Extend bearing service life with NitroMax

The high-nitrogen steel for super-precision angular contact ball bearings

Longer bearing service life

In extremely demanding applications, such as high-speed machining centres and milling machines, bearings are frequently subjected to any one or a combination of the following operating conditions:

- very high speeds
- high temperatures
- heavy loads
- thin-film lubrication conditions
- contaminated and corrosive environments
- frequent, rapid starts and stops

Under any of these conditions, bearings can fail prematurely from either surface or subsurface initiated metal fatigue. The result: machine downtime, lost productivity and increased maintenance costs.

To enable longer bearing service life and reduce the costs associated with downtime, SKF has developed a superior high-nitrogen steel. The use of nitrogen as an alloying element is not new. What is new is the SKF optimized solution to nitrogen alloying: NitroMax steel[1)].

NitroMax is a new generation stainless steel with superior corrosion resistance, enhanced fatigue strength and a high degree of impact toughness. This ultra-clean steel, with a high nitrogen content, can extend bearing service life in applications under good (full-film) lubrication conditions. But more importantly, it can significantly extend bearing service life under critical (thin-film) lubrication conditions.

NitroMax steel also has a very low coefficient of thermal expansion. This enables bearings made from NitroMax steel to better maintain their preload during operation, even at high speeds, which means less heat generated by the bearings and longer grease service life.

The enhanced performance of bearings made from NitroMax steel means that bearing maintenance cycles are extended and machine uptime is increased. The end result: bearings made from NitroMax steel significantly reduce the cost of ownership.

Features and properties of NitroMax steel

- High nitrogen content
- Ultra clean
- Fine, uniform microstructure
- Superior corrosion resistance
- Very high rolling contact fatigue strength
- Very good wear resistance
- High degree of impact toughness
- High degree of (hot) hardness
- Very low coefficient of thermal expansion
- Low magnetizability

Benefits of NitroMax steel

- Longer bearing service life under full-film lubrication conditions
- Significantly longer bearing service life under thin-film lubrication conditions
- Higher operational speeds
- Less heat generated by the bearings
- Extended grease service life
- Lower preload increase at high speeds
- Improved thermal stability for high and very low temperatures

1) Also known as VC444 steel.

reduces cost of ownership

Hybrid bearings made from NitroMax steel run faster, cooler, longer

The SKF assortment of super-precision angular contact ball bearings made from NitroMax steel has rolling elements made of ceramic (bearing grade silicon nitride) as standard. Features and benefits of ceramic rolling elements include:

- **Lower density** – Ceramic rolling elements are 60% lighter than similarly sized steel rolling elements. Less weight and lower inertia translates into exceptionally high speeds and superior behaviour during rapid starts and stops.
- **Lower friction** – The lower density of a ceramic rolling element, combined with its low coefficient of friction, significantly reduces bearing temperatures at high speeds. Cooler running enables higher speeds while extending the service life of the bearing and the lubricant.
- **High hardness and high modulus of elasticity** – The high degree of hardness of ceramic rolling elements provides a high degree of wear resistance, increased bearing stiffness and longer bearing service life in contaminated environments.
- **Low coefficient of thermal expansion** – Compared to steel, ceramic rolling elements have a lower coefficient of thermal expansion. This means less sensitivity to temperature gradients at high speeds and better, more accurate preload.

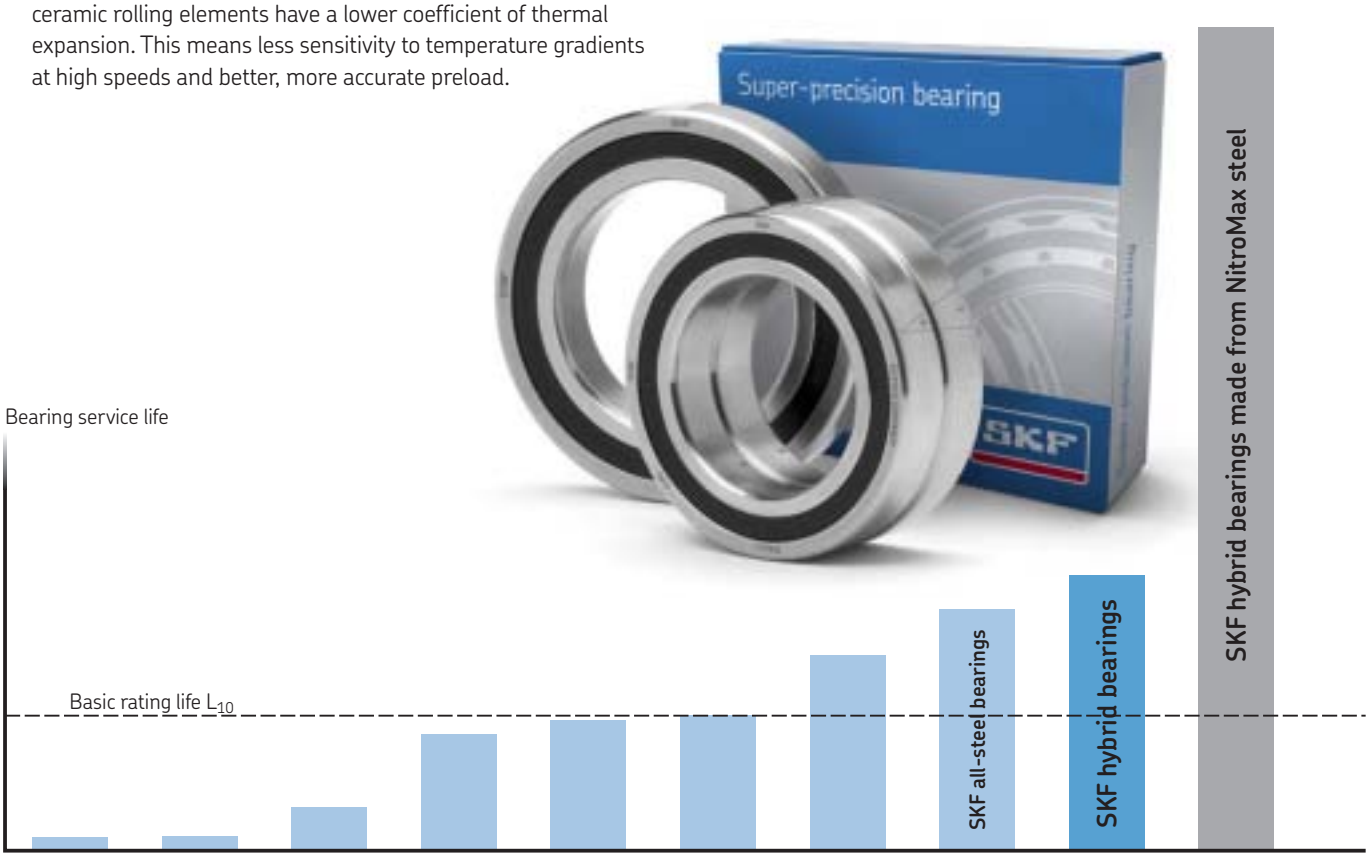
The combined properties of NitroMax steel rings and ceramic rolling elements greatly improve bearing performance, enabling these bearings to run several times longer than conventional hybrid bearings.

Seal longer service life into the bearing

Standard bearings made from NitroMax steel have an integral seal fitted on both sides and are filled with premium grease. The non-contact seals virtually eliminate the problem of premature bearing failures resulting from the ingress of contaminants into the bearing. And because these seals are non-contacting, they are very effective at containing the grease without compromising the speed capability of the bearings.

Sealed super-precision hybrid bearings made from NitroMax steel are relubrication-free under normal operating conditions.

Bearings without seals are also available.



SKF super-precision hybrid bearings made from NitroMax steel last longer than other precision bearings.

NitroMax steel – a superior superior bearing performa

Exceptional by comparison

The most common steel used for precision bearings is a through-hardened carbon chromium steel, 100Cr6. This steel, which has undergone significant improvements over the years, is still an excellent material for a variety of applications. However, high-nitrogen steels are becoming the popular choice for demanding precision applications.

To illustrate why NitroMax steel is superior to other bearing steels (→ **table 1**), it is necessary to define the way that nitrogen influences the microstructure of the steel and how this is optimized during the heat treatment process.

Superior corrosion resistance

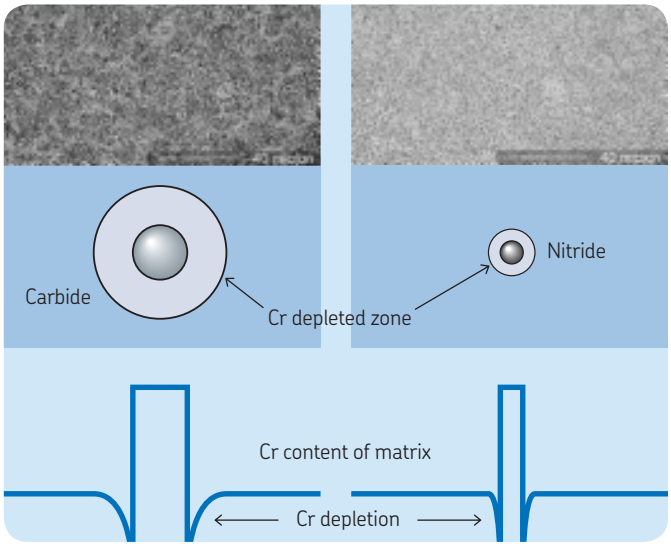
When carbon chromium steel is heat treated, the process produces large, brittle chromium carbides. On the other hand, when NitroMax steel is hardened and tempered, small, fine chromium nitrides are formed. This occurs because the nitrogen replaces the carbon, which enables a much higher content of chromium to be dissolved in the steel matrix. The resulting, smaller chromium-denuded zone around the nitrides makes the high-nitrogen steel much more corrosion resistant.

Enhanced fatigue strength

The enhanced fatigue strength of NitroMax steel is associated with the coherent nature and fine distribution of the chromium nitride precipitates.

Hard, but super tough

In the final quenching and tempering stages of the heat treatment process, bearing rings made from NitroMax steel achieve a unique combination of (hot) hardness (> 58 HRC), impact toughness and dimensional stability.



The microstructure of NitroMax steel (right) consists of a fine distribution of chromium nitrides, compared to the larger, brittle chromium carbides of conventional bearing steel (left).

Why choose NitroMax?

The features and properties of NitroMax steel are not only superior to conventional bearing steels but also to other high-nitrogen steels. And, with virtually no primary carbides and a minimum number of inclusions, NitroMax is almost certainly the cleanest high-nitrogen alloyed steel in the industry – another confirmation of SKF's commitment to continuous improvements in the field of bearings and related sciences.

Table 1 – Comparison of the properties of various bearing steels

Bearing steel	Property Corrosion resistance	Fatigue strength	Wear resistance	Toughness
100Cr6 (carbon chromium steel)	–	+	+	–
AISI 440C (corrosion resistant steel)	+	+	+++	–
Nitroalloy / Chromex 40 (medium-nitrogen steel)	++	++	++	+
NitroMax (high-nitrogen steel)	+++	+++	+++	++

– low + medium ++ high +++ very high

bearing material for nce

Suitable for extremely demanding applications

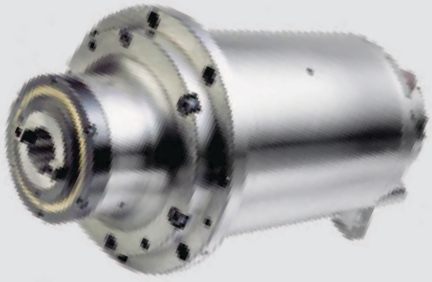
The favourable properties of NitroMax steel, coupled with those of bearing grade silicon nitride (ceramic balls), make SKF super-precision hybrid angular contact ball bearings well suited for extremely demanding, high-speed applications.

Industries
- Machine tools
- Air conditioning (HVAC)
- Aerospace
- Medical
- Chemical and petrochemical
- Semiconductors
- Oil and gas
- Defence
- Sub-sea technology
- Food and beverage

Applications
- High-speed machining centres
- High-speed milling machines
- Refrigerant compressors
- Pure refrigerant lubrication (PRL) compressors
- Vacuum applications
- Sea pumps
- LNG (liquid nitrogen gas) pumps
- Medical engineering applications
- High frequency motors
- Food and beverage processing

Hermle machining centre C series

Electro-spindle



Outstanding performance

Fatigue life tests

The life of a rolling bearing is defined as the number of revolutions or the number of operating hours at a given speed that the bearing, under a certain load, is capable of enduring before the first sign of metal fatigue (flaking, spalling) occurs on one of its rings or rolling elements. This fatigue is typically subsurface initiated fatigue under full-film lubrication conditions and surface initiated fatigue under thin-film lubrication conditions.

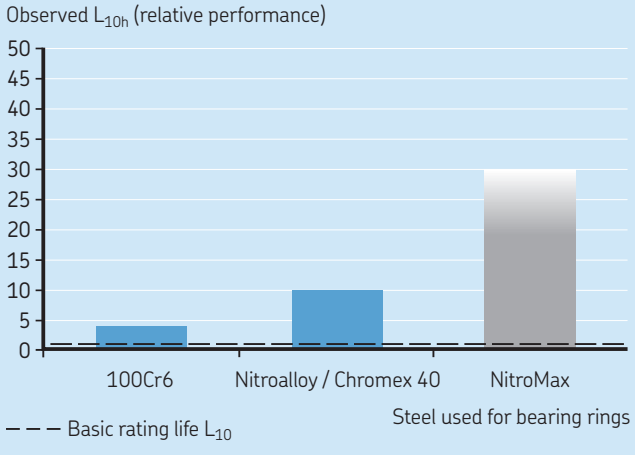
Fatigue life tests were conducted on (open) hybrid bearings made from 100Cr6 (carbon chromium) steel, Nitroalloy / Chromex 40 (medium-nitrogen) steel and NitroMax steel.

The superior performance of bearings made from NitroMax steel is demonstrated by the test results. Depending on the bearing arrangement and operating conditions, the bearings lasted at least three times longer than bearings made from conventional bearing steel, under full-film (→ **diagram 1**) and thin-film (→ **diagram 2**) lubrication conditions.

Blunt notch impact test

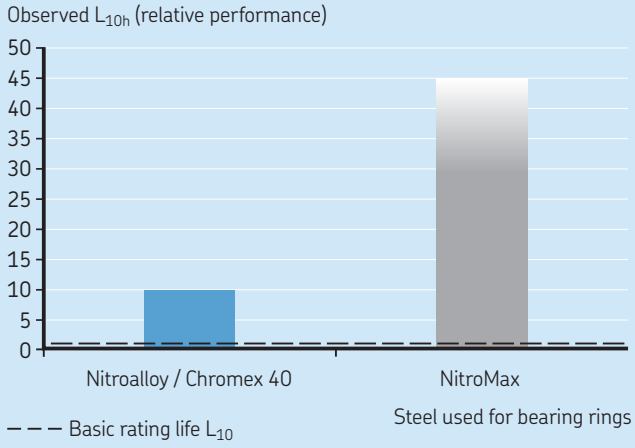
The blunt notch impact (Charpy) test, which measures the amount of energy absorbed by a material during fracture, is used to determine the impact toughness of the material. The test was conducted on specimens of 100Cr6 (carbon chromium) steel and NitroMax steel. When compared to 100Cr6, NitroMax steel has a much higher degree of impact toughness (→ **diagram 3**). This enables bearings made from NitroMax steel to have a high resistance to tensile ring (hoop) stresses, which could otherwise lead to ring cracking.

Diagram 1 – Fatigue life tests under full-film lubrication conditions



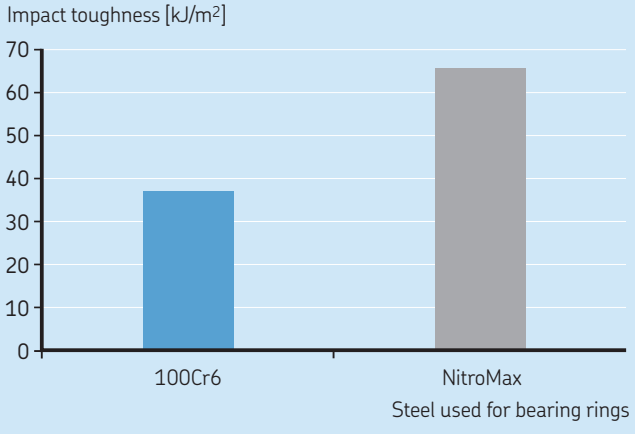
Note: Life test results depend on the lubrication conditions i.e. the values for the viscosity ratio κ and the film thickness to surface roughness ratio λ.

Diagram 2 – Fatigue life tests under thin-film lubrication conditions



Note: Life test results depend on the lubrication conditions i.e. the values for the viscosity ratio κ and the film thickness to surface roughness ratio λ.

Diagram 3 – Blunt notch impact test



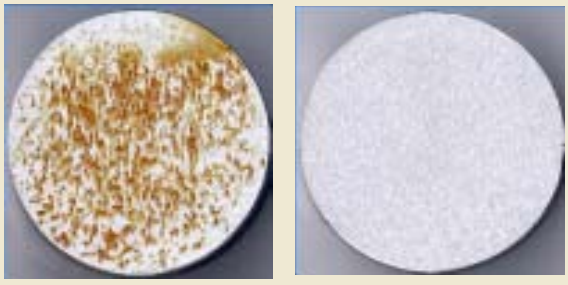
under arduous conditions

Salt spray test

The salt spray test is a standardized test that assesses the corrosion resistance of comparable materials. The test was conducted, in accordance with ISO 9227, on specimens of 100Cr6 (carbon chromium) steel and NitroMax steel. The steels were subjected to a corrosive attack for 100 hours, after which the presence of oxides on each material was evaluated (→ **fig. 1**).

The results of the salt spray test confirm that NitroMax steel has a far superior corrosion resistance.

Fig. 1



100Cr6 NitroMax

Setting the highest standard for precision bearings

A brief overview of the new assortment of SKF super-precision hybrid angular contact ball bearings in the 719 and 70 series is provided in **table 2**.

Hybrid bearings made from NitroMax steel are identified by the designation prefix V e.g. SV71914 ACB/P4AQBCA.

Table 2 – Overview of SKF super-precision high-speed hybrid angular contact ball bearings in the 719 and 70 series

Bearing design		Hybrid variant Sealing	Bearing ring material	New assortment[1)] SKF bearings in the series
High-speed, B design	 ISO 19	Open	Carbon chromium steel Nitrogen alloyed steel	719 .. B/HC V719 .. B (NitroMax)
		Sealed	Carbon chromium steel Nitrogen alloyed steel	S719 .. B/HC SV719 .. B (NitroMax)
	 ISO 10	Open	Carbon chromium steel Nitrogen alloyed steel	70 .. B/HC V70 .. B (NitroMax)
		Sealed	Carbon chromium steel Nitrogen alloyed steel	S70 .. B/HC SV70 .. B (NitroMax)
High-speed, E design	 ISO 19	Open	Carbon chromium steel Nitrogen alloyed steel	719 .. E/HC V719 .. E (NitroMax)
		Sealed	Carbon chromium steel Nitrogen alloyed steel	S719 .. E/HC SV719 .. E (NitroMax)
	 ISO 10	Open	Carbon chromium steel Nitrogen alloyed steel	70 .. E/HC V70 .. E (NitroMax)
		Sealed	Carbon chromium steel Nitrogen alloyed steel	S70 .. E/HC SV70 .. E (NitroMax)

Explanation of designation prefixes for SKF bearing variants:
– Open bearing (no designation prefix)
S Sealed bearing
V NitroMax steel rings and ceramic (bearing grade silicon nitride Si_3N_4) rolling elements

Explanation of designation suffixes for SKF bearing variants:
– Ceramic (bearing grade silicon nitride Si_3N_4) rolling elements, standard for bearings made from NitroMax steel (no designation suffix)
HC Ceramic (bearing grade silicon nitride Si_3N_4) rolling elements, when required for bearings made from carbon chromium steel

[1)] For additional information, refer to the SKF publications *Super-precision angular contact ball bearings: High-speed, B design* (Publication No. 6939) and *Super-precision angular contact ball bearings: High-speed, E design* (Publication No. 10112).