SV30 Stainless Steel for Ball Bearings

Allaying Failure with Nitrogen Alloy Bearings

AST® Bearings — *Value Beyond the Part™*

This study shows that a clear reduction of wear and the probability of bearing failures can be achieved for miniature and small-size bearings by utilizing nitrogen alloy steel for rolling bearings. This is the result of tests that were carried out to study corrosion resistance and wear performance during dry running and working life under mixed friction conditions. It was only proven, however, for a combination of different materials (steel rings, ceramic balls) and excluding absolute dry running.

Introduction

Over the decades, the standard steel 52100 (100Cr6, 1.3505) for rolling bearings proved to be excellent regarding wear resistance in ball bearings. For the application of miniature and small size bearings, however, the need for materials with a higher corrosion resistance soon arose because of the application in diverse areas, e.g. in the medical, dental, saltwater, or aeronautics fields. Materials sensitive to corrosion in high precision instrument ball bearings immediately influence the efficiency of the whole component with regard to friction, accuracy of movement, and vibration/noise.

The material AISI 440C (X102CrMo17, 1.3543) initially became the standard material in the area of miniature and small-size ball bearings. This material is a corrosion resistant Martensit chromium alloy steel and, because of this, can be hardened to at least 700 HV2, thus meeting the basic demand for low-noise and loadbearing capacity. The relatively good corrosion resistance of the steel 440C is paid for with more-coarse grain structure and with significantly larger carbides. This influences the noise level significantly in the above mentioned area of miniature and instrument ball bearings. That is why some manufacturers, at the end of the 1980s, changed over to the steel X65Cr13 (1.4037, also called 440D or ACD 34, although no official AISI code exists) which, because of a finer structure, combines the corrosion resistance of the 440C steel and the low-noise level of the 52100 chrome steel.

In addition to the above materials, and the possibility of passivating or surface coating, nitrogen alloy steels such as the SV30 steel X30CrMoN15-1 (similar to 1.4108) are now available for application in corrosive media or environments, which excel in the following properties:

- The corrosion resistance, especially against chloride ions, at a comparable hardenability is significantly improved by partially substituting carbon, which was necessary for hardening of Martensit steels, by nitrogen.
- The evenly distributed fine nitrides form a very homogenous structural composition (see fig. 1). This gives comparable, if not improved, mechanical properties against conventional materials regarding vibration/noise, mixed friction, and over-rolling behavior.

This contribution deals with validating these theoretical facts and connections:

- Investigation of the (tribo-) chemical resistance by salt spray test and in corrosive applications in practice.
- Wear dimension measurements regarding wear performance in an unlubricated state (primarily avoidance of adhesion by pairs of different materials: steel-ceramics)
- Investigation of wear influenced working life under mixed friction in high-speed spindle ball bearings.

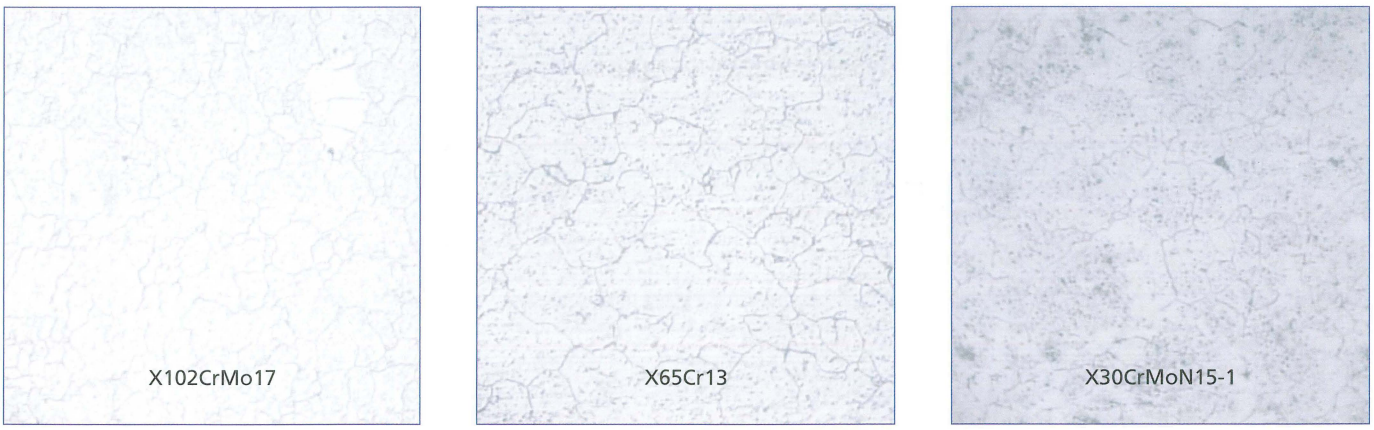

Figure 1: Comparison of structures 440C (X102CrMo17), X65Cr13, SV30 (X30CrMoN15-1) by micrographs

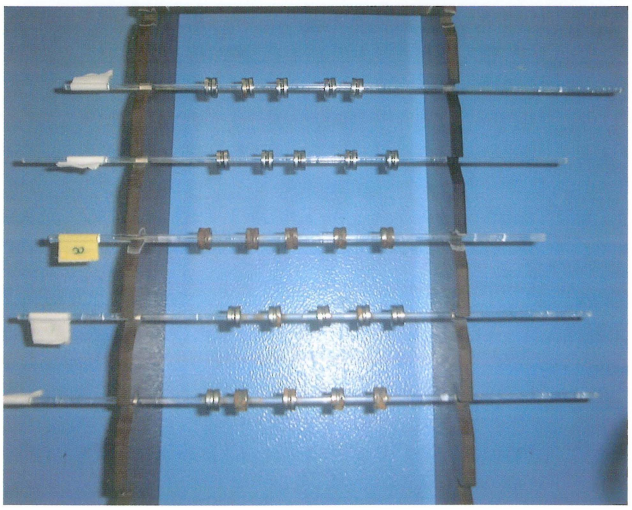

Figure 2: Environmental test chamber for salt spray test to DIN 50021

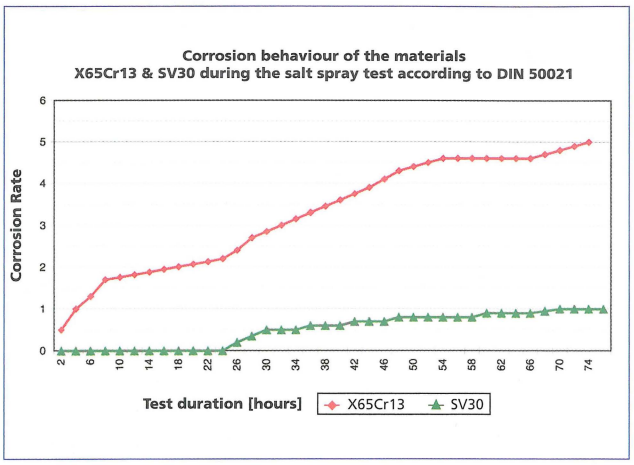

Figure 3: Comparison of corrosion behavior of X65Cr13 and SV30. Corrosion rate: 0 no signs; 1 starting, barely visible; 2 below average; 3 average; 4 above average; 5 high; 6 very high.

Corrosion Behavior

Test Performance

On the one hand, a salt spray test was carried out to DIN 50021 and ASTM-B-117-73 under laboratory conditions (see figure 2) with parameters defined as follows:

- Focus on chemical durability only: Outer bearing race at standstill
- Bearing type: 608 (8 x 22 x 7 mm)
- Salt concentration: 5 percent aqueous NaCl-solution
- Temperature: 35°C
- Spray mode: continuously

On the other hand the corrosion behavior was tested in cooperation with diverse users, e.g. in medical and flow measurement applications. In this case the data of running tests with "unlubricated" hybrid radial deep groove ball bearings (bearing rings from various steels, balls from Si3N4-ceramics), amongst others of the type 682, were collected in blood and tap water conditions.

Test Results

The results of the salt spray tests under laboratory conditions are shown in figure 3 during the test and in figure 4 by the resulting corrosion rate.

Furthermore, figure 5 shows a comparison of the working life of ball bearings, which in a medical application ran directly in blood. This medium served, at the same time, as "lubrication."

Result Discussion

The nitrogen alloy rolling bearing steel SV30 proved to be more corrosion resistant than the steel X65Cr13 which, so far, has been used for this kind of application under laboratory conditions as well as in practice. Already in previous investigations, during the changing over from the steel 440C to steel X65Cr13, a comparable corrosion resistance had been established.

Figure 4: Comparison of corrosion rate 52100, X65Cr13 and SV30

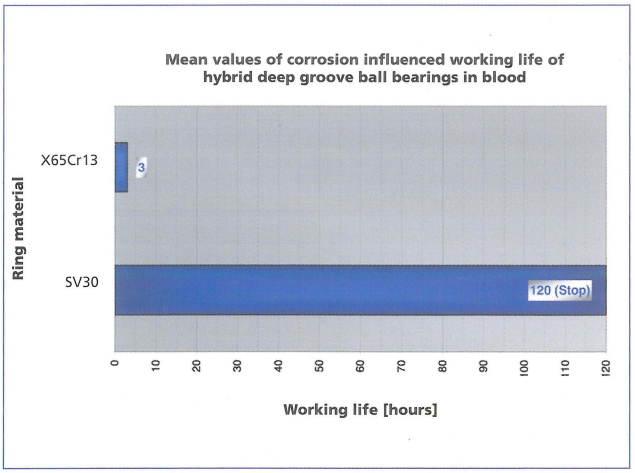

Figure 5: Corrosion influenced working life of ball bearings from X65Cr13 and SV30 in blood.

Corrosion Behavior in an Unlubricated State

Test Arrangement

Figure 6 shows the test arrangement for measuring the wear rate in dry, full complement hybrid ball bearings:

The material pairing of steel rings and ceramic balls avoided adhesion by cold welding in the contact area between the bearing components. Furthermore, a cage was omitted in the test design, as pre-tests showed the working life of various cage designs to be very much below the working life of the bearing rings themselves.

Test performance

The following parameters were defined:

- Bearing type: 6800/001 VAC1 (10 x 19 x 7 mm); full complement, angular contact on the outer ring; not removable
- Ring material: 52100, X65Cr13, SV30
- Ball material: Si3N4
- Number of balls: Z = 17
- Bearing arrangement: Preload 10 N by wavy washer; DB-arrangement; Locating-/Floating bearing arrangement (Test bearing = Locating bearing, Floating bearing: grease lubricated standard bearing)
- Speed: n = 5,000 min^{-1}
- Load: radially: Fr = 10 N by 1kg weight and return pulley; axially: Fa = 10 N by wavy washer
- Test duration: 150 hours
- Temperature: Room temperature

Test Results

Figure 7 shows, after an operating time of 150 hours, the wear rate and the deviation in micro-gram of the respective pairs of ball bearing rings in correlation to the used material.

The balls were not included in the measurement of the wear rate in order for the ring material that might be deposited on the ceramic surface not to be taken into account.

Result Discussion

Despite the fine and homogenous structure of the nitrogen alloy steel – to be noted: under absolute dry running conditions – there is no improvement in the wear rate compared with the steel X65Cr13. It shows that the standard rolling bearing steel 52100 still has the highest wear resistance. On the other hand, absolute dry running conditions occur only rarely in practice as, mostly at high speed, at least minimal lubrication remains. In vacuum applications, however, solid lubricants are used, and even in floated bearings the medium itself builds up a thin "lubricating film."

Therefore, the behavior in the mixed friction area was investigated in addition by the example of "spindle ball bearings of high speed grinding spindles."

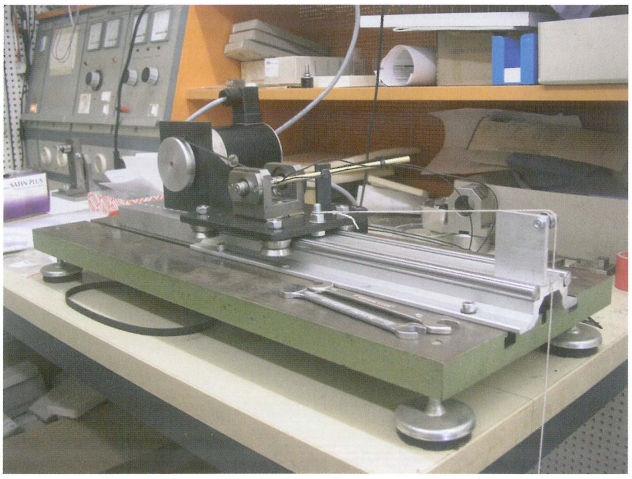

Figure 6: *Test arrangement for measuring the wear rate in unlubricated, full complement hybrid AC bearings.*

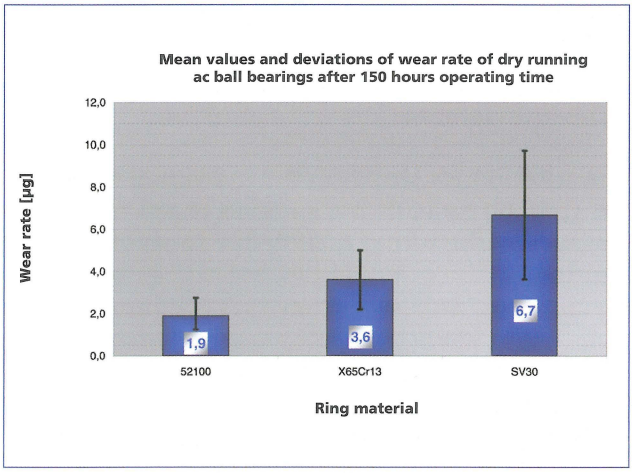

Figure 7: *Wear rate in µg of the bearing ring materials 52100, X65Cr13, SV30*

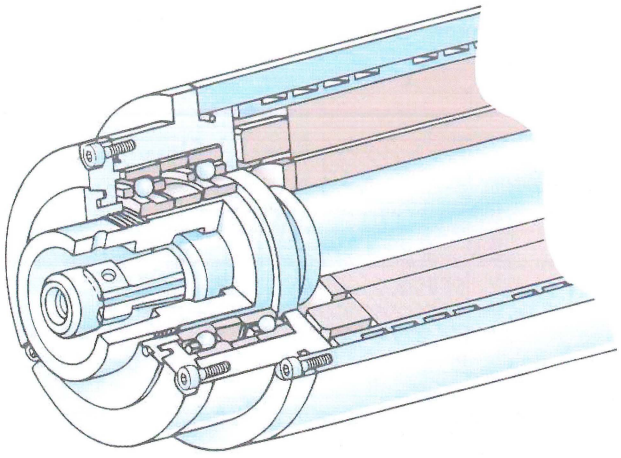

Figure 8: *Basic scheme of the HF spindle for the determination of the wear related working life (Source: Gamfior S.p.A.: Spindle catalogue, Torino)*

Wear Influenced Working Life of High Speed Spindle Ball Bearings

Test Arrangement

High frequency grinding spindles are used for the production of ball bearing rings. These, again, are excellently suitable to test the wear related working life of spindle ball bearings of GRW's own manufacture. The bearings were, therefore, used under defined conditions of a field test in our own production.

Test Performance

Dismountable angular contact bearings of the type 607 (7x19x6 mm), with relieved shoulders of the inner ring and solid phenolic retainers, were installed into the HF-spindles of the manufacturer Gamfior in a field test, so far running for two years, and under the following conditions:

- Ring material: 52100, SV30
- Ball material: Si3N4
- Speed range: 120.000-170.000 min^{-1}
- Lubrication: Electronic minimum air/oil lubricating device, mineral oil
- Load: Collective load (Field test), axial preload 100 N
- Bearing arrangement: Locating/Floating bearing, DF-arrangement

The criterion for stopping the individual tests was the running noise of the spindles or the resulting loss in manufacturing quality due to wear of the bearings.

Test Results

Figure 9 shows the resulting, wear related working life in the previously mentioned field test.

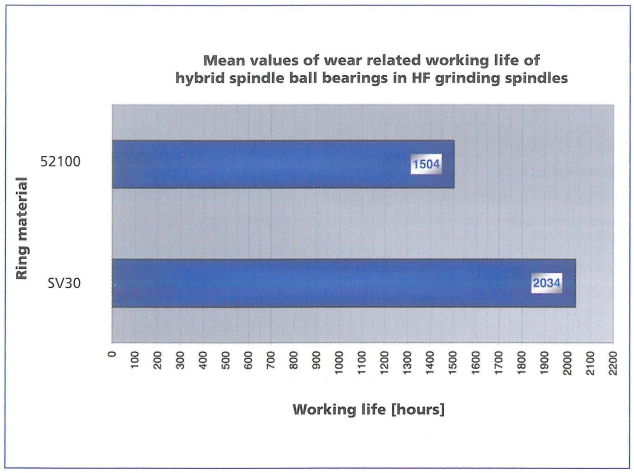

Figure 9: Wear related working life as a function of the applied ring material for the HF grinding spindle bearing in field test.

Result Discussion

In contrast to pure dry running, an improvement in the wear related working life of approximately 30-35 percent due to the use of nitrogen alloy steel can be detected. In the case of mixed friction or minimum lubrication, the homogeneous structure of the SV30 steel has a positive influence on the mechanical properties and the resulting working life of the bearing.

"Nitrogen alloy steels are now available for application in corrosive media or environments, which excel in the areas of corrosion resistance and minimizing vibration/noise, mixed friction, and over-rolling behavior."

Summary

This study shows that a clear reduction of wear and, due to this, a reduction of the probability of bearing failures can be achieved for miniature and small-size bearings by utilizing nitrogen alloy steel for rolling bearings. This is the result of tests which were carried out to study corrosion resistance and wear performance during the dry running and working life under mixed friction conditions. It was proven, however, only for pairs of different materials (steel rings, ceramic balls) and excluding absolute dry running.

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