way, the motion of the bearing components can be visualized together with the pressures and slippage in the contacts.

Caba3D – A validated tool



Caba3D is validated using tests and FEM calculations

Wide range of results: What interests our customers?

Due to its comprehensive results, Caba3D allows us to answer many questions, including:

- At which contact does the greatest power loss occur?
- Why does the greatest power loss occur exactly there?
- Is sufficient load applied to the bearing or do potentially damaging slippage conditions occur?
- Is there a risk of wear under the analyzed operating conditions?

In addition, Caba3D is the perfect solution for investigating the noise and vibration behavior of rolling bearings. We also use the results from Caba3D as input values for FEM calculations to assess the strength of bearing components. There is also an interface to our Telos contact simulation program. This can be used for analyzing the influence of coatings on the conditions in the contact, for example.

High level of customer acceptance through validation

The validation of calculation programs is a fundamental task, which is of importance for software developers, users, and end customers alike. This applies in particular to a tool such as Caba3D because it generates a wide array of detailed results. We can only ensure that the simulation results and the products that are developed on this basis meet the high requirements of our customers by carrying out a systematic validation.

We have verified the results of Caba3D both in theory and practice for the validation. Firstly, a comparison was made with the results from other calculation programs such as Bearinx, for example. In addition, we carried out a series of bearing tests and used, amongst other things, frictional torque, kinematics, and cage loads as comparative variables.

Proven in everyday practice

The diagram on the left shows a comparison between Caba3D and a measurement on a test rig as an example. It can be seen how slippage of the rolling elements occurs in a bearing that is subjected to insufficient loads (the radial load is only 15 % of the recommended minimum load). There is a very good correlation between the simulation results and the measurements.

Caba3D is also subjected to a continuous comparison with actual applications because we use it every day as a tool for designing our rolling bearings.

With Caba 3D, we have an excellent, validated, and very powerful calculation tool for the analysis and design of rolling bearings for your applications.

Fit for new challenges

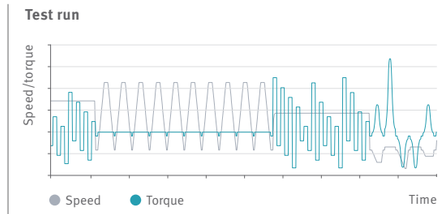
The requirements for rolling bearings in new drive concepts are increasing for fully electric and hybrid drive systems. A key requirement is the suitability for high speeds.

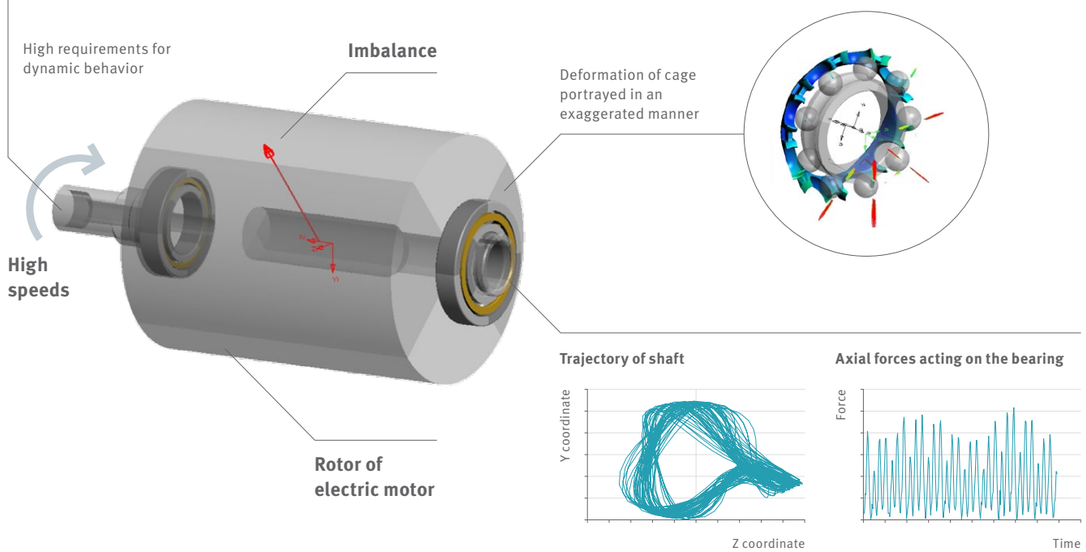
At high speeds, not only is the fatigue life of a rolling bearing often a decisive factor but also the strength of the bearing cage. Furthermore, there are additional loads such as vibrations caused by imbalance or torsional accelerations.

A typical scenario in which high cage loads can occur is shown below. The strong imbalance forces in the upper speed range lead to rapidly alternating radial loads on the rolling bearing. This results in an asymmetrical trajectory of the shaft. The resulting forces acting on the bearing alternate between the minimum and maximum load. A dynamic axial load is also applied to the bearing due to the contact angle. This leads to significant, high-frequency vibrations in an axial direction.

The described dynamic effect results in additional loads on the cage because these vibrations are also transmitted to the cage and the unloaded rolling elements via the rolling elements in the load zone. This effect is in addition to the centrifugal force caused by the rotation of the cage about its own axis, which has a relevant influence at high speed.

Caba3D can map all these interactions between the system and bearings and is therefore fit for new challenges.





Further information

www.schaeffler.de/calculation

Information on other parts of the Bearinx Simulation Suite

SIMPLA – Dynamic system simulation with rolling bearing expertise
www.schaeffler.de/Publication_SIMPLA

Information on other parts of the Bearinx Simulation Suite

Bearinx – High-Level Bearing Design
www.schaeffler.de/Publication_BEARINX

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