BEARINGS OVERVIEW

Introduction

It has been estimated that roughly 70-80% of all LVM failures are bearing related. Consequently, bearing design is a major factor in influencing motor life. The selection of bearing types is influenced by a number of factors, including motor hp, speed, as well as environment, lubrication practices, and other issues. Anti friction bearings (ball and roller) are most common in lower hp ratings, with sleeve bearings used generally only for higher hp, higher speed, applications. Anti friction bearings may be of the shielded, sealed for life (i.e. double sealed, with no additional lubrication required), regreaseable, or oil mist lubricated types.

There are relative advantages and disadvantages of each type of lubrication method. For smaller hp motors, double sealed (greased for life) bearings are often preferred, because of the long life of grease in smaller bearings. This also avoids the inconvenience and cost of greasing smaller motors. In larger hp ratings, regreaseable bearings are more commonly used. This permits an open bearing construction, which helps to limit bearing temperature rises.

A well-accepted rule of thumb is that for every $15^{O}C$ that the lubrication temperature rating is exceeded, the life of the grease is halved. IEEE RP841 recommends that the maximum bearing temperature rise be limited to $45^{O}C$ ($50^{O}C$ for 2 pole motors), based upon an assumed ambient of $40^{O}C$.

Types of Bearings

The most common bearing found in horizontal foot mount electric motors is the Single Row Deep Groove Ball Bearing. This bearing is used in most motors on the **O**pposite **D**rive **E**nd (ODE) and on the **D**rive **E**nd (DE). Another common bearing is the Cylindrical Roller Bearing. Roller bearings are used on the DE of larger HP low voltage motors that are designed for belt drive applications.

For vertical flange mounted motors with thrust loading, angular contact ball (single or duplex type), Conrad deep-groove or spherical roller thrust bearings are recommended. Sometimes Double Row Angular Contact Ball Bearings are used on the ODE of a horizontal foot mount motor which is going to be mounted vertically. On higher HP motors, Sleeve Bearings are used. Many other bearing types exist but are not commonly used on typical motors found in a mill or plant.

Cage Material

The cage of a bearing is what keeps the individual balls or roller separated from each other. This cage can be made of machined brass, cast iron, pressed steel, machined light alloy, injection molded glass-fibre reinforced polyamide, fabric reinforced phenolic resin or injection molded polyamide material. Brass typically provides the best life. Brass operates more quietly than steel and tends to be the most common bearing used by high quality manufacturers. Polymer based cages also operate more quietly than steel.

Bearing Clearances

Bearing clearance is the space between the balls or rollers and the inner and outer races. Different clearances are available. Typically motors use C3 fit bearings. The clearance values are defined as follows:

C1	Clearance less than C2
C2	Clearance less than normal
C3	Clearance greater than normal
C4	Clearance greater than C3
C5	Clearance greater than C4

Too little clearance can cause problems during starting. When a motor first starts, the rotor heats up much more quickly than the stator and frame. This causes the shaft to expand, which, due to hoop stresses, increases the diameter of the bearing's inner race. The bearing's outer race, however, is still cool because the frame and bearing bracket haven't heated up yet. This causes the clearance to decrease and in an extreme case, becomes a negative clearance resulting in excessive heating and bearing damage. Once the motor is up to speed, the rotor starts to cool down and the frame starts to warm up. After a period of time, the bearing temperature reaches equilibrium and the designed clearance is realized. The trick is to pick a bearing which has enough clearance to allow for unequal heating at startup but have the minimum amount of clearance at equilibrium. Too much clearance causes potential for an uneven air gap and subsequent vibration, noise and other detrimental effects. C3 clearance provides a good compromise.

Bearing Designations

Bearing numbers define bearing type and size. As an example consider a 6313C3 bearing. The '6' means that the bearing is a single row deep groove ball bearing. The '3' refers to the bearing width. Widths range from 0 – 4 with 4 being the widest. '13' refers to the bearing ID. For bearings with the last 2 digits greater than or equal to '04' the ID can be determined by multiplying by 5. In the 6313C3 bearing, 5 x 13 = 65mm ID.

Bearing numbers not only define the bearing type and size but also can include prefixes and suffixes that identify specific characteristics of the bearing. Bearing manufacturers don't always use the same designations but in general there is consistency throughout the industry. Prefixes can identify special properties of a bearing such as heat treatment for operation at high temperatures. Suffixes are used to identify special internal designs, special chamfers, cage material, seal or shield type, ring modifications, duplex arrangements, internal clearances, tolerances and type of pre-lubrication. Refer to the specific manufacturer for interpretation of prefixes and suffixes. In the 6313C3 example above, the C3 identifies the bearing internal clearance as being C3.

Bearing Life

Mechanical bearing life is typically defined in L-10 hours. L-10 life indicates that 90% of all bearings loaded in this manner will exceed the hours of life noted.

The formulas for calculation of anticipated bearing life are as follows:

Roller Bearings

$$\text{L10 Life} = \frac{(\text{Rating}_8)^{10/3}}{(\text{Load}_E)^{10/3}} \times \frac{1{,}000{,}000}{60 \times n} \text{ Hours}$$

Ball Bearings

$$\text{L10 Life} = \frac{(\text{Rating}_8)^{3}}{(\text{Load}_E)^{3}} \times \frac{1{,}000{,}000}{60 \times n} \text{ Hours}$$

where:

L_{10} Life Number of hours that 90% of a group of bearings should attain or exceed prior to onset of fatigue failure

Rating_8 Basic dynamic load rating for a given bearing

Load_E Equivalent radial load impressed on a bearing including radial and axial loads.

n RPM

Note: These formulas show that the theoretical bearing life can be increased by a factor of 10 times for roller bearings and 8 times for ball bearings if imposed loading can be halved. Even more dramatically, it shows that its theoretical life can be increased 39 times for roller bearings and 27 times for ball bearings if the equivalent load can be dropped by a factor of 3 times. Calculated life using the above formulas are considered to have a 90% reliability rate.

Calculating radial loading for belt drive application is done using the following formula:

$$\text{Load}_E = \frac{126{,}050}{\text{RPM} \times D} \times \text{HP} \times f_b \times K$$

where:

D Motor sheave diameter

f_b Belt factor (typically 1.5 – 2.0)

K Load or service factor (1.2 – 1.8 for continuous operation typically 1.6)

Bearing Temperature

As a general guide, bearing temperature limits are as follows:

	Lubricants	
	Standard	**Synthetic**
Normal	80^{O}C or lower	110^{O}C
Alarm	90^{O}C	120^{O}C
Shutdown	100^{O}C	130^{O}C

The IEEE 841 spec calls for a maximum bearing temperature rise of 45^{O}C (50^{O}C for two pole motors) as measured by a thermometer or thermocouple on the surface of the bearing housing as close to the outer race as possible.

New Bearing Designs

Some bearing manufacturers are manufacturing bearings with “Tough Metal” or “Tough Steel”. This “TMB” bearing has a life expectancy of over 3 times that of a standard good quality bearing when clean grease is used. When grease is contaminated, the life expectancy is between 6 and 7 times greater than a standard bearing. The “Tough Metal” has reduced micro-stress on the raceways and lower crack sensitivity due to special treatment. This means that contaminants have less detrimental effect on the bearing as compared to standard metal, which translates into greatly improved life.