Impact of Balancing on Bearing Life and Machine Reliability

Howard W Penrose, Ph.D., CMRP
Vice President, Engineering & Reliability
Dreisilker Electric Motors, Inc.

***Abstract:** There is a direct correlation between the vibration and unbalance of an electric machine and the bearing life and reliability of the machine. In this paper we will review several instances of a rotor only on bearings, leaving out the attached components, thrust, load, thermal and environmental considerations in the life of the bearings on a machine. Instead, we will assume that all of these conditions are the same and will review only the L10 life of the bearings and the impact of direct unbalance. In addition, we will compare the L10 life of the bearing assuming only the weight of the rotor (perfect balance) versus the standard G2.5 balance specification, a commonly found unbalance condition of a rotor and the standard to which Dreisilker Electric Motors, Inc. accomplishes.*

INTRODUCTION

The L10 life of a bearing is the calculated value at which a population of 10% of bearings will fail. This value is calculated using Eq. 1 and assumes a perfect environment.

L10 = (1,000,000/(RPM*60))*(C/P)^r (Eq. 1)

Where RPM is speed, C is the catalog dynamic rating of the bearing, P is the effective load, and r is 3 for ball bearings and 3-1/3 for all other types. It is important to keep all data in the appropriate form, such as we will use lbs force instead of Newtons in this article.

ISO Standard 281[1] further identifies the calculated life/reliability of the bearing by including modification factors (Eq. 2) which are used to include the operating environment.

Lnm = a1*aISO*L10 (Eq. 2)

Lnm is the life rating, a1 is the multiplier based upon the percent surviving bearings, and aISO involves environmental and lubrication influences. For the purposes of this paper, we are going to represent both multipliers as ‘1’ such that they do not have an impact on the purpose behind this discussion.

The P, or effective load, on the bearing is calculated several ways. One is the weight of the rotor on the bearing (basically, half the rotor weight across two bearings) and the rest are loads based upon other components attached to the shaft, unbalance, misalignment, belt tension, etc. For our purposes, we are only going to explore the rotor weight and unbalance impact and use one bearing on the rotor as an example.

We often hear of vibration in terms of mils (displacement), in/sec (or mm/sec – both are velocity) or g (acceleration). In the case of determining the amount of force due to unbalance, alone, you need to determine the pound-inch (lb-in) unbalance of the motor and attached components. This can be calculated as shown in Eq. 3, where Flbs is force in pounds.

Flbs = 1.770*(rpm/1000)^2*lb-in (Eq. 3)

Therefore, an 1800 rpm rotor with 1/16th lb-in unbalance and a diameter of 24 inches (12 inch radius) would have a radial force of 68.76 lbs.

This force (Flbs) is then multiplied against a constant that can be added to the forces calculated for the L10 life of the motor. In effect, the additional value to add to the weight of the rotor for P is Flbs*1.333, or for the example above, P = 91.45lbs. If this rotor is 200lbs, then the life reduction can be calculated by comparing the bearing life before and after by adding the additional force for a second calculation and noting the difference.

ROTOR EXAMPLE

The rotor shown in Figure 1 is actually vertically mounted with the result being that the bearings are larger in order to handle high axial thrust versus radial loading. For the purpose of this example, we will calculate the bearing life and impact based upon the rotor being horizontal and the load being primarily radial.

[1] ISO 281-2007, “Rolling Bearings – Dynamic Load Ratings and Rating Life,” 2007

Figure 1: Rotor for Example

The rotor weighs 265 lbs with a motor speed of 3560 RPM. The bearings are each 6316 ZZ bearings with a C dynamic loading of 27,427 lbs. The acceptable G2.5 unbalance, per the ISO 1940-2003[2] is 37 gram-inch and the as-found was 98.3 gram-inch. Upon completion of balancing at Dreisilker Electric Motors, Inc., the final balance was 0.382 gram-inch. For purpose of the calculation, all information was converted to pound-inch (lb-in). The rotor is 8.25 inches in diameter, or 4.185inch radius.

If we assume that conditions are such that an average bearing operates for five years in specific conditions and those conditions are the same when we compare the three different results, we have the following based upon the calculated L10 life.

Table 1: L10 Comparison with Unbalance

Condition	**% of Possible L10 Life**	**L10 Life Based Upon 5 Years**
G2.5 Value	80.02%	4 years
As Found Value	57.16%	2.86 years
After Dreisilker Balancing	99.76%	4.99 years

[2] ISO 1940-2003, "Mechanical Vibration, Balance Quality Requirements for Rotors in a Constant (Rigid) State, Specification and Verification of Balance Tolerances," British Standard.

CONCLUSION

As noted, the potential life for the bearings of an electric machine are significantly improved with precision balancing of the electric motor. With bearing failures making up more than 53% of motor reliability issues, balancing, alone, can improve the overall reliability of your system and, as a result, decrease your maintenance costs.

BIO

Howard W Penrose, Ph.D., CMRP is the Vice President of Engineering and Reliability for Dreisilker Electric Motors, Inc. He also serves as the Webmaster for the Institute of Electrical and Electronics Engineers, Inc.'s Dielectrics and Electrical Insulation Society and is the Outreach Director for the Society for Maintenance and Reliability Professionals. Dr. Penrose can be reached via email at hpenrose@dreisilker.com.