TECHNICAL INSIGHT

NSK

PRODUCT AND APPLICATION ENGINEERING INFORMATION

A PUBLICATION OF NSK AMERICAS

SUBMERGED CRYOGENIC PUMP BEARINGS

INTRODUCTION

NSK has been the world leader in cryogenic pump bearings since their development in the 1970s. Early designs used phenolic or nylon cages with standard 52100 bearing steel rings and rolling elements. Through continuous material development, NSK was able to improve bearing ring material and cage designs to meet the increasing demands for longer life and reliability. NSK worked with the top cryogenic pump manufacturers to develop and prove reliability and performance in the field. Today, NSK provides a highly engineered product designed to meet the harsh demands of submerged cryogenic pumps ranging from liquid butane to liquid nitrogen.

Cryogenic pumps create their own unique challenges for bearings. Cryogenic pump bearings typically see light loads and moderate speeds, however external lubrication of the bearings is virtually non-existent. Due to such low temperatures of operation, the bearings cannot use traditional means of lubrication such as grease or oil. The cryogenic liquid flows through the bearings with a very low viscosity therefore not providing much lubricity. Cleanliness of the fluid also determines the amount of contamination the bearing will see. In some cases, dirty fluids cause premature bearing failures.

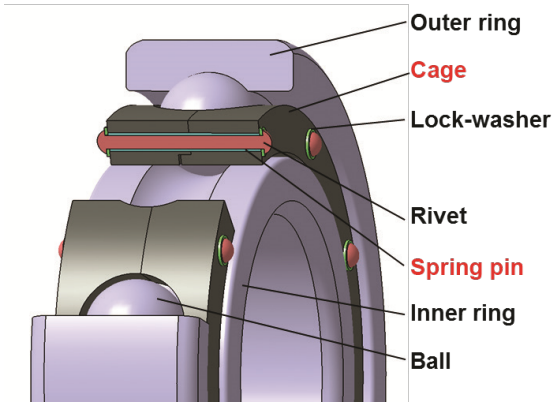
Due to low temperatures and a lack of traditional lubrication, predicting bearing life is challenging when trying to use standard life equations. Over many decades, NSK has worked with cryogenic pump manufacturers to use field testing as a prediction for bearing life.

NSK CRYOGENIC PUMP BEARING COMPOSITION

Stainless Steel Bearings

To cope with these tough conditions, NSK stainless steel ball bearings for cryogenic pumps are made with high carbon, high chromium AISI 440C steel to provide corrosion resistance. The bearing cage (Figure 1) is made from fluororesin, a material that offers the extremely useful property of being self-lubricating, even at very low temperatures. The significance is during operation, the cage – a two piece unit held together by special rivets – transfers a thin film of fluororesin from the retainer pocket to the ball, and then to the raceway surface, maintaining adequate lubrication conditions.

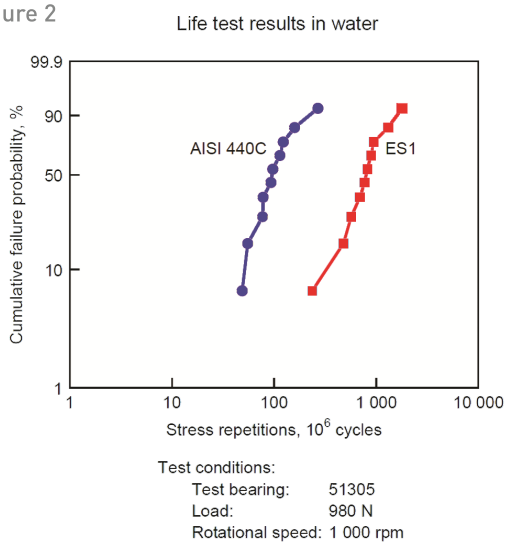
Figure 1



On certain sizes, a special stainless steel material can be used called ES1 (Excellent Stainless Steel). ES1 steel consists of finer carbides, nitrides and a strong martensitic structure, resulting in improved resistance to corrosion and fatigue compared to AISI 440C.

Test results show that ES1 has about five times longer life than AISI 440C in water (Figure 2).

Figure 2



Ceramic Hybrid Bearings

In recent years, ceramic hybrid bearings have become the industry standard in high performance for cryogenic pumps. These bearings consist of stainless steel rings and silicon nitride balls. NSK uses the same flouroresin cage as in stainless steel bearings to provide lubrication. The advantages of ceramic hybrid bearings compared to stainless steel bearings are:

- Improved wear resistance
- Electrical corrosion resistance

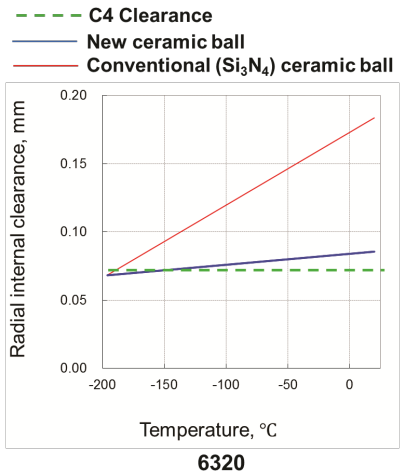
Through testing NSK has found the ceramic hybrid bearings outperform stainless steel bearings in both poor lubrication conditions and contaminated conditions. With the use of VFD motors, electrical corrosion can occur, causing premature failure of bearings. Ceramic balls provide the necessary insulation.

New Ceramic Hybrid Bearings

Bearings for liquefied gas pumps are used with a variety of liquefied gases, each of which operates at different temperatures. However, since conventional ceramic material (silicon nitride) has only one-fourth the linear expansion coefficient as the stainless steel used in the inner and outer raceways, there is a problem of clearance changing in the bearing due to temperature variances. For this reason, it has become necessary to use a bearing with an initial clearance specific to the particular liquefied gas being used.

In response to this, NSK developed a new, high-performance ceramic ball bearing that can accommodate all types of liquefied gases using the same initial clearance setting. This ceramic material has a linear expansion coefficient similar to stainless steel, therefore the same bearing can be used from -196°C for LN2 up to 20°C room temperature (Figure 3).

Figure 3

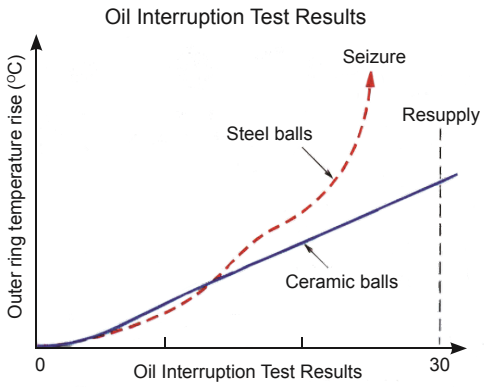


PERFORMANCE OF CRYOGENIC BEARINGS

Seizure

As shown in Figure 4, hybrid bearings have greater resistance to seizure compared to stainless steel bearings. Both bearings were run starved of lubrication, until seizure occurred. The hybrid bearing did not seize.

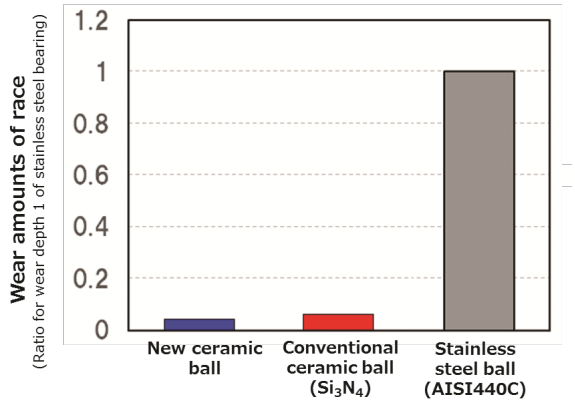
Figure 4



Wear Reistance

Figure 5 shows comparative wear amounts on bearing inner rings after running in liquid nitrogen for 7 days. Hybrid bearings have ~10x less wear than stainless steel bearings.

Figure 5



Endurance Life

Figure 6 shows fatigue life in a clean environment. Hybrid bearings have over 30x life.

Figure 6

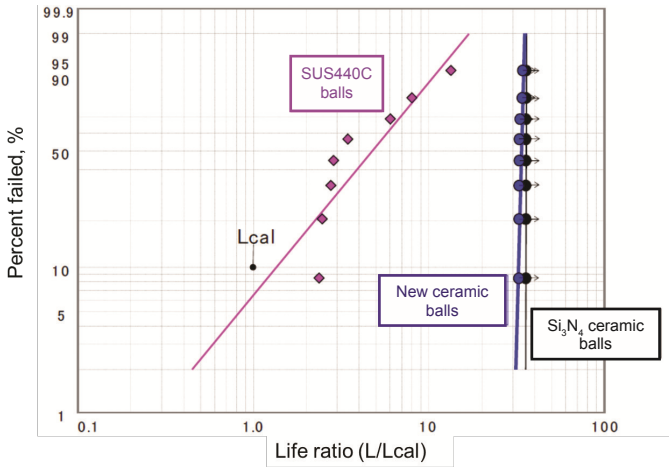
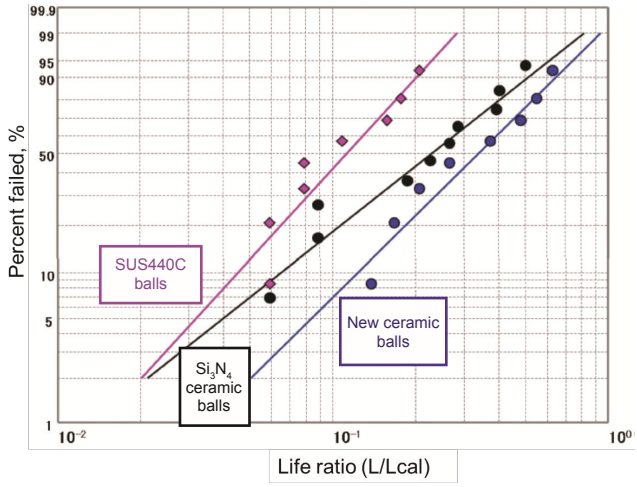


Figure 7 shows fatigue life in a contaminated environment. Hybrid bearings have better performance with contamination present than standard stainless steel bearings.

Figure 7



Solid Lubricant Coatings

NSK currently uses solid lubricant coatings on special environment bearings where grease or oil cannot be used for lubrication (due to high temperature or clean environments). A layer of molybdeum disulfide (MoS2), a low friction material, is applied to the surface of the ring to provide another method of lubrication to the bearing. NSK has begun applying this technology to cryogenic pump bearings. This additional lubricant may also help contamination particles flow through the bearing, preventing the contamination particles from denting the surface of the bearing rings.