MOTION & CONTROL
NSK

Large Hi-TF Bearings

The ideal balance between outstanding service life and moderate cost.

Outstanding toughness, performance and economy — NSK technology sets a new standard for long service life

Outstanding Performance

NSK's Large Hi-TF Bearings have been especially designed for outstanding toughness under harsh conditions of use where they surpass even NSK's TF Bearings. Incorporating new materials and new heat treatment technology, they combine long service life under contaminated lubrication with good resistance to wear and seizure to achieve outstanding cost-performance. In comparison with bearings made of conventional materials, Hi-TF Bearings offer

- 7 times the service life under contaminated lubrication,
- 1.5 times the service life under clean lubrication,
- less than half the rate of wear and a 20% improvement in seizure resistance, and
- dimensional stability superior to that of JIS (Japanese Industrial Standards) SUJ2 bearing steel or ASTM 52100 bearing steel.

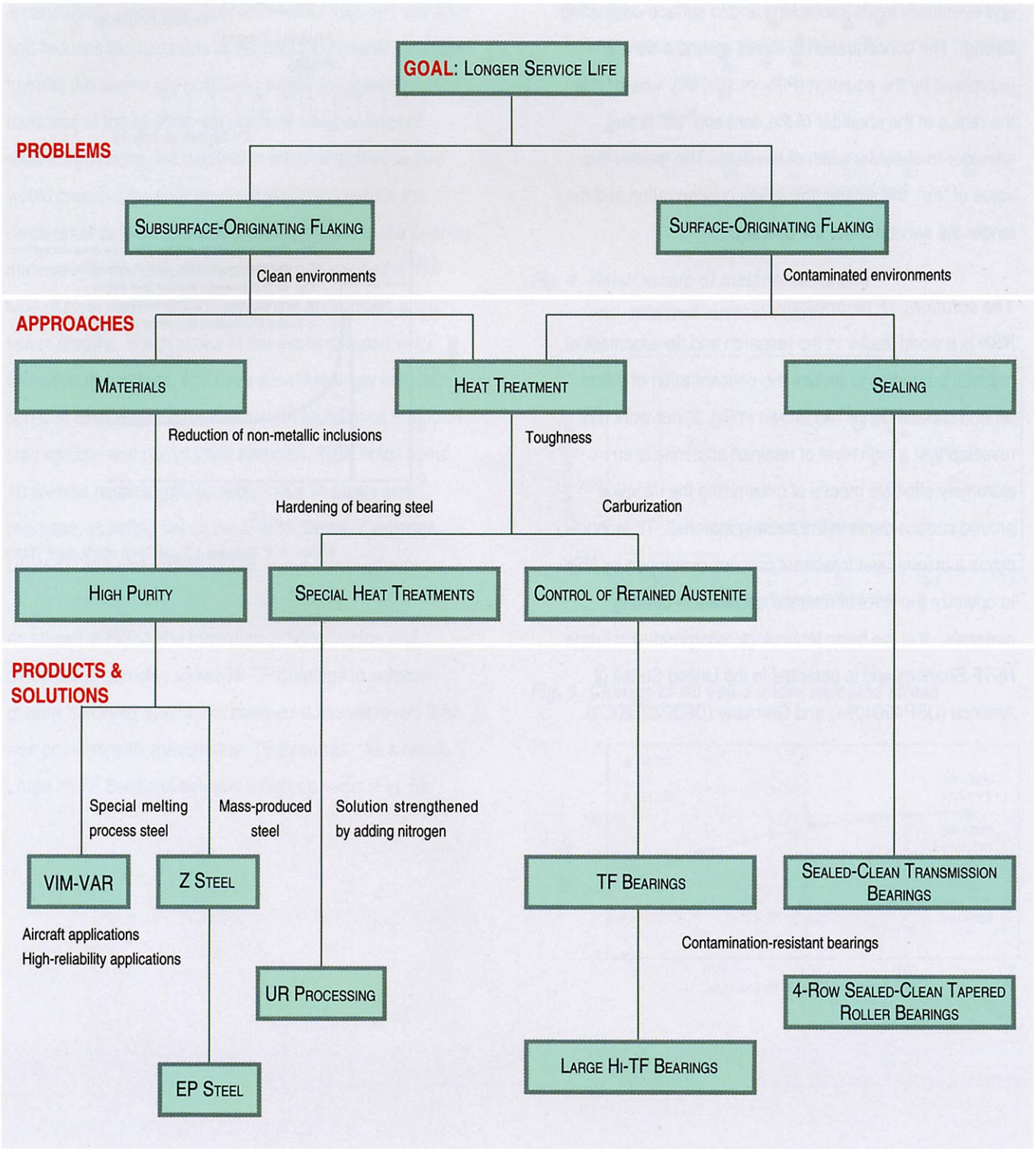
Applications of Large Hi-TF Bearings

Large Hi-TF Bearings are ideally suited to a wide range of applications requiring long service life under contaminated lubrication conditions because of their high wear and seizure resistance. Typical applications include steel and non-ferrous metal rolling mills.

Large Hi-TF Bearings and TF Technology

In its quest for longer bearing service life, NSK has spent many years analyzing the mechanisms of fatigue in bearings and researching and developing materials, heat treatment processes and operating conditions. The range of approaches to achieving longer service life taken by our research team are shown in Fig. 1. The technology incorporated in our Large Hi-TF Bearings is designed to maximize service life under conditions where bearings are subject to surface-originating flaking.

Fig. 1 Approaches to achieving longer service life in bearings



The Development of Hi-TF Bearings

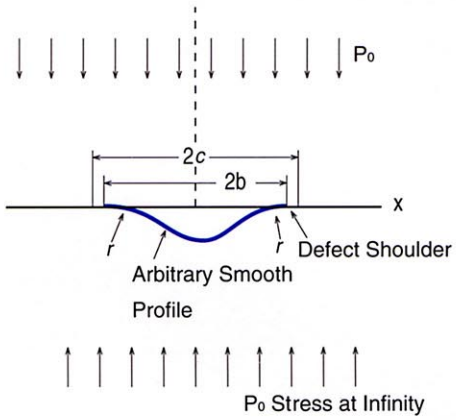
The problem: Contaminated lubrication conditions

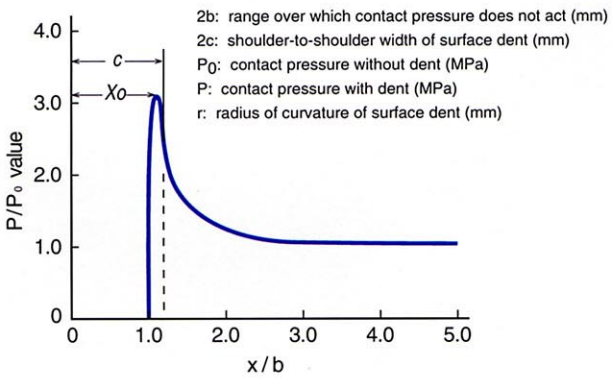
Bearings may be required to operate under clean or dirty conditions; under dirty conditions their lubricating oil is easily contaminated. Metal particles or casting sand in the lubricating oil make dents in the contact surfaces. As shown in Fig. 2, stress is concentrated around these dents and eventually leads to cracking and to surface-originating flaking. The concentration of stress around a dent is expressed by the equation [$P/P_0 \propto (r/c)^{-0.24}$], where "r" is the radius at the shoulder of the dent and "2c" is the shoulder-to-shoulder width of the dent. The greater the value of "r/c", the smaller the stress concentration and the longer the service life of the bearing.

The solution: TF technology

NSK is a world leader in the research and development of material properties to reduce the concentration of stress around surface dents. As shown in Fig. 3, our work has revealed that a high level of retained austenite is an extremely effective means of maximizing the r/c value around surface dents in the bearing material. TF technology is a unique heat treatment process developed by NSK to optimize the level of retained austenite in bearing materials. It is the basic technology incorporated in Large Hi-TF Bearings and is patented in the United States of America (USP4904094) and Germany (DE3922720C2).

Fig. 2 Concentration of stress around a surface dent





Source: Y. P. Chiu and J. Y. Liu, Trans-ASME, Ser-F (1970).

Material Properties of Large Hi-TF Bearings

As we have seen, the approach to achieving long service life taken in NSK's Hi-TF Bearings is to minimize the concentration of stress around the shoulders of surface dents. A high level of retained austenite helps to maximize the value of r/c and reduce the concentration of stress around dents. However, austenite itself has a soft structure and reduces the hardness of the bearing material. In order to meet the seemingly conflicting needs for greater hardness of the bearing material and a higher level of retained austenite, we decided to adopt a technique that would promote the uniform distribution and reduce the diameter of carbide and carbonitride particles in the bearing material. To this end, our researchers developed a new type of steel named SAC1, containing appropriate quantities of chrome, which is one of the elements used in the formation of carbides, and have developed new carburization and carbonitriding heat treatment techniques that form finer carbide and carbonitride particles. NSK holds some 10 patents regarding these techniques in Japan and overseas, including two in the United States of America, USP4871268 and USP5137375.

As shown in Fig. 4, the formation of finer carbide and carbonitride particles allows Hi-TF Bearings to achieve greater hardness and higher retained austenite levels than was possible with conventional TF Bearings. As a result, Large Hi-TF Bearings achieve a high r/c value (Fig. 5).

Fig. 3 Relationship of r/c value to retained austenite level

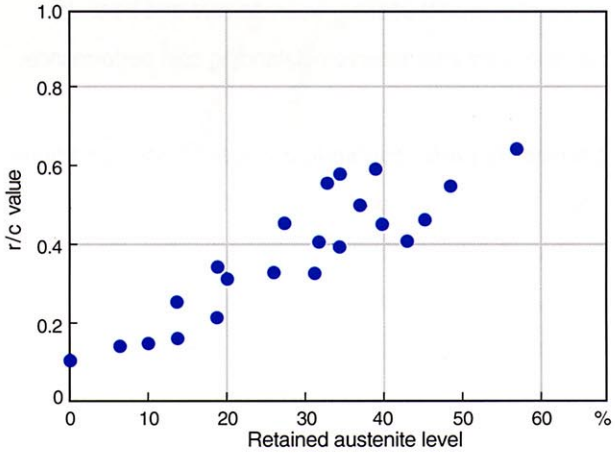


Fig. 4 Relationship of material hardness and retained austenite level

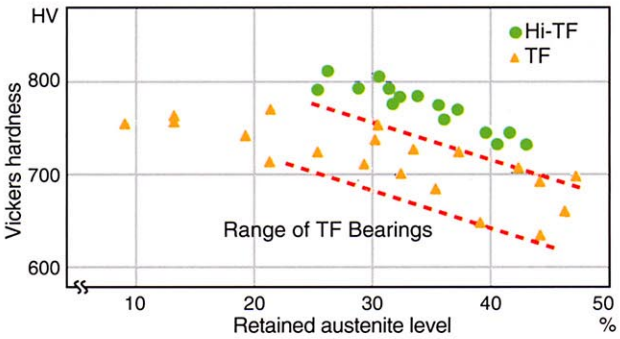
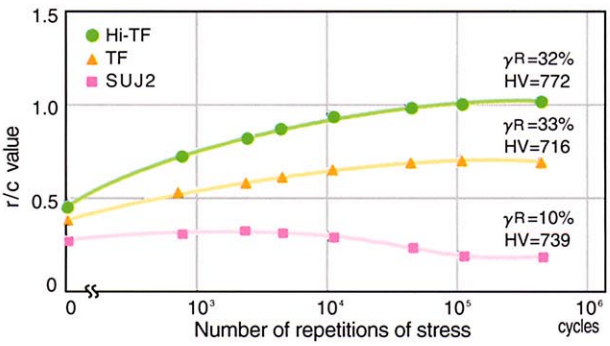


Fig. 5 Change of r/c value under repeated stress



Characteristics of Large Hi-TF Bearings

Large Hi-TF Bearings not only achieve longer service life under contaminated lubrication, but also offer higher resistance against peeling, wear, seizure and heat. In addition, they also achieve outstanding cost performance.

Service life under contaminated lubrication conditions

Table 1 and Fig. 6 show the results of service life tests conducted under contaminated lubrication conditions with NSK L44649/10 tapered roller bearings. If the service life of an ordinary carburized steel bearing of this type is taken as 1, then the L_{10} life of TF and Hi-TF Bearings will be respectively 4.5 and 7.1 (Table 1). NSK's Large Hi-TF Bearings thus offer over seven times the service life of ordinary carburized steel bearings. Service life is generally affected both by the conditions in which the bearing is used and by the amount of contamination in the lubricant. Under harsh conditions, service life may fall to as little as 1/5 of the catalog life. Large Hi-TF Bearings for the first time assure a service life under contaminated lubrication that exceeds the catalog life of existing products (Fig. 7).

Table 1 Comparison of service life of L44649/10 tapered roller bearings

Bearing material	Ordinary carburized steel	TF	Hi-TF
Life ratio	1	4.5	7.1

Service life under clean lubrication conditions

Fig. 8 shows the results of service life tests under clean lubrication conditions using 6206 deep-groove ball bearings. Under clean lubrication, Hi-TF Bearings show a slightly longer service life than those made of SUJ2, but the difference is not as great as under contaminated lubrication. The most important factor determining service life under clean lubrication is the purity of the steel from which the bearing is made, materials with a greater degree of purity offering longer service life.

Fig. 6 Service life of L44649/10 bearings under contaminated lubrication

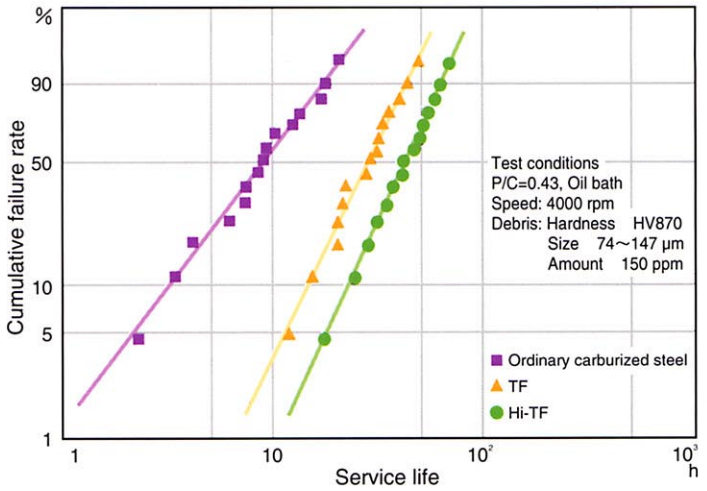


Fig. 7 Comparison of service life under contaminated lubrication

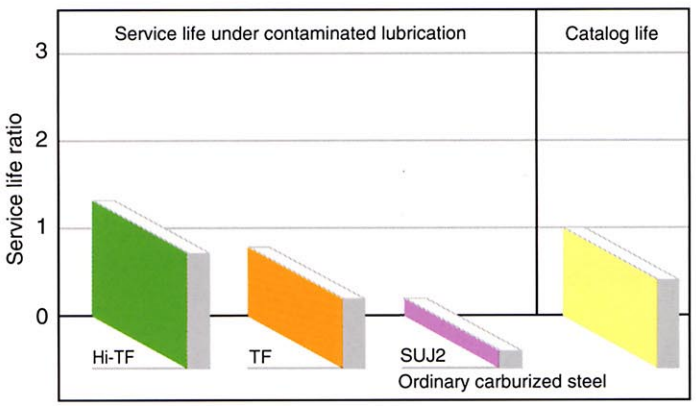
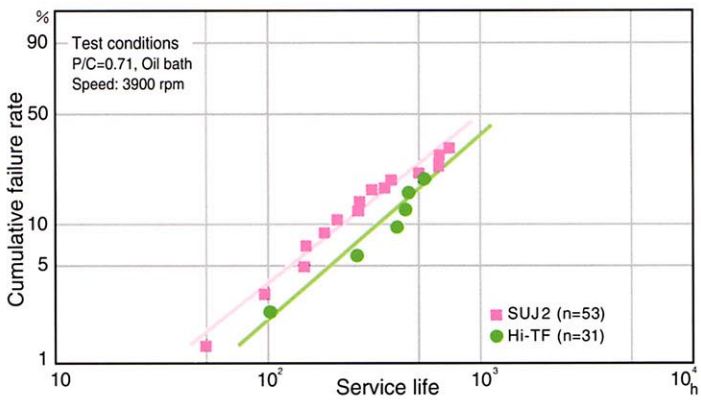


Fig. 8 Service life tests of 6206 bearings under clean lubrication



Service life under boundary lubrication conditions

Under boundary lubrication conditions where there is insufficient EHL film, metal surfaces come into direct contact, reducing bearing life. Fig. 9 shows the results of service life tests conducted under conditions where oil film parameter Λ, which represents the ratio of the thickness of the oil film to the roughness of the surface, is very small (Λ=0.3). When Λ is very small, peeling damage occurs (Fig. 10), but in Large Hi-TF Bearings, the concentration of stress around the projections of the contact area is reduced, giving a service life approximately 4.7 times that of ordinary carburized steel bearings.

Fig. 9 Service life tests with boundary lubrication conditions

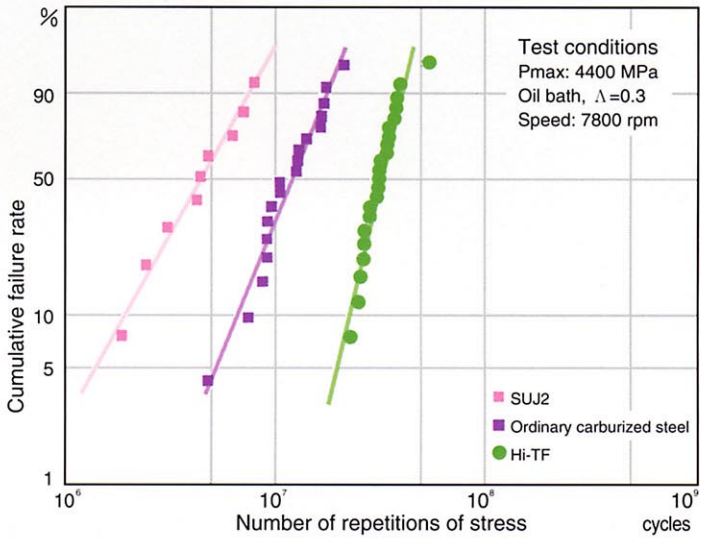
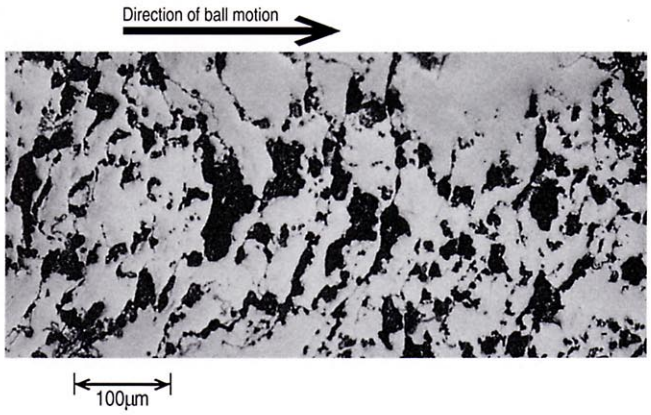


Fig. 10 Peeling damage



Wear and seizure resistance

Besides extending service life under contaminated lubrication conditions, another goal is to increase the bearing's resistance to wear and seizure by ensuring the dispersion of a large number of fine carbides and nitrides in the bearing material. Fig. 11 presents the results of a Sawin-type wear test, showing the degree of wear and the seizure limit for different types of bearing material. The test reveals that Large Hi-TF Bearings have superior wear resistance to both SUJ2 steel and TF Bearings. Hi-TF Bearings are also 20% more resistant to seizure than both SUJ2 steel and TF Bearings.

Fig. 11 Comparison of wear resistance