NSK

SOLUTIONS FOR WIND TURBINE MAIN SHAFTS

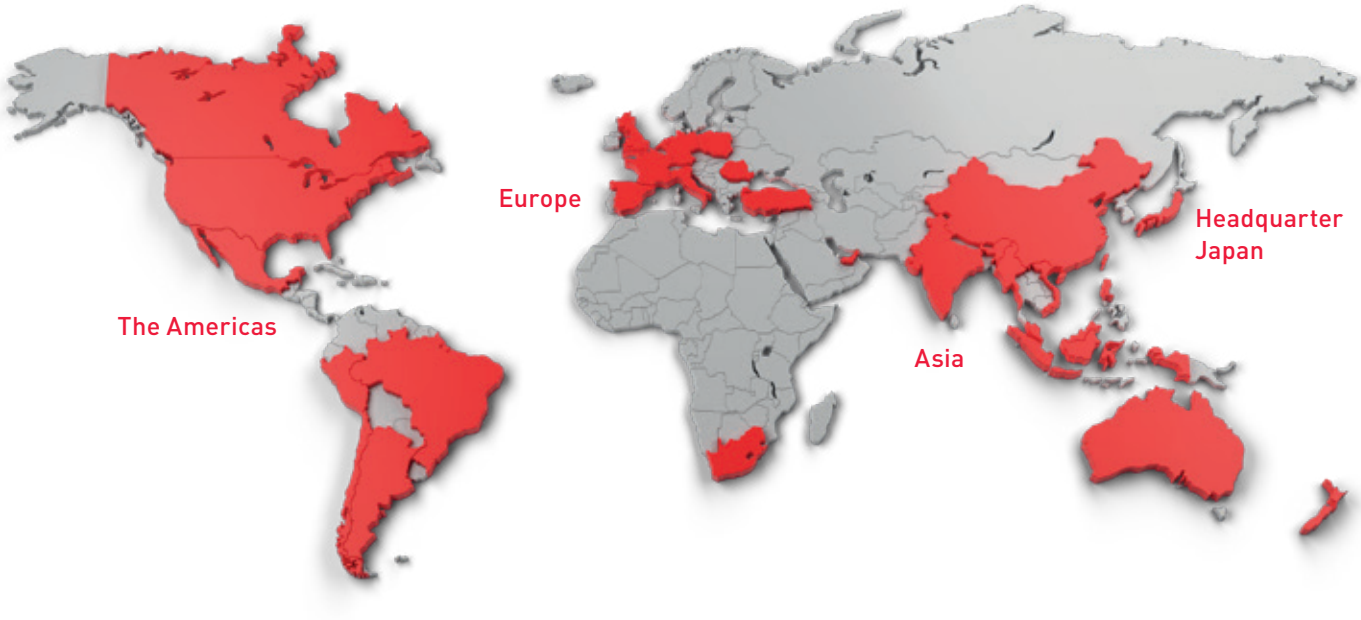


BRANDS OF **NSK EUROPE**

NSK RHP *bearings* PPL

SETTING THE FUTURE IN MOTION

We are among the leading manufacturers for rolling bearings, linear technology components and steering systems worldwide. We can be found on almost every continent – with production facilities, sales offices and technology centres – because our customers appreciate short decision-making channels, prompt deliveries and local service.



The NSK company

NSK commenced operations as the first Japanese manufacturer of rolling bearings back in 1916. Ever since, we have been continuously expanding and improving not only our product portfolio but also our range of services for various industrial sectors. In this context our worlwide research and production facilities are linked together in a global network. Here we concentrate not only on the development of new technologies, but also on the continuous optimisation of quality – at every process stage. Among other things, our research activities include product design, simulation applications using a variety of analytical systems and the development of different steels and lubricants for rolling bearings.

More about NSK under: www.nsk.com/eu-en/

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SUSTAINABLE SOLUTIONS

ROLLING BEARINGS FOR WIND ENERGY

Modern wind turbines are immense structures, typically weighing over 200 tons with each rotor blade spanning 37 meters or more. Operating in high-speed and frequently changing winds, the mass of these systems, the staggering kinetic forces, and the uniquely challenging operating conditions place significant demands on a wind turbine's components - particularly the bearings.

Reliability is essential. Turbines are often remote and difficult to access, so service and maintenance on these machines is complex, costly and scheduled sparingly – with intervals as long as ten years. Any instance of unplanned downtime for bearing repairs or replacement has intolerable consequences to cost-competitive energy generation.

For turbine builders and operators alike, predictable and cost-effective operation requires a development partner to simulate, test and deploy advanced product technologies that deliver the highest level of performance.

A partner like NSK.

LONG-LIFE RELIABILITY: SUPER-TF BEARINGS

Wind turbine main shaft bearings work under immense and continuous dynamic wind loads while rotating at ultra-low speeds, a fraction of those at which they would typically operate. The interaction of these conditions and the resulting mechanical stress on power train components presents challenges to bearings for wind turbine main shafts that can result in excessive wear and unattainable requisite life requirements.

That is, for conventional bearing solutions.

NSK's Super-TF (STF) spherical roller bearings for main shafts are anything but conventional. Engineered to deliver superior and sustainable performance – through advanced material technology and applied manufacturing process controls – STF bearings are built to endure, delivering high-capacity performance for a significantly longer and more reliable operating life.

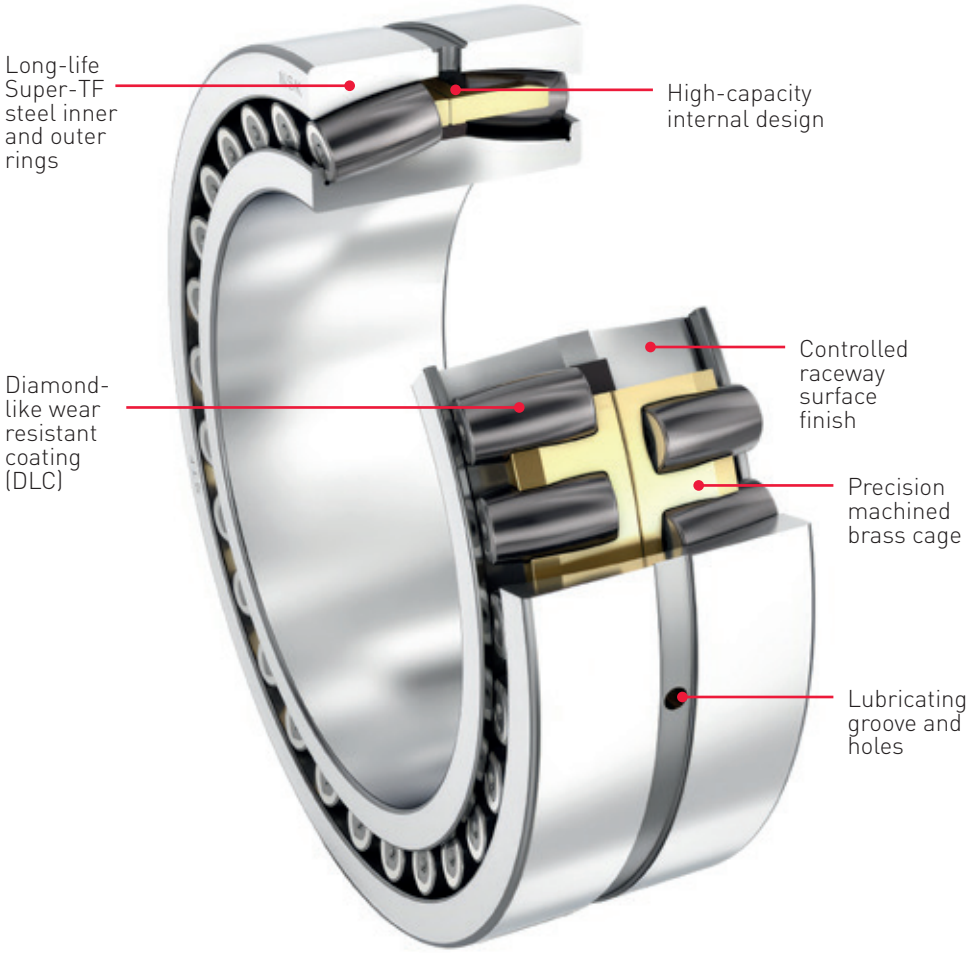


PROVEN ADVANTAGES:

- Super-TF steel promotes longer life with dramatically increased resistance to wear and seizure
- Special roller surface treatment - DLC coating - increases roller toughness and endurance
- Controlled raceway surface finish improves lubrication performance and augments wear resistance

DESIGN AND OPERATING ADVANTAGES

Super-TF (STF) series bearings are designed to deliver outstanding durability in operating environments subject to contamination, or conditions that instigate severe wear. Utilising advanced material engineering and heat treatment technology, they provide the longest bearing life for the wind turbine industry.



DESIGN FEATURES

- Ultra-large spherical roller bearing with optimised, high-capacity internal design
- Bearing rings manufactured with long-life Super-TF steel for dramatically longer service life
- Rollers are treated with wear-resistant diamond-like coating (DLC)
- Heavy duty, precision machined two-piece brass cage
- Special / custom radial internal clearance
- Outer ring lubricating groove with optimised size and quantity of lubricating holes
- Superior raceway surface finish process for main shaft applications

HIGH PERFORMANCE FACTORS

1 ADVANCED MATERIAL TECHNOLOGY

- Super-TF steel promotes longer life with dramatically increased resistance to wear and seizure

2 MACHINED BRASS CAGE

- Heavy-duty two-piece cage design delivers superior performance in applications subject to heavy and/or impact loading
- Cage pocket geometry and finger length provide superior roller guidance and controlled roller skew
- Precision-machined contours optimise lubricant flow to rolling contact surfaces

3 WEAR-RESISTANT ROLLERS

- Diamond-like coating (DLC) increases roller surface toughness with extremely low friction and considerable hardness
- Mitigates roller wear and damage, contributing to a significant increase in bearing service life

4 ADVANCED RACEWAY SURFACE FINISH

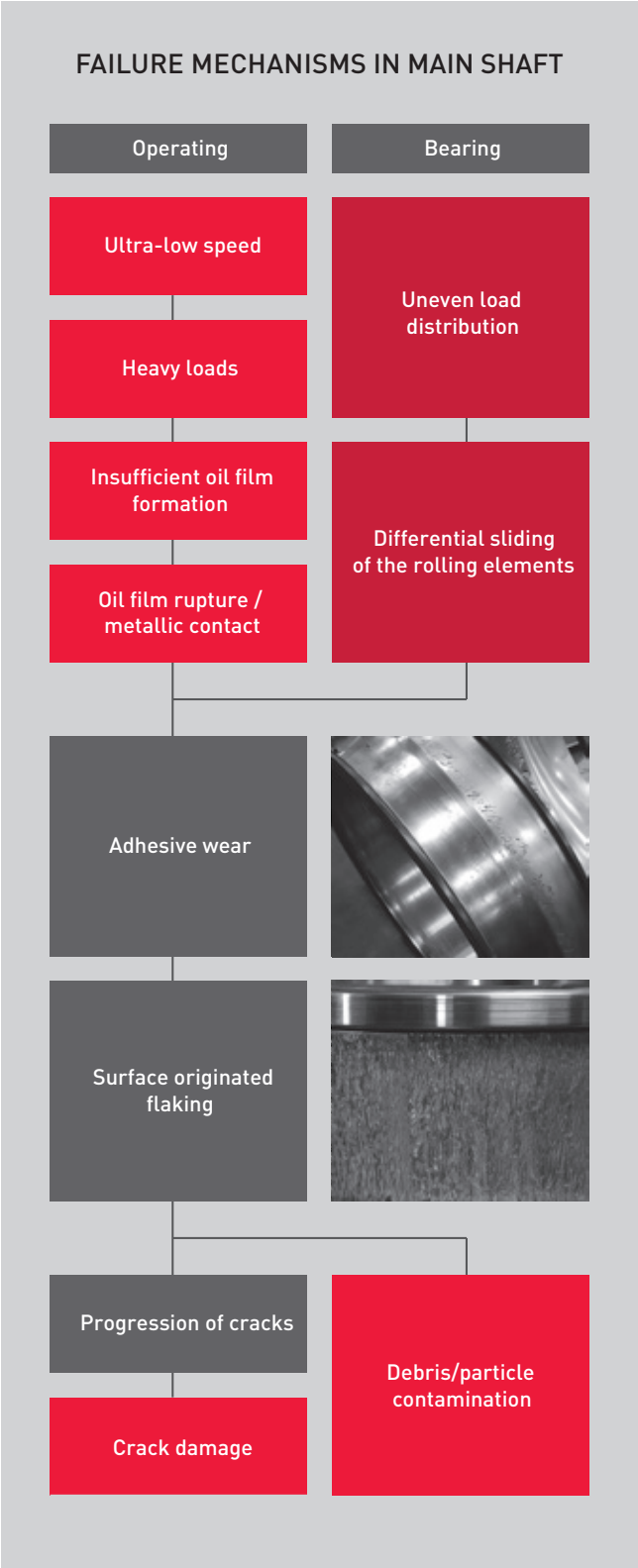
- Superior ring grinding technology, in conjunction with optimised roller-to-raceway profiles, controls roller motion within the bearing, reducing bearing wear and improving bearing fatigue life
- Controlled asperity peaks - at a micro level - improve lubrication performance and augment wear resistance



LONG-LIFE SUPER-TF STEEL

- NSK's advanced material composition and proprietary heat-treatment technology
- Organically higher dynamic load capacity – up to 23%
- Exponentially longer life in contaminated and boundary lubrication conditions versus ordinary carburised steel
- As low as one-third the normal rate of wear versus standard bearing steel
- Up to 40% improvement to seizure resistance versus standard bearing steel

HIGH PERFORMANCE FACTORS: SUPER-TF STEEL



SUPER-TF (STF) MATERIAL TECHNOLOGY

With the expectation to operate successfully for 20 years or longer, durability is crucial for the spherical roller bearings used in wind turbine main shafts. During their operating life they must endure immense radial and axial loads while operating at ultra-low speeds. Effective lubrication of rolling contact surfaces is compromised, and rollers are prone to differential slip - initiating inordinate stress, wear and potential bearing failure.

NSK's Super-TF (STF) series spherical roller bearings are designed to deliver outstanding durability in these environments. Through advanced material engineering and heat treatment technology, they mitigate the impact of these conditions and perform with superior resistance to wear, seizure and heat.

Material composition	Containing appropriate levels of chrome and molybdenum for increased hardness
Special heat-treatment	Optimised dispersion of finer carbide and carbonitride particles
Retained austenite	Alleviation of the stress concentration on the contact surface

In severe, contaminated, and boundary-lubrication conditions, Super-TF bearings deliver exponentially longer life when compared to conventional carburised bearings. For main shaft applications this translates to achieving total cost and performance expectations without unexpected downtime and maintenance incidents.



Life test: Result under foreign contamination

1	General carburised steel
10	Super-TF steel

* tapered roller bearings

Life test: Result under boundary lubrication (Λ=0.3)

1	General carburised steel
5.5	Super-TF steel

* ball-rod rolling contact fatigue test

DEVELOPMENT OF SUPER-TF STEEL

SUPER-TF LONG-LIFE STEEL

Bearings can be required to operate under conditions where lubricating oil is easily contaminated. Metal particles or casting sand in the lubricant create dents in the rolling contact surfaces, and stress concentrated around these dents eventually leads to cracking and to surface-originating flaking. Reducing the concentration of stress around the shoulders of surface dents is directly related to achieving longer service life from the bearing.

NSK research has revealed that a high level of retained austenite is an extremely effective means of maximising the r/c value around surface dents in the bearing material and reducing stress concentration. However, austenite itself has a soft microstructure and reduces the hardness of bearing material. To meet the seemingly conflicting needs for greater hardness with a higher level of retained austenite, NSK has adopted an advanced material composition and proprietary heat-treatment technology to promote the uniform distribution of larger numbers of finer carbide and carbonitride particles in the bearing material. Super-TF bearing steel (SAC2) contains specific amounts of chrome and molybdenum to optimise the formation of carbides.

Figures 2 and 3 illustrate that Super-TF Bearings have a greater amount of fine-size carbide and carbonitride particles than ordinary carburised bearings, giving them a greater degree of hardness as well as higher retained austenite for a long service life (Fig. 4).

Fig. 1 Relationship of r/c value to retained austenite

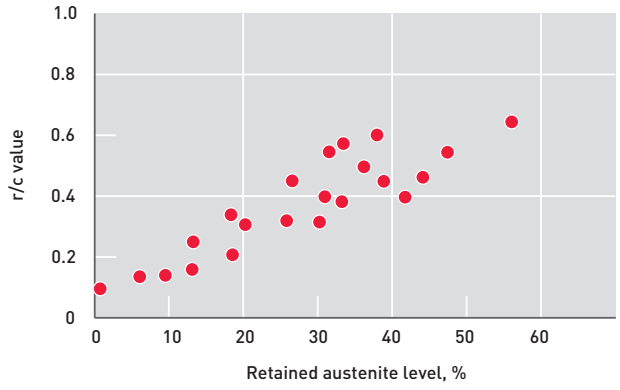


Fig. 2 Average diameter of carbide and carbonitride particles, Super-TF bearing

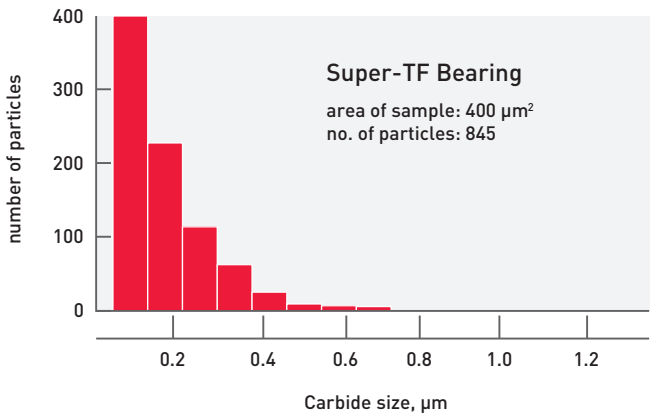


Fig. 3 Average diameter of carbide and carbonitride particles, ordinary carburised bearing

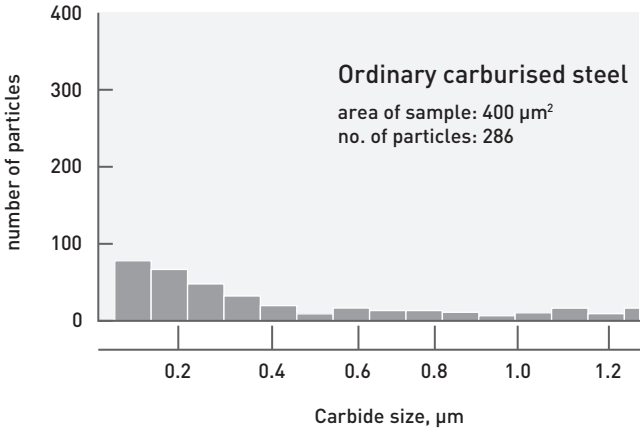
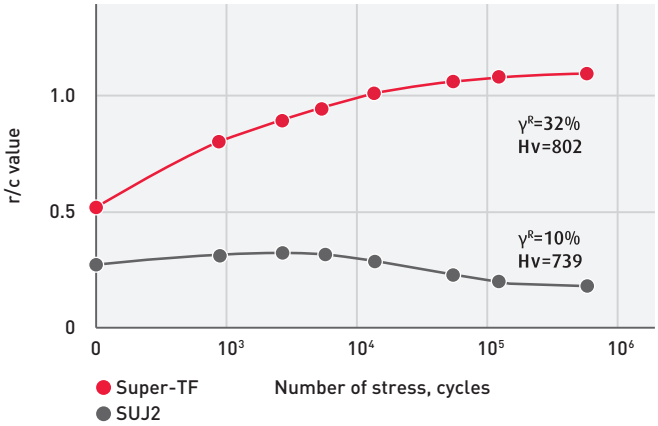


Fig. 4 Change of r/c value under repeated stress



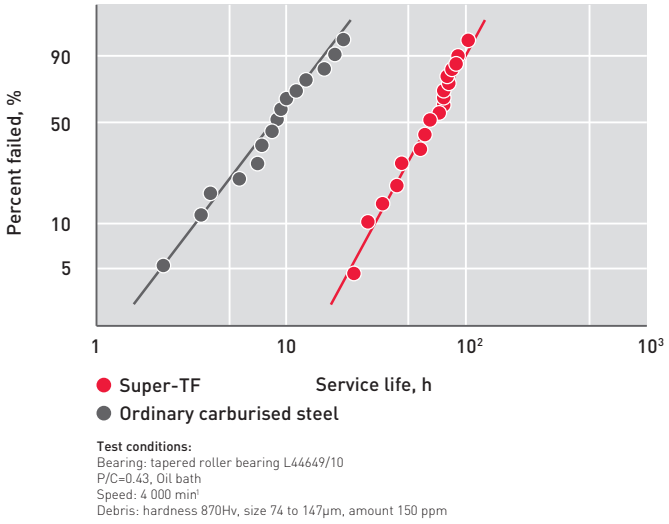
OPERATING CHARACTERISTICS

SERVICE LIFE UNDER CONTAMINATED LUBRICATION CONDITIONS

Bearing service life is generally impacted by the conditions in which the bearing is used and by the amount of contamination in the lubricant. Under contaminated lubricated conditions, service life may fall to as little as 1/5 of the catalogue life.

Designed specifically to deliver longer service life in such conditions, Super-TF Bearings can achieve service life that exceeds the catalogue life of comparable conventional products. In service life tests conducted under contaminated lubrication conditions, the L_{10} life of Super-TF Bearings is more than ten times that of ordinary carburised steel bearings.

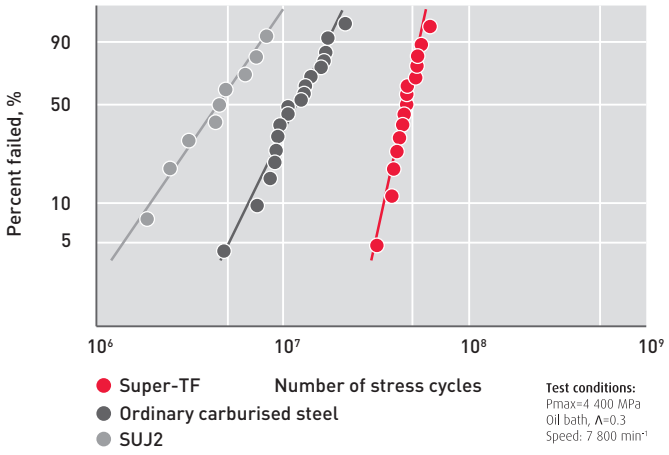
Fig. 5 - Service life under contaminated lubrication



SERVICE LIFE UNDER BOUNDARY LUBRICATION CONDITIONS

Where there is an insufficient amount of EHL film, bearing damage from metal-to-metal contact occurs. In service life tests conducted under conditions where the oil film parameter is very small, peeling damage occurs. With Super-TF Bearings, the reduced concentration of stress around the projections of the contact area delivers a service life approximately 5.5 times greater than that of ordinary carburised steel bearings.

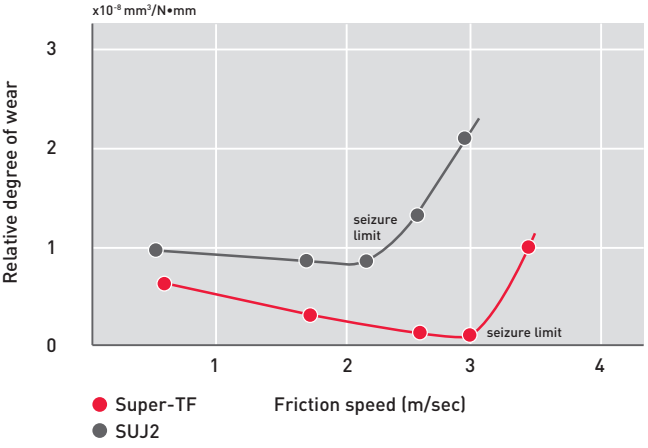
Fig. 6 - Service life tests under boundary lubrication



WEAR AND SEIZURE RESISTANCE

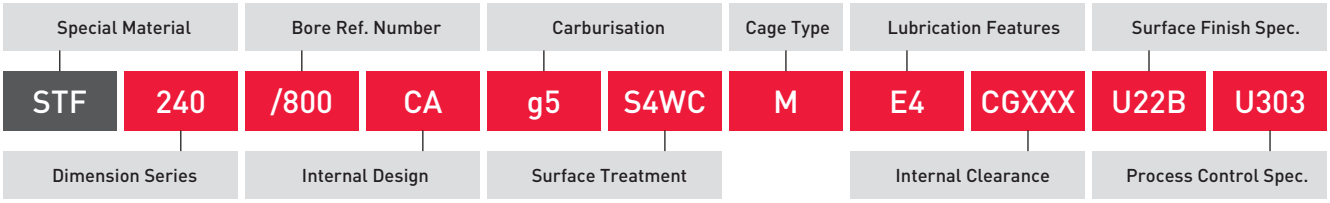
The dispersion of a large number of fine carbides and nitrides in the bearing material increases STF bearings' resistance to wear and seizure. In a Sawin test showing the degree of wear and the seizure limit, Super-TF Bearings demonstrate superior wear resistance to SUJ2 steel with 40% greater seizure resistance.

Fig. 7 - Comparison of wear resistance



DESIGNATION SYSTEM

SUPER-TF SPHERICAL ROLLER BEARINGS FOR MAIN SHAFT



DESIGNATION		ATTRIBUTE
Special Material Designation	blank	standard bearing steel
	STF	long-life Super-TF™ steel
Dimensional Series	240	wide series 240 most commonly used in main shaft applications
	230	
Bore Reference Number		500 mm and greater expressed with a "/" eg. /500 = 500 mm
Internal Design	CA	high capacity internal design
Carburisation	g5	inner and outer rings
Surface Treatment	S4WC	diamond-like protective coating applied to roller contact surfaces
Cage Type	M	two-piece machined brass cage

DESIGNATION		ATTRIBUTE
Lubrication Features	E4	lubrication groove and holes in the outer ring
Internal Clearance	CGXXX	custom radial clearance, in microns
Surface Finish Specification	U22B	advanced raceway surface finish to promote reduced wear
Process Control Specification	U303	special process control for all NSK wind turbine bearings

ACCUMULATED EXPERTISE

For main shaft, gearbox and generator applications alike, NSK deploys our accumulated expertise in collaboration with turbine builders and operators to achieve:

- optimum engagement with our global technology network and design solutions
- intensive project management, comprehensive engineering support
- advanced design and material technologies for high-capacity, long-life performance
- innovative solutions to negate unique phenomena such as white etching cracks (WEC) and electrical erosion
- undeterred equipment performance with condition monitoring
- control measures and processes - the NSK Wind Standard

With NSK as a development partner, our customers can embark on a critical path to realising a high level of performance, predictable reliability and total cost-efficiency in renewable energy generation.



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