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Calculation of bearings along ISO/TS 16281 using KISSsoft

Speaker:
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Application Engineer

Kugel- und Rollenlagerwerk Leipzig GmbH
1. Company Kugel- und Rollenlagerwerk Leipzig GmbH

2. Lifetime calculation / Influencing parameter

3. Possibilities to calculate bearings in KISSsoft

4. KRW Calculation example: Gear shaft

5. Summary
1. Company Kugel- und Rollenlagerwerk Leipzig GmbH

1.1 History
1.2 Applications
1.3 Products
1.4 Certificates
1.5 Engineering competence
1.6 References in gearboxes
1.7 KRW advantages

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Dipl.-Ing. Andreas Poltsch
Managing Director (Sales & Engineering)
1.1 History

1904 Foundation of DKF (Deutsche Kugellagerfabriken Deutschland) in Leipzig

1955 DKF becomes VEB DKF Wälzlagerwerk Leipzig and thus state-owned property of the then German Democratic Republic (DDR)

1990 After the reunification of Germany VEB DKF Wälzlagerwerk Leipzig becomes a member of the FAG group

1993 Kugel- und Rollenlagerwerk Leipzig GmbH (KRW) is founded

2010 China, Shanghai Representation office
India, Secunderabad Representation office

2013 New owner of KRW is ZWZ, Wafandiang Bearing group, China
1.2 Applications

Heavy Industry  Rail & Transport  Energy & Power Plants  Machines & Equipment  Ship- & Port Technology
# 1.3 Products

<table>
<thead>
<tr>
<th>Bearing type</th>
<th>Dimension (outer diameter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep groove ball bearings</td>
<td>Ø 125 - 1300 mm</td>
</tr>
<tr>
<td>Angular contact bearings</td>
<td>Ø 125 - 1300 mm</td>
</tr>
<tr>
<td>Angular contact bearings, double row</td>
<td>Ø 125 - 1300 mm</td>
</tr>
<tr>
<td>Four point contact bearings</td>
<td>Ø 140 - 540 mm</td>
</tr>
<tr>
<td>Angular contact thrust ball bearings</td>
<td>Ø 125 - 1300 mm</td>
</tr>
<tr>
<td>Cylindrical roller bearings, single row</td>
<td>Ø 68 - 1300 mm</td>
</tr>
<tr>
<td>Cylindrical roller bearings, multi row</td>
<td>Ø 200 - 1300 mm</td>
</tr>
<tr>
<td>Cylindrical roller bearings (full complement), single row</td>
<td>Ø 68 - 1300 mm</td>
</tr>
<tr>
<td>Cylindrical roller bearings (full complement), multi row</td>
<td>Ø 200 - 1300 mm</td>
</tr>
<tr>
<td>Cylindrical roller thrust bearings</td>
<td>Ø 60 - 1300 mm</td>
</tr>
<tr>
<td>Tapered roller bearings</td>
<td>Ø 170 - 1300 mm</td>
</tr>
<tr>
<td>Tapered roller thrust bearings</td>
<td>Ø 200 - 1300 mm</td>
</tr>
<tr>
<td>Spherical roller bearings</td>
<td>Ø 140 - 1300 mm</td>
</tr>
<tr>
<td>Spherical roller bearings, double row</td>
<td>Ø 170 - 1300 mm</td>
</tr>
<tr>
<td>Spherical roller thrust bearings</td>
<td>Ø 400 - 1300 mm</td>
</tr>
<tr>
<td>Thin section bearings</td>
<td>Ø 200 - 1300 mm</td>
</tr>
<tr>
<td>Special bearings</td>
<td>Ø 200 - 1300 mm</td>
</tr>
</tbody>
</table>
1.4 Certificates

• Certified according to DIN EN ISO 9001: 2008
• Q1 supplier of Deutsche Bahn with HPQ
1.5 Engineering competence

- Standard bearings
- Customized bearing design
  - Customized dimensions and clearance (e.g. C4, C5)
  - Special tolerances (e.g. P5, . . . SP)
  - Special coatings (e.g. ceramic, black oxide)
  - Special lubrication design
  - Special heat stability
  - Special heat treatment
- Development of customized bearings
  - Bearing selection
  - Bearing calculation

KRW takes care from development to prototype manufacturing to serial production

- Mounting bearings
- Support in case of failures (e.g. vibration analysis)
- Reconditioning of bearings
- Workshops for customers
1.6 References in gearboxes

- Siemens
- Elecon
- DB Mobility Networks Logistics
- Rexroth Bosch Group
- Voith
- BHEL
- FLENDER
- SEW Eurodrive
- Eickhoff
- Alstom
- RENK
- Jakoe
- Gmeinder Getriebe
- SIEBENHAAR Antriebstechnik GmbH
- NORD
- Moventas
- PIV
- Russian Railways
- Zollern
- NAF Driven by Innovation
- Keller
1.7 KRW advantages at a glance

- KRW manufactures bearings at highest quality level  
  Made in Germany – 100%!
- More than 100 years of experience in development and manufacture of bearings
- Manufacturing of standard and special/customized bearing solutions, also in smaller lot sizes
- Shortest development and delivery times → 10 weeks (fastest 6 weeks if raw material is available)
- KRW guarantees shortest developing times to realize your project just in time

KRW is your partner from the first steps in engineering up to a reliable serial supply
2. Definition of lifetime calculation / Influencing parameter
3. Possibilities to calculate bearings in KISSsoft
4. KRW Calculation example: Gear shaft
   4.1 Modeling in KISSsoft by KRW company
   4.2 Input bearing data
   4.3 Calculation results
   4.4 Influence of radial clearance (bearing NU2248E)
   4.5 Influence of temperature (oil, shaft)
   4.6 Influence direction of load (bearings 32248A)
5. Summary
### 2. Definition of lifetime calculation

**Basic life** $L_{10}$
- ISO 281

\[ L_{10} = \left( \frac{C}{P} \right)^p \]

**Modified life** $L_{nm}$
- ISO 281

\[ L_{nm} = a_1 \cdot a_{ISO} \cdot \left( \frac{C}{P} \right)^p \]

**Basic reference rating life** $L_{10r}$
- ISO/TS 16281

\[ L_{10r} = \left( \sum_{k=1}^{n_S} \left[ \left( \frac{q_{kci}}{q_{kai}} \right)^{-4.5} + \left( \frac{q_{kci}}{q_{kai}} \right)^{-4.5} \right] \right)^{-8/9} \]

**Modified reference rating life** $L_{nmr}$
- ISO/TS 16281

\[ L_{nmr} = a_1 \left( \sum_{k=1}^{n_S} \left[ \left( \frac{q_{kci}}{q_{kai}} \right)^{-4.5} + \left( \frac{q_{kci}}{q_{kai}} \right)^{-4.5} \right] \right)^{-8/9} \]
2. Influencing Parameters

- Selection of parameter

- Operating condition:
  - Speed
  - Vibration
  - Shock load
  - Acceleration
  - Misalignment
  - Axial/ radial load
  - Required service life

- Lubrication:
  - Pollution
  - Viscosity
  - Thickener
  - Relubrication
  - Oil lubrication
  - EP / AW additive
  - Grease lubrication
  - Lubricant film thickness

- Bearing:
  - Type
  - Stiffness
  - Clearance
  - Cage design
  - Minimum load
  - Reference speed
  - Internal geometry
  - Run-out accuracy
  - Dimensional stabilization
  - Dynamic / static load rating

- Assembly situation:
  - Fit
  - Wear
  - Preload
  - Material
  - Clearance
  - Roundness
  - Assembling
  - Temperature
  - Wall thickness
  - Shaft deflection
  - Mounting space
  - Horizontal / vertical position

- Damages:
  - Wear
  - Corrosion
  - Indentations
  - Smear marks
  - Mounting error
  - Material fatigue
  - Passage of current

- Other:
  - Noise
  - Friction moment
  - Failure probability
  - Required certification
  - Customer experience

- Definition of lifetime calculation / Influencing parameters:

\[ L_{10} = L_{10r} + L_{nm} \]

- Equation:

\[
L_{nm} = L_{nmr} + L_{10r} + L_{10}
\]
3. Possibilities to calculate bearings in KISSsoft

- **Shaft calculation**
  - Bearings with shaft and housing
  - Life calculation: $L_{10}$, $L_{nm}$, $L_{10r}$, $L_{nmr}$

- **Rolling bearing ISO 281, ISO 76**
  - Single bearings
  - Life calculation: $L_{10}$, $L_{nm}$

- **Rolling bearing ISO/TS 16281**
  - One bearing
  - Life calculation: $L_{10r}$, $L_{nmr}$
4. KRW Calculation example: Gear shaft

**Given data**

**Gearwheel shaft with coupling**
- Drive torque $T_y$: 70 kNm
- Speed: ± 250 rpm
- Force $F_z$: 200 kN
- Shaft dimensions
- Gear data
- Temperatures: $\theta_{\text{shaft}} = 60 \, ^{\circ}\text{C}$
- $\theta_{\text{housing}} = 35 \, ^{\circ}\text{C}$
- $\theta_{\text{lubricant}} = 50 \, ^{\circ}\text{C}$
- Material of shaft and housing
- Lubrication oil: ISO VG220
- Impurity of oil

**Which bearing solution?**

$L_{10h} > 40.000 \, \text{h}$

- Adjusted bearing (X-arrangement)
  - Tapered roller bearing e.g. 32248A

- Selected bearing type

- Radial bearing
  - Cylindrical roller bearing e.g. NU2248E
4.1 Modeling in KISSsoft by KRW company

1. Modeling shaft

2. Insert coupling, force, gear

3. Select bearing type

4. Input operating conditions

KRW Calculation example: Gear shaft
4.2 Input bearing data

- Standard bearing catalog (KRW, FAG, SKF etc.)
- Special bearing design (own input)
### 4.3 Calculation results

**Results:** $L_{10h}$, $L_{nmh}$, $L_{10rh}$, $L_{nmrh}$, max. pressure, forces

<table>
<thead>
<tr>
<th>Bearing service life</th>
<th>$S_0$</th>
<th>$L_{nh}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>32248A_Left</td>
<td>17.29</td>
<td>162995 h</td>
</tr>
<tr>
<td>32248A_Right</td>
<td>11.78</td>
<td>45364 h</td>
</tr>
<tr>
<td>NU2248E</td>
<td>11.68</td>
<td>58093 h</td>
</tr>
</tbody>
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</table>

**Speed clockwise:**
- $L_{10h} > 40,000$ h

**Speed counterclockwise:**

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4.3 Calculation results

- Hertzian pressure (inner ring)
  - 32248A_left
  - 32248A_right
  - NU2248E

- Shaft deformation 3D

- Shaft displacement ($u_x, u_y, u_z, u_r$)

- Bearing stiffness
  - 32248A_left axial & radial
  - NU2248E radial

- Stress resultant ($x, y, z, r$)
4.4 Influence of radial clearance (bearing NU2248E)

**Results**
- Maximum deflection
- Maximum equivalent stress
- Minimum bearing service life
- Minimum static bearing safety

**Bearing service life**
- 32240A_Left: 35936 h
- 32240A_Sight: 131210 h

**Operating clearance**:
- **C2**: -54.4 µm
- **CN**: 10.6 µm
- **C4**: 135.6 µm

**Load distribution 3D**

**Load distribution 2D**
4.5 Influence of temperature (shaft, oil)

**Shaft temperature:** 60°C
Operating clearance: 10.6 µm

<table>
<thead>
<tr>
<th>Results</th>
<th>L_{10rh}</th>
<th>L_{nmrh}</th>
</tr>
</thead>
<tbody>
<tr>
<td>max deflection</td>
<td>282.99 µm</td>
<td>288.57 µm</td>
</tr>
<tr>
<td>max equivalent stress</td>
<td>67.85 N/mm²</td>
<td>57.78 N/mm²</td>
</tr>
<tr>
<td>min bearing service life</td>
<td>624781.31 h</td>
<td>680165.93 h</td>
</tr>
<tr>
<td>min static bearing safety</td>
<td>11.78</td>
<td>11.05</td>
</tr>
</tbody>
</table>

**Oil temperature:** 50°C
Viscosity ratio: κ = 4.78

<table>
<thead>
<tr>
<th>Results</th>
<th>L_{nmh}</th>
</tr>
</thead>
<tbody>
<tr>
<td>max deflection</td>
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<td>min bearing service life</td>
<td>624781.31 h</td>
</tr>
<tr>
<td>min static bearing safety</td>
<td>11.78</td>
</tr>
</tbody>
</table>

**Shaft temperature:** 80°C
Operating clearance: -68.3 µm

<table>
<thead>
<tr>
<th>Results</th>
<th>L_{10rh}</th>
<th>L_{nmrh}</th>
</tr>
</thead>
<tbody>
<tr>
<td>max deflection</td>
<td>282.99 µm</td>
<td>236.02 µm</td>
</tr>
<tr>
<td>max equivalent stress</td>
<td>67.85 N/mm²</td>
<td>48.5628 N/mm²</td>
</tr>
<tr>
<td>min bearing service life</td>
<td>624781.31 h</td>
<td>675465.65 h</td>
</tr>
<tr>
<td>min static bearing safety</td>
<td>11.78</td>
<td>13.34</td>
</tr>
</tbody>
</table>

**Oil temperature:** 80°C
Viscosity ratio: κ = 1.34

<table>
<thead>
<tr>
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<th>L_{nmh}</th>
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</thead>
<tbody>
<tr>
<td>max deflection</td>
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<td>624781.31 h</td>
</tr>
<tr>
<td>min static bearing safety</td>
<td>11.78</td>
</tr>
</tbody>
</table>

**Shaft temperature:** 100°C
Operating clearance: -147.2 µm

<table>
<thead>
<tr>
<th>Results</th>
<th>L_{10rh}</th>
<th>L_{nmrh}</th>
</tr>
</thead>
<tbody>
<tr>
<td>max deflection</td>
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</tr>
<tr>
<td>min static bearing safety</td>
<td>11.78</td>
<td>13.34</td>
</tr>
</tbody>
</table>

**Oil temperature:** 100°C
Viscosity ratio: κ = 0.70

<table>
<thead>
<tr>
<th>Results</th>
<th>L_{nmh}</th>
</tr>
</thead>
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<tr>
<td>max deflection</td>
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</tr>
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<td>min static bearing safety</td>
<td>11.78</td>
</tr>
</tbody>
</table>
4.6 Influence direction of load (bearings 32248A)

- Radial load
- Axial load

Stress distribution on race

KRW Calculation example: Gear shaft

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5. Summary

Bearing calculation in KISSsoft Software

- Lifetime calculation according to ISO 281 and ISO/TS 16281
- Possibilities to calculate bearings in KISSsoft
- Use KISSsoft for bearing calculation
- Influence of operating / assembly conditions on lifetime
Thank you for your attention.

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