Steinbeis-Transferzentrum
Neue Technologien in der Verkehrstechnik
Verkehrstechnik.Simulation.Software

Fatigue Calculation of a Constant Velocity Joint using RecurDyn and winLIFE

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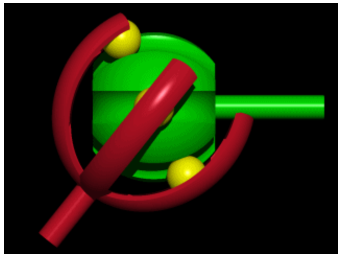
Agenda



- Steinbeis Companies mission
- History of winLIFE
- Functionality of a Constant Velocity Joint
- Building a RECURDYN Model
- Combining Finite Element Analysis (FEA)
- Fatigue Analysis
- Conclusion

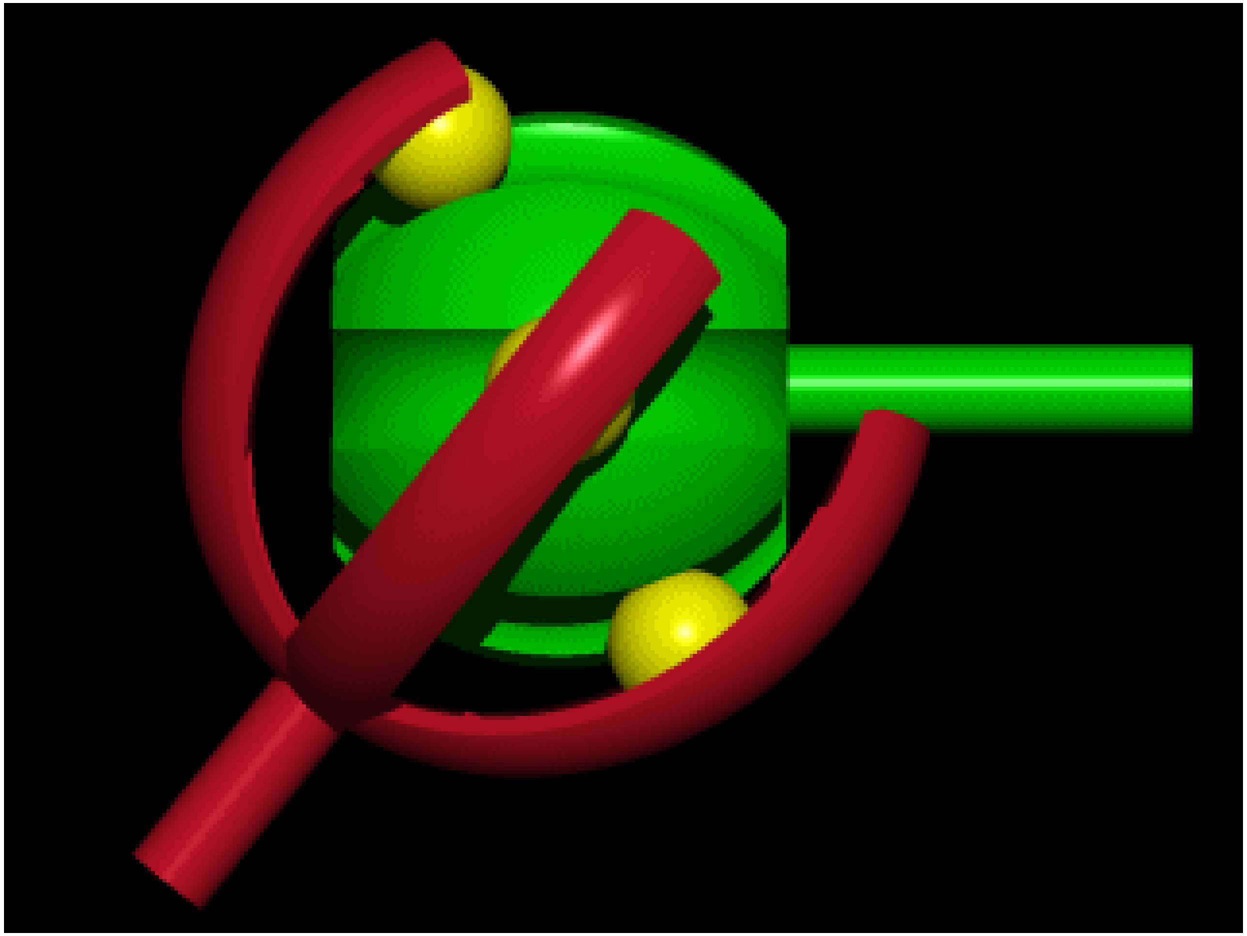
History of winLIFE (Life Information using Finite Elements)

- History
  - winLIFE developed by Steinbeis since 1984
  - Worldwide more than 240 licenses sold
  - Close link to FEA: ABAQUS, ANSYS, FEMAP, MARC, Nx,,
    MBS: RECURDYN software

Modules (cover the whole range of fatigue calculation)

- winLIFE QUICK CHECK (static and endurance proof (FKM-guideline)9
- winLIFE BASIC
- winLIFE MULTIAXIAL(including welding)
- winLIFE GEARWHEEL AND BEARING
- winLIFE CRACK PROPAGATION
- winLIFE RANDOM

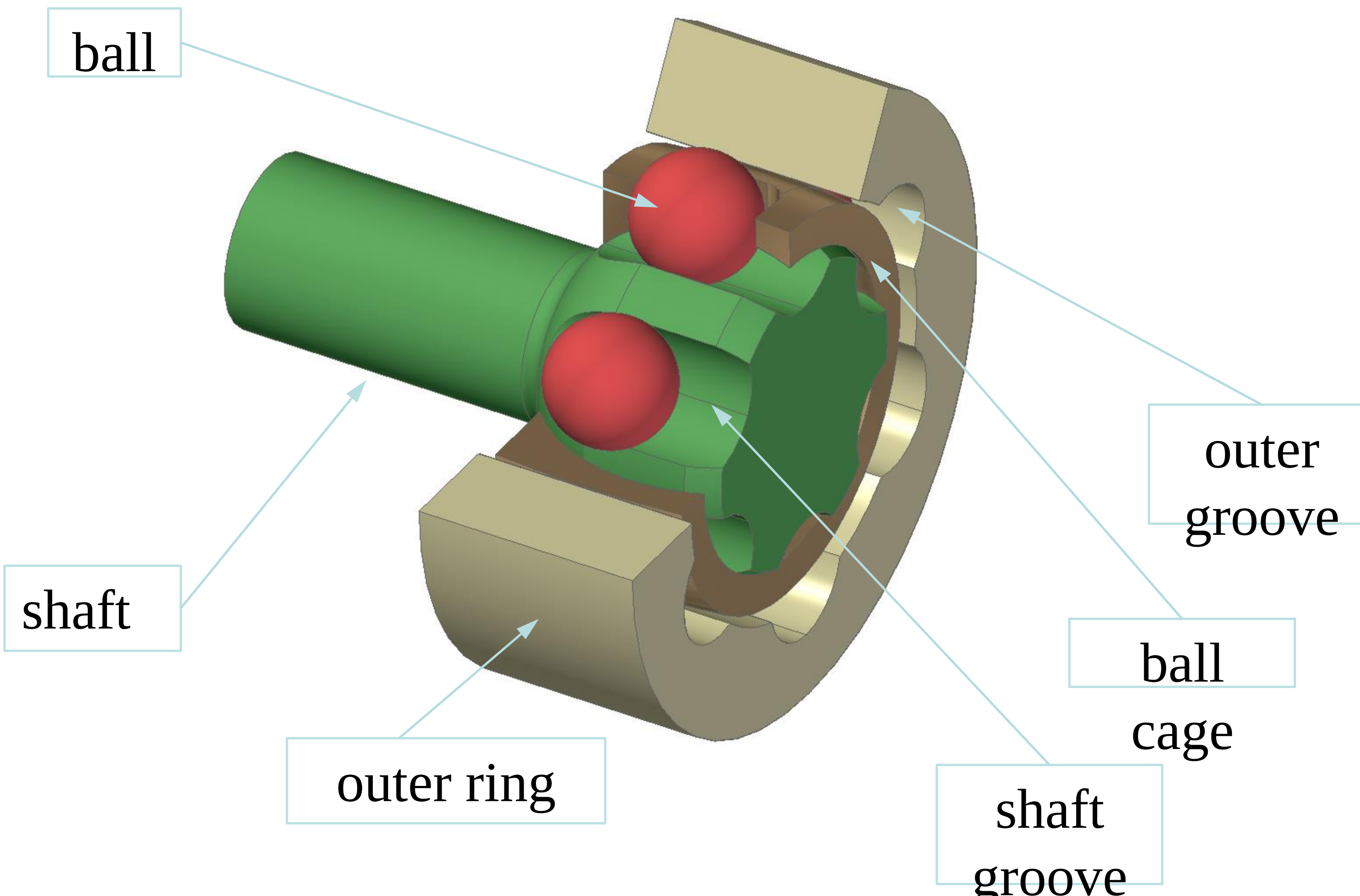
Functionality of a Constant Velocity Joint (CVJ) (video source: Wikipedia)



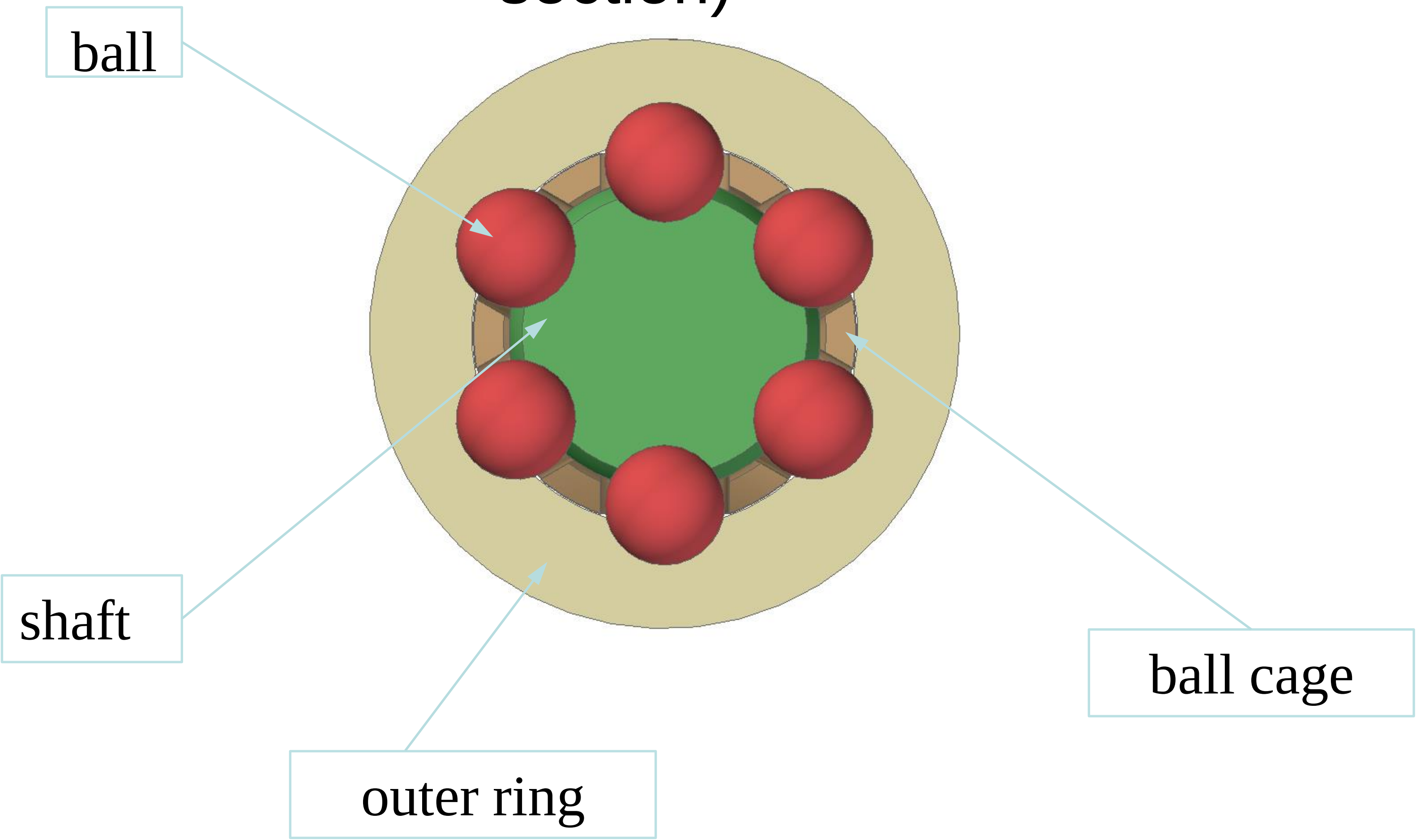
Steps

- Building a **RECURDYN model** with analytic bodies to calculate the forces and contact conditions of the joint
- Using the calculated contact forces as an input for a nonlinear **FEA-model** to calculate the stresses
- **Creating life curves** taking into account the hardening of the surface by creating S-N-curves with a fatigue limit corresponding to the measured hardening
- **Calculating the stresses** caused by the rolling of the ball by super-positioning different static stress results
- **Damage accumulation and superposition** of total damage sum

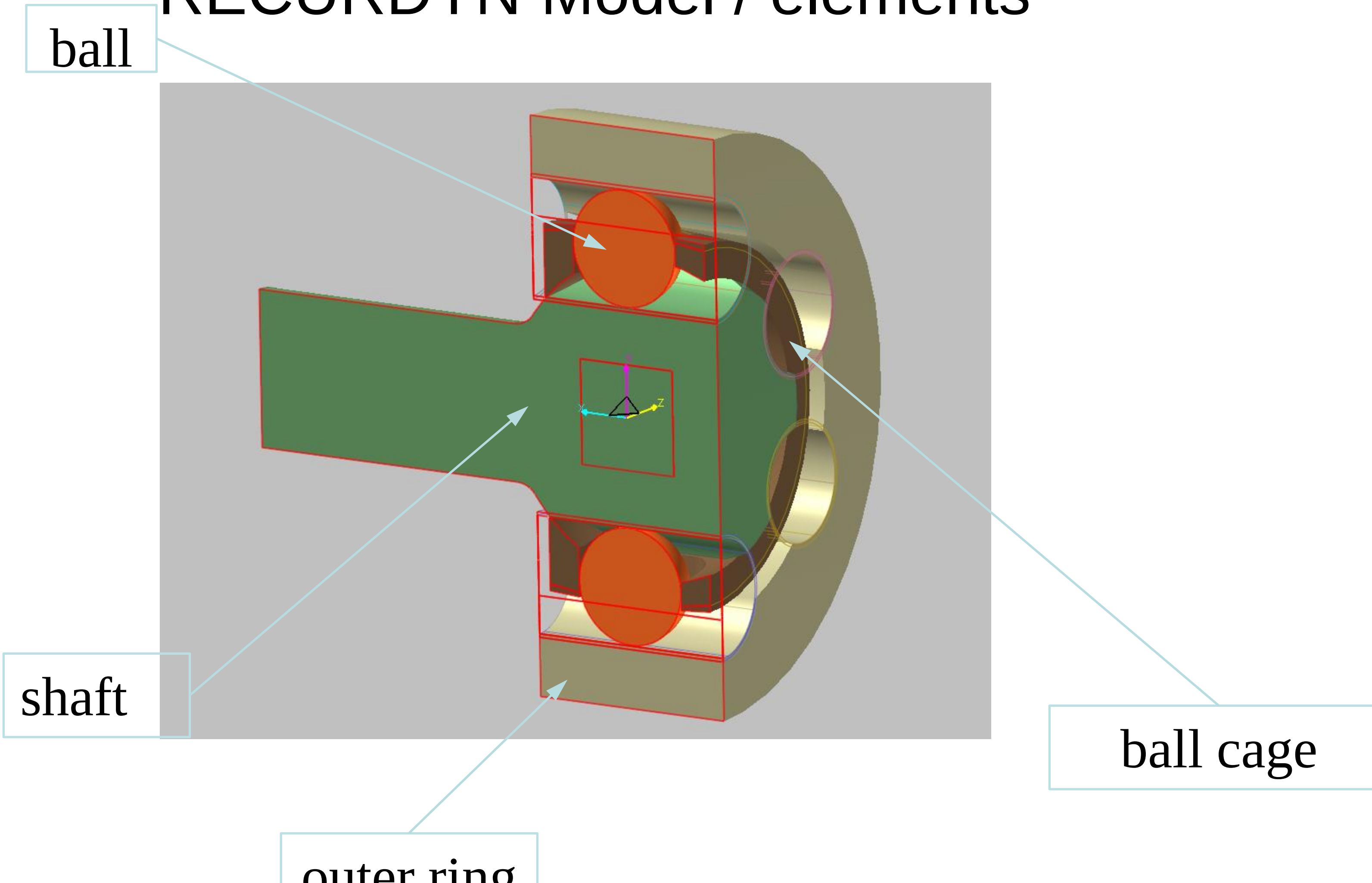
RECURDYN Model / CVJ - components



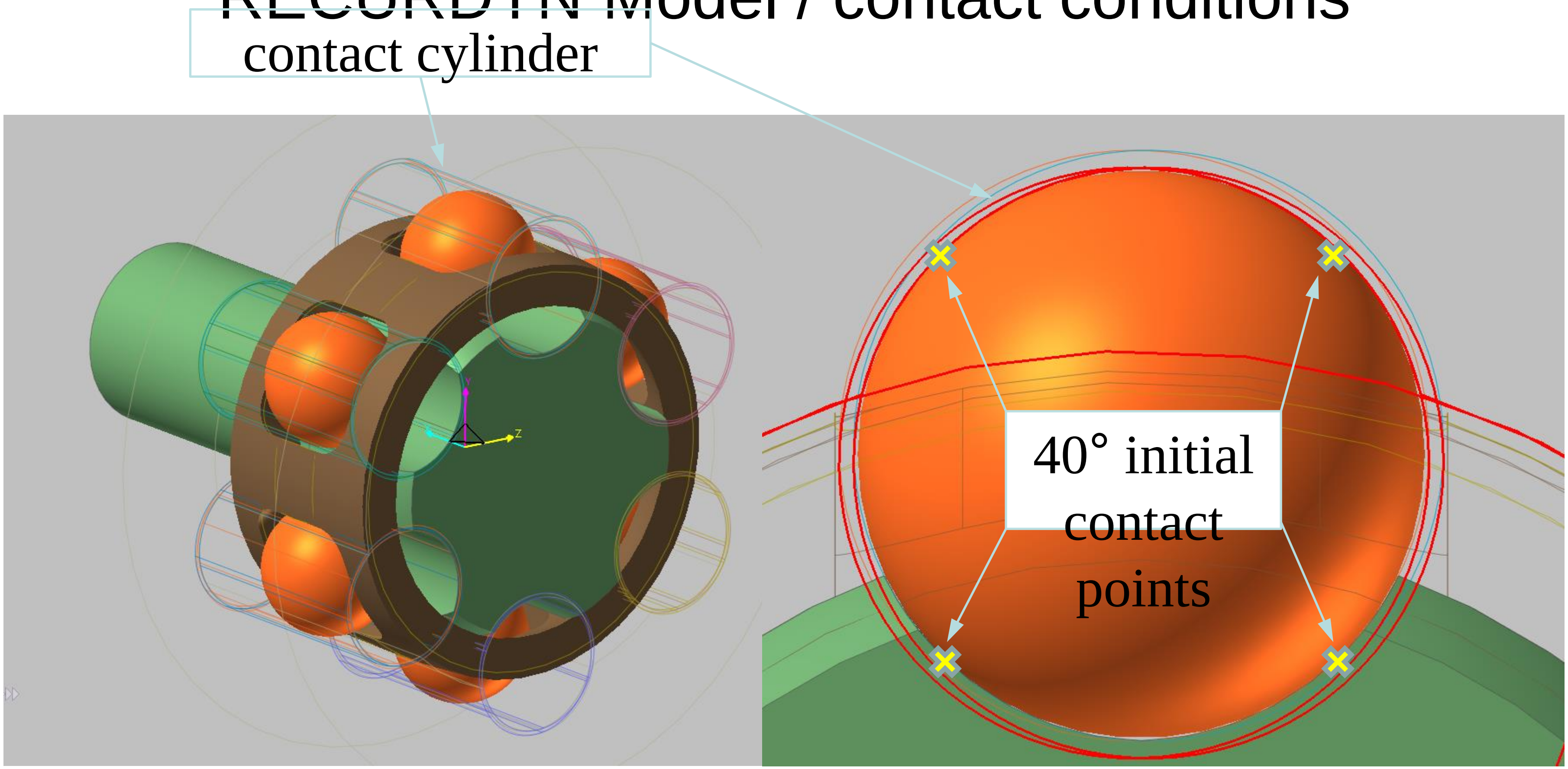
RECURDYN Model / CVJ – components (cross section)



RECURDYN Model / elements

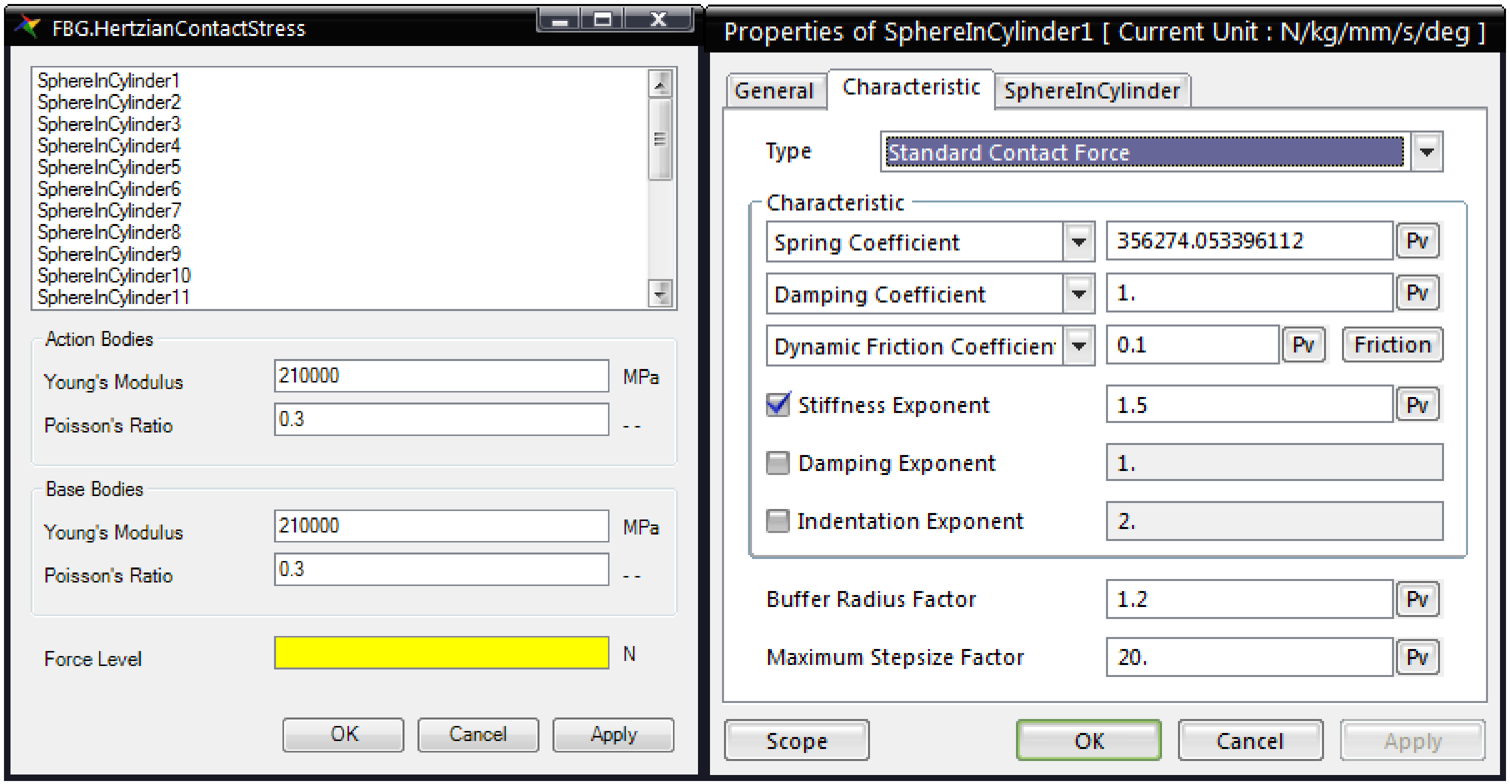


RECURDYN Model / contact conditions



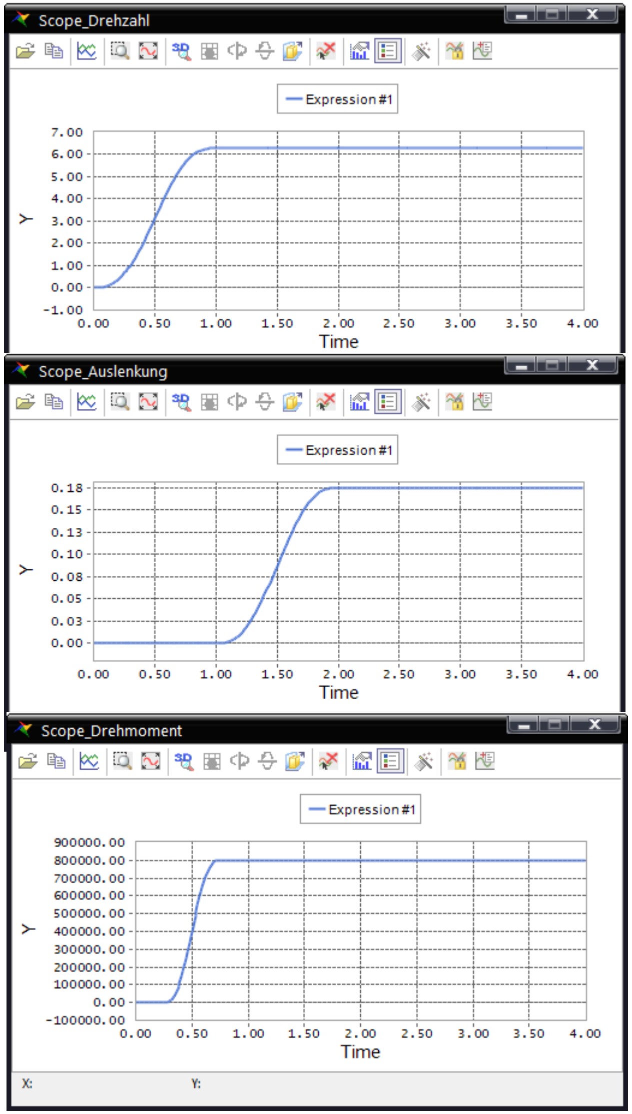
The contact between the grooves and the ball were set up as „Sphere in Cylinder“ contact. The cylinder bodies are offset from the initial ball center to define a 40° contact angle in the initial position.

RECURDYN Model / User actions



The contact parameters were set up with FBGs „Hertzian Contact Stress Tool“ – a perfect assistant for determining the proper stiffness factor

RECURDYN Model / Simulation



The simulation represents a sequence of the following:

1) rotation of the shaft
2) 10° swivel of the shaft axis
3) load torque on outer ring

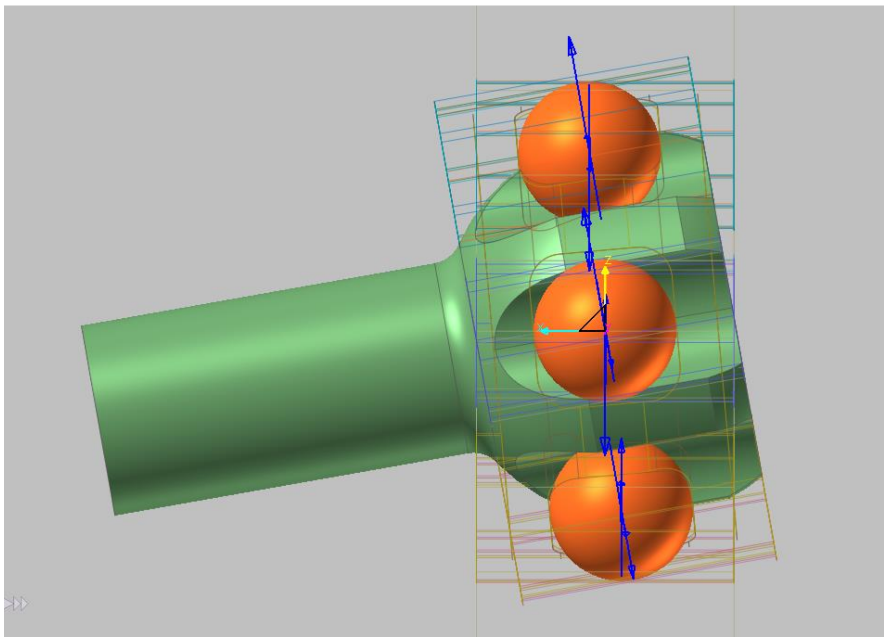
RECURDYN Simulation

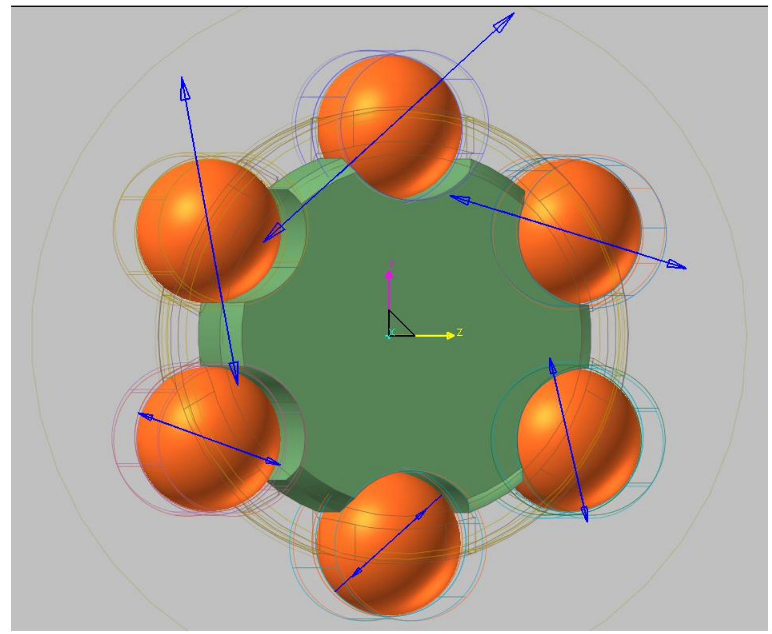
Ball cage rotates the half of the shafts angle.

Blue arrows show the contact forces

GLG01-1.avi

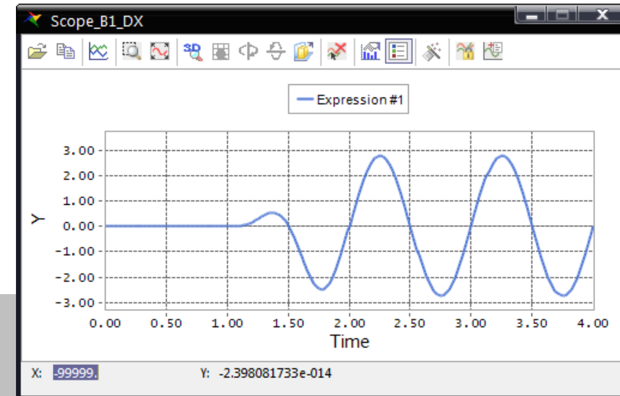
GLG01-2.avi

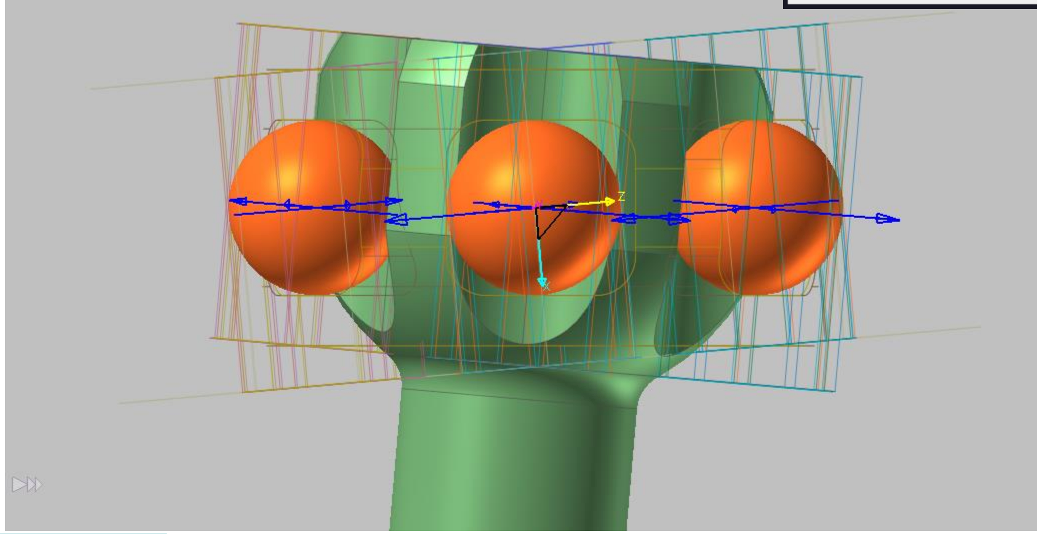




RECURDYN Simulation

Riding on the ball cage shows the axial movement (+/- 2.7mm) of the ball relative to the shaft‘s and outer ring‘s groove

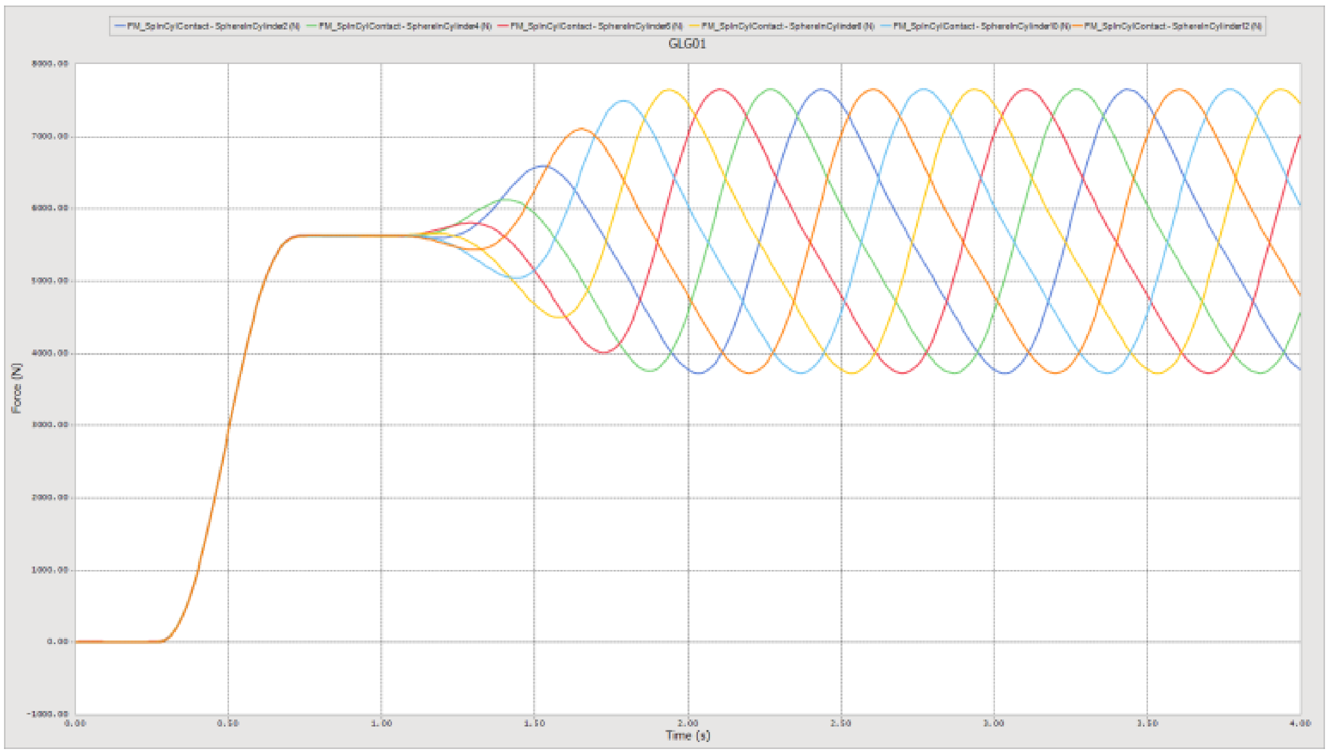




GLG01-3.avi

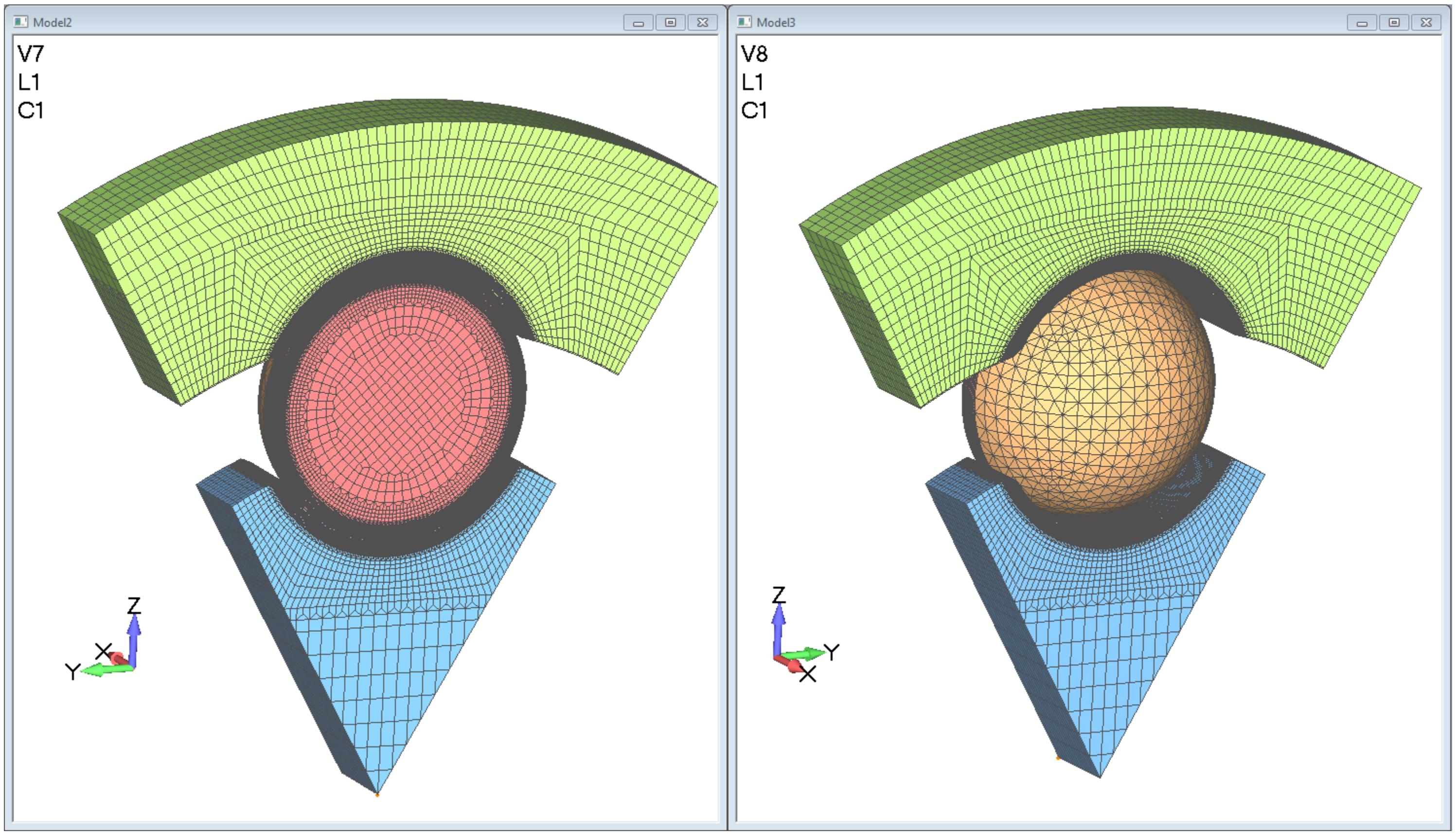
RECURDYN Simulation

Depending on the angular position of the ball, the contact force varies +/- 35% due to the shaft pitch angle of 10°.
Forces are shown for 800 Nm Torque Load Level



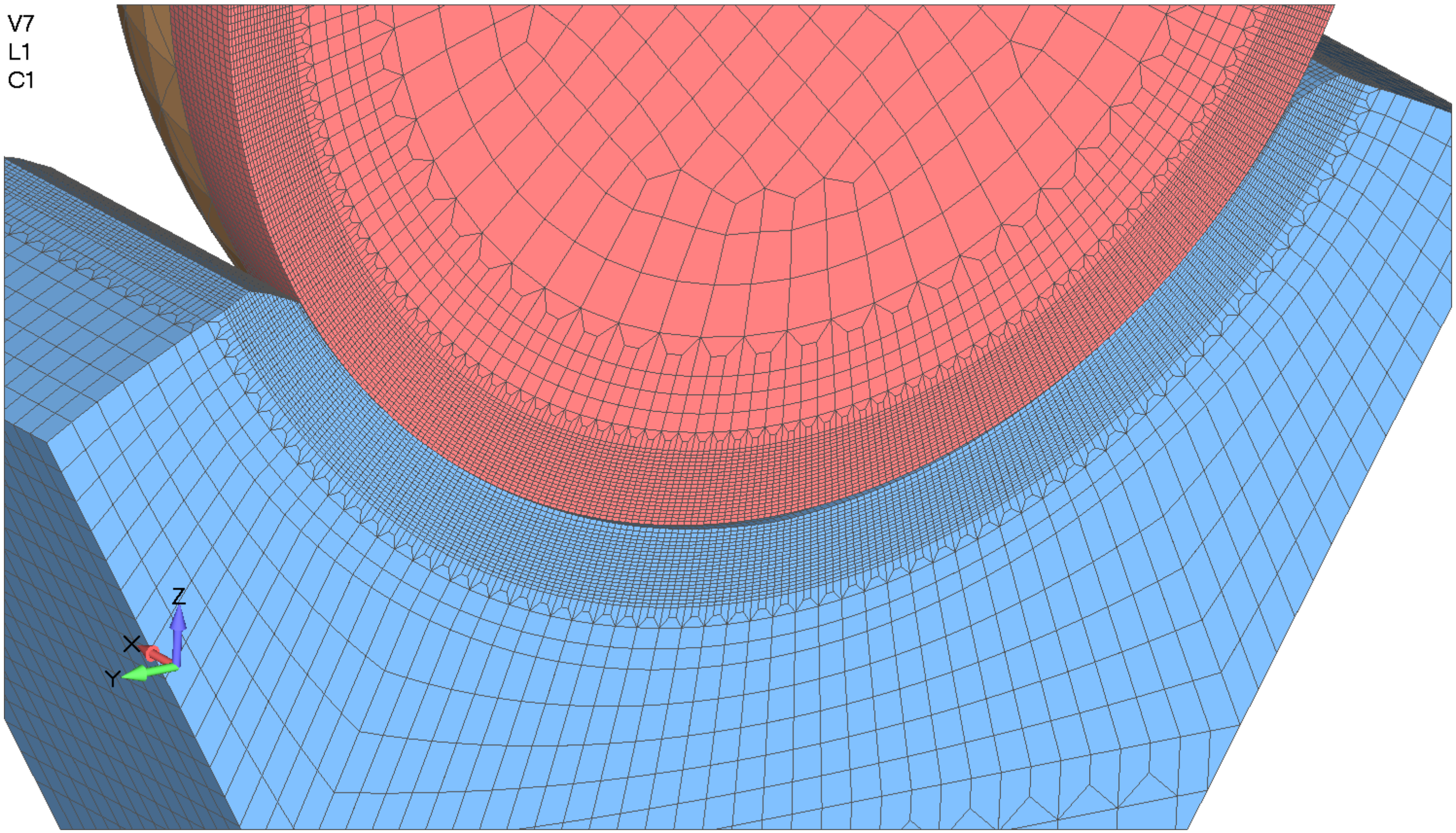
FEA Simulation

A half cyclic symmetric model of one ball was set up to determine the local stress distribution



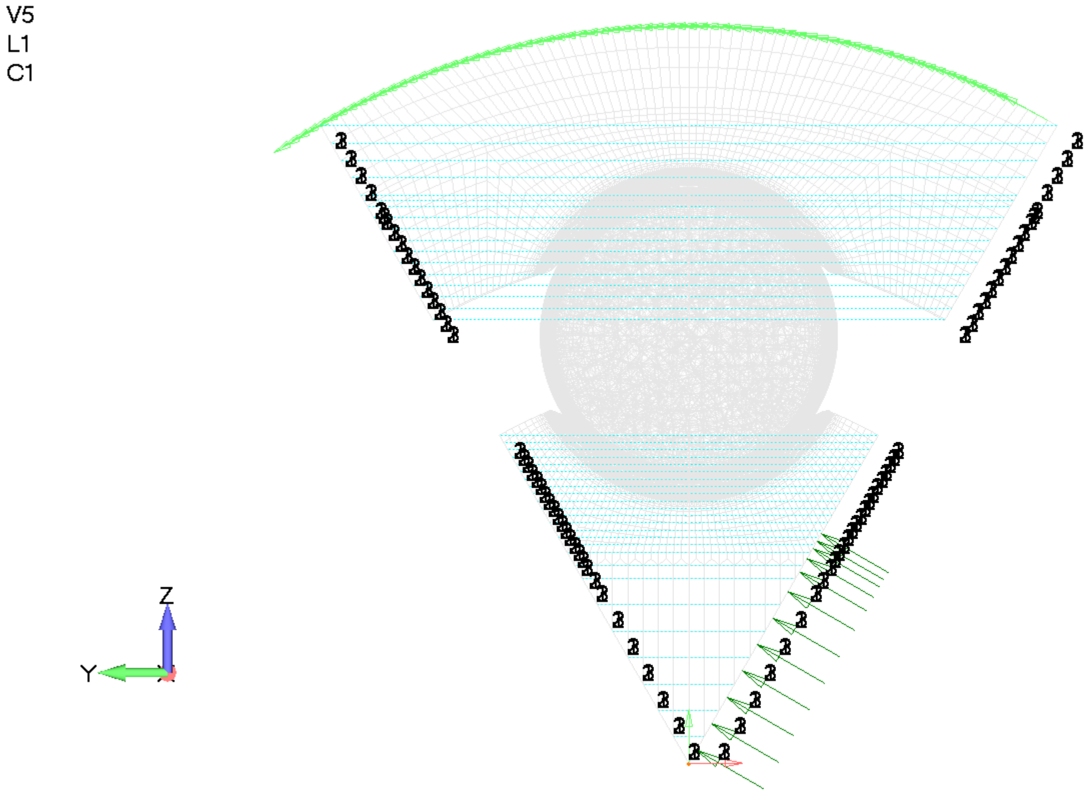
FEA Simulation

A fine mesh with high quality is required to guarantee local stresses with high quality



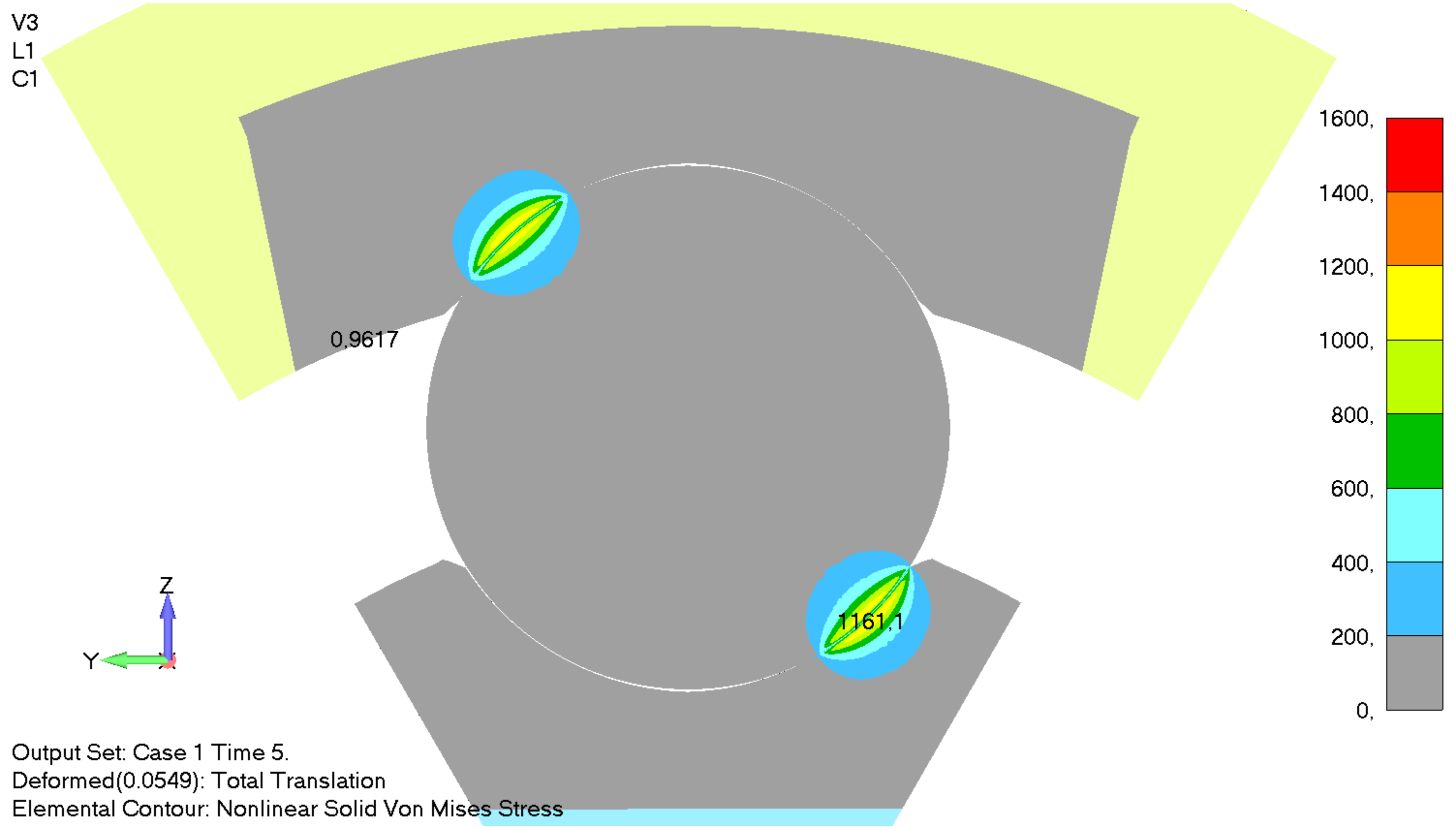
FEA Simulation

The Torque Load was applied on the shaft increased stepwise up to 1200 Nm. Cyclic symmetry was set up with the proper constraint equations, and the tangential boundary conditions are defined at the surface of the outer ring.



FEA Simulation

At 600 Nm Torque the v. Mises Stress distribution is symmetric to the contact point, according to the analytical calculation of Hertz theory



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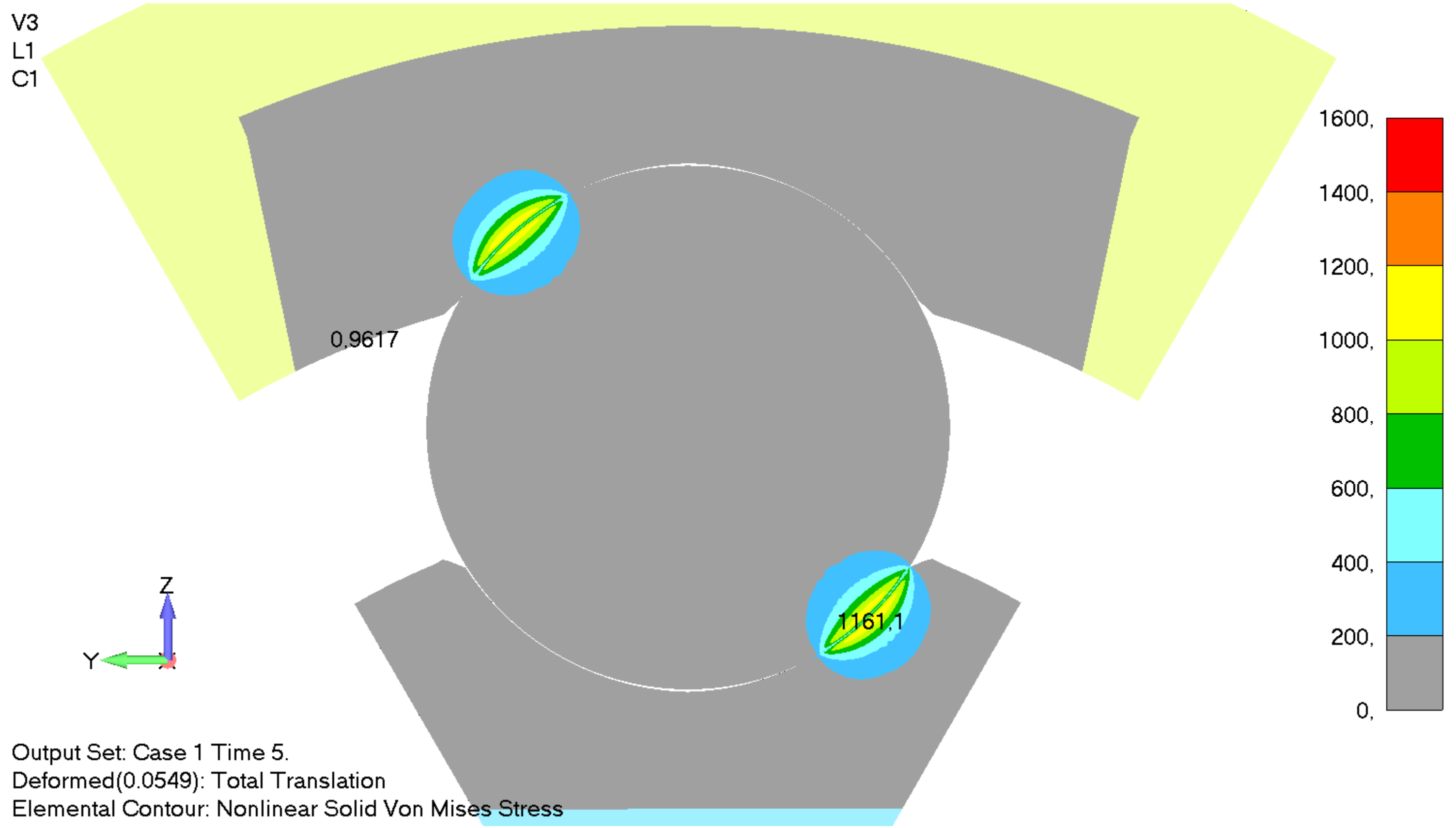
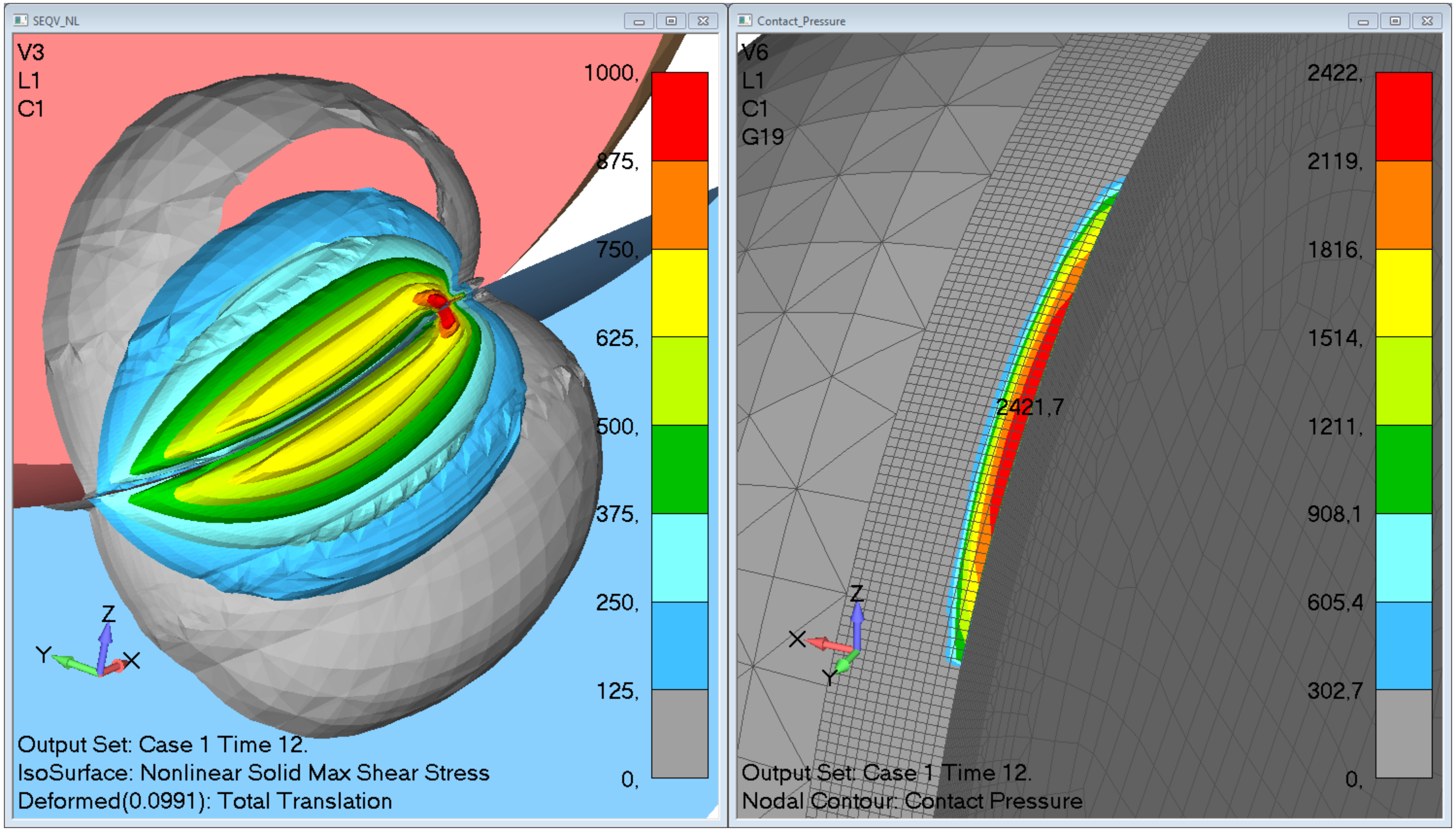
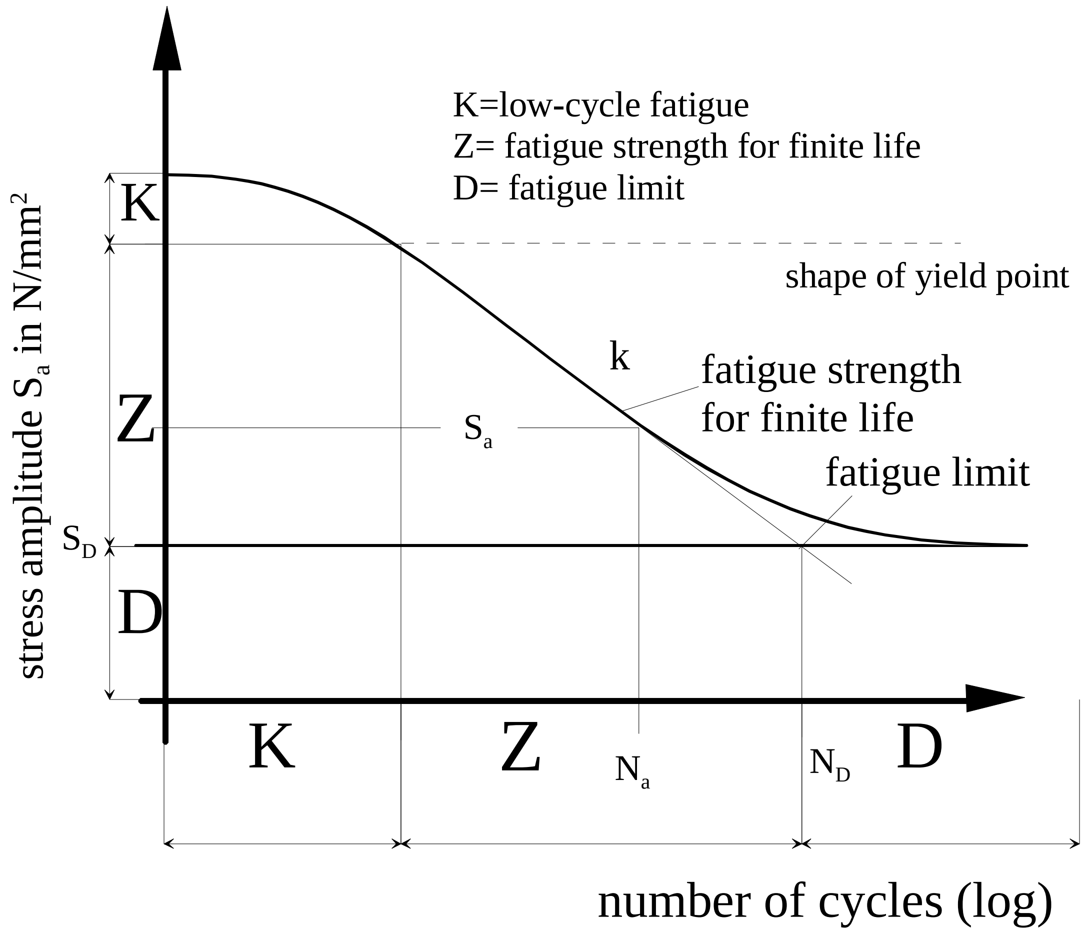


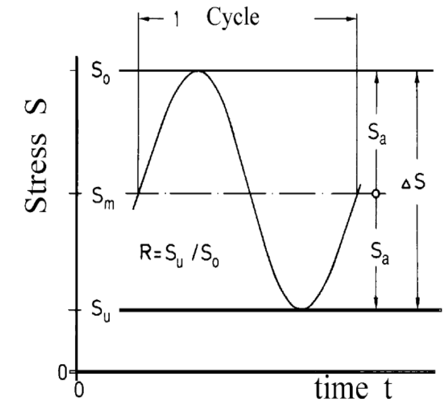
FEA Simulation

The Iso surface plot shows the local concentration of the maximum stress on the groove‘s edge.



Fatigue Analysis/ / Stress Life Curve

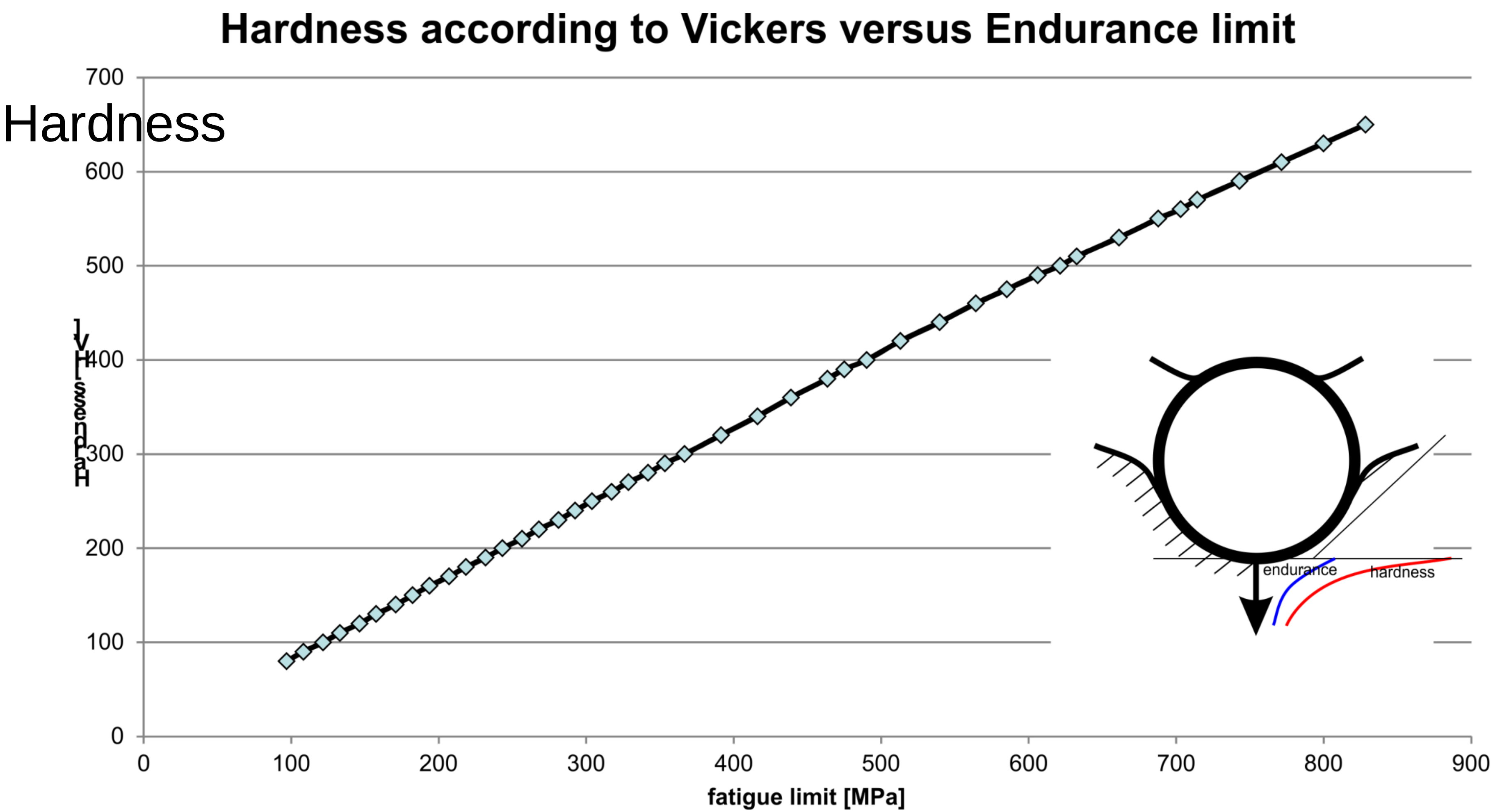




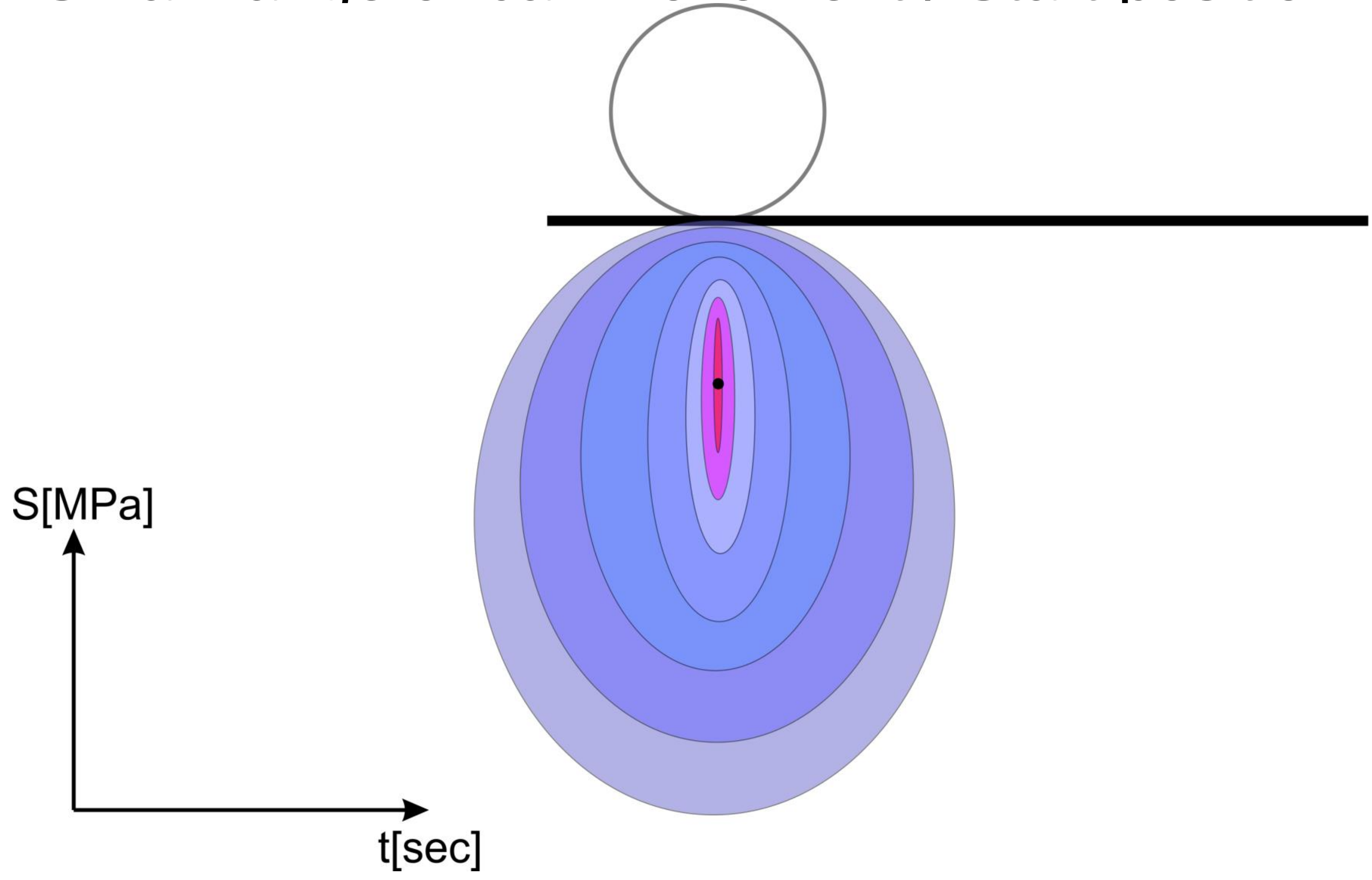
Used for fatigue life analysis with

- Real Stress according to v. Mises

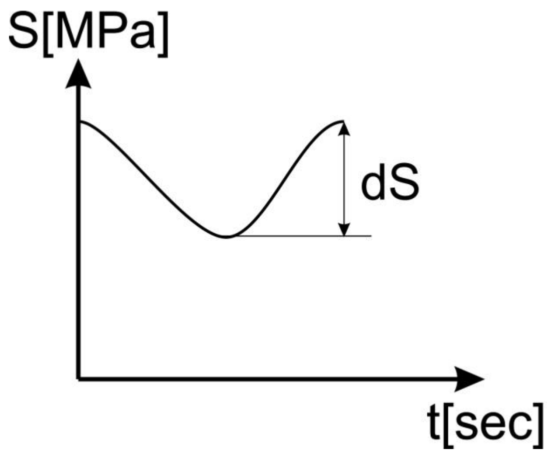
Fatigue Analysis/ Stress Life Curve

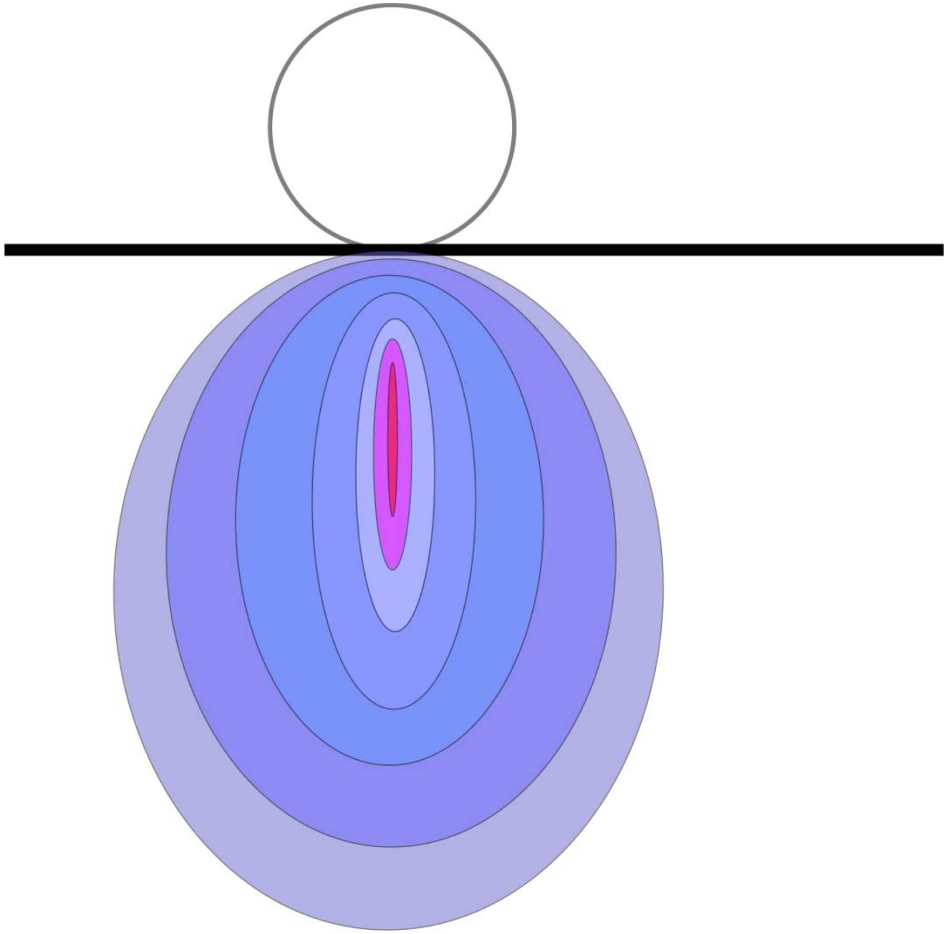


Fatigue Analysis / Small range of ball movement / Start position



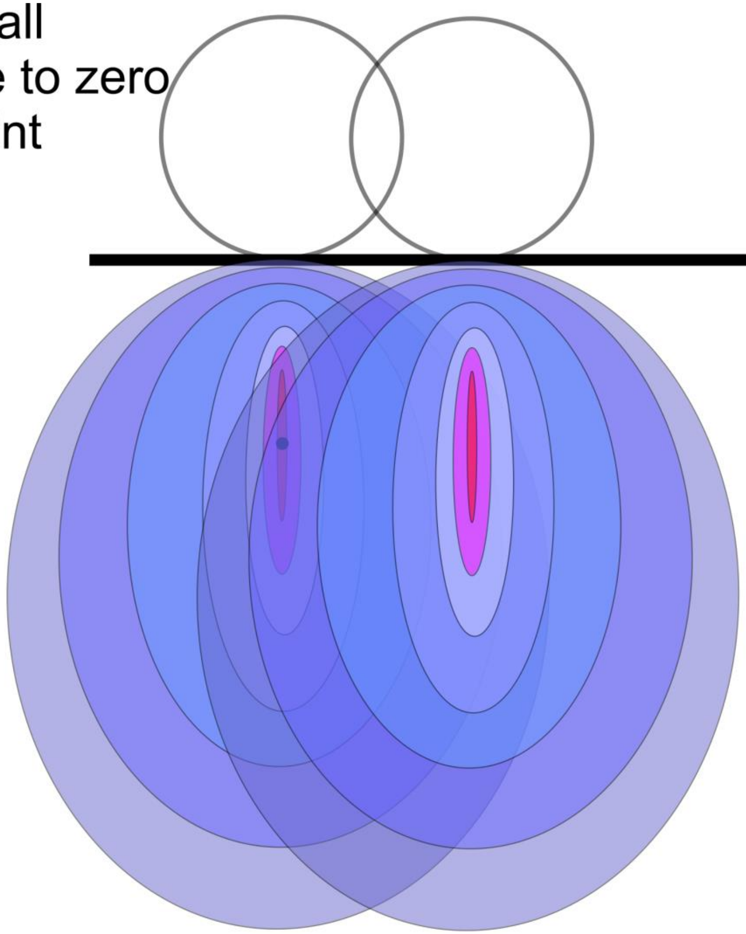
Fatigue Analysis /Small range of ball movement / end position

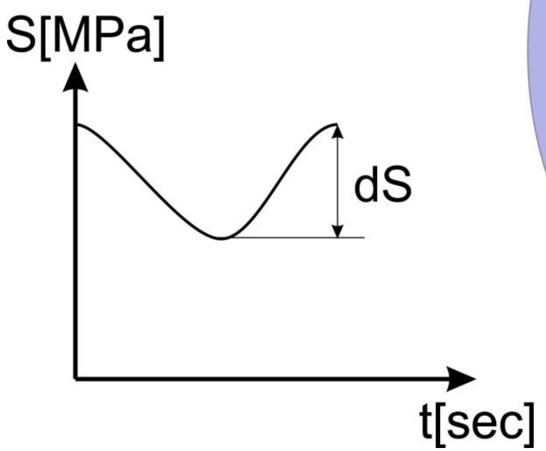




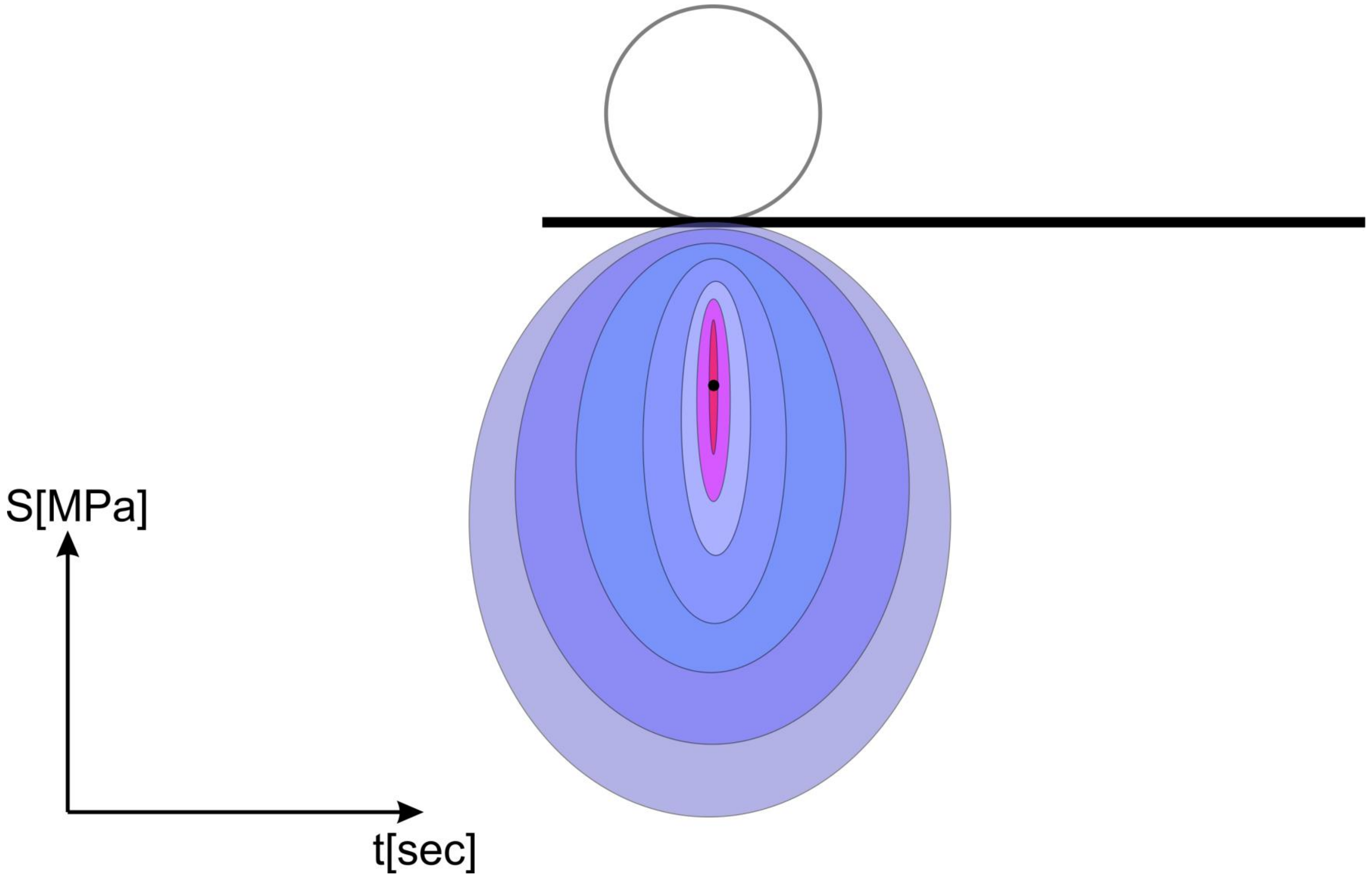
Fatigue Analysis / small range of ball movement

ball displacement small
that no stress release to zero
in the refererence point
happens



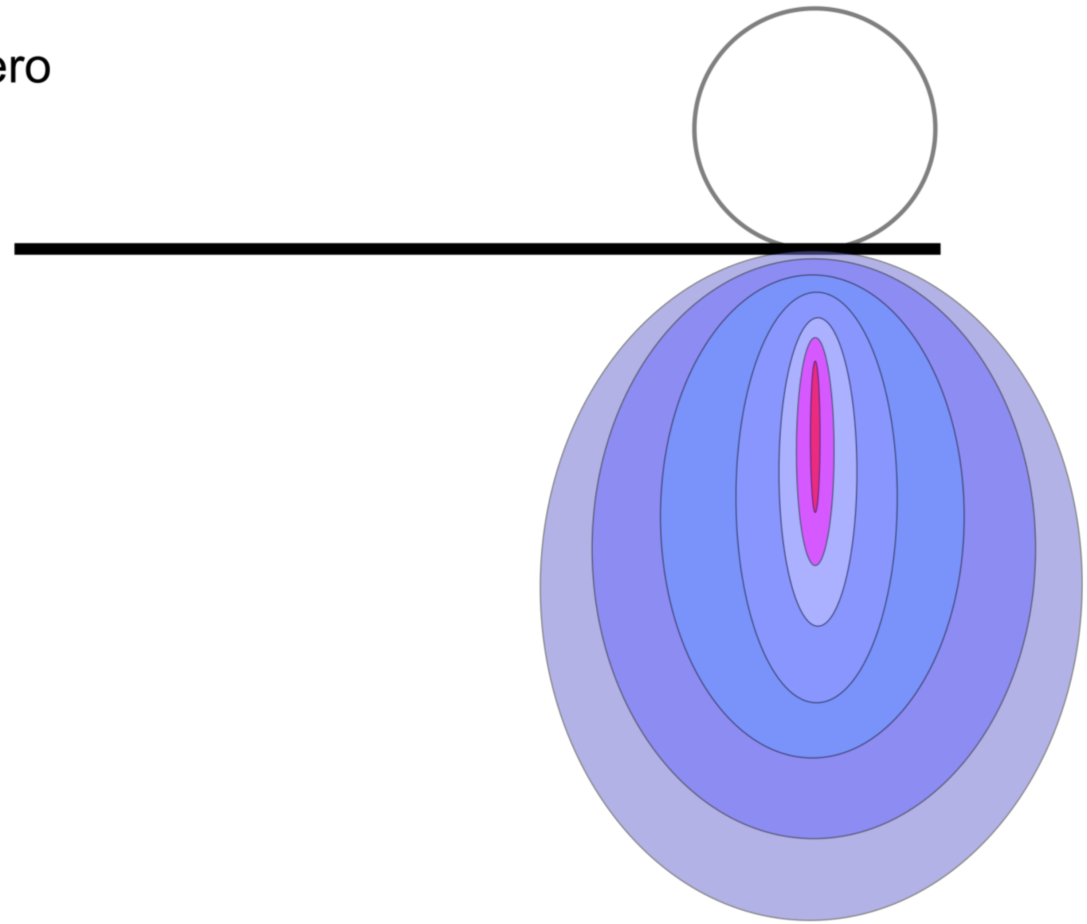


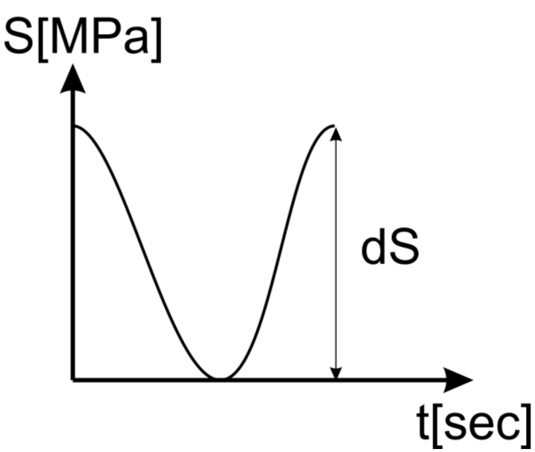
Fatigue Analysis / large range of ball movement



Fatigue Analysis / Large range of ball movement

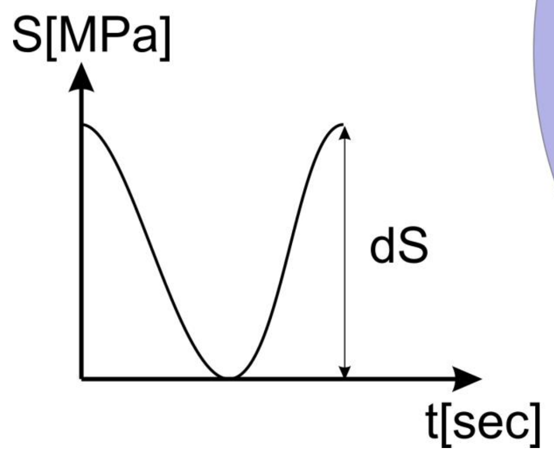
ball displacement large
that stress releases to zero
in fererence point

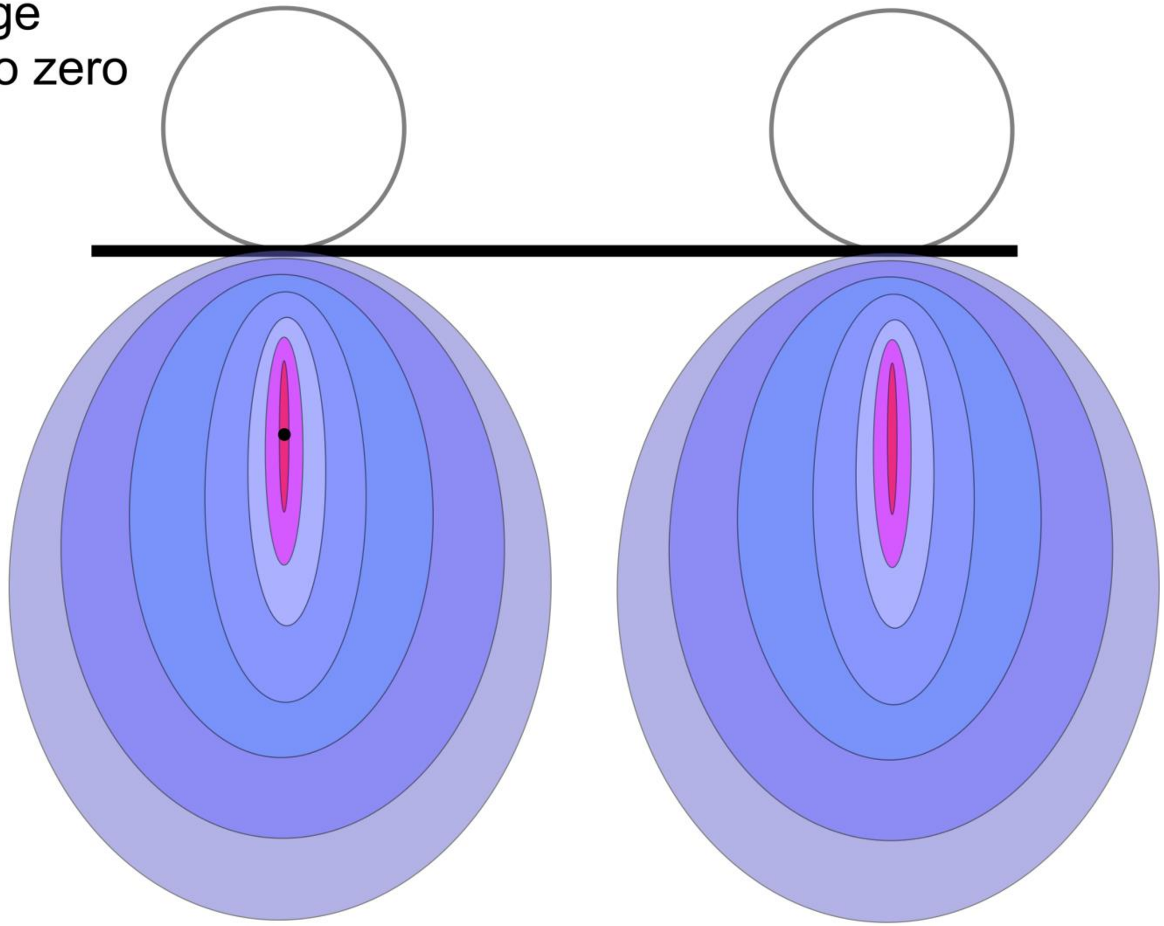




Large range of ball movement / both positions

ball displacement large
that stress releases to zero
in fererence point





Getting the stress history

- It was assumed that the torque does not change during one rotation
- For each position of the ball depending on the torque and angle a nonlinear FEA was done and a stress distribution was obtained.
- To simplify the analysis it is possible to assume a pulsating stress as explained before. This reduces the number of load cases to be analysed.
- The stress cycle for each element was obtained for one rotation. Depending on the distance to the surface the corresponding S-N curve was used and a damage accumulation was done according to Palmegren/Minder.
- As a result a damage share for each node was obtained.

Fatigue Analysis/ Damage Accumulation

- individual damage for each stress level

$$D_i = n_i / N_i$$

- total damage over all stress levels

$$D = \sum \mathrm{D}_i$$

Conclusion

- It is possible with MBS-software such as RECURYN to calculate the contact forces between the ball and the surfaces including all relevant kinematic and dynamic effects.
- Then a nonlinear FEA calculation is necessary because very fine meshes have to be used.
- The huge number of load cases coming from FEA results and the organisation of different S-N curves can be handled with winLIFE.
- Material data for hardened surfaces depending on the hardness versus the distance of the surface are (mostly) available from the manufacturer of the parts and can be used to predict the S-N-curves.
- Fatigue life prediction of components loaded by dynamic forces, complex contact situation like CVJ or general bearings are possible and can be done with limited effort using container project concept within winLIFE.

Thank you for your interest