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.

<table>
<thead>
<tr>
<th>Material solution, heat treatment</th>
<th>Resistance to</th>
<th>Price[^1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Cr6, martensite SN (reference 1)</td>
<td>=</td>
<td>–</td>
</tr>
<tr>
<td>100Cr6, martensite S0 (reference 2)</td>
<td>=</td>
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<tr>
<td>100Cr6, martensite S1</td>
<td>=</td>
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<tr>
<td>100Cr6, bainite S1</td>
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<td>+</td>
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<tr>
<td>St4, case hardened</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>100CrMnSi6-4, modified martensite</td>
<td>+</td>
<td>=</td>
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<tr>
<td>100CrMnSi6-4, carbonitrided</td>
<td>++</td>
<td>–</td>
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<tr>
<td>Case hardening steel, case hardened</td>
<td>+</td>
<td>=</td>
</tr>
<tr>
<td>Case hardening steel, carbonitrided</td>
<td>++</td>
<td>=</td>
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<tr>
<td>Cronidur 30</td>
<td>+++</td>
<td>= ... +++[^4]</td>
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<tr>
<td>Cronitect</td>
<td>+</td>
<td>=</td>
</tr>
</tbody>
</table>

In technical comparison with reference:

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

In price comparison with reference:

- ^<^ Slightly more expensive
- ^≈^ 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]: = 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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<tr>
<td></td>
<td>Fatigue</td>
<td>Thermal influences</td>
</tr>
<tr>
<td>100Cr6, martensite SN (reference 1)</td>
<td>=</td>
<td>–</td>
</tr>
<tr>
<td>100Cr6, martensite S0 (reference 2)</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>M50, martensite</td>
<td>=</td>
<td>++</td>
</tr>
<tr>
<td>M50NiL, case hardened</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Austenite, carburised</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>M50NiL, duplex hardened</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>32CrMoV13, nitrided</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Si(_3)N(_4) (rolling elements)</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>ZrO(_2) (rolling elements)</td>
<td>–</td>
<td>+++</td>
</tr>
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In technical comparison with reference:

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

In price comparison with reference:

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

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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.
Standard solutions
**100Cr6 (reference 1)**

**Martensitic hardening, thermal stabilisation SN**

### Characteristics, special features
- **Base material**
  - 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.

- **Heat treatment**
  - Martensitic hardening and tempering at low temperatures.

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

- **Operating limits**
  - Operating temperatures over +120 °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 (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 (austempering)

- 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

Characteristics, special features

- Base material
  - Case hardening steel St4 (USA: DDS, Japan: SPCD) in rolling bearing quality with good forming characteristics

- Heat treatment
  - Case hardening, martensitic hardening and tempering

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

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

Advantages, customer benefits

- Main area of application
  - Universally applicable, used mainly for small parts only

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

- Customer benefits
  - 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 steel based on 100CrMnSi6-4 (SAE52100 Grade2/SUJ3/STB3), 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.
12CrMnSi6-4 100CrMnSi6-4 Carbonitriding

**Characteristics, special features**

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

- **Heat treatment**
  Carbonitriding, martensitic hardening, tempering at low temperatures or dimensional stabilisation

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

- **Operating limits**
  High shock-type loads, corrosion.

**Advantages, customer benefits**

- **Main area of application**
  Bearings at high risk due to particle overrolling

- **Advantages**
  Significantly higher resistance to surface damage, high wear resistance

- **Customer benefits**
  Extended bearing life in poor lubrication conditions, especially where there is a high risk of contamination.

**Applications**

- **Hydraulic axial piston motor:**
  Output shaft bearing arrangement

- **Construction/ agricultural machinery:**
  Gearbox 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
- Wind turbines: main rotor bearings
- Heavy duty trucks: wheelset bearings.

Case hardening (carburisation and martensitic hardening)

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

- Carburising and martensitic hardening
- Hardness up to 64 HRC, hard surface layer with tough core
- Operating temperatures over +120 °C, corrosion.

- 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.
Case hardening steel

Characteristics, special features
- Base material
  Case hardening steel (DIN EN 10084) in rolling bearing quality, e.g. 17MnCr5 (SAE5280), 17CrNiMo7-6 (SAE4320), 32MnCrMo6-4-3 or higher alloy
- Heat treatment
- Brief characterisation
  Hardness up to 65 HRC, case hardening zone with increased toughness and higher resistance to particle overrolling
- Operating limits
  Operating temperatures over +120 °C (possible for short periods), corrosion.

Advantages, customer benefits
- Main area of application
  Bearings at high risk due to particle overrolling, bearings subjected to high loads combined with poor lubrication
- Advantages
  Very high wear resistance and increased resistance to surface damage
- Customer benefits
  Longer operating life in unfavourable lubrication conditions, when using the material Mancrodur (32MnCrMo6-4-3): increased dynamic load carrying capacity (EHD).

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), 32MnCrMo6-4-3 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 limits
  Operating temperatures over +120 °C (possible for short periods), corrosion.
**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, 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.
## Cronitec 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, through hardening 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 do not offer not 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.
**M50NiL**

**Duplex hardening**

**Characteristics, special features**
- Base material: Thermally stable, through hardening 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 during 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.
### Characteristics, special features

- **Base material**
  - Quenched and tempered steel 32CrMoV13 (32CDV13)

- **Heat treatment**
  - Prehardened and high tempered at more than +570 °C and nitried (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 operating 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.
Silicon nitride $\text{Si}_3\text{N}_4$

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

Advantages, customer benefits
- Main area of application

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.

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

Hybrid bearings with significantly higher load carrying capacity than $\text{ZrO}_2$, 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.
**Zirconium oxide ZrO₂**

### Characteristics, special features
- **Base material**: Oxide-based ceramic ZrO₂
- **Heat treatment**: Not required, sintering during manufacturing
- **Brief characterisation**: Hardness in the region of 1400 HV, density between Si₃N₄ and steel, non-magnetic, excellent corrosion and media resistance
- **Operating limits**: Contact pressures over 1500 MPa, normally used only as rolling elements in contact with steel-based bearing rings.

### Advantages, customer benefits
- **Main area of application**: Bearings subjected to low loads (hybrid bearings), lubricant starvation, dry running, media lubrication, corrosive environments
- **Advantages**: Usable up to 600 °C, thermal expansion close to that of steel
- **Customer benefits**: Current insulation, high wear resistance, reduction in friction, initial lubrication, usually more cost-effective than Si₃N₄.

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