GRW

High-Precision Ball Bearings

KAMAN

Specialty Bearings & Engineered Products

’RELIEVING THE PAIN’ –
DENTAL BEARINGS WITH TILT COMPENSATION

Gebrüder Reinfurt GmbH & Co. KG

1. INTRODUCTION

GRW Orakel 3 test rig

A screaming, tormenting humming - many connect the sound of the dentist's drill to aching teeth.

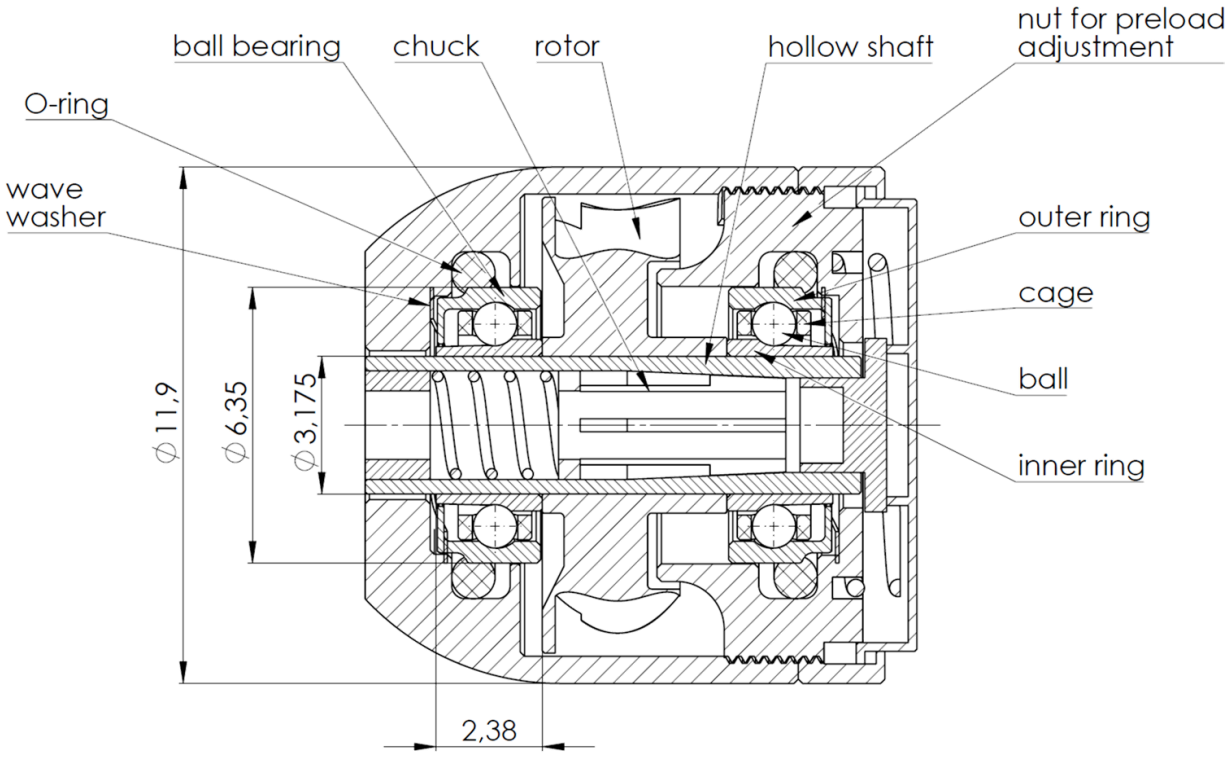
Root canal treatment is not a pleasant experience in itself. Additional high-frequency sounds of the supposed torture tool squeaking at the patient’s eardrum inevitably lead to a negative connotation of the dentist and the dental devices.

Besides the pain the patient might feel on the dentist chair, a dental handpiece, is also a “painful” challenge for bearings.

2. DENTAL HANDPIECE / A HIGH-TECH SYSTEM

Dental Handpieces

- The dental handpiece is part of the basic equipment of every dental treatment
- It incorporates the various tools necessary for dental care



Key data

- pneumatic drive of the turbine
  → up to 500,000 rpm
- X-arrangement of ball bearings
  → O-rings and wave washers
- hollow shaft with integrated chuck
  → tool holder

3. DENTAL BEARINGS – A COMPLEX TRIBO SYSTEM

Dental bearing – customized design to beat the challenges:

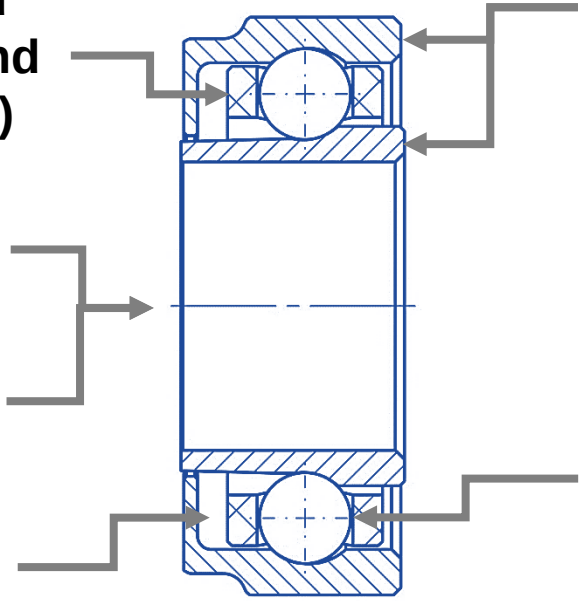
- The harsh environment of dental bearings in a dental handpiece, are one of the most challenging operation conditions for rolling bearings
- Several key features are needed to provide the best bearings for this special & complex tribological system

Chemically bonded PAI/PTFE-compound retainer (XTRAlon®)

Thigh bore diameter tolerance classes

Usually ABEC7/7P tolerance accuracy class

Grease: poly-urea based



Stainless steel rings (X65Cr13)

Standard sizes:

- 6.35mm OD
- 3.175mm ID
- 1mm Ball Dia.
- „Cap design“

Ceramic balls (Si_3N_4)

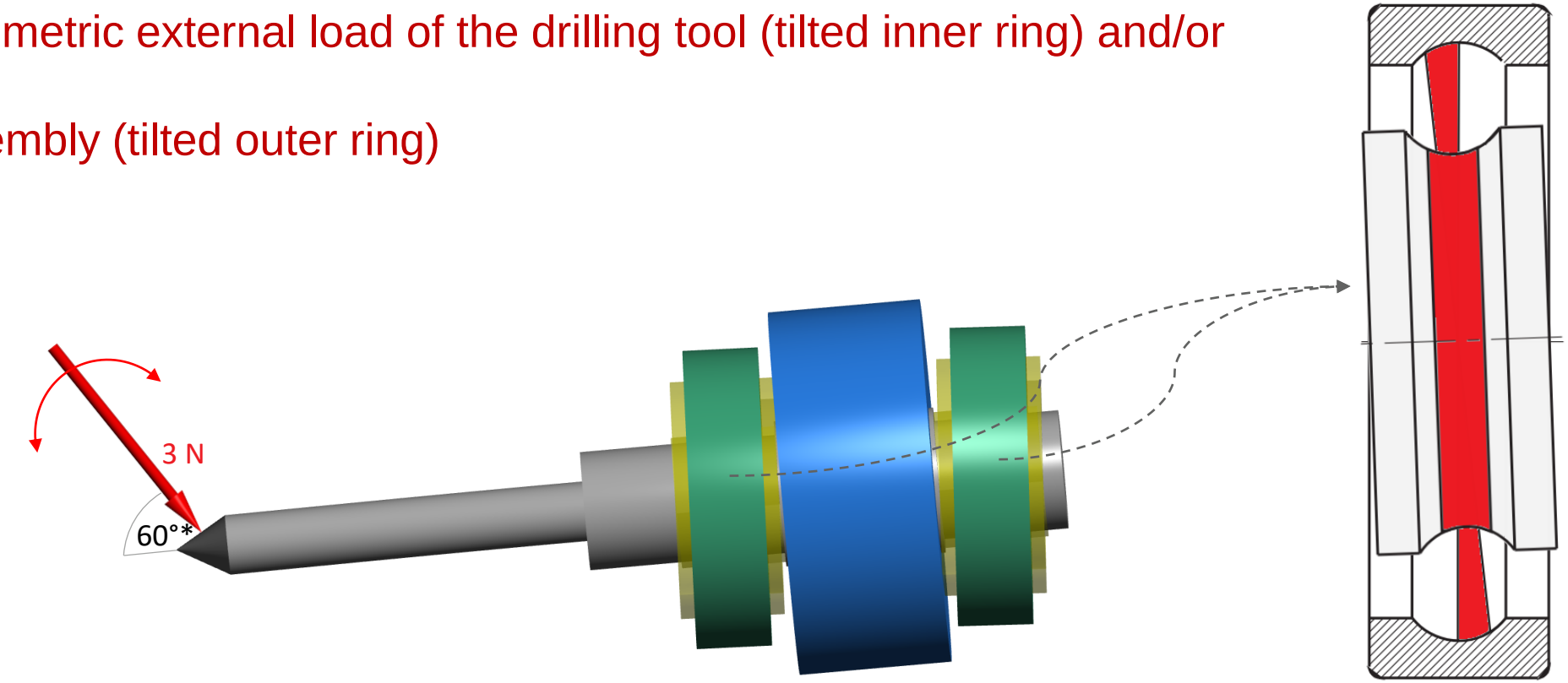
Operating conditions

- Speed up to **500.000 rpm ($n*d_m$ = 1.5Mio – 2Mio mm/min)**
- **Fast acceleration / deceleration** of the bearing
- **Air flow through the bearing** during operation (lube discharge)
- **Poor lubrication** / only re-oiling during cleaning cycles
- **134°C (273°F) hot steam** sterilization
- Partly **contaminated by sanitizer** (strong bases)

4. FAILURE MECHANISMS OF TURBINE BEARINGS

There is one more challenge for the bearings:

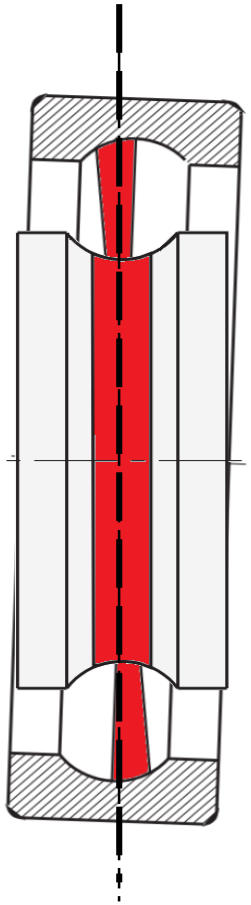
- High asymmetric external load of the drilling tool (tilted inner ring) and/or
- Tilted assembly (tilted outer ring)

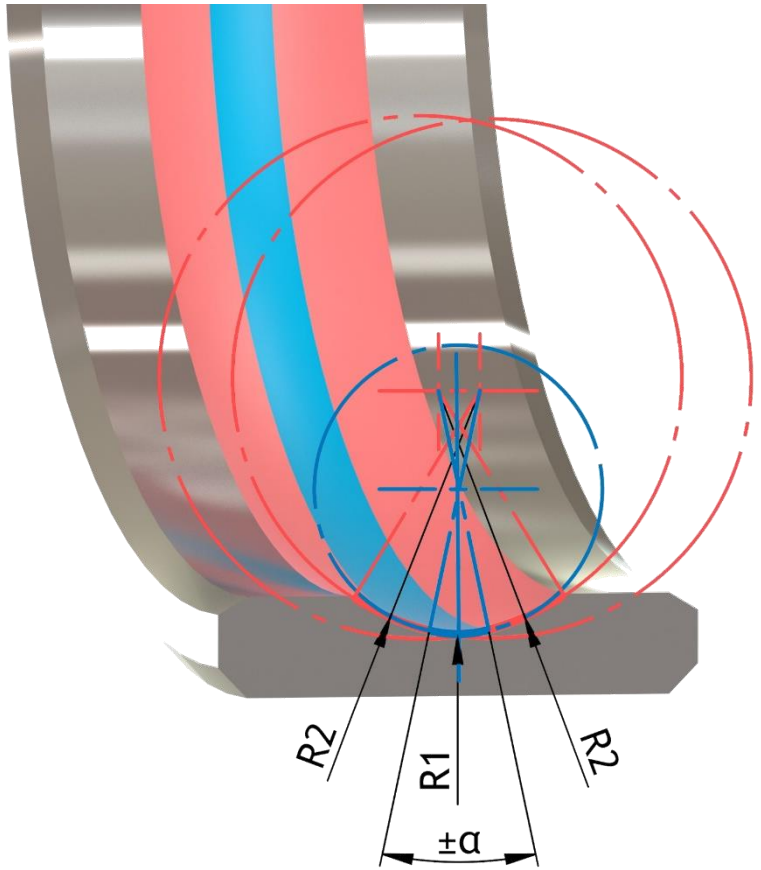


*Standard parameter for durability tests

5. SOLUTION: BALL BEARING WITH NEW RACEWAY DESIGN

How to deal with high asymmetric external load and/or the sub-optimal assembly???





’three-way’ outer ring design

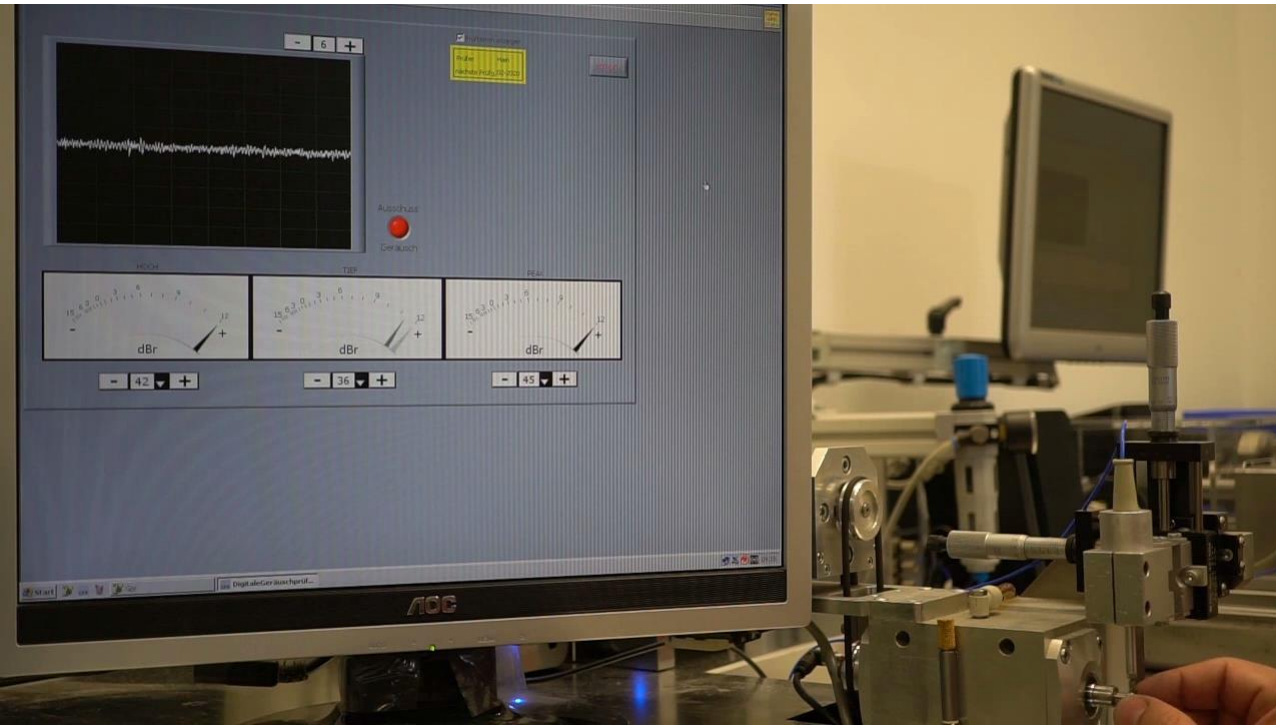
A raceway with three differently curved zones
→ patent pending

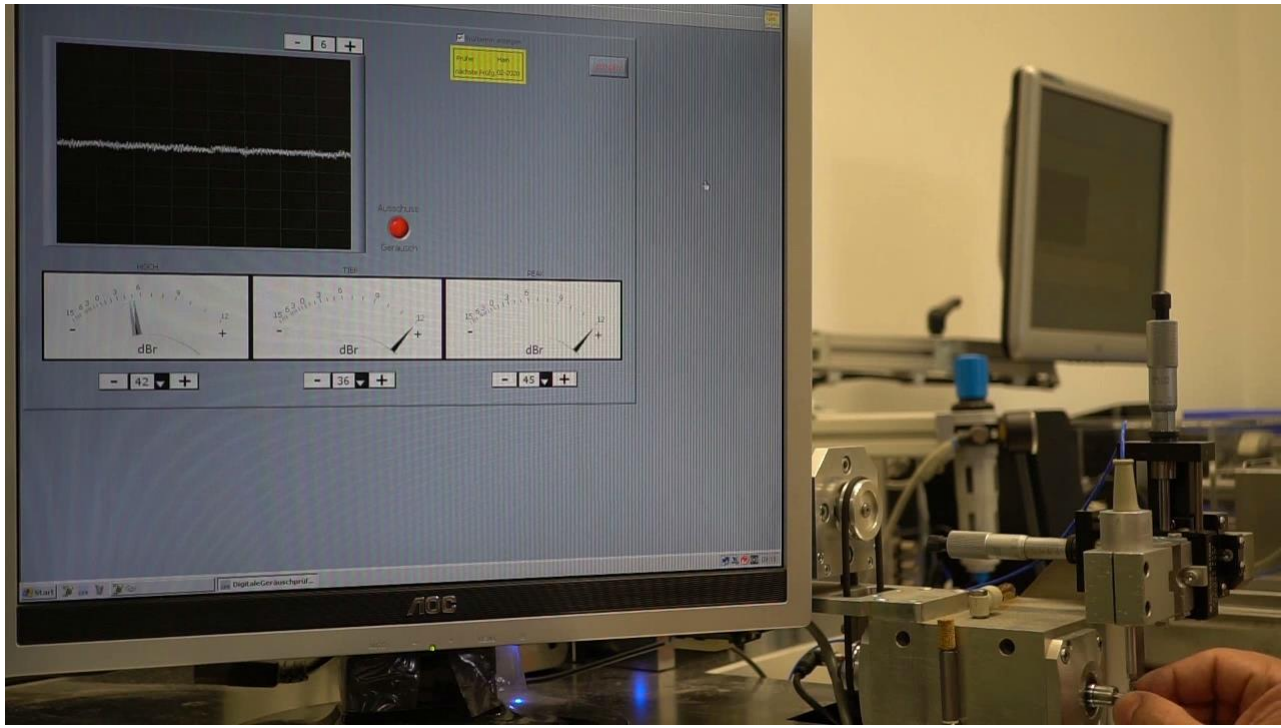
R1
standard radius for standard operating condition
→ no difference to standard raceway
→ „smooth“ transition from R1 to R2

R2
larger radii for tilted operating condition
→ ***R2 ≈ 2 x R1***
→ contact angle **±α** determines the segment width of the middle raceway

Result:
Reduction of the elliptical character of the running track / approximation to a circular path

6. VALIDATION: BEARING NOISE IMPROVEMENTS





‘three-way’

low running noise

low running noise

standard conditions

tilted outer ring

operating conditions

‘raceway’

low running noise

noticeable noise

7. VALIDATION: ADVANCED DYNAMIC SIMULATION

Dynamic simulation using LS-DYNA

- Discretization/Model

  → 545.477 Nodes
  → 571.042 Elements
  → 37 Components

- considered boundary conditions

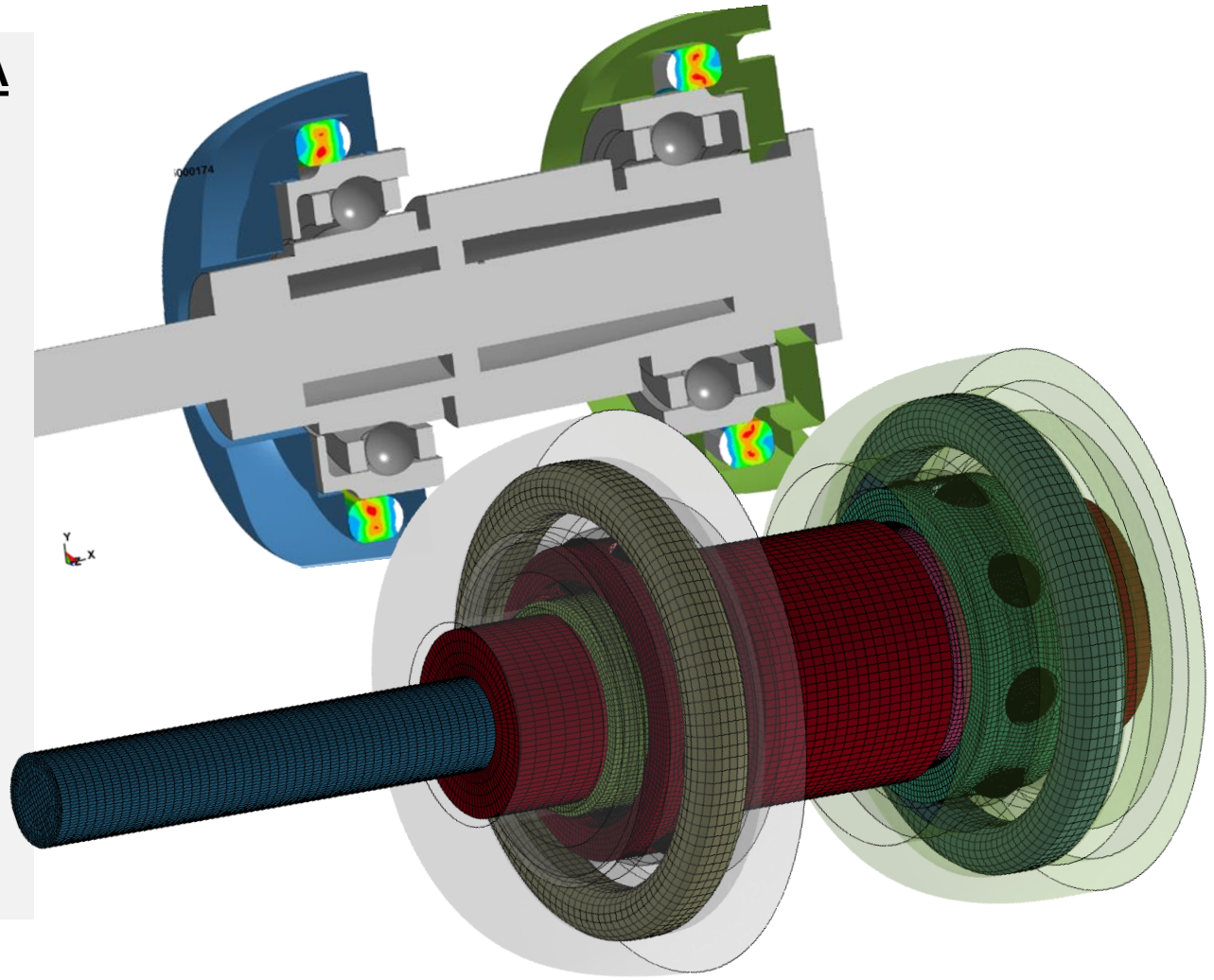
  → drill force (3 N)

  → wave washer force (2 N)

  → defined friction coefficents

  → hyper elastic material behavior (O-ring)

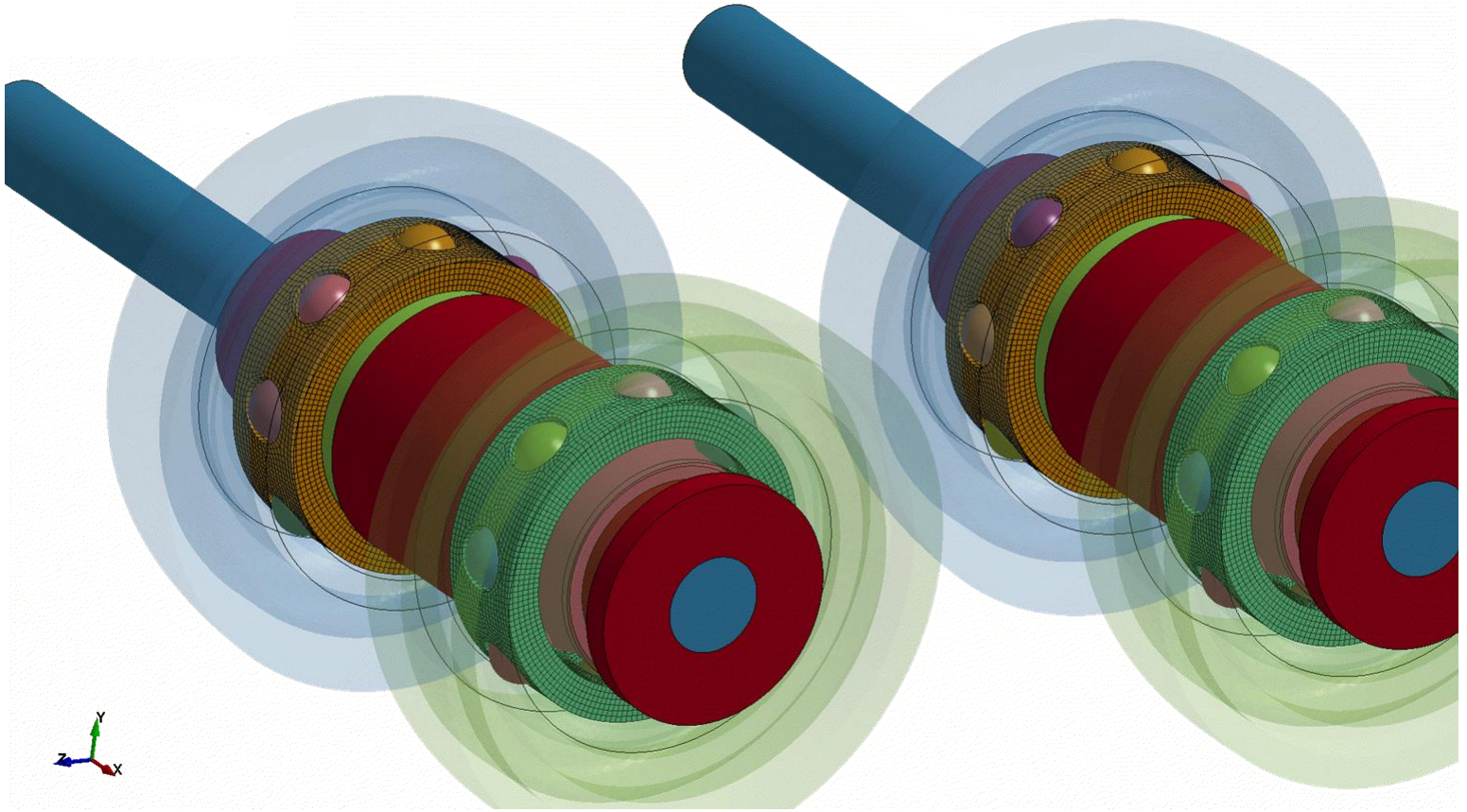
  → steel and ceramic material properties



8. VALIDATION: ADVANCED DYNAMIC SIMULATION

Cage kinematics

- cage deflections
  → true scaled
- simulation time
  → 7 ms
- operating conditions
  → tilted outer ring



‘three-way‘

→ smooth movement of the cage and the drill tip

‘standard raceway‘

→ chaotic movement of the cage and the drill tip due to high dynamic forces

8. VALIDATION: ADVANCED DYNAMIC SIMULATION

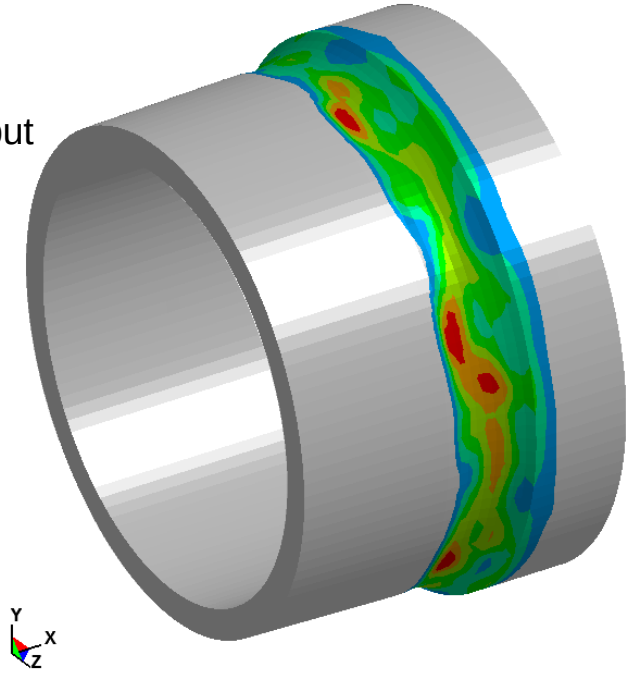
Surface energy density (@ same tilting angle & boundary conditions)

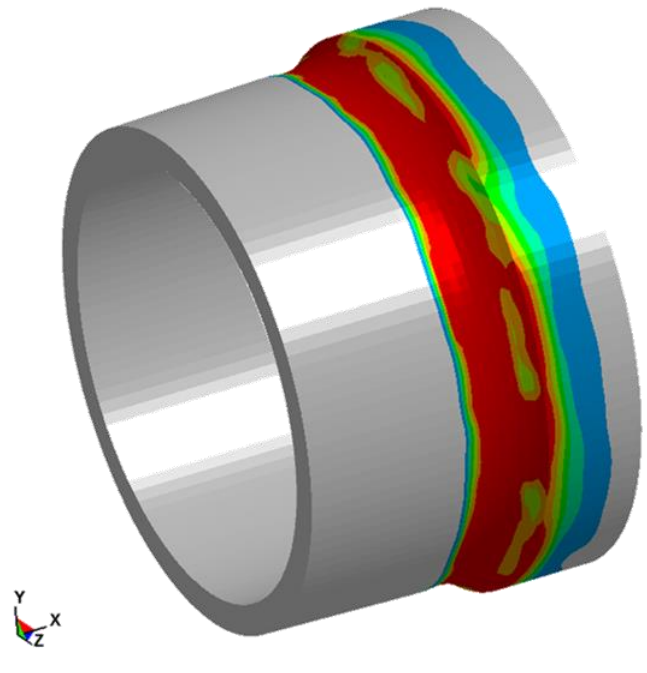
- high
Surface energy density
- low

Inner Ring Raceway

‘three-way‘

→ low frictional forces result in a low energy input





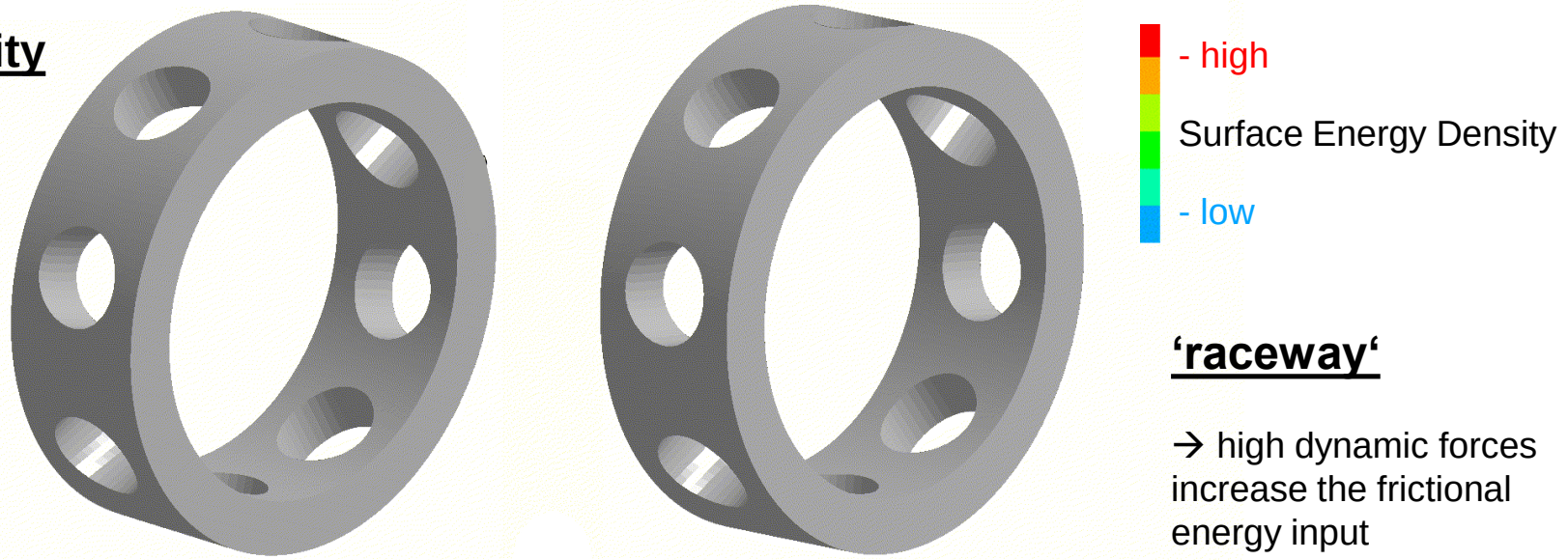
‘raceway‘

→ high dynamic forces increase the frictional energy input

approx. 50% less energy density in IR, compared to standard raceway.

8. VALIDATION: ADVANCED DYNAMIC SIMULATION

Surface Energy Density



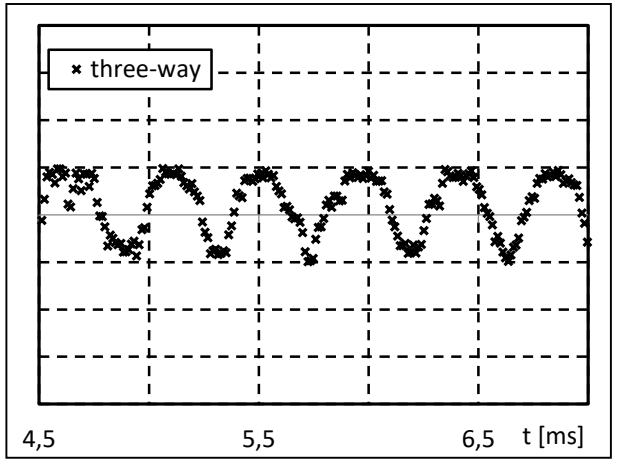
‘three-way‘

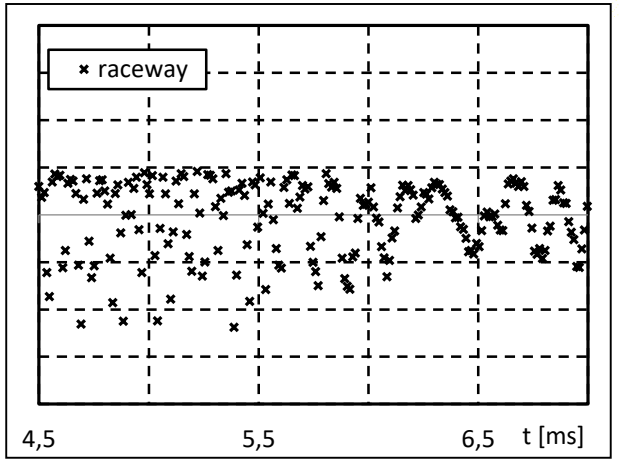
→ low frictional forces result in a low energy input

‘raceway‘

→ high dynamic forces increase the frictional energy input

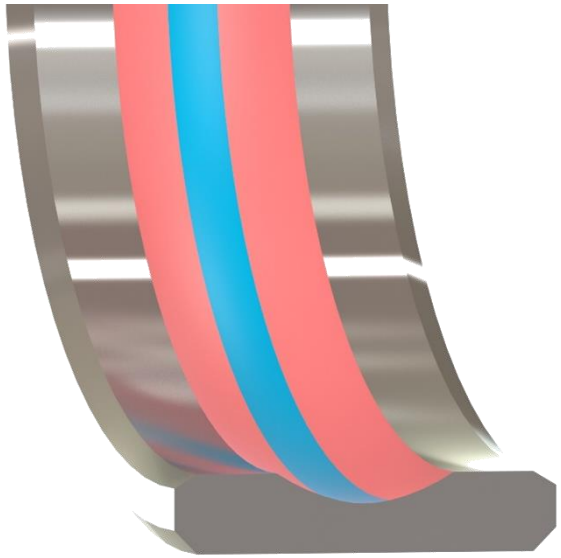
radial cage deflection





radial cage deflection

9. CONCLUSION & FURTHER VALIDATION



Benefits

- improvement of the cage kinematics
- lower energy density less cage wear → longer bearing life
- supporting feature to cage material XTRAlon® and special cage designs
- **relieving the pain**

→ patient:	lower running noise when tilted
→ dentist:	extended service intervals
→ handpiece manufacturer:	decreased warranty claims

Further validation

- completion of internal life tests (to increase statistics/randomly tilting)
- completion of field testing (>1 year)

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