SCHAEFFLER

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.

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
+ 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	++	++	++	+	++	≡	≫
Vacrodur	+++[4]	+++	++	++	+++	≡	≫
Cermadur	++	+++	+++	≡	+++	+++	⋙
Si_3N_4 (rolling elements)	+	+++	++	≡	≡	++	⋙
ZrO_2 (rolling elements)	–	+++	≡	–	–	+++	≫

In technical comparison with reference:

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

In price comparison with reference:

≻ Slightly more expensive
≫ More expensive
⋙ 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)

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.

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.

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

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

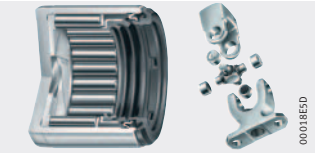
Universally applicable, used mainly for small parts only

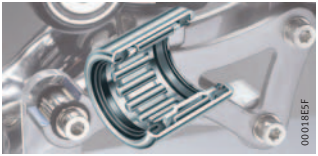
High hardness and wear resistance with good resistance to overrolling

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.





100CrMnSi6-4

Martensitic hardening with defined residual austenite

Characteristics, special features

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

Through hardening rolling bearing steel 100CrMnSi6-4 (SAE52100 Grade2/ SUJ3/STB3), based on 100Cr6 with 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.

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

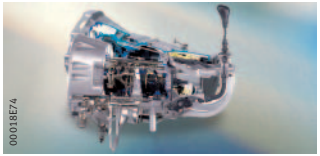
Universally applicable, preferably for lubricant contamination risk

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.

Applications

- Steel production
- Automotive:
  passenger car gearboxes.



Characteristics, special features

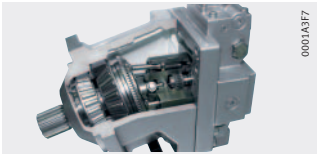
- Base material: Through hardening rolling bearing steel 100CrMnSi6-4 (SAE52100 Grade2/ SUJ3/ STB3), based on 100Cr6 with modified Mn and Si content
- Heat treatment: Carbonitriding, martensitic hardening, tempering at low temperatures or dimensional stabilisation
- Brief characterisation: Hardness up 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

Case hardening (carburisation and martensitic hardening)

Characteristics, special features

- Base material

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

- Heat treatment

Carburising and martensitic hardening

- Brief characterisation

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

- Operating limits

Operating temperatures over +120 °C, corrosion.

Advantages, customer benefits

- Main area of application

Medium and large size bearings

- Advantages

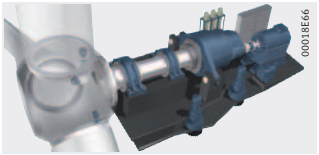
Residual compressive stresses in the surface layer under load

- Customer benefits

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.



Carbonitriding

Characteristics, special features

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

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

Advantages, customer benefits

- Main area of application
- Advantages
- Customer benefits

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).

Applications

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

Characteristics, special features

- Base material
- Heat treatment
- Brief characterisation

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 limits

Operating temperatures over +150 °C, corrosion by strong acids.

Advantages, customer benefits

- Main area of application

Bearings subjected to high loads, lubricant starvation, dry running, media lubrication, corrosive environments

- Advantages

Corrosion resistance, increased dynamic load carrying capacity (EHD)

- Customer benefits

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.

Applications

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

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

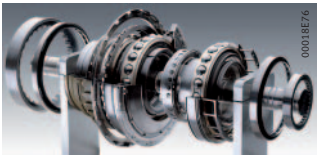
M50

Martensitic hardening

Characteristics, special features	
Base material	Thermally stable, through hardening rolling bearing steel M50, vacuum remelted
Heat treatment	Martensitic hardening
Brief characterisation	Hardening up to 64 HRC, high temperature strength of +350 °C to +400 °C
Operating limits	Corrosion, extremely high centrifugal forces.
Advantages, customer benefits	
Main area of application	Turbine bearing
Advantages	Thermal stability with increased toughness
Customer benefits	Limited cooling requirements, prevention of premature failures.

Applications

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



Case hardening (carburisation and martensitic hardening)

Characteristics, special features

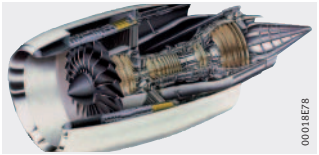
Base material	Thermally stable, case hardened rolling bearing steel M50NiL, vacuum remelted
Heat treatment	Carburising and martensitic hardening
Brief characterisation	Surface hardening up to 64 HRC, high temperature strength of +350 °C to +400 °C, residual compressive stresses
Operating limits	Corrosion.

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

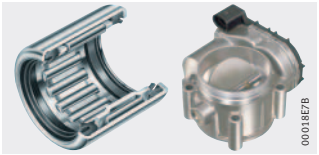
- Base material — Austenitic steel, e.g. X5CrNi18-10 (USA: AISI 304)
- Heat treatment — Carburised
- Brief characterisation — Thin load-bearing surface layer (hardness approx. 58 HRC) with tough core
- Operating limits — Rings over 300 mm, loads over 2 000 MPa, high tangential stresses.

Advantages, customer benefits

- Main area of application — Where amagnetism is required, in aggressive environments (involving acids, for example), where martensitic steels do not offer 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, 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.

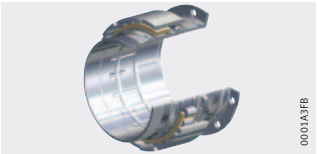
Applications

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

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.



Characteristics, special features

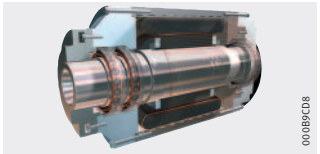
Base material	High-speed steel produced by powder metallurgy
Heat treatment	Martensitic hardening, repeated tempering at high temperature
Brief characterisation	Hardness up to 66 HRC, consistently high hardness distributed over circumference and cross-section
Operating limits	Corrosive attack.

Advantages, customer benefits

Main area of application	Bearings subjected to high loads, risk of brinelling, lubricant starvation, particle overrolling
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

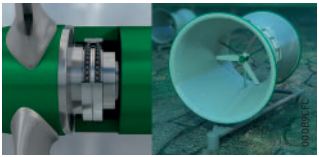
- Base material — Hard metal with metallic binding phase
- Heat treatment — Not required, sintering during production
- Brief characterisation — Hardness > 1 300 HV, very high density, excellent corrosion and media resistance, non-magnetic
- Operating limits — Maximum component dimensions 400 mm, wide temperature fluctuations.

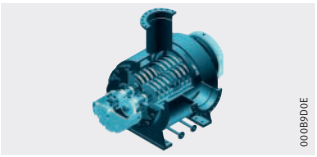
Advantages, customer benefits

- Main area of application — 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
- Advantages — Very high values for heat resistance, modulus of elasticity, wear resistance, corrosion resistance and robust resistance to particle overrolling
- Customer benefits — 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.

Applications

- Ocean energy generation
- Pumps, compressors.





Silicon nitride Si_3N_4

Characteristics, special features

- Base material — Nitride-based ceramic Si_3N_4
- Heat treatment — Not required, **H**ot **I**sostatic **P**ressing (**HIP**) during production
- Brief characterisation — Hardness in the region of 1 500 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_2

Characteristics, special features	
Base material	Oxide-based ceramic ZrO_2
Heat treatment	Not required, sintering during production
Brief characterisation	Hardness in the region of 1 400 HV, density between Si_3N_4 and steel, non-magnetic, excellent corrosion and media resistance
Operating limits	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	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 Si_3N_4.

Applications

- Automotive: motors for electric windows
- Food technology.

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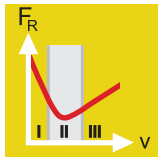
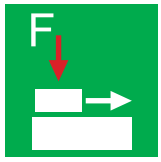
Legend

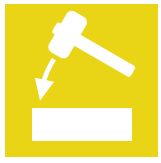
Suitability for increased load carrying capacity (basic dynamic load rating, EHD)



Suitability for mixed friction



Suitability under sliding load (slippage)



Suitability for high shock loads

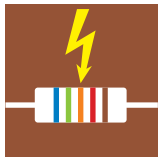
Suitability for high temperatures (dimensional stability, heat resistance)

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