SKF General Catalog 6000.
Principles of Bearing selection and Application: Selection of Bearing Size
Using the Life Equations: SKF Rating Life

Summary
The General Catalog has several well worked-out examples applying the SKF rating life that you can explore. But what do the factors mean in a practical sense? Is there anything you can do in the field to realistically extend bearing life?

email: info@aptitudexchange.com
Internet: http://www.aptitudexchange.com
Introduction

In the last article, we explored Basic Rating Life as a simple way to estimate bearing life and size a bearing for an application. This is an ISO approved technique (ISO 281:1990) for life estimation, but it is also an incomplete representation of “real world” conditions.

Practical experience and research have shown that, under certain conditions, SKF bearings attain a much longer life than predicted by standardized life calculation methods, particularly when loads are light and operating conditions are clean. These special conditions apply when the rolling surfaces (raceways and rolling elements) are effectively separated by a lubricant film and when surface damage caused by contaminants is limited. Infinite bearing life is possible under ideal conditions.

From our previous article, the basic rating life equation is

\[ L_{10} = \left( \frac{C}{P} \right)^p \]

This life equation has been modified and approved by ISO 281:1990/Amd 2:2000:

\[ L_{10m} = a_1 a_{SKF} \left( \frac{C}{P} \right)^p \]

This life equation is called modified life, or SKF rating life.

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A relatively new factor has been added to the equation: \( a_{SKF} \).

Life Adjustment Factor \( a_1 \)

To choose a higher level of reliability, a table in the General Catalog allows us to select the factor for life adjustment. For example, to achieve 99% reliability, the \( a_1 \) factor would be 0.21, or approximately 5 times life reduction to achieve a 1% chance of failure after one million revolutions of operation versus the 10% failure chance specified by the basic rating life equation.

A 10% chance of failure might be acceptable for a ground-based gas turbine engine in a power plant. However, if we were to put that same gas turbine engine on an aircraft carrying passengers, we would demand much higher reliability. In real life aircraft gas turbine applications, instead of increasing the size of the bearing to achieve higher reliability, the bearing reliability requirement is increased. Ground based gas turbine power generating applications are usually continuously monitored and often run for 40,000 hours or longer. Aircraft applications are typically overhauled at 1000-2000 hours, or 20-40 times less than a power plant turbine. After a short run time (generally 1000-2000 hours), the aircraft turbine is removed from service. The bearings are removed, rigorously inspected and the turbine is rebuilt. If the bearings pass inspection, they can often be re-used several times.
Factor $\alpha_{SKF}$

The second factor, $\alpha_{SKF}$, looks deceptively simple, but behind it lies decades of research and life testing of bearings to firmly establish the SKF rating life new method theory on current bearings with quality steels and modern manufacturing practices. What was known about the basic rating life was that is many cases, it did not predict life in all situations – especially in very clean or very dirty applications, or in lightly loaded machines.

There are some new concepts underlying the factors upon which the new $\alpha_{SKF}$ factor depends. The new concepts are $P_u$ (pronounced P-sub-you), $\eta_c$ (pronounced ‘eita-see, or ‘eita-sub-see), and $\kappa$ (pronounced kappa.)

$P_u$ Fatigue Load Limit

A quick look at any catalog data page on any particular bearing now reveals the existence of an additional column directly after the “Basic Load Ratings” columns: fatigue load limit. This fatigue load limit represents that load below which fatigue will not occur in the bearing steel under ideal conditions. (An analogy would be a bending a piece of wire: bend a wire ninety degrees several times and it generally breaks, or fatigues. If we only bend the wire, say, two degrees, will the wire still fatigue fail?)

Estimating bearing life using the basic life rating method, bearing failure was inevitable. SKF rating life predicts that under clean conditions, with proper lubrication and light loading, bearings may achieve infinite life.

To give your bearings the best chance at infinite life, start by using proactive maintenance practices such as machinery alignment and balancing to reduce unwanted parasitic loads. Smoothly running machines have longer running bearings.

$\eta_c$ Contamination level

This factor estimates the contamination effect in a bearing. It make sense that the higher the contamination in the bearing, the shorter the life. Prior to extensive research carried out by SKF since the 1970’s, there was no way to quantify the effect of solid particle contamination on life. Most bearings fail due to contamination and ineffective lubrication.

The methodology used for to experiment the effects of contamination was to precisely dent bearings in contaminated oil and run them in clean oil to failure. One not so surprising finding was that if the raceway surface of a bearing is dented only 10%, the bearing life can be reduced as much as 90%.

Another finding: large, soft particles such as paper dust, plastic, or textile fibers can be just as damaging to small bearings as small, hard particles. At the contacting roller or ball contact with the raceway surfaces, a rolling element bearing acts like two flat plates rolling on top of one another. Large or small, the contaminant particles are rolled over under extremely high pressure. This leaves permanent, plastic deformations (dents) in the bearing steel. These dents interrupt the smooth transfer of load from rollers to raceways, much like a pothole in a road; the greater number and size of the dents, the higher the probability of failure.
Since the SKF Rating Life Method has been accepted by ISO, more manufacturers and end users have begun to take serious steps toward contamination control and reduction. For manufacturers and End users, SKF has been recommending increased use of sealed or shielded bearings where possible as a simple, cost-effective way to exclude contamination. For end users, changing oil in new machines more frequently or simply filtering oil can greatly increase bearing life. The effects of improved filtration can be predicted more accurately using the SKF rating life method, and the return on investment calculated.

There is considerable guidance in the Catalog on determination of $\eta_c$, such as guideline values based on expected contamination conditions; as well as charts to estimate $\eta_c$ when contaminant sizes and contaminant hardnesses are known from lubricant analysis. For specific applications, it’s recommended the SKF Applications Engineering Service be consulted.

**κ kappa**

Kappa is the ratio of the actual operating oil viscosity ($\nu$) in the application and the minimum required oil viscosity($\nu_1$). Another way to think about Kappa is related to the surface roughness of the contact surfaces in the bearing: a kappa of 1 indicates that the oil film thickness is on the same order as the “roughness” of the contact surfaces. Higher kappa values indicate a “thicker” oil film. Kappa below one means the lubricant does not have sufficient viscosity for the applications. Kappa values selectable on the Factor $\alpha_{SKF}$ charts in the General Catalog range from 0.1 to 4. Kappa values greater than 4 offer little improvement in rating life, and the life reduction effect of Kappa values less than 1.0 are significant.

How can you control Kappa in the field? In some cases, oils (or greases) can be selected with higher base oil viscosities (or higher viscosity indexes) to improve oil film thickness. Carefully lowering oil levels in wet sump applications may reduce sump temperatures, or cooling systems can be applied to reduce oil temperatures. Flow rates in dry-sump circulating systems should generally be optimized for lowest bearing operating temperatures.

Take care if you’re thinking of changing to synthetic oils. Most synthetic oils have higher viscosity indexes, retaining more viscosity than equivalent mineral oils at higher temperatures.

In–service bearing damages are not always produced in ways that are predicted by bearing life calculations. To quote Archie Young, a recently retired Senior SKF Applications
Engineer: “There are only two ways a bearing can fail: from the inside, or from the outside.” Bearing life calculations are predictions based on “inside-out failure” – that is to say, failures that are produced by subsurface material fatigue of the bearing steel. Field reports estimate that one-third or more of bearing damages are produced by lubrication problems.

The ISO 15243:2004 standard discusses bearing damages in detail, with 6 major categories of bearing damages. With some damage types, such as wear, actual bearing “life” is very difficult to predict. Elimination, or at least mitigation, of these non-predicted damage types is necessary to achieve confidence in bearing life estimates.

In our next article, we will look at guideline values for bearing life and how to calculate dynamic bearing loads.