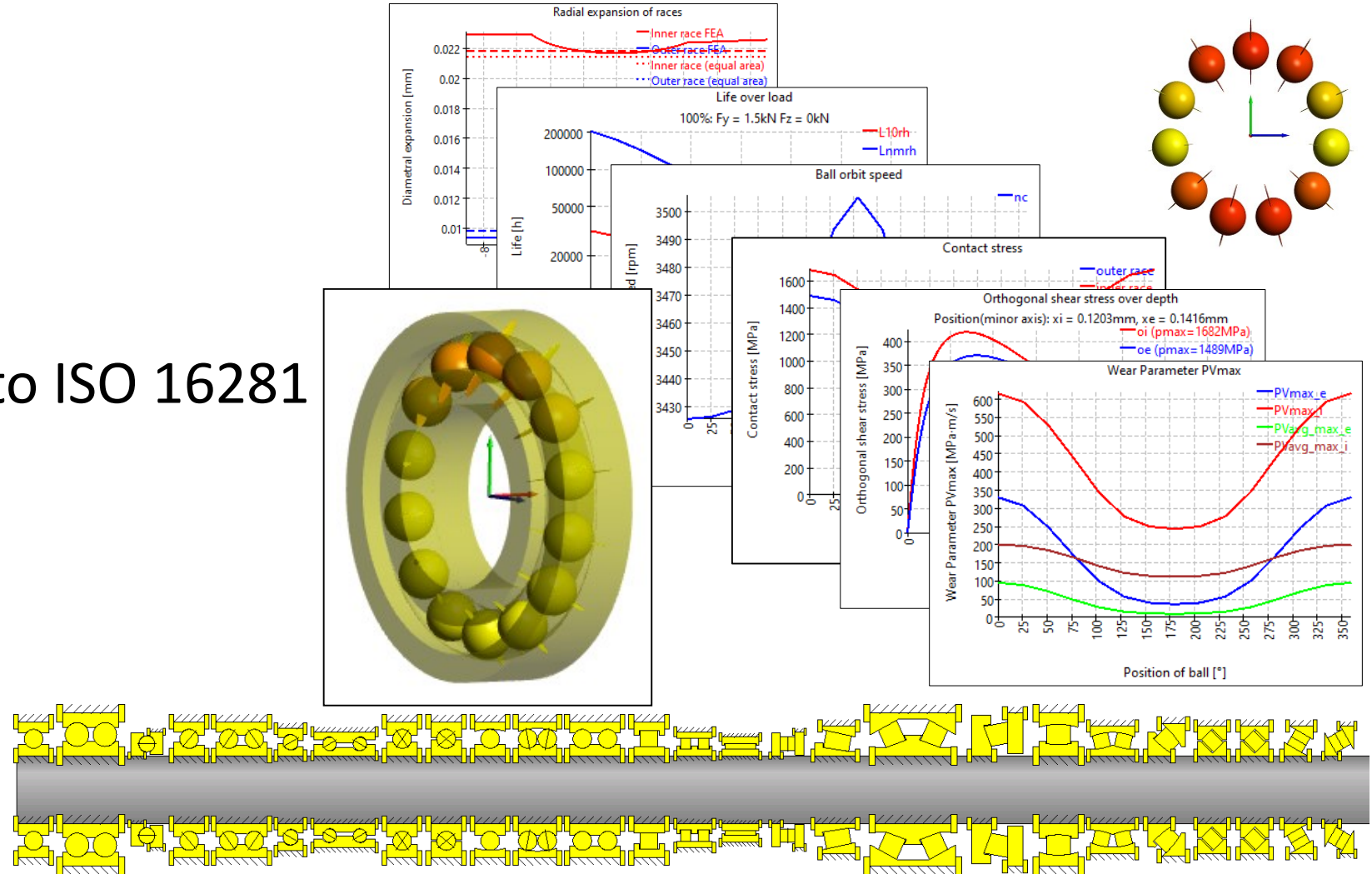


# MESYS Rolling Bearing Calculation

Calculation according to ISO 16281



- **Nominal life according ISO 281**

The nominal life  $L_{10}$  in million rotations is calculated using dynamic load capacity  $C_r$  and dynamic equivalent load  $P$ .

- **Modified life according ISO 281**

The modified life  $L_{nm}$  is calculated from nominal life using the factors  $a_1$  and  $a_{ISO}$ . These factors take into account reliability, lubrication and cleanness.

- **Nominal Reference-Life according ISO 16281**

The reference life  $L_{10r}$  is calculated from load distribution within the bearing and dynamic load capacity. Considering the load distribution in the bearing clearance and tilting angle is taken into account.

- **Modified Reference-Life according ISO 16281**

Using the factors  $a_1$  and  $a_{ISO}$  the influence of reliability, lubrication and cleanness is considered in modified Reference-Life  $L_{nmr}$ .

- **Static safety according ISO 76**

The static safety is calculated as  $S = C_0/P_0$  using the static load capacity  $C_0$  and the static equivalent load  $P_0$ . The static load capacity is based on a contact pressure of 4200 MPa for ball bearings and 4000MPa for roller bearings.

- **Static safety based on the load distribution**

The static safety factor  $SF$  is calculated using the actual contact stress and the permissible contact stress. For ball bearings the safety factor is calculated as  $SF = (p_{perm}/p_{max})^3$  and for roller bearings as  $SF = (p_{perm}/p_{max})^2$ .

As alternative the static safety factor  $SF$  can also be based on rolling element forces.

- **Static safety according to ISO 17956**

The static safety factor  $S_{0eff}$  is calculated based on the draft for ISO 17956. For ball bearings it is based on the rolling element forces, for roller bearings on the force per lamina. A certain influence of tilting angles is therefore covered, but no edge stresses.

# Settings for calculation

The screenshot shows the 'Rolling Bearing Calculation' window in the mesys software. The interface includes a navigation bar with tabs for 'General', 'Bearing geometry', 'Bearing configuration', 'Material and Lubrication', 'Loading', and 'Track roller'. The 'General' tab is active, displaying the following settings:

- Project name: [Text input field]
- Calculation description: [Text input field]
- Settings section:
  - Reliability: S 90 % (Callout: Reliability)
  - Limit for aISO: aISOMax 50 (Callout: Maximum value for aISO)
  - Friction coefficient:  $\mu$  0.1 (Callout: Friction coefficient for calculation of torque)
  - Calculate lubricant film thickness
  - Consider centrifugal force (Callout: Centrifugal force can be considered for fast running bearings)
  - Consider temperature gradient in fits
  - Oscillating bearing
  - Calculate required hardness depth
  - Use fatigue strength for hardness depth (Callout: For surface hardened bearings the required hardness depth can be calculated)
  - Required subsurface safety: Ssmin 1
  - Calculation for medium clearance (dropdown menu)
  - Rolling element has maximum temperature (dropdown menu)
  - First rolling element on y-axis (dropdown menu with '+' button) (Callout: Position for first rolling element)
  - Gyroscopic moment is not considered (dropdown menu) (Callout: Gyroscopic moment)
  - Rolling element set life is not calculated (dropdown menu)
  - Elastic ring expansion is not considered (dropdown menu with '+' button) (Callout: Elastic ring expansion)
  - Use load spectrum (Callout: Calculation with load spectra is possible)
  - Calculate modified life
  - Use extended method for pressure distribution (Callout: Extended method for pressure distribution in roller bearings)
  - Calculate static safety factor based on stress

Callouts on the right side of the interface point to specific dropdown menus:

- Position in tolerance field for clearance
- Temperature for rolling element
- Position for first rolling element
- Gyroscopic moment
- Elastic ring expansion
- Calculation with load spectra is possible
- Extended method for pressure distribution in roller bearings

# Bearing geometry

The screenshot shows a software interface for configuring bearing geometry. The 'Bearing geometry' tab is active, showing a 'Deep groove ball bearing' selected. The interface is divided into several sections: 'General', 'Bearing geometry', 'Bearing configuration', 'Material and Lubrication', 'Loading', and 'Track roller'. The 'Bearing geometry' section includes fields for 'Inner diameter' (d), 'Outer diameter' (D), 'Width' (B), 'Number of rolling elements' (Z), 'Pitch diameter' (Dpw), 'Conformity inner ring' (fi), 'Conformity outer ring' (fe), 'Shoulder diameter inner ring' (dSi), and 'Shoulder diameter outer ring' (dSe). The 'Bearing configuration' section includes 'Dynamic load number' (C), 'Static load number' (C0), 'Fatigue load limit' (Cu), 'Bearing clearance' (ISO 5753 - CN), 'Diametral clearance' (Pd), 'Bearing tolerance' (ISO 492 - P6), 'Fit to shaft' (k6), 'Surface roughness shaft' (Rz), 'Shaft inner diameter' (dsi), 'Fit to housing' (H7), 'Surface roughness housing' (Rz), and 'Housing outer diameter' (dhe). Callouts explain the following parameters:

- Conversion between conformity and radius
- Conformity  $f_i = r_i / D_w$
- Shoulder diameter to check extension of contact ellipse
- Load capacities can be calculated or input
- Nominal clearance before mounting
- Conversion between radial and axial clearance
- Change of clearance because of fits
- Fits can be defined as ISO tolerances or as user input
- Surface roughness for reduction of interference in fits

# Bearing configuration for multiple row bearings

General Bearing geometry Bearing configuration Material and Lubrication Loading Track roller

Consider group of bearings

	Position [mm]	Axial Offset [mm]	Center of contact cone
1	-10	0	left
2	10	0	right

Positions for multiple rows

Displacement of outer ring to generate pretension

Direction of contact angle

+ - ✕

Multiple row bearings can be defined easily using the bearing configuration. The bearing rings are connected rigidly. Thermal elongation is considered in axial offset.

# Material and lubrication

The screenshot shows the 'Material and Lubrication' tab of a software interface. It is divided into two main sections: 'Material' and 'Lubrication'. The 'Material' section includes input fields for surface hardness (inner and outer race), core strength (inner and outer race), hardness depth (inner and outer race), and surface roughness (inner and outer race, and roller). It also features dropdown menus for material selection (inner race, outer race, rolling element, shaft, housing) and buttons to add new materials. The 'Lubrication' section includes a dropdown for oil type (ISO VG 220 mineral oil), a dropdown for oil treatment (Oil lubrication with on-line filter ISO4406 -/17/14), and input fields for viscosity at 40°C (nu40 = 220 mm²/s), viscosity at 100°C (nu100 = 19 mm²/s), temperature (TOil = 70 °C), oil density (rho = 890 kg/m³), and pressure viscosity coefficient (alpha = 0.0174449 1/MPa). There is also a checkbox for 'contains effective EP additives'.

**Callouts:**

- The surface hardness can lead to a reduction of load capacities
- Core strength for the calculation of hardness depth
- Surface roughness for the calculation of lubricant film thickness
- Inputs for lubrication to calculate modified life
- Hardness depth as input or required hardness depth as output
- Material data for calculation of load distribution, user input available
- Selection for lubricant cleanliness or user input for eC
- Pressure viscosity coefficient for the calculation of lubricant film thickness

# Loading of bearing

The screenshot shows the 'Loading' tab of the mesys software interface. The interface is divided into several sections with input fields and radio buttons. Callouts provide explanations for these fields:

- Force in three directions:** Points to the Axial load (Fx), Radial load (Fy), and Radial load (Fz) input fields.
- Tilting moment around two axes:** Points to the Moment (My) and Moment (Mz) input fields.
- Speed for inner and outer ring:** Points to the Speed inner ring (ni) and Speed outer ring (ne) input fields.
- Selection of input values for load/displacement for all five components:** Points to the radio buttons for Displacement and Rotation angle for each of the five load/moment components.
- Displacements in three directions:** Points to the ux, uy, and uz input fields.
- Tilting angle:** Points to the ry and rz input fields.
- Temperatures with influence on operating clearance:** Points to the Temperature of shaft (Ti) and Temperature of housing (Te) input fields.
- Selection which ring rotates relative to load has influence on life:** Points to the checkboxes for 'Inner ring rotates to load' and 'Outer ring rotates to load'.

A 3D diagram of a bearing is shown at the bottom left, with a coordinate system (y, z) and arrows indicating the direction of forces and moments.



# Calculation with elastic outer ring for track rollers

General | Bearing geometry | Bearing configuration | Material and Lubrication | Loading | Track roller

consider elastic outer ring

Axial [mm]	Radial [mm]	Radius [mm]	

manually enter geometry data

Second momentum axial direction Iaa 0 mm<sup>4</sup>

Second momentum radial direction Irr 0 mm<sup>4</sup>

Second momentum tangent direction Itt 0 mm<sup>4</sup>

Second momentum axial/radial Iar 0 mm<sup>4</sup>

Center of gravity, axial s\_a 0 mm

Center of gravity, radial s\_r 0 mm

Cross section A 0 mm<sup>2</sup>

geometry is symmetric

Consider shear deformations

Calculate standard values (Cw, C0w, ...)

Calculate Cw using L10r=1

Calculate C0w, Cuw using standard stresses, ignoring edge stresses

Permissible static bending stress  $\sigma_{bsp}$  0 MPa

Permissible dynamic bending stress  $\sigma_{bdp}$  0 MPa

Mean stress influence  $\Psi$  0.3

Input of outer ring geometry

Shear deformations in outer race

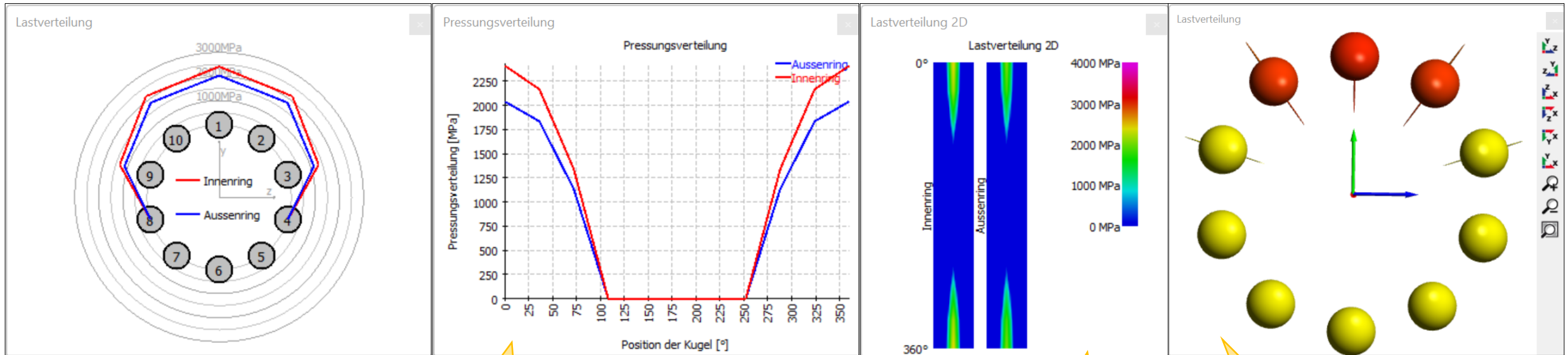
Calculation of reduced effective load capacity

Options for calculation of effective load capacity

Permissible stresses in outer ring

Resulting parameters for geometry could be entered directly using CAD data

# Distribution of contact stress

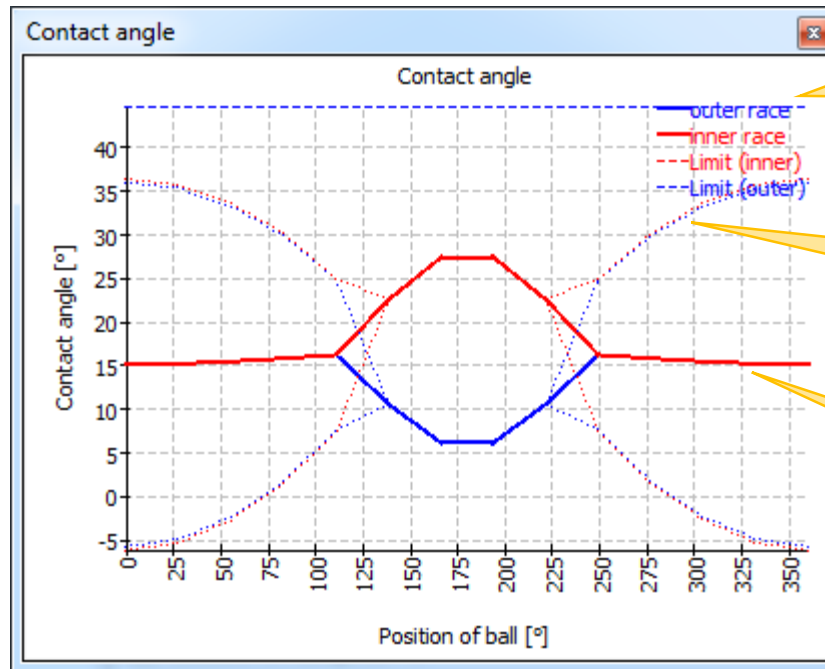


Contact stress over angular position of rolling element

Load distribution 2D

Load distribution 3D

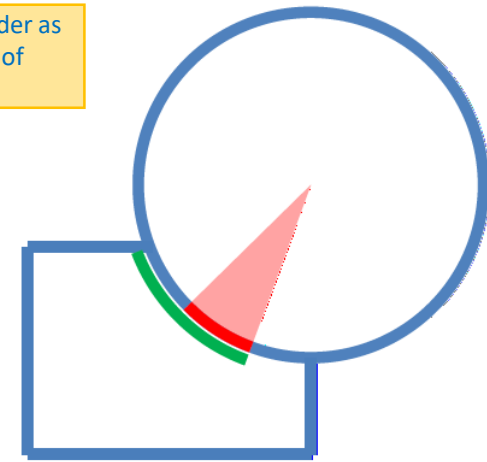
# Extension of contact ellipse



Contact angle at shoulder as limit for the extension of contact ellipse

Extension of contact ellipse

Contact angle in the center of contact ellipse

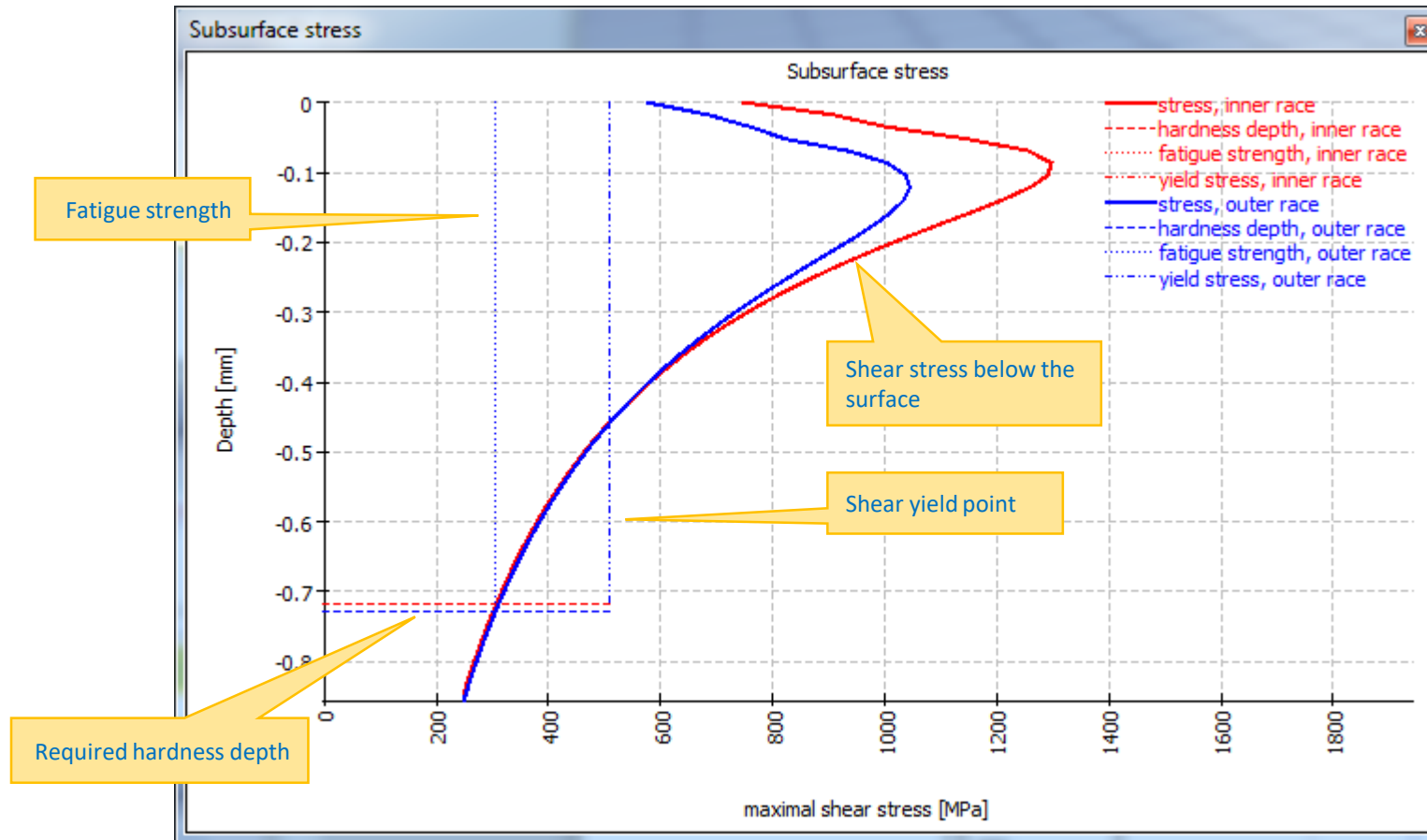


Extension contact ellipsis inner ring	dCimax	58.1451	mm
Extension contact ellipsis outer ring	dCemin	71.8924	mm
Ellipsis length ratio outer race	eLR_e	123.284	%
Ellipsis length ratio inner race	eLR_i	121.799	%

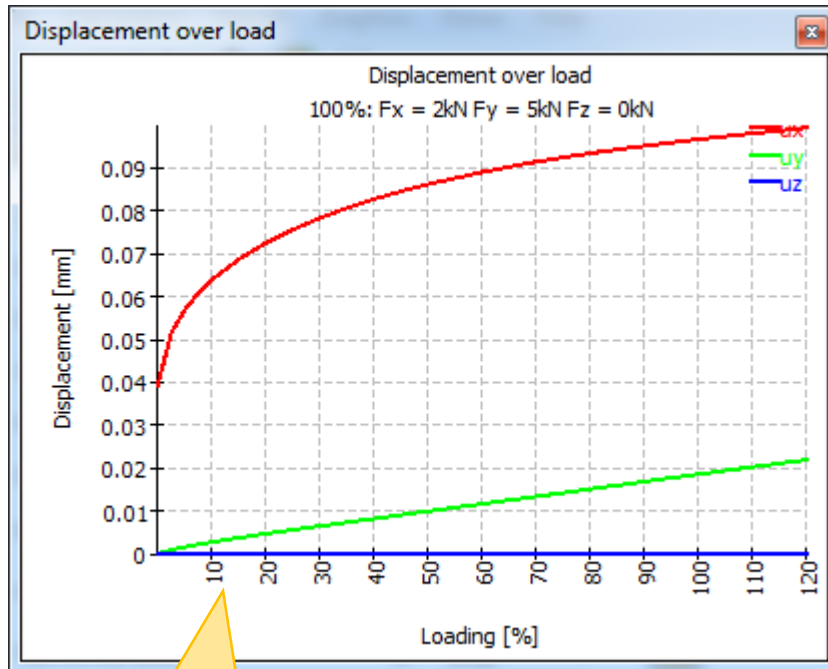
Maximum extension of the pressure ellipse

The length ratio is the relationship between the green and the red line

# Extension of contact ellipse



# Bearing stiffness



Graphics for displacement over load

## Bearing stiffness matrix

	$u_x$ [ $\mu\text{m}$ ]	$u_y$ [ $\mu\text{m}$ ]	$u_z$ [ $\mu\text{m}$ ]	$r_y$ [mrad]	$r_z$ [mrad]
$F_x$ [N]	58.214	67.753	-0.000	-0.000	-1053.343
$F_y$ [N]	67.761	236.142	-0.000	0.000	-1982.788
$F_z$ [N]	-0.000	-0.000	268.921	2374.462	-0.000
$M_y$ [Nm]	-0.000	-0.000	2.399	31.032	-0.000
$M_z$ [Nm]	-1.064	-2.003	0.000	-0.000	30.455

Stiffness matrix in the report. Here for a radially and axially loaded deep groove ball bearing