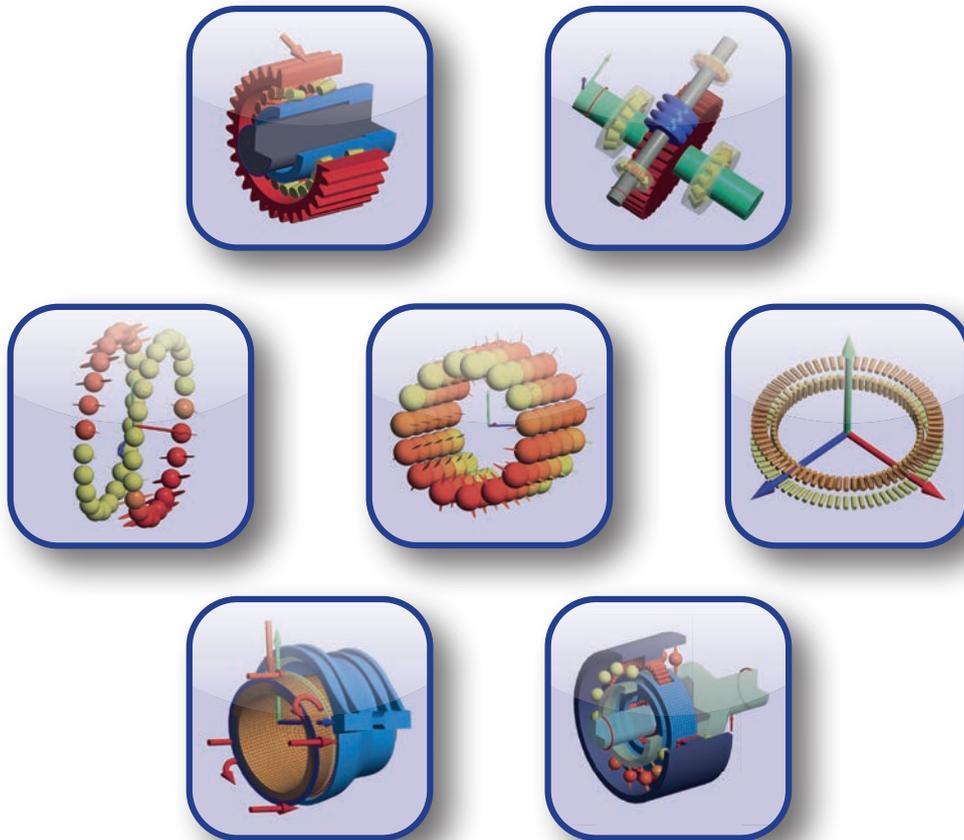


# MESYS

## Calculation software for mechanical engineering



# Calculation software for mechanical engineering

The company MESYS AG in Zurich offers calculation software for mechanical engineering, custom software development as well as engineering services.

## Roller bearing analysis

- Load distribution
- Life according to ISO/TS 16281
- Influence of clearance, tilting angle, centrifugal forces, load spectra
- Track rollers with elastic outer ring
- Parameter variations

## Shaft analysis

- With integrated bearing analysis and nonlinear bearing stiffness
- Strength according to DIN 743
- Natural frequencies
- Coaxial shafts
- Load spectra
- Parameter variations

## Shaft systems

- Coupling of shafts by gear pairs
- Data exchange with gear calculations
- Calculation of rotational speeds
- Natural frequencies at system level
- Load spectra and gear shifts
- 3D elastic housings and planet carriers

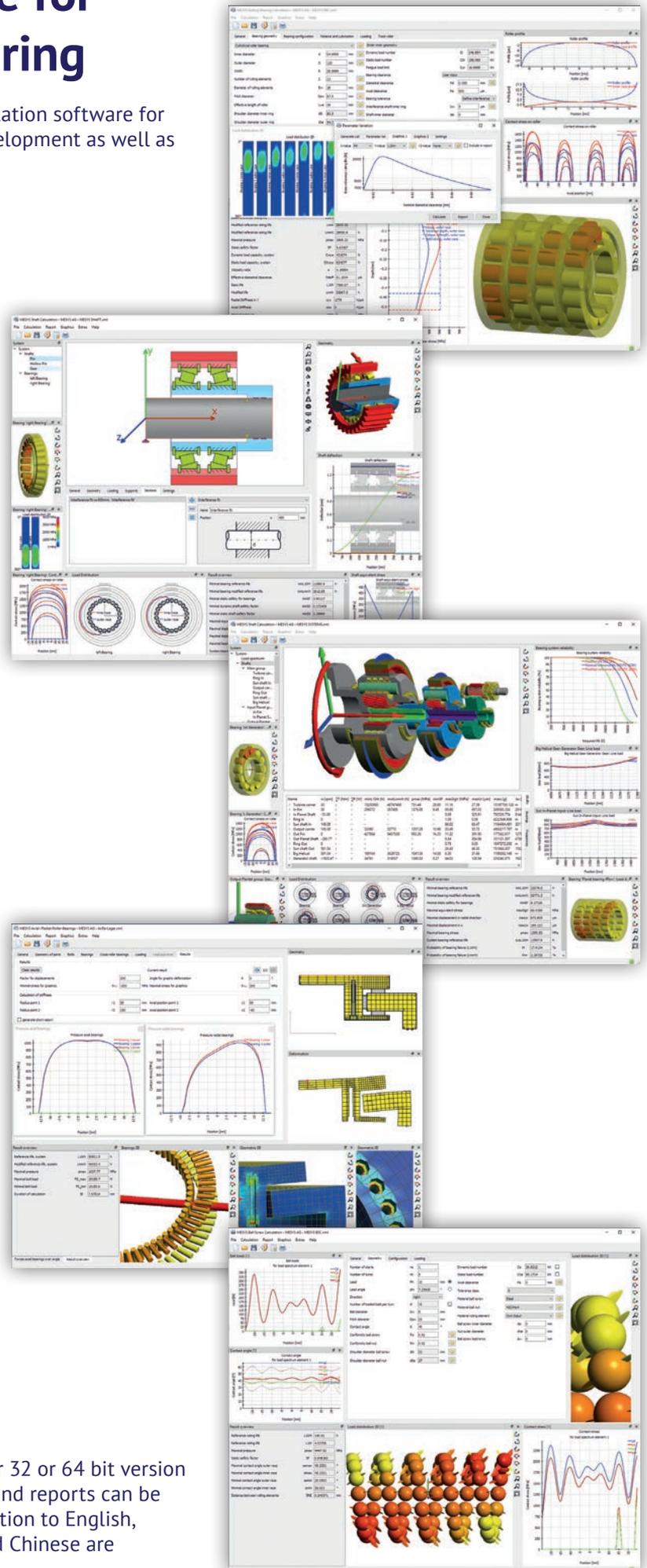
## Axial-radial cylindrical roller bearings

- FEM-based calculation for axial-radial cylindrical roller bearings
- Consideration of the ring deformations

## Ball screws

- Calculation of the load distribution in ball screws under axial and radial loading as well as tilting moment.
- Calculation of life analogous to ISO/TS 16281
- Integration in shaft analysis
- Parameter variations

The software is available for windows in either 32 or 64 bit version as well as for macOS. Both the user interface and reports can be switched between different languages. In addition to English, German, French, Spanish, Korean, Japanese and Chinese are supported.



# Bearing calculation according to ISO/TS 16281

The bearing life calculation according to ISO/TS 16281 (2008) is the latest standardized version of a bearing life calculation. The bearing life is calculated using the load distribution on each rolling element and is therefore not limited to an external force but can also consider tilting moments and the influence of clearance or pretension. For each of the five degrees of freedom either a load or a displacement/rotation can be specified.

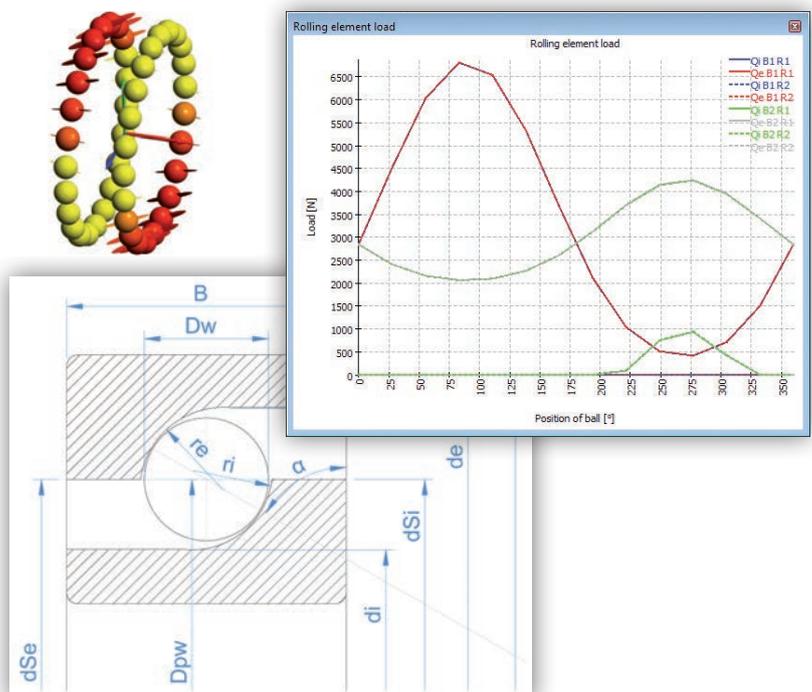
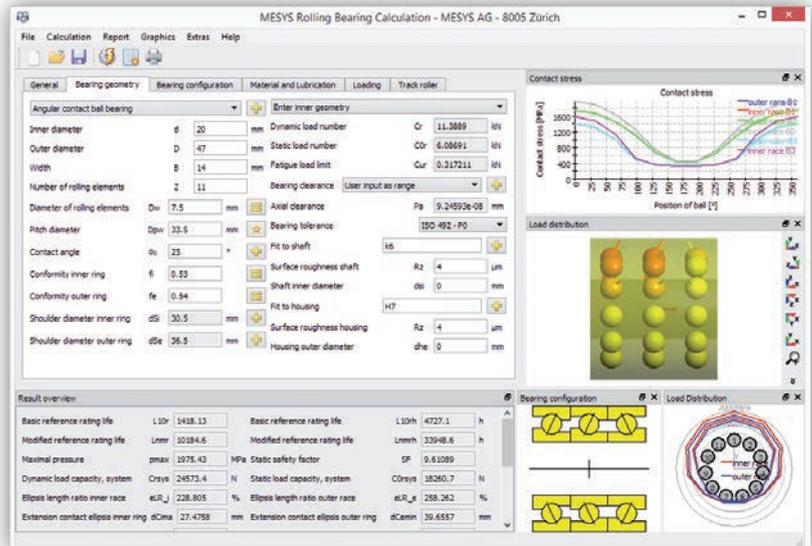
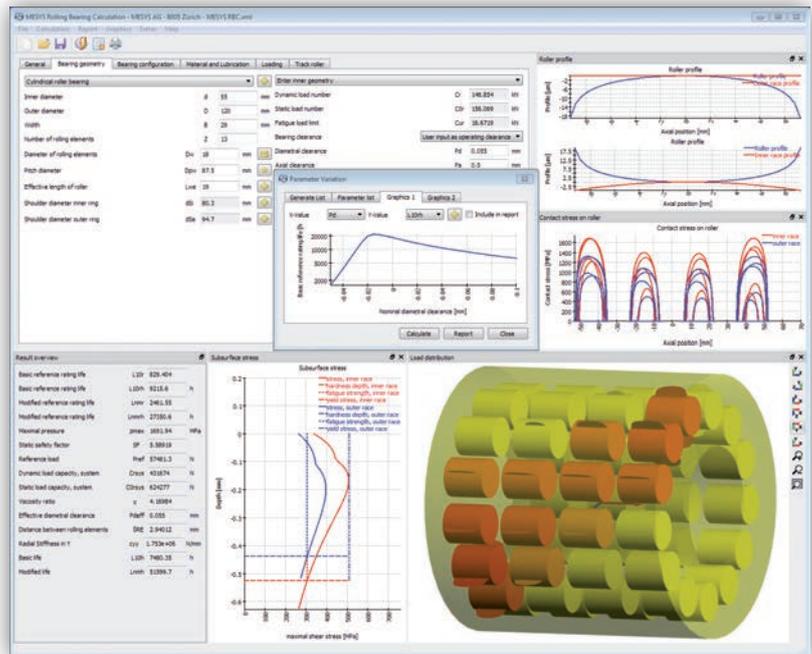
As with the classical calculation according to ISO 281 the influence of the lubricant in the life expectancy can be also considered.

## The software is considering the following effects:

- Bearing clearance
- Change of clearance through thermal effects
- Change of clearance due to fits
- Roller profile
- Centrifugal loads
- Life reduction due to reduced hardness
- Lubricant and Lubricant film thickness
- Load spectra
- Bearing sets (of several bearings)
- Hybrid or ceramic bearings
- Reliability
- Elastic deformations of the outer ring for track rollers as extension module

## As results you will get

- The load distribution in the bearing
- The Hertzian contact stress
- The stresses below the surface for determining the required hardness depth
- The load dependent friction moment for ball bearings
- The contact angle under load
- The displacement and tilting of the bearing
- The minimal film thickness
- The spin-to-roll ratio
- The extent of pressure ellipse
- The load distribution in a set of bearings



## Typical applications

### Single bearing under tilting moment

Generally, the tilting moments are to be avoided on a bearing, but in track rollers or slewing rings the tilting moment can be the main load.

For roller bearings the influence of tilting on the load distribution or life can be checked.

### Sets of angular contact bearing

Angular contact bearings are often used in sets, but the load distribution between the single bearings is difficult to assess. Using the software the load distribution, life and stiffness can be calculated in dependency on the pretension of the bearing set. The pretension can be individually set for each bearing.

This also allows the user to check if the pretension is large enough and whether the bearings get load in each load case or not.

### Influence of clearance and pretension

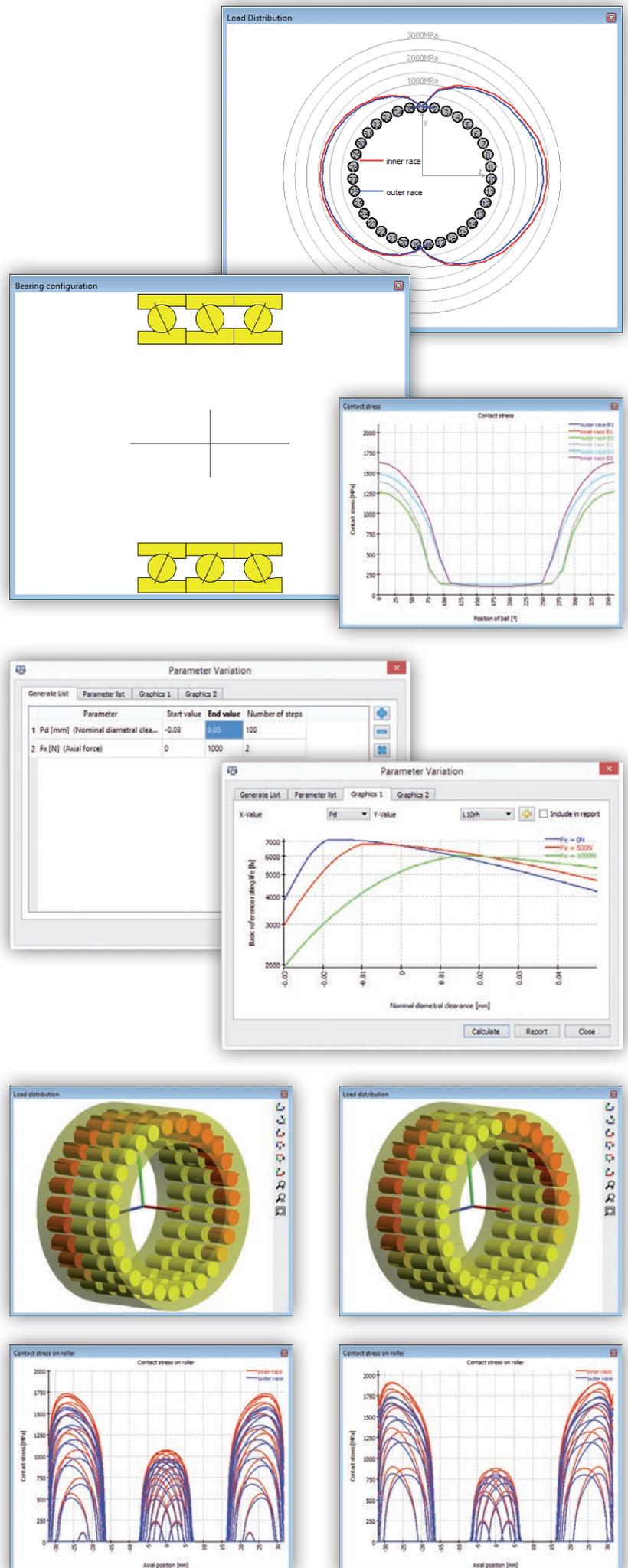
The influence of bearing clearance and pretension of bearing life and load distribution can be evaluated. The change of clearance because of fits, thermal effects, centrifugal loads and optionally elastic expansion determines the operating clearance. With the help of the parameter variation, the influence of the clearance on the bearing life and pressure can be clearly represented.

### High speed

In most instances, the bearing inner race is higher loaded than the outer ring. For high speed this can change because of centrifugal load. The contact angle will be changed too.

### Support of a planet gear using several cylindrical roller bearings

Planetary gears in planet gear sets can be supported using several cylindrical roller bearings. Using helical gears will lead to a tilting moment in addition to the radial load. This tilting moment has to be supported by the bearing set. The bearing clearance has an influence both on the tilting angle, which should be minimal for the gear contact, and on the load distribution within the bearing, in which the tilting should also be avoided. Here an example of the load distribution in a set of three cylindrical rolling bearings with different clearance is shown.

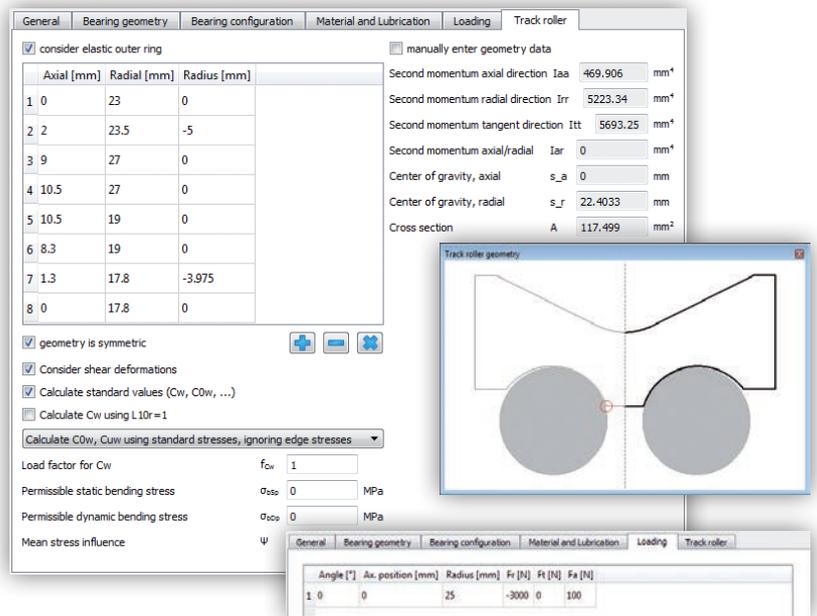


## Specialties for track rollers

In contrast to bearings whose outer ring is supported by the housing, no such support is available for track rollers. The load is introduced on a point on the outer ring. The outer ring is deforming which is also the reason for usually stiffer outer rings as in normal bearings.

The bearings analysis software extension for track rollers allows the definition of outer ring geometry and loading in radial and axial direction on several locations on the outer ring. The load distribution is then calculated considering the elastic deformations of the outer ring.

Multi-row bearings are supported. In the current version an elastic outer ring can be considered for radial deep groove ball bearings, radial angular contact bearings, radial four point bearings and radial cylindrical roller bearings.



### Effective load capacities

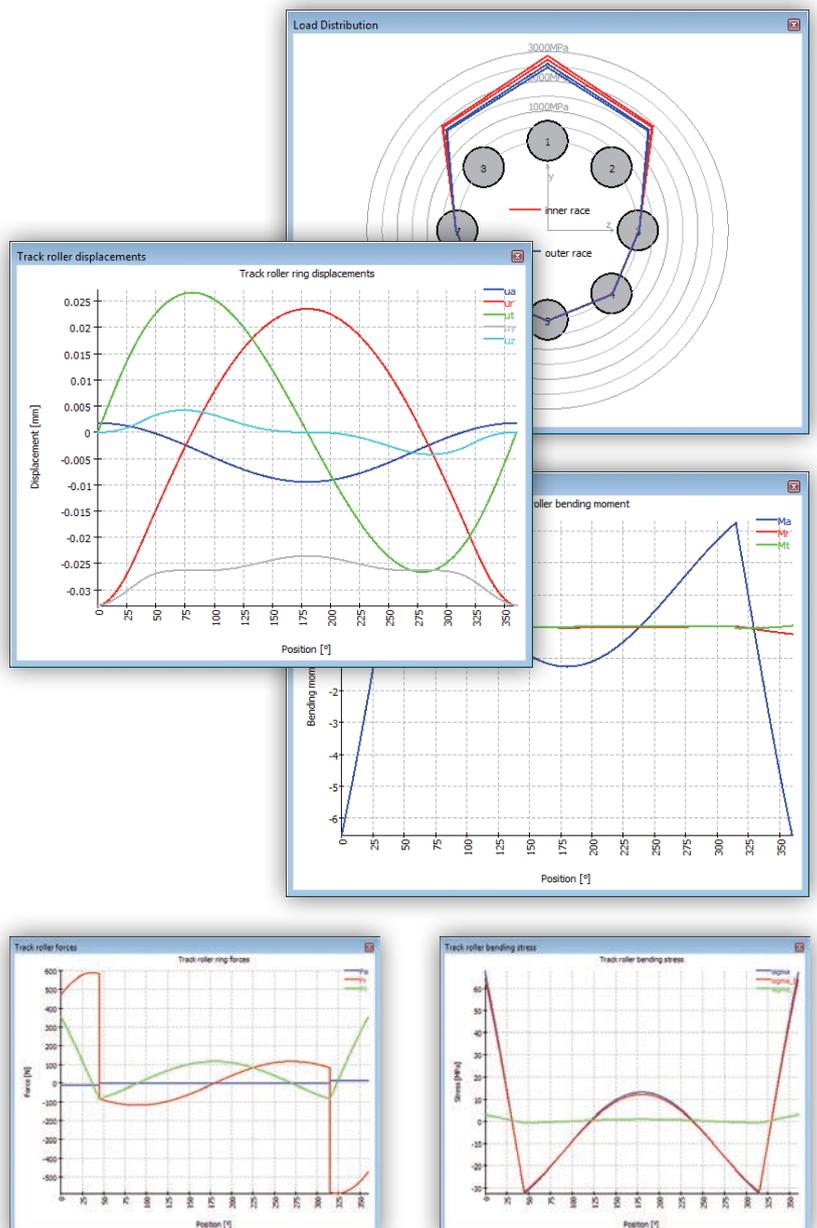
In catalogues for track rollers often reduces effective load capacities are provided, which are considering the different load distribution. They are calculated by the software in addition to maximal permissible radial load. It is important to consider that the loading should be considered at a location of a rolling element for the calculation of load capacities, but between two rolling elements for calculation the maximal permissible radial load.

### Geometry und loading

Outer ring geometry can be defined as a polygon and radii. Also unsymmetrical cross sections are possible. The second momentums and the position of center of gravity are calculated or they can be provided by the user directly. The loading of the outer ring can be specified on several locations: The only restriction is a zero torque on the bearing.

### Results

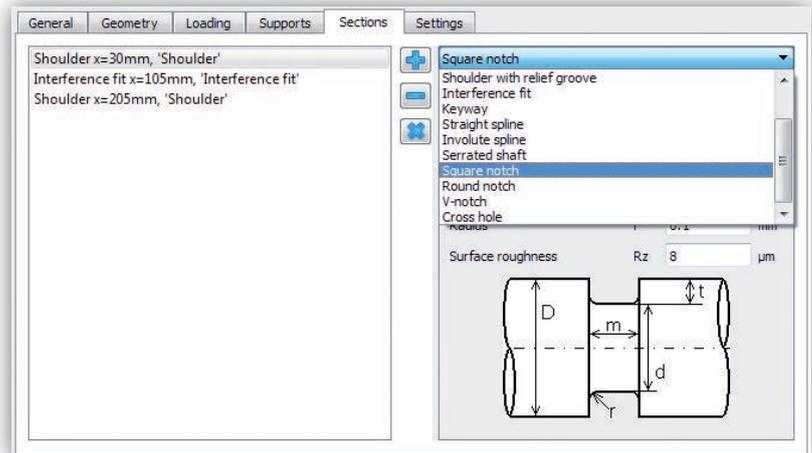
As results the same values as for rigid bearings are calculated. Additionally, for track rollers, the effective load capacities, the permissible radial load, the stresses in outer ring and the deformations of outer ring are given as well.





## Strength calculation

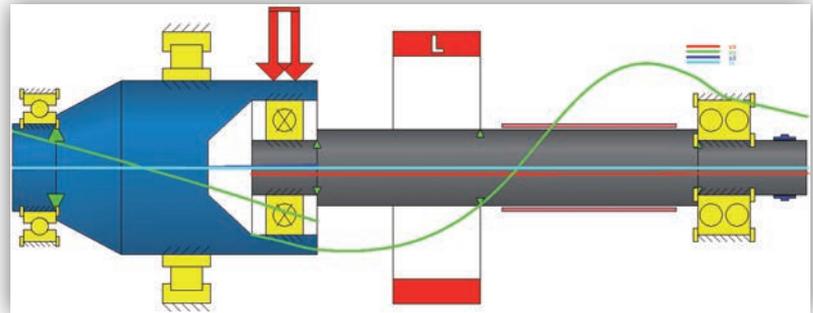
Shaft strength can be calculated according to DIN 743 (2012). All notch factors of the standard can be selected in the software. In calculations with load spectrum either a calculation for infinite life for each load can be run or a calculation with an equivalent amplitude according to DIN 743 part 4.



## Natural frequencies and mode shapes

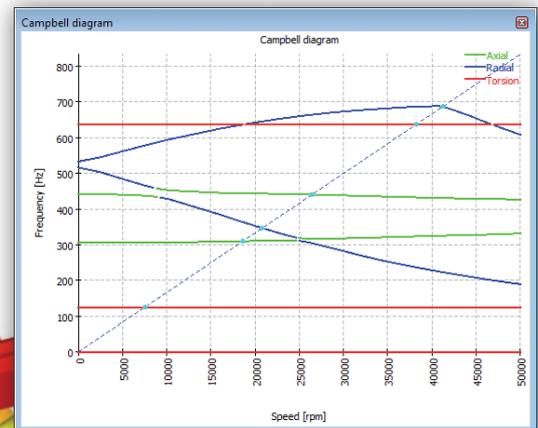
Natural frequencies are calculated considering bending, axial, and torsional modes. These modes can be coupled, like seen here for an axial mode (red) with a bending mode (blue), because of the bearing stiffness.

Additional masses can be defined for each shaft. The gyroscopic effect can be considered and a Campbell diagram is also provided in the software. In addition to the 2D visualization, also a 3D animation is available.



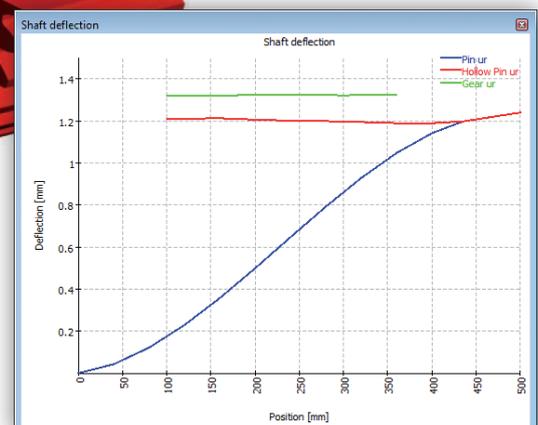
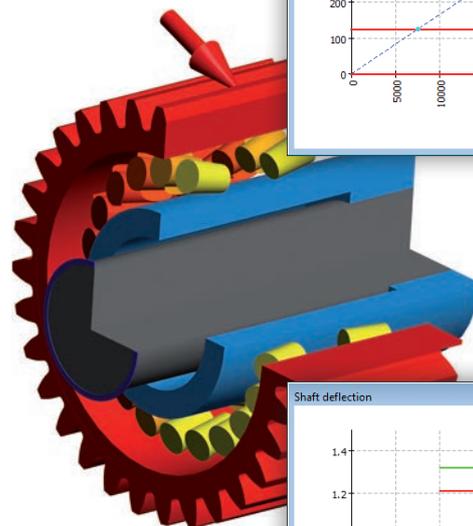
## Campbell Diagram and harmonic response

The speed dependency of natural frequencies can be shown in a Campbell diagram. Axial, torsional and bending modes are shown in different colors for better understanding. The critical frequencies are shown in an additional report. The harmonic response to periodic loads and displacements like unbalance is calculated and can be shown over speed or over time.



## Planetary gear on a flex pin

An example for the usage of several coaxial shafts is the support of a planetary gear using a flex pin. A pin is fixed in the planet carrier on the left side. On this pin there is a hollow shaft which is connected to the planetary gear with taper roller bearings in this example. As seen in the diagram for deflection, the gear stays horizontal and just moves horizontally because of the configuration. Because of the central loading both bearings carry the same load. The axial load is introduced by contact angles of the bearing.



# MESYS Shaft systems calculation

The shaft calculation can be extended to include the calculation of shaft systems. One one hand a version limited to parallel shafts coupled by cylindrical gears is available, on the other hand shaft systems with arbitrary direction coupled by planetary gear sets, bevel or worm gears are possible.

The rotational speeds of the shafts are calculated on the basis of the couplings. In a calculation with load spectrum it is only needed to define the input values; all the inner forces and rotational speeds are calculated. Shift gearboxes can be taken into account by means of the so-called "Configurations" in the software.

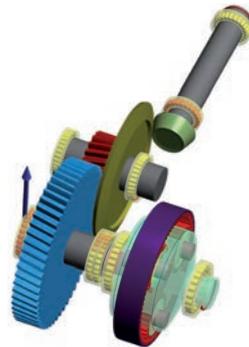
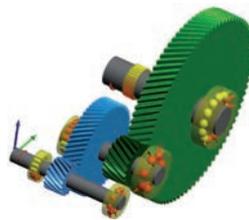
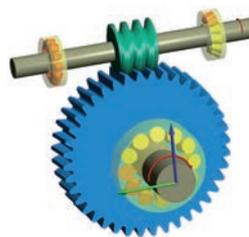
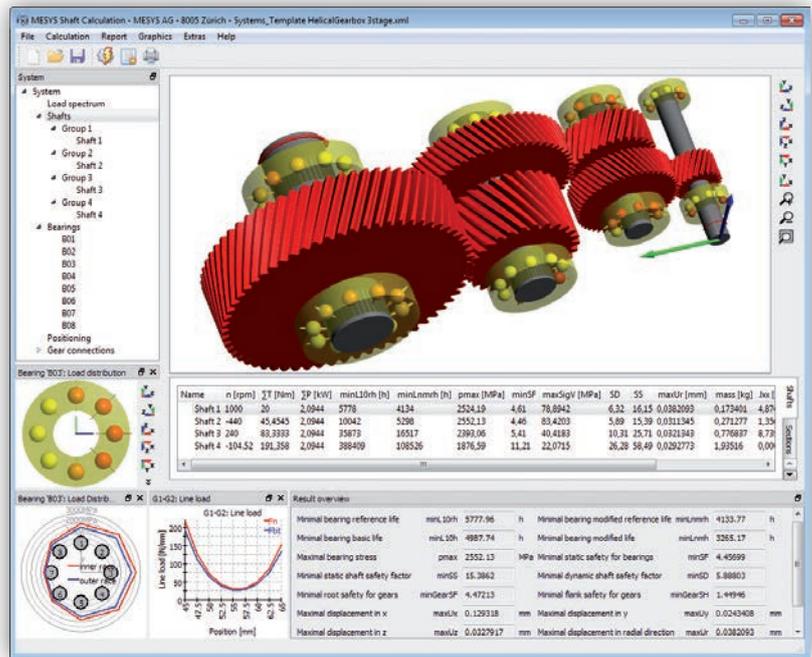
The following results are available:

- Rotational speeds for shafts
- Torques in gear pairs
- Safety factor for shaft strength according to DIN 743
- Safety factors for gears (calculated through external programs)
- Bearing life according to ISO/TS 16281 and ISO 281
- Elastic curve and force diagrams in each shaft

## Coupling by gears

Besides the existing input values for gears at the force element dialog under shafts, additional data fields regarding gear pairs are available at the connections page. Cylindrical gears can be considered as a line load with predefined mesh stiffness. The load distribution along the tooth width provides a clue on the necessary flank modifications, which can be undertaken in the software.

The gearing data can be exchanged with gear calculation programs. The safety factors are updated in the background during each calculation and are displayed at the results overview. The interface of the gear calculation programs accessed from shaft system calculation and all the corresponding information is saved together the shaft system data.

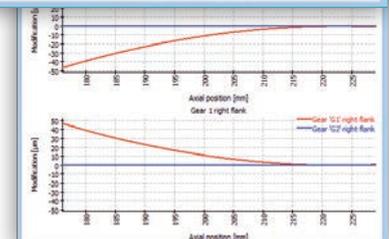
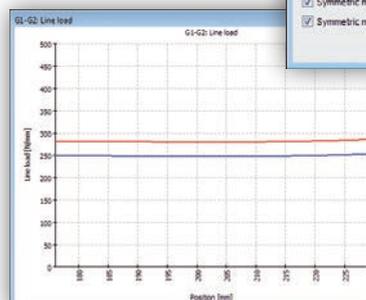


|                           |                 |                  |               |
|---------------------------|-----------------|------------------|---------------|
| Color                     | Color           |                  |               |
| Shaft                     | Input           | Intermediate     |               |
| Gear                      | G1              | G2               |               |
| Position                  | 202,5           | 135,5            | mm            |
| Number of teeth           | 15              | 26               |               |
| Width                     | 53              | 53               | mm            |
| Profile shift coefficient | -0,0403         | -0,0403          |               |
| Normal module             | mn              | 6                | mm            |
| Normal pressure angle     | $\alpha_n$      | 20               | °             |
| Helix angle               | $\beta$         | 30               | °             |
| Helix direction           | Helix left hand | Helix right hand |               |
| Center distance           | a               | 141,54           | mm            |
| Cumferential backlash     | j               | 0,1              | mm            |
| Gear mesh stiffness       | $C_y$           | 20               | N/mm/ $\mu$ m |
| Calculation               | TBK 2014        |                  |               |
| Tooth flank modifications |                 |                  |               |

|                                      | Gear 1 right flank [mm] | Gear 2 right flank [mm] |
|--------------------------------------|-------------------------|-------------------------|
| Flank line crowning Cp               | 0,015                   | 0                       |
| Flank line slope modification CHp    | -0,046                  | 0                       |
| Flank line end relief amount I CpI   | 0                       | 0                       |
| Flank line end relief length I LC1   | 0                       | 0                       |
| Flank line end relief amount II CpII | 0                       | 0                       |
| Flank line end relief length II LC2  | 0                       | 0                       |

Symmetric modifications for gear 1  
 Symmetric modifications for gear 2

OK Cancel



## Planetary stages

All the planets of a planet stage are considered in the calculation. Therefore, the sun can be centered by means of the planets. The load sharing among the planets arise from the loads, deformations and mesh stiffness.

Planet carriers can be considered as 3D elastic parts defined by parameters or by CAD import.

## Positioning

Different conditions can be defined for the positioning of groups, shafts and gears. In this way the shafts can be automatically positioned at the proper distance in accordance with the gearing data.

## Configurations

The so-called configurations allow the user to activate and deactivate any coupling conditions previously defined. With this option the gear shifting of a gearbox can be simulated and considered. Each created configuration can be then selected in a load spectrum as if it was a load case.

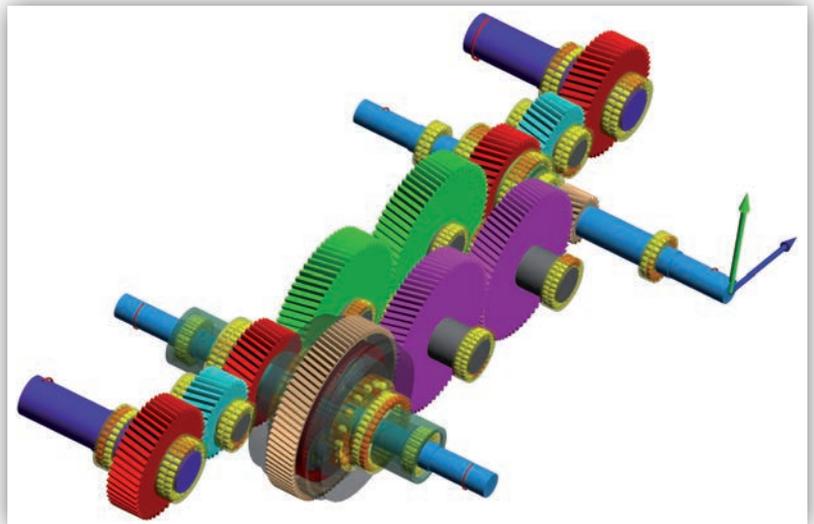
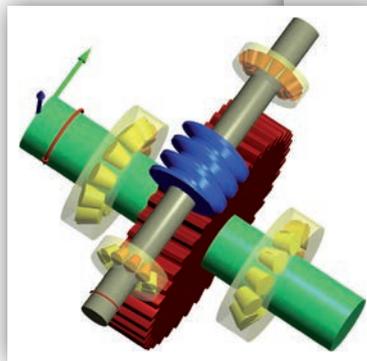
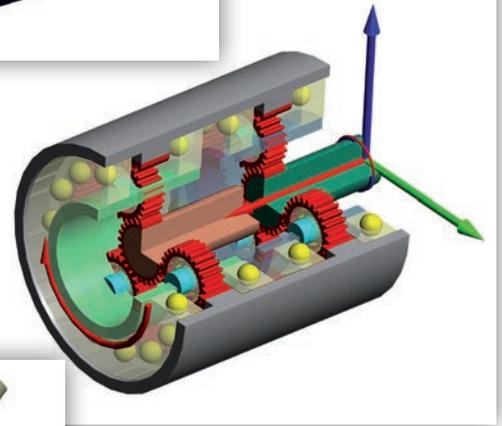
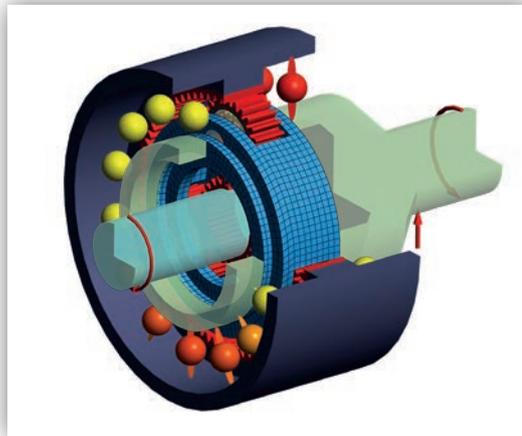
## Natural frequencies on system level

Frequencies can be calculated on system level too. Gear pairs lead to a coupling of axial, torsional and bending modes. Mode shapes can be animated in the 3D view. 3D elastic housings can be considered by modal reduction.

## Results

The results are shown at different levels. There are results for the system such as the minimum safety factors for the shaft strength and gears, or the minimum life expectancy. Additionally, there are also results overviews for each bearing, group, shaft and its corresponding analyzed cross sections.

Besides the report for the shaft system, which contains the main results of bearings and gear calculations in table form, it is also possible to generate a full report. The full report contains detailed results for each bearing and each gear pair.



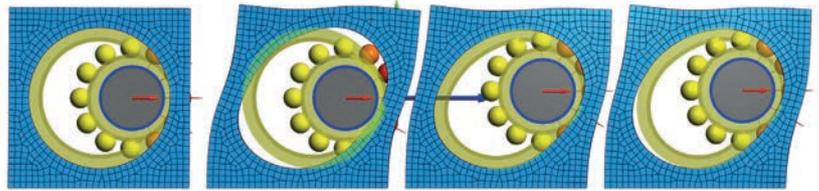
| Name              | L10h [h] | Lnmh [h] | L10rh [h] | Lnrmh [h] | pmax [MPa] | SF   | Fx [kN]  | Fy [kN]   | Fz [kN]  | Mx [Nm] | My [Nm]   | Mz [Nm]    |
|-------------------|----------|----------|-----------|-----------|------------|------|----------|-----------|----------|---------|-----------|------------|
| ▲ Input           |          |          |           |           |            |      |          |           |          |         |           |            |
| Fixed 1           | 1664     | 12975    | 2348      | 22787     | 2661,51    | 3,93 | -7       | -3,45012  | -4,56675 | 0       | 70,9758   | -49,3255   |
| Floating 1        | 12624    | 79769    | 39675     | 198610    | 1834,38    | 4,75 | 0        | -1,6019   | -7,59944 | 0       | -4,0218   | 1,17074    |
| ▲ Intermediate    |          |          |           |           |            |      |          |           |          |         |           |            |
| Fixed 2           | 64329    | 926288   | 178172    | 971834    | 1629,59    | 6,03 | -5,13333 | -2,21418  | 15,2794  | 0       | -0,599061 | -0,0869705 |
| Floating 2        | 6089     | 22275    | 13192     | 37225     | 2284,5     | 3,07 | 0        | -1,72013  | 17,9024  | 0       | 21,53     | 2,55805    |
| ▲ Output          |          |          |           |           |            |      |          |           |          |         |           |            |
| Reaction coupling |          |          |           |           |            | 0    | 0        | 0         | 0        | 1892,8  | 0         | 0          |
| Fixed 3           | 21825    | 413128   | 24981     | 526299    | 2217,92    | 6,79 | 12,1333  | -0,215938 | -5,19207 | 0       | -51,8783  | 9,76645    |
| Floating 3        | 10259    | 36975    | 28221     | 91044     | 2122,66    | 3,55 | 0        | 8,86665   | -15,8235 | 0       | -11,6149  | -4,68101   |

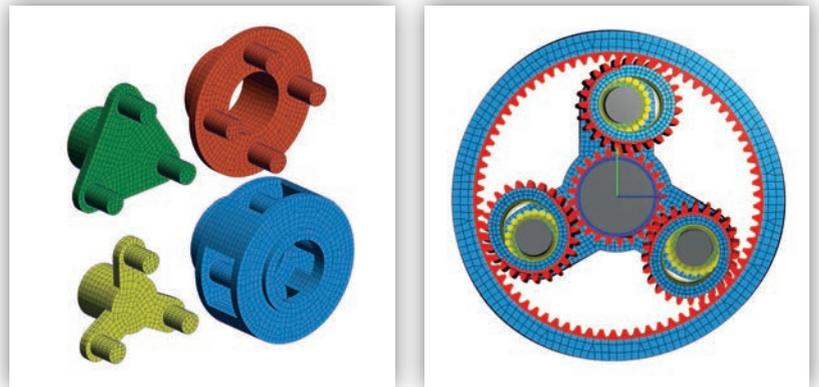
| Result overview                         |         |   |  |          |     |   |           |    |
|---|---------|---|--|----------|-----|---|-----------|----|
| Minimal bearing reference life minL1    | 2347,67 | h | Minimal bearing modified reference life minL | 22787,4  | h   | Minimal bearing basic life minL10h      | 1664,21   | h  |
| Minimal bearing modified life minLn     | 12975,2 | h | Maximal bearing stress pmax                  | 2661,51  | MPa | Minimal static safety for bearings minS | 3,06575   |    |
| Minimal static shaft safety factor minS | 9,50499 |   | Minimal dynamic shaft safety factor minS     | 1,8109   |     | Minimal root safety for gears minGez    | 6,73548   |    |
| Minimal flank safety for gears minGez   | 1,31998 |   | Maximal displacement in x maxLx              | 0,295108 | mm  | Maximal displacement in y maxLy         | 0,0295775 | mm |

# FEA-based 3D-elastic parts

The shaft and shaft system calculation allow the integration of FEA based 3D-elastic parts for more accurate consideration of deformations. Shafts and planet carriers can be defined parametrically or an import of a STEP-file is possible for shafts, carriers and housings. The meshing and static and optionally modal reduction is done within the software.

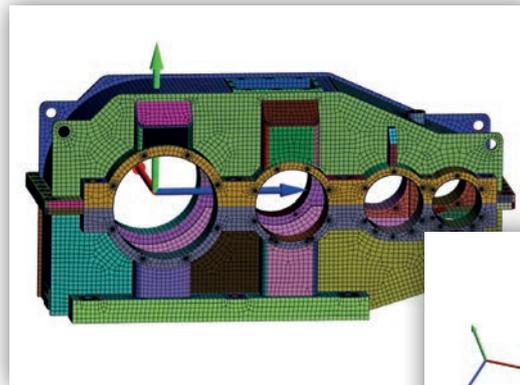


Several options for reductions are supported: rigid condensation to central nodes, averaging on central nodes, elastic bearing rings with and without contact and elastic gears.

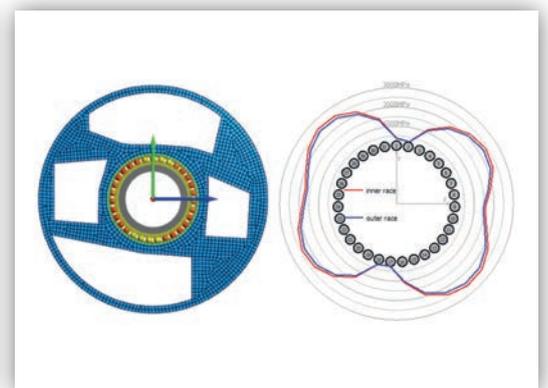
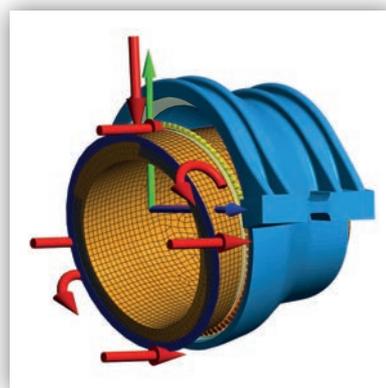
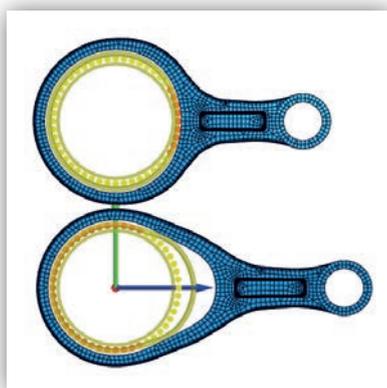
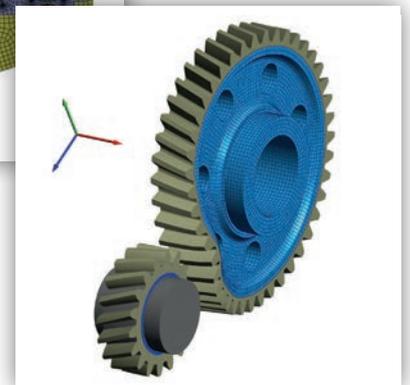


Elastic deformations of planet carriers can be considered. Several variants can be defined parametrically. For planetary gears an elastic gear body can be considered together with an elastic bearing ring.

Elastic deformations of bearing rings are of interest for strongly asymmetric housings or for large bearings. Contact between bearing ring and part can be considered optionally. The fitting is then taken into account within the contact model.



The influence of weight and temperature is taken into account. For rotating parts optionally centrifugal expansion can be considered. The meshing can be done using hexahedral or tetrahedral elements either with linear or quadratic shape functions.



# Bearing calculation for axial-radial roller bearings

The calculation software for axial-radial cylindrical roller bearings considers deformations of the bearing rings based on a finite element calculation. The geometry of rotationally symmetric construction parts can be defined by means of polygonal lines by the user. It is possible to define an arbitrary number of cylindrical rollers.

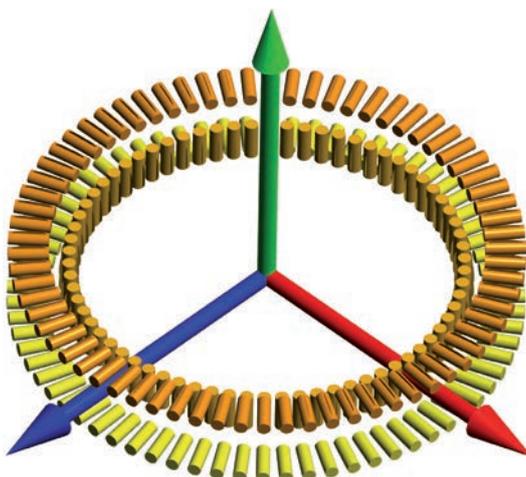
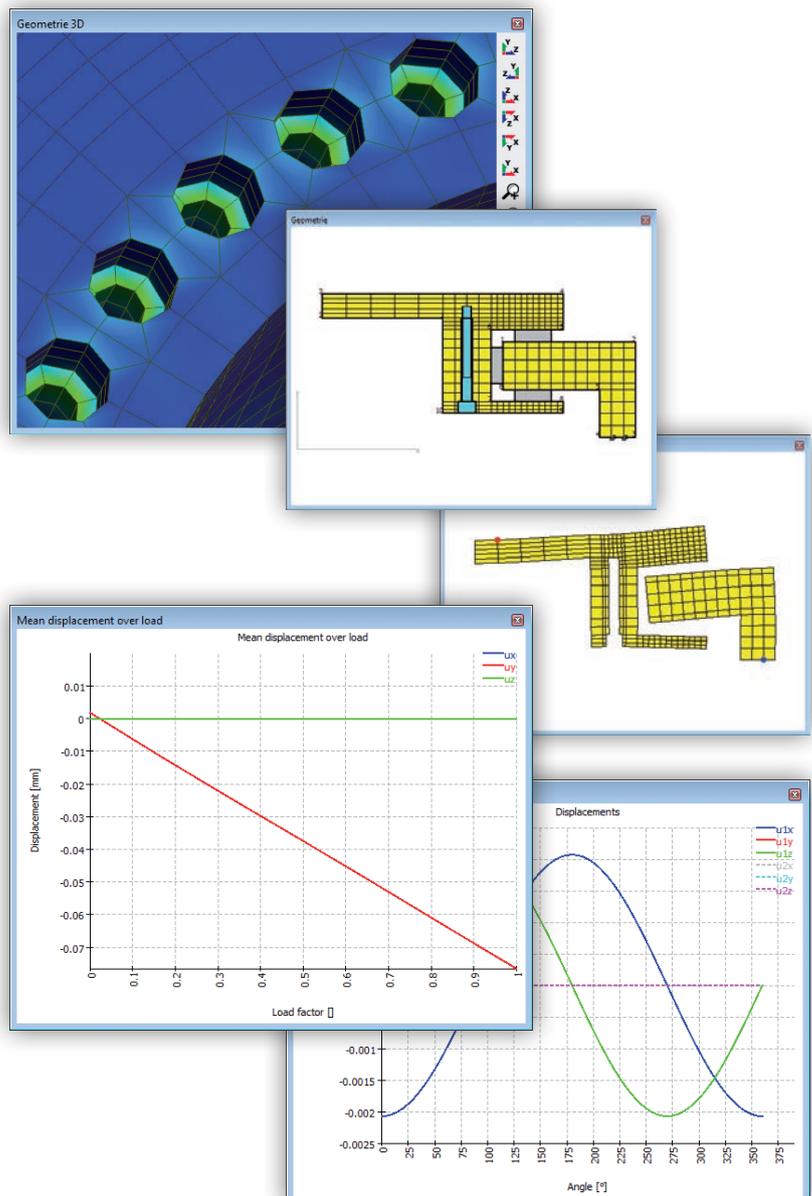
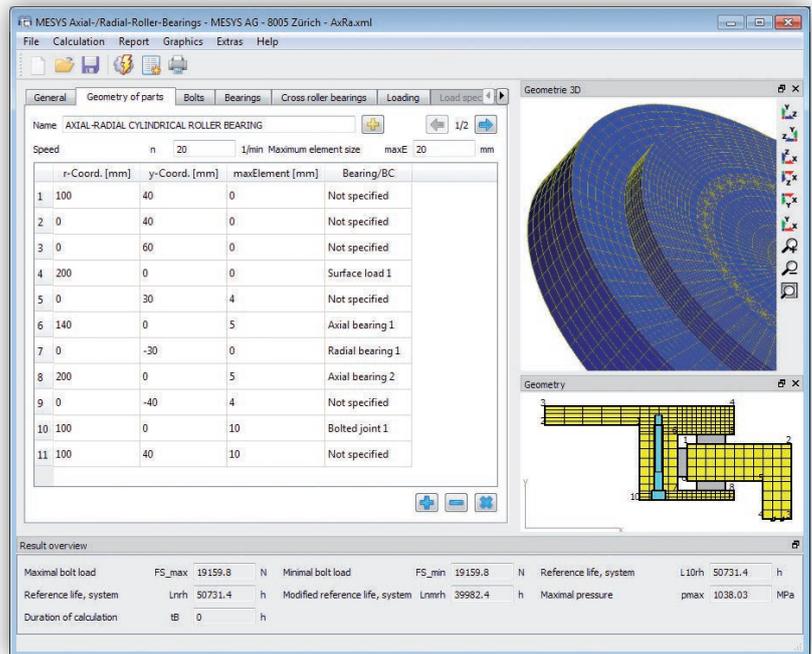
The following bearing types are supported:

- Axial-radial cylindrical rolling bearing
- Radial cylindrical rolling bearing
- Crossed roller bearing
- Angular roller bearing

Additionally, the bolt pretension in one or several bolted joints can be considered. Loads can be defined either on surfaces or in singular points. For the definition of stiffness, a calculation of a series with variation of load and a load spectrum calculation are possible.

By means of multiple graphics and a PDF-report the following results are available:

- The load distribution on the rollers along the roller length as well as the load sharing among the rollers.
- The nominal and modified life expectancy for each bearing row and the system according to the ISO/TS 16281.
- The deformation and the stiffness defined through two arbitrary eligible points.
- The maximum and minimum bolt load.
- The graphical representation of the exaggerated deformations either in 3D or in 2D-view of the axial section in accordance with a chosen angle.



# Calculation for ball screws

In most cases the loading of ball screws is purely axial. For this reason, the life expectancy according to ISO 3408-5 only considers axial loads.

The software calculates the load distribution in a ball screw as a result of axial and radial loading, and tilting moment. Based on the Hertzian pressure theory, the load distribution is calculated under the assumption of rigid screw and rigid nut by considering the contact stiffness of the balls. With the help of the software option "Configurations" it is possible to calculate prestressed nuts. The raceways can be design as gothic arches or full radii. The life expectancy is resolved analogously to ISO/TS 16281 from the load distribution. The load capacities can be calculated either according to ISO 3408-5 or to a method analogous to the ISO 281/ISO 76.



A parameter variation allows an automatic combination and variation of input values and a graphical representation of the results. The calculation for ball screws can also be used integrated into the shaft calculation.

The following results are available:

- Reference rating life according to ISO/TS 16281
- Load distribution between rolling elements
- Reaction forces/moments and displacements/rotations
- Contact pressure for each contact
- Contact angle according to the axial position of the ball
- Static safety factor

