

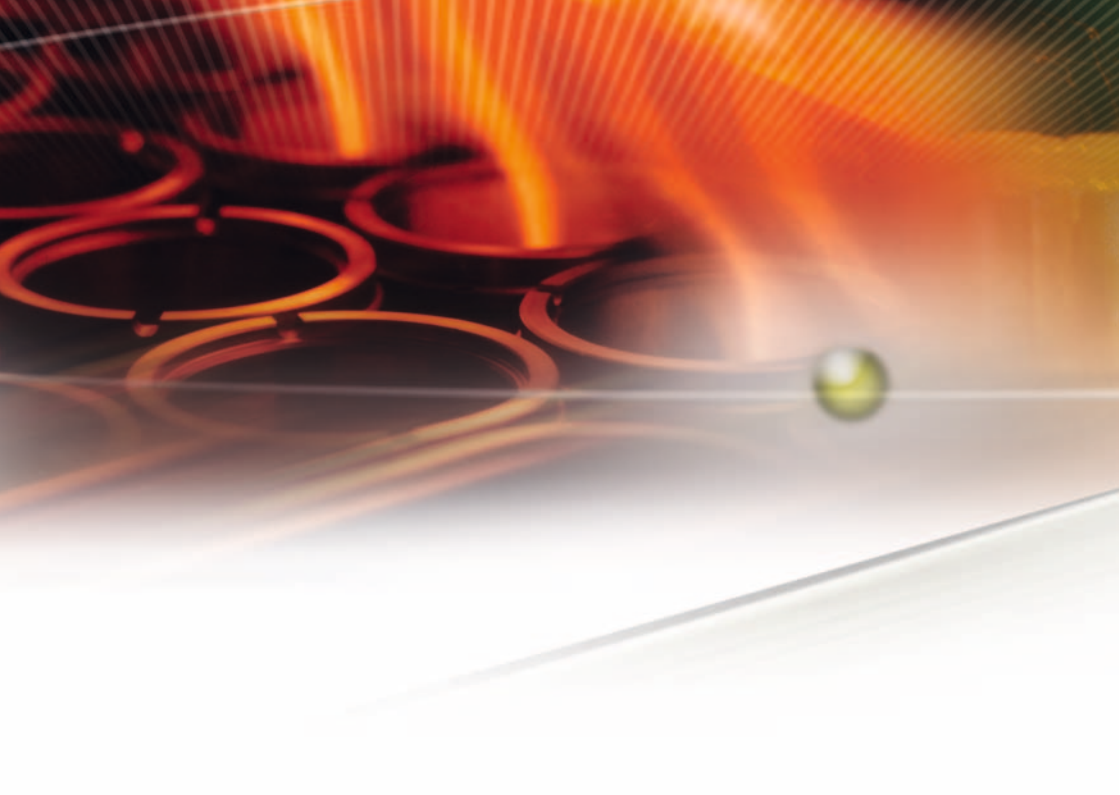


FAG



Materials for Rolling Bearing Technology

SCHAEFFLER



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.

Material solution, heat treatment	Resistance to						Price ¹⁾
	Fatigue	Thermal influences	Sliding (slippage) load	Mechanical shock ²⁾	Particle overrolling	Corrosion ³⁾	
100Cr6, martensite SN (reference 1)	≡	–	≡	≡	≡	≡	≡
100Cr6, martensite S0 (reference 2)	≡	≡	≡	≡	≡	≡	≡
100Cr6, martensite S1	≡	+	+	–	--	–	≡
100Cr6, bainite S1	+	+	+	+	+	–	≡
St4, case hardened	–	–	≡	≡	≡	≡	≡
100CrMnSi6-4, modified martensite	+	≡	≡	≡	+	≡	^
100CrMnSi6-4, carbonitrided	++	–	+	≡	++	–	^
Case hardening steel, case hardened	+	≡	+	+	++	–	^
Case hardening steel, carbonitrided	++	≡	+	+	++	–	^
Cronidur 30	+++	≡ ... ++ ⁴⁾	++	≡	++	++	⋈
Cronitect	+	≡	+	≡	≡	++	^

In technical comparison with reference:

- +++ Excellent
- ++ Significantly 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.

Material solution, heat treatment	Resistance to						Price ¹⁾
	Fatigue	Thermal influences	Sliding (slippage) load	Mechanical shock ²⁾	Particle overrolling	Corrosion ³⁾	
100Cr6, martensite SN (reference 1)	≡	–	≡	≡	≡	≡	≡
100Cr6, martensite S0 (reference 2)	≡	≡	≡	≡	≡	≡	≡
M50, martensite	≡	++	≡	≡	–	–	⋈
M50NiL, case hardened	++	++	++	++	+	–	⋈
Austenite, carburised	–	+	≡	≡	–	+	⋈
M50NiL, duplex hardened	++	++	++	++	++	–	⋈
32CrMoV13, nitrided	++	++	++	+	++	≡	⋈
Si ₃ N ₄ (rolling elements)	+	+++	++	≡	≡	++	⋈
ZrO ₂ (rolling elements)	–	+++	≡	–	–	+++	⋈

In technical comparison with reference:

- +++ Excellent
- ++ Significantly better
- +
- ≡ Identical
- Worse

In price comparison with reference:

- ⋈ Slightly more expensive
- ⋈ More expensive
- ⋈ Significantly more expensive

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- 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



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.

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.



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00018EE7



Characteristics, special features

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

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

Martensitic hardening and tempering at high temperatures

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

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

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Versatile in application

High hardness and wear resistance with good resistance to overrolling

Internationally available, very good price/performance ratio.

Applications

- Rolling bearings:
all series.





Characteristics, special features

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

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

Martensitic hardening and tempering at high temperatures

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

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

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Versatile in application

High hardness and wear resistance with good resistance to overrolling

Internationally available, very good price/performance ratio.

Applications

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





Characteristics, special features

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

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Applications

- Bucket wheel excavators
- Trams:
wheelset bearings.

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

Bainitic hardening (austempering)

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

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

Roller bearings with high sliding contact in rolling contact

Combination of hardness, wear resistance, very good overrolling resistance

Internationally available, very good price/performance ratio, considerably reduced risk of crack formation even with surface damage.





Characteristics, special features

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

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.

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

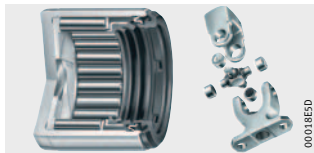
Universally applicable, used mainly for small parts only

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.





Characteristics, special features

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

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Applications

- Steel production
- Automotive:
passenger car gearboxes.

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

Martensitic hardening, tempering at low temperatures with increased residual austenite content

Hardness to 65 HRC, consistently high hardness distributed over circumference and cross-section, residual austenite content approx. 15%

Operating temperatures over +120 °C, (higher temperatures possible for short periods), high shock-type loads, sliding contact load, corrosion.

Universally applicable, preferably for lubricant contamination risk

High hardness and wear resistance with good resistance to overrolling

Better price/performance ratio cost than carbonitrided 100Cr6 bearings with same fatigue strength in particle overrolling.





Characteristics, special features

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

Through hardening rolling bearing steel, based on 100CrMnSi6-4 (SAE52100 Grade2/SUJ3/ STB3), 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.

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

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.

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.



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.



Case hardening steel (DIN EN 10084) in rolling bearing quality, e.g. 17MnCr5 (SAE5280), 17CrNiMo7-6 (SAE4320), 32MnCrMo6-4-3 or higher alloy

Carbonitriding and hardening (single hardening)

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 (32MnCrMo6-4-3): increased dynamic load carrying capacity (EHD).





Characteristics, special features

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

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

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.

Applications

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





Characteristics, special features

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

Corrosion-resistant case hardening steel

Surface layer nitriding (nitrogen in solution), martensitic hardening

Hardness up to 62 HRC, hard corrosion-resistant surface layer with tough core

Very high loads, operating temperatures over +180 °C,
corrosion by strong acids.

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Lubricant starvation, initial lubrication, dry running, media lubrication,
corrosive environments

Corrosion resistance and effective resistance to overrolling

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.





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Special solutions



Characteristics, special features

■ Base material

■ Heat treatment

■ Brief characterisation

■ Operating limits

Advantages, customer benefits

■ Main area of application

■ Advantages

■ Customer benefits

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.

Applications

■ Aircraft engines:
main shaft bearing

■ Current generation for aerospace:
turbine rotor bearing arrangement.



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 bearings rotating at
extremely high speeds.



Thermally stable, through hardening rolling bearing steel M50NiL, vacuum remelted

Carburising and martensitic hardening

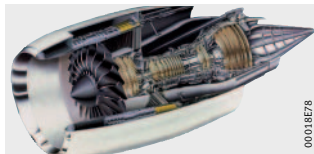
Surface hardening up to 64 HRC, high temperature strength of +350 °C to +400 °C, residual compressive stresses

Corrosion.

Turbine bearings with very high speeds

Thermal stability with significantly increased toughness, resistance to fractures

Limited cooling requirements, prevention of premature failures.





Characteristics, special features

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

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Austenitic steel, e.g. X5CrNi18-10 (USA: AISI 304)

Carburised

Thin load-bearing surface layer (hardness approx. 58 HRC) with tough core
Rings over 300 mm, loads over 2 000 MPa, high tangential stresses.

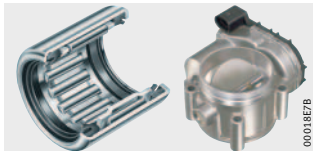
Where amagnetism is required, in aggressive environments (involving acids, for example), where martensitic do not offer not sufficient resistance

Non-magnetisability, excellent resistance in media

Elimination of shielding measures.

Applications

- Butterfly valve:
positioning bearing arrangement
- Gimbal mounting:
stud bearing arrangement.



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 bearings rotating at
extremely high speeds.



Thermally stable, through hardening rolling bearing steel M50NiL, vacuum remelted

Carburising and martensitic hardening, plus nitriding

Surface hardening up to 70 HRC, high temperature strength of +350 °C to +400 °C, very high residual compressive stresses

Corrosion.

Bearings subjected to high loads, very high rotational speeds, high damage tolerance (good characteristics during particle overrolling)

High temperature strength with considerably higher fracture resistance, very good wear resistance, very good resistance to surface damage by particles

Limited cooling requirements, prevention of premature failures, damage tolerance.





Characteristics, special features

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

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Quenched and tempered steel 32CrMoV13 (32CDV13)

Prehardened and high tempered at more than +570 °C and nitrided (long period)

Hardness up to 64 HRC, hard surface layer with tough core, entire cross-section thermally stable up to +350 °C

Hardening depths more than 0,6 mm (Nht), corrosion.

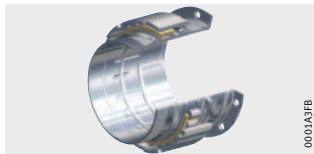
Aircraft engine bearings, other bearings and components subjected to thermal loads, outside diameter up to ≈ 160 mm

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

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 Si_3N_4



Characteristics, special features

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

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

Applications

- Food industry
- Machine tools: spindle bearings.

Nitride-based ceramic Si_3N_4

Not necessary, **Hot Isostatic Pressing (HIP)** during production

Hardness in the region of 1 500 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 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

Reduced mass, usable up to 700 °C

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.



Zirconium oxide ZrO_2



Characteristics, special features

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

Oxide-based ceramic ZrO_2

Not required, sintering during manufacturing

Hardness in the region of 1 400 HV, density between Si_3N_4 and steel, non-magnetic, excellent corrosion and media resistance

Contact pressures over 1 500 MPa, normally used only as rolling elements in contact with steel-based bearing rings.

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

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_3N_4 .

Applications

- Automotive: motors for electric windows
- Food technology.



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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