Materials for Rolling Bearing Technology
Foreword

This publication provides an overview of the range of material solutions that are used at Schaeffler, especially in the Industrial Division, as a widely applied standard or in the form of a specific special solution.

The overview serves as an initial reference for Business Units, Sectors, particularly their Application Engineering and Product Design functions, External Sales, Commercial functions and those interested in getting more intensively involved in the field of materials technology. This overview should be regarded as a summary which can be used to make qualitative comparisons and is in no way a substitute for specific application support service provided by the specialist department.

The information contained on the following pages is not intended to generate a “definitive image” of a material or its heat treatment. The aim of this publication is rather to present characteristics, advantages and disadvantages as a means of illustrating the technical facets of individual solutions in comparison with each other.

We hope that you enjoy reading this compact reference work and, above all, that it provides you with additional information, helps in your day-to-day work and provides an introduction to materials technology at Schaeffler.
Comparison of standard solutions
Classification of material and heat treatment according to performance capability under various requirements.

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<th>Material solution, heat treatment</th>
<th>Resistance to</th>
<th>Price¹)</th>
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<td>Fatigue</td>
<td>Thermal influences</td>
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<td>100Cr6, martensite SN (reference 1)</td>
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<td>St4, case hardened</td>
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<td>Cronitect</td>
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In technical comparison with reference:

+++ Excellent
++ Significantly better
+ Better
= Identical
– Worse
–– Significantly worse

1) The cost-effectiveness only provides an initial qualitative indication, while the costs and prices are essentially dependent on the product and quantity.
2) Stress peaks in the region of the static load carrying capacity.
3) The classification can differ depending on the medium and the temperature.
4) = With standard heat treatment (W230),
   ++ With heat treatment for dimensional stabilisation (W230S, secondary hardening).
## Comparison of special solutions
Classification of material and heat treatment according to performance capability under various requirements.

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<td>M50, martensite</td>
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<td>M50NiL, case hardened</td>
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<td>Austenite, carburised</td>
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<td>M50NiL, duplex hardened</td>
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<tr>
<td>32CrMoV13, nitrided</td>
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<td>Vacrodur</td>
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<td>Cermadur</td>
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<td>Si(_3)N(_4) (rolling elements)</td>
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<td>+++</td>
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<tr>
<td>ZrO(_2) (rolling elements)</td>
<td>–</td>
<td>+++</td>
</tr>
</tbody>
</table>

In technical comparison with reference:

\(+++\) Excellent  
\(++\) Significantly better  
\(+\) Better  
\(=\) Identical  
\(–\) Worse

In price comparison with reference:

\(\wedge\) Slightly more expensive  
\(\wedge\wedge\) More expensive  
\(\wedge\wedge\wedge\) Significantly more expensive

\(^1\) The cost-effectiveness only provides an initial qualitative indication, while the costs and prices are essentially dependent on the product and quantity.  
\(^2\) Stress peaks in the region of the static load carrying capacity.  
\(^3\) The classification can differ depending on the medium and the temperature.  
\(^4\) Higher performance capability compared with Cronidur 30.
Standard solutions
100Cr6 (reference 1)

Characteristics, special features

- Base material
- Heat treatment
- Brief characterisation
- Operating limits

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Applications

- Rolling bearings: all series.

Martensitic hardening, thermal stabilisation SN

Through hardening rolling bearing steel 100Cr6 (SAE52100/SUJ2/STB2/GCr15). Depending on the wall thickness of the components, it may be necessary to use a higher grade alloy taking account of hardenability

Martensitic hardening and tempering at low temperatures

Hardness up to 64 HRC, consistently high hardness distributed over circumference and cross-section

Operating temperatures over +120 °C, high shock-type loads, sliding contact, lubricant starvation, corrosion.

Versatile in application

High hardness and wear resistance with good resistance to overrolling

Internationally available, very good price/performance ratio.
100Cr6 (reference 2)  

Martensitic hardening, thermal stabilisation S0

Characteristics, special features

- Base material
  Through hardening rolling bearing steel 100Cr6 (SAE52100/SUJ2/STB2/GCr15), modified where necessary. Depending on the wall thickness of the components, it may be necessary to use a higher grade alloy taking account of hardenability

- Heat treatment
  Martensitic hardening and tempering at high temperatures

- Brief characterisation
  Hardness up to 62 HRC, consistently high hardness distributed over circumference and cross-section

- Operating limits
  Operating temperatures over +150 °C, high shock-type loads, sliding contact, lubricant starvation, corrosion.

Advantages, customer benefits

- Main area of application
  Versatile in application

- Advantages
  High hardness and wear resistance with good resistance to overrolling

- Customer benefits
  Internationally available, very good price/performance ratio.

Applications

- Rolling bearings: all series.
100Cr6 Martensitic hardening, thermal stabilisation S1

Characteristics, special features

- Base material
  Through hardening rolling bearing steel 100Cr6 (SAE52100/SUJ2/STB2/GCr15), modified where necessary. Depending on the wall thickness of the components, it may be necessary to use a higher grade alloy taking account of hardenability.

- Heat treatment
  Martensitic hardening and tempering at high temperatures.

- Brief characterisation
  Hardness up to 62 HRC, consistently high hardness distributed over circumference and cross-section, thermal stabilisation as required.

- Operating limits
  Operating temperatures over +200 °C, high shock-type loads, sliding contact, lubricant starvation, corrosion.

Advantages, customer benefits

- Main area of application
  Versatile in application.

- Advantages
  High hardness and wear resistance with good resistance to overrolling.

- Customer benefits
  Internationally available, very good price/performance ratio.

Applications

- Small combustion engines
- Fan bearing supports for steel mills.
100Cr6

Bainitic hardening, thermal stabilisation S1

Characteristics, special features
- Base material
- Through hardening rolling bearing steel 100Cr6 (SAE52100/SUJ2/STB2/GCr15), higher grade alloys where necessary. Depending on the wall thickness of the components, it may be necessary to use a higher grade alloy taking account of hardenability.

- Heat treatment
- Bainitic hardening

- Brief characterisation
- Hardness up to 62 HRC, uniformly high hardness over circumference and cross-section, residual compressive stresses in surface zone

- Operating limits
- Operating temperatures over +200 °C, lubricant starvation, corrosion.

Advantages, customer benefits
- Main area of application
- Roller bearings with high sliding contact in rolling contact
- Advantages
- Combination of hardness, wear resistance, very good overrolling resistance
- Customer benefits
- Internationally available, very good price/performance ratio, considerably reduced risk of crack formation even with surface damage.

Applications
- Bucket wheel excavators
- Trams: wheelset bearings.
Case hardening steel St4 (USA: DDS, Japan: SPCD) in rolling bearing quality with good forming characteristics

Case hardening, martensitic hardening and tempering

Hardness up to 62 HRC, consistently high hardness distributed over circumference, comparatively soft core, thermal stabilisation as required

Operating temperatures over +120 °C, high shock-type loads, sliding contact, lubricant starvation, corrosion.

Universally applicable, used mainly for small parts only

High hardness and wear resistance with good resistance to overrolling

Internationally available, very good price/performance ratio especially when used for large volume production of formed parts.

Applications

Universal joints:
- drawn cup needle roller bearings with closed end, all types

Motorcycles:
- chassis, swing arm arrangement.
**100CrMnSi6-4**

### Martensitic hardening with defined residual austenite

**Characteristics, special features**
- **Base material**
  - Through hardening rolling bearing steel 100CrMnSi6-4 (SAE52100 Grade2/SUJ3/STB3), based on 100Cr6 with modified Mn and Si content
- **Heat treatment**
  - Martensitic hardening, tempering at low temperatures with increased residual austenite content
- **Brief characterisation**
  - Hardness to 65 HRC, consistently high hardness distributed over circumference and cross-section, residual austenite content approx. 15%
- **Operating limits**
  - Operating temperatures over +120 °C, (higher temperatures possible for short periods), high shock-type loads, sliding contact load, corrosion.

**Advantages, customer benefits**
- **Main area of application**
  - Universally applicable, preferably for lubricant contamination risk
- **Advantages**
  - High hardness and wear resistance with good resistance to overrolling
- **Customer benefits**
  - Better price/performance ratio cost than carbonitrided 100Cr6 bearings with same fatigue strength in particle overrolling.

### Applications
- **Steel production**
- **Automotive:** passenger car gearboxes.
**100CrMnSi6-4**

**Carbonitriding**

**Characteristics, special features**
- Base material
- Heat treatment
- Brief characterisation
- Operating limits

**Advantages, customer benefits**
- Main area of application
- Advantages
- Customer benefits

**Applications**
- Hydraulic axial piston motor: output shaft bearing arrangement
- Construction/agricultural machinery: gearbox bearings.

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Through hardening rolling bearing steel **100CrMnSi6-4 (SAE52100 Grade2/SUJ3/STB3)**, based on **100Cr6** with modified Mn and Si content

Carbonitriding, martensitic hardening, tempering at low temperatures or dimensional stabilisation

Hardness up to **66 HRC (62 + 4 HRC)** in the outer functional layer with increased residual austenite content

High shock-type loads, corrosion.

Bearings at high risk due to particle overrolling

Significantly higher resistance to surface damage, high wear resistance

Extended bearing life in poor lubrication conditions, especially where there is a high risk of contamination.
Case hardening steel

Characteristics, special features
- Base material
- Heat treatment
- Brief characterisation
- Operating limits

Advantages, customer benefits
- Main area of application
- Advantages
- Customer benefits

Case hardening (carburisation and martensitic hardening)

Case hardening steel (DIN EN 10084) in rolling bearing quality, e.g. 17MnCr5 (SAE5280), 17CrNiMo7-6 (SAE4320), Mancrodur or higher alloy

Carburising and martensitic hardening

Hardness up to 64 HRC, hard surface layer with tough core

Operating temperatures over +120 °C, corrosion.

Advantages, customer benefits

Medium and large size bearings

Residual compressive stresses in the surface layer under load

Increased fracture resistance under shock-type loads or surface damage, reduced crack formation with surface damage.

Applications
- Wind turbines: main rotor bearings
- Heavy duty trucks: wheelset bearings.
Case hardening steel  

Characteristics, special features
- Base material
- Heat treatment
- Brief characterisation
- Operating limits

Advantages, customer benefits
- Main area of application
- Advantages
- Customer benefits

Applications
- Steel production: rolling mill bearings
- Wind power gearboxes.

Carbonitriding

Case hardening steel (DIN EN 10084) in rolling bearing quality, e.g. 17MnCr5 (SAE5280), 17CrNiMo7-6 (SAE4320), Mancrodur or higher alloy

Heat treatment Carbonitriding and hardening (single hardening)

Brief characterisation Hardness up to 65 HRC, case hardening zone with increased toughness and higher resistance to particle overrolling

Operating temperatures over +120 °C (possible for short periods), corrosion.

Bearings at high risk due to particle overrolling, bearings subjected to high loads combined with poor lubrication

Very high wear resistance and increased resistance to surface damage

Longer operating life in unfavourable lubrication conditions, when using the material Mancrodur: increased dynamic load carrying capacity (EHD).
Cronidur 30 Martensitic hardening

Characteristics, special features
- Base material
- Heat treatment
- Brief characterisation
- Operating limits

Advantages, customer benefits
- Main area of application
- Advantages
- Customer benefits

Applications
- Machine tools: spindle bearing arrangement
- Fluid technology: process pump.

Nitrogen alloyed chromium steel X30CrMoN15-1 (AMS5998)
Martensitic hardening; tempering at low (or possibly high) temperature
Hardness up to 62 HRC, consistently high hardness distributed over circumference and cross-section, corrosion resistance
Operating temperatures over +150 °C, corrosion by strong acids.

Bearings subjected to high loads, lubricant starvation, dry running, media lubrication, corrosive environments
Corrosion resistance, increased dynamic load carrying capacity (EHD)
Very good fatigue life, robust bearing solution: downsizing possible through omission of costly seals, very good corrosion resistance, very good overrolling resistance compared to corrosion-resistant standard rolling bearing steels.
Cronitect Case hardening with nitrogen

**Characteristics, special features**
- Base material: Corrosion-resistant case hardening steel
- Heat treatment: Surface layer nitriding (nitrogen in solution), martensitic hardening
- Brief characterisation: Hardness up to 62 HRC, hard corrosion-resistant surface layer with tough core
- Operating limits: Very high loads, operating temperatures over +180 °C, corrosion by strong acids.

**Advantages, customer benefits**
- Main area of application: Lubricant starvation, initial lubrication, dry running, media lubrication, corrosive environments
- Advantages: Corrosion resistance and effective resistance to overrolling
- Customer benefits: Significantly improved resistance to overrolling compared with conventional corrosion-resistant rolling bearing steels, very good corrosion resistance.

**Applications**
- Food industry: bottle filling plant
- Sport and fitness: inline skates.
Special solutions
M50

Martensitic hardening

Characteristics, special features

- Base material
- Heat treatment
- Brief characterisation
- Operating limits

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Applications

- Aircraft engines: main shaft bearing
- Current generation for aerospace: turbine rotor bearing arrangement.

Thermally stable, through hardening rolling bearing steel M50, vacuum remelted

Martensitic hardening

Hardening up to 64 HRC, high temperature strength of +350 °C to +400 °C

Corrosion, extremely high centrifugal forces.

Turbine bearing

Thermal stability with increased toughness

Limited cooling requirements, prevention of premature failures.
M50NiL

Case hardening (carburisation and martensitic hardening)

Characteristics, special features

- Base material
  Thermally stable, case hardened rolling bearing steel M50NiL, vacuum remelted
- Heat treatment
  Carburising and martensitic hardening
- Brief characterisation
  Surface hardening up to 64 HRC, high temperature strength of +350 °C to +400 °C, residual compressive stresses
- Operating limits
  Corrosion.

Advantages, customer benefits

- Main area of application
  Turbine bearings with very high speeds
- Advantages
  Thermal stability with significantly increased toughness, resistance to fractures
- Customer benefits
  Limited cooling requirements, prevention of premature failures.

Applications

- Aircraft engines: main shaft bearings rotating at extremely high speeds.
### Austenite Carburisation

**Characteristics, special features**
- Base material: Austenitic steel, e.g. X5CrNi18-10 (USA: AISI 304)
- Heat treatment: Carburised
- Brief characterisation: Thin load-bearing surface layer (hardness approx. 58 HRC) with tough core
- Operating limits: Rings over 300 mm, loads over 2 000 MPa, high tangential stresses.

**Advantages, customer benefits**
- Main area of application: Where amagnetism is required, in aggressive environments (involving acids, for example), where martensitic steels do not offer sufficient resistance
- Advantages: Non-magnetisability, excellent resistance in media
- Customer benefits: Elimination of shielding measures.

**Applications**
- Butterfly valve: positioning bearing arrangement
- Gimbal mounting: stud bearing arrangement.
### Characteristics, special features

- **Base material** Thermally stable, case hardened rolling bearing steel M50NiL, vacuum remelted
- **Heat treatment** Carburising and martensitic hardening, plus nitriding
- **Brief characterisation** Surface hardening up to 70 HRC, high temperature strength of +350 °C to +400 °C, very high residual compressive stresses
- **Operating limits** Corrosion.

### Advantages, customer benefits

- **Main area of application** Bearings subjected to high loads, very high rotational speeds, high damage tolerance (good characteristics following particle overrolling)
- **Advantages** High temperature strength with considerably higher fracture resistance, very good wear resistance, very good resistance to surface damage by particles
- **Customer benefits** Limited cooling requirements, prevention of premature failures, damage tolerance.

### Applications

- **Aircraft engines:**
  - main shaft bearings rotating at extremely high speeds.
**32CrMoV13 Nitriding**

**Characteristics, special features**
- Base material: Quenched and tempered steel 32CrMoV13 (32CDV13)
- Heat treatment: Prehardened and high tempered at more than +570 °C and nitrided (long period)
- Brief characterisation: Hardness up to 64 HRC, hard surface layer with tough core, entire cross-section thermally stable up to +350 °C
- Operating limits: Hardening depths more than 0,6 mm (Nht), corrosion.

**Advantages, customer benefits**
- Main area of application: Aircraft engine bearings, other bearings and components subjected to thermal loads, outside diameter up to ≈ 160 mm
- Advantages: High fatigue strength (especially at temperatures over +150 °C), good overrolling resistance even with lubricant starvation, good resistance to surface damage by particles, high resistance to false brinelling
- Customer benefits: Extended bearing life, especially at high temperatures, under poor lubrication conditions and/or with risk of particles in the rolling contact, internationally available, good price/performance ratio.

**Applications**
- Aircraft engines: main shaft bearing arrangement.
Vacrodur

Characteristics, special features

- Base material
- Heat treatment
- Brief characterisation
- Operating limits

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Operating limits

Corrosive attack.

Advantages

High hardness, high static and dynamic load carrying capacity, wear and heat resistance

Customer benefits

Very robust bearing solution, long rating and operating life, therefore downsizing and reduction in overall operating costs possible.

Applications

- Spindle bearing arrangement of machine tools
- Engine components.
Cermadur

Characteristics, special features
- Base material
- Heat treatment
- Brief characterisation
- Operating limits

Advantages, customer benefits
- Main area of application
- Advantages
- Customer benefits

Applications
- Ocean energy generation
- Pumps, compressors.

Hard metal with metallic binding phase
Not required, sintering during production
Hardness $> 1300$ HV, very high density, excellent corrosion and media resistance, non-magnetic
Maximum component dimensions 400 mm, wide temperature fluctuations.

Dry running and media lubrication, particularly in conjunction with highly corrosive media or environments and in the presence of severe contamination or very high temperatures
Very high values for heat resistance, modulus of elasticity, wear resistance, corrosion resistance and robust resistance to particle overrolling
Avoidance of conventional lubricants, use of ambient medium for lubrication/cooling of the rolling bearing, for example replacement of oil recirculation with media lubrication, extremely high robustness despite corrosive environment, contamination and high temperature exposure.
Characteristics, special features

- Base material: Nitride-based ceramic $\text{Si}_3\text{N}_4$
- Heat treatment: Not required, **Hot Isostatic Pressing (HIP)** during production
- Brief characterisation: Hardness in the region of 1500 HV, very low density, non-magnetic, excellent corrosion and media resistance
- Operating limits: Normally used only as rolling elements in contact with steel-based bearing rings.

Advantages, customer benefits

- Main area of application: Hybrid bearings with significantly higher load carrying capacity than ZrO$_2$,
in case of matched material solution for rings (Cronidur 30 or carbonitriding),
significant improvement possible in rating life and operating life even under high loads in comparison with rolling elements made from steel; high speeds (spindle bearings), lubricant starvation, dry running, media lubrication, corrosive environments
- Advantages: Reduced mass, usable up to +700 °C
- Customer benefits: Very high speed capacity, current insulation, very high wear resistance, reduced friction, increased grease operating life, replacement of recirculating oil lubrication by grease lubrication, initial lubrication.

Applications

- Food industry
- Machine tools: spindle bearings.
Zirconium oxide ZrO\textsubscript{2}

Characteristics, special features
- Base material
- Heat treatment
- Brief characterisation
- Operating limits

Advantages, customer benefits
- Main area of application
- Advantages
- Customer benefits

Applications
- Automotive: motors for electric windows
- Food technology.

Oxide-based ceramic ZrO\textsubscript{2}
- Not required, sintering during production
- Hardness in the region of 1400 HV, density between Si\textsubscript{3}N\textsubscript{4} and steel, non-magnetic, excellent corrosion and media resistance
- Contact pressures over 1500 MPa, normally used only as rolling elements in contact with steel-based bearing rings.

Bearings subjected to low loads (hybrid bearings), lubricant starvation, dry running, media lubrication, corrosive environments
- Usable up to +600 °C, thermal expansion close to that of steel
- Current insulation, high wear resistance, reduction in friction, initial lubrication, usually more cost-effective than Si\textsubscript{3}N\textsubscript{4}. 
All data have been prepared with a great deal of care and checked for their accuracy. However, no liability can be assumed for any incorrect or incomplete data. We reserve the right to make technical modifications.

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TPI 226 GB-D
Legend

- Suitability for increased load carrying capacity (basic dynamic load rating, EHD)
- Suitability for mixed friction
- Suitability under sliding load (slippage)
- Suitability for high shock loads
- Suitability for high temperatures (dimensional stability, heat resistance)
- Suitability for corrosive environments and operation in media
- Suitability for media lubrication and dry running
- Suitability for increased wear resistance (hardness)
- Suitability for particle overrolling (damage tolerance)
- Suitability for electrical insulation