

The Impact on Bearing Life of Overtensioned Belts

by Jeremy Davis and Hunter Golden

One of the leading causes of premature bearing failure can be attributed to overload and overstress conditions. A common catalyst for this type of condition is improper belt tensioning. Increasing the radial load on a bearing will drastically reduce the expected bearing life span and can be graphically illustrated as $y=1/x$ ($0 < x < \infty$). In order to achieve optimal design expectations, procedure based, precision maintenance practices must be utilized.

Test methods and precision tools ought to be employed to allow for quick, accurate and repeatable measurements rather than using inaccurate tools. In some plants, the most common malpractice in belt tension measurement is the use of the “calibrated thumb” technique.

Most maintenance professionals understand that there is a correlation between bearing life and belt tension, but what is that correlation numerically and can it be determined? Will just a few pounds of extra tension really do anything? The answer is yes. Actually, belt tension should be tight enough to prevent slippage on a sheave, but not any tighter. In some instances, a 10% increase in tension (which is a very common mistake) may reduce bearing life by up to 50% depending on the system. The purpose of the Bearing Life Reduction Calculator is to quantify the potential drastic decrease in bearing life as a result of over tensioned belts. Ultimately, by using the Bearing Life Reduction Calculator the positive effects of precision maintenance can be accurately quantified.

Background

The motivation for the development of the formulas to evaluate and illustrate the effects of improper tensioning, stem from a specific problem with an air handling unit (AHU). This particular AHU exhibited several bearing failures since its commissioning, with the first occurrence just six months after installation. After the first incident, the bearings were replaced without any type of failure analysis and the unit was immediately put back into service.

Six months later, the bearings failed again. This second failure initiated a failure investigation in which the cause of bearing failure was determined to be excessive loading in the primary load zone of that bearing. The excessive loading of the bearing was determined to be the result of over tensioning of the belts. While working with the technicians during the installation of new bearings, the reliability group on site stressed the importance of accurate and proper belt tension. The technicians complied and were confident that the belt tension was accurate according to the readings they gathered from their tensiometer pen. Six months later, the bearings failed again due to overloading.

Following the second failure, a new belt tension meter was purchased which measures belt natural frequency as an indication of tension characteristics. Natural frequencies vary based on the stiffness of the belt and can be measured by plucking the belt and reading the frequency response of resulting vibration. The tension meter comes with a tuning fork that

vibrates at a known frequency and the meter can be tested for accuracy by reading the vibration of that tuning fork. Due to the nature of this tension meter, values can be recorded in Hz and may be converted to Lbs using the following formula:

$$\text{Tension (lbs)} = \frac{4 \times \text{Belt Density} \times \text{Belt Span Length}^2 \times \text{Frequency}^2}{}$$

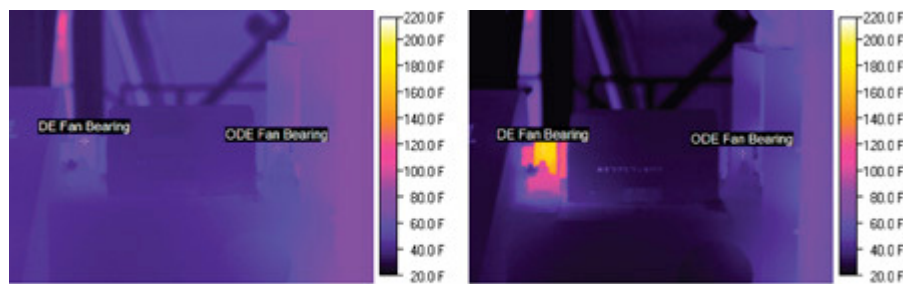
Findings

While using the new tension meter to tension the belt after the third failure, it was difficult to tension all three belts to the same value due to slightly misaligned and worn sheaves. At this point the decision was made to tension all three belts to slightly different degrees and to insure the belts were tensioned just above the slippage point on the sheave. As a result of this concession, some belts had to be slightly over tensioned, but how would slight over tension affect bearing life? The Bearing Life Reduction Calculator was developed to answer this question. The calculator uses the principles of the L10 Bearing Life formula and takes into account belt data, bearing data, bearing load zones, and system data all which can be found through inspection or manufacturer specifications. Currently, the Bearing Life Reduction Calculator yields extremely accurate values for systems where a rotor is center-hung or over-hung (note: for systems where the rotor is over-hung additional inputs are required).

After the belt on this air handling unit was tensioned appropriately with the new belt tension meter, the system has been running without failure for slightly over a year, double the previous runtime. Although the effects of precision maintenance are apparent and successful, the Bearing Life Reduction Calculator uncovered a design problem for this particular AHU. Based on the output of the Bearing Life Reduction Calculator, the optimal bearing life for this system is slightly over one year. After analyzing vibration data points over the period of one year, outer race defects were recently observed in the vibration spectrum of the faulty bearing. The Bearing Life Reduction Calculator predicted accurately, suggesting that there is need to replace the current bearing and use a bearing more suitable for this particular application.

In addition to using the Bearing Life Reduction Calculator to quantify the effects of over tensioned belts, belts were intentionally over tensioned on another unit so the mechanical effects could be measured by thermography. Figure 1 shows two thermography images. The image on the left is taken when the belts are accurately tensioned, and the image on the right when the belt is over tensioned. The image to the right shows the direct mechanical effects on bearings due to over tensioned belts. As the picture indicates, the bearing undergoes more load when belts are tighter which decreases the life of that bearing. The heat increase of the bearing indicates the greater stresses and friction on the bearing purely caused by belt over tensioning. Over tensioning not only causes adverse mechanical effects, but environmental effects as well. By pulling belts too tight, additional amperes are drawn off the motor causing an increase in power needed. In this particular case, amperage increased by roughly 1 ampere due to the over tensioned belts corresponding to a yearly 2000 kWh increase. While this increase seems minimal for an entire year, it is important to recognize that this is just one system. Considering that the entire site has roughly 100 air handling units, site wide savings

in energy costs could be roughly \$20,000 each year, purely by purchasing more accurate tensioning tools and then training the maintenance personnel to use these more accurate tools appropriately.



Figures 1a (left) and 1b (right) - Thermographs showing the direct mechanical effects of over tensioned belts.

Initially, the motivation to provide site wide training in accurate belt tensioning was to increase asset health and minimize downtime of air handling units due to overloaded bearing failures. Although the energy impact does not seem significant, it does add up over time. Not only are emissions lowered but energy costs are reduced as well. For a very simple method of tensioning belts accurately, savings in energy alone will more than pay for the tools and training; however, savings in healthier equipment and downtime reduction will be the most significant.

Recommended Solution

Based on the findings of the experiment with this air handling unit, the recommendation is to purchase an appropriate tension meter that yields accurate results. Using a precision tension meter, with established procedures and acceptable parameters, will ensure that qualified technicians will be able to perform these tasks consistently and effectively. The single most important thing about a precision belt tension meter is that the results must be repeatable. In many cases, different technicians may record different values of belt tension using the exact same tool; however, by using a tension meter that measures the natural vibration frequency of a belt, different technicians will record the same value of tension. After purchasing the appropriate tools, technicians must be trained to not only use the tools, but also be trained on the drastic effects that over tensioned belts have on bearing life. Quantifying the reduction of bearing life due to over tensioning allows technicians to see visually and numerically how important it is to tension belts properly.

Results of the Bearing Life Reduction Calculator:

Inputting all of the required values of the Bearing Life Reduction Calculator will generate the following outputs:

- Expected bearing life with optimal belt tension
- Expected bearing life with a specified value of belt over tension
- Percent of bearing life reduction due to over tensioned belts

Additionally, these plots are produced in the Bearing Life Reduction Calculator:

- Bearing life in days with the corresponding value of over tension (Figure 2)
- Percent life reduction with corresponding value of over tension (Figure 3)
- Chart of the bearing load zones (figure 4)

Figure 2

Figure 2 illustrates the estimated potential effect on bearing life due to over tensioning. A graphical representation is depicted in Hz as well as Lbs so that a correlation can be observed regardless of the measurement method used. As discussed earlier, the shape of this plot resembles the shape of the plot of $y=1/x$. The purpose of this plot is to show the adverse affects that over tensioning has on bearing life and is to be used as a reference sheet for technicians in the field. By having a visual image of the damage that may be caused by over tensioning, technicians will be careful during the tensioning process and be less inclined to use the badly practiced “calibrated thumb” technique to measure belt tension.

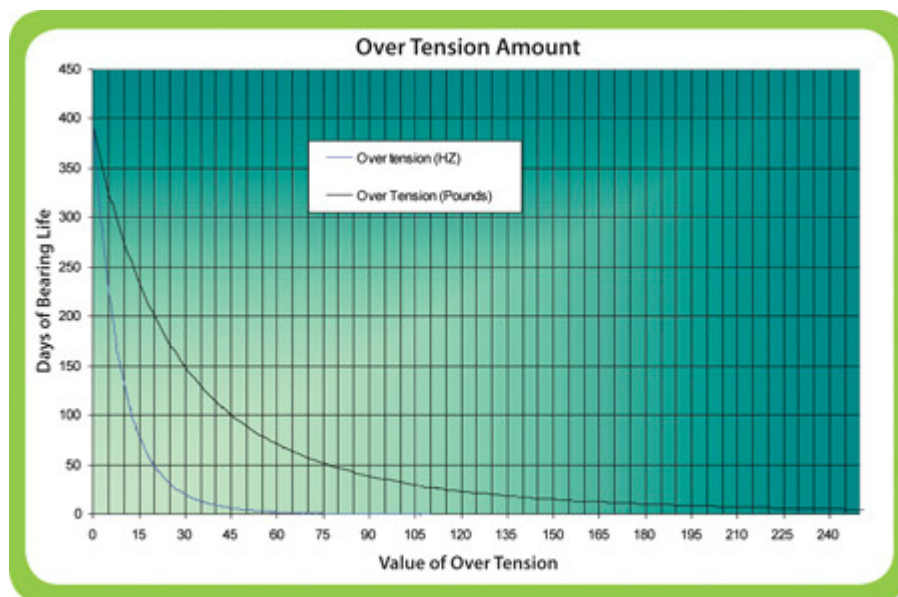


Figure 2 - Effect of Over Tension Amount on Bearing Life

Figure 3

The two lines depicted in figure 3 represent the over tension value in Hz and Lbs as compared to percent estimated bearing life reduction. As with the previous plot, this graph can also be used as a tool in the field to illustrate the importance of precision maintenance practices. This plot is logarithmic in nature and it approaches its horizontal asymptote of 100% fairly quickly in this particular system.

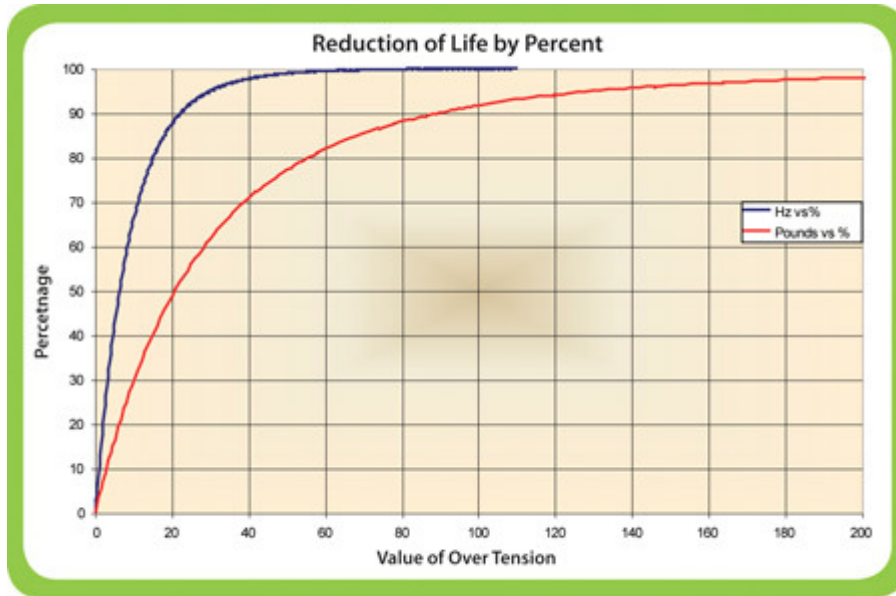


Figure 3 - Over Tension Effects on Bearing Life in Percentage

Figure 4

Figure 4 on the following page depicts the three different load zones on the bearing. The vertical black line indicates the vector direction of the load zone due to the weight of the rotor. The blue line indicates the vector direction of the load zone due to the force of the tension of the belt. The red line indicates the vector direction of the sum of the rotor load and belt load vectors when the belt is tensioned to its optimal amount. The bearing will see the most load in the direction indicated by the red line when a belt is tensioned to its optimal amount. The green line indicates the new direction of the combined vector load when a belt is over tensioned. In this case, the overloaded bearing sees the most load in the direction indicated by the green line. Figure 5 is included to assist in visualization of the vectors referenced in Figure 4.

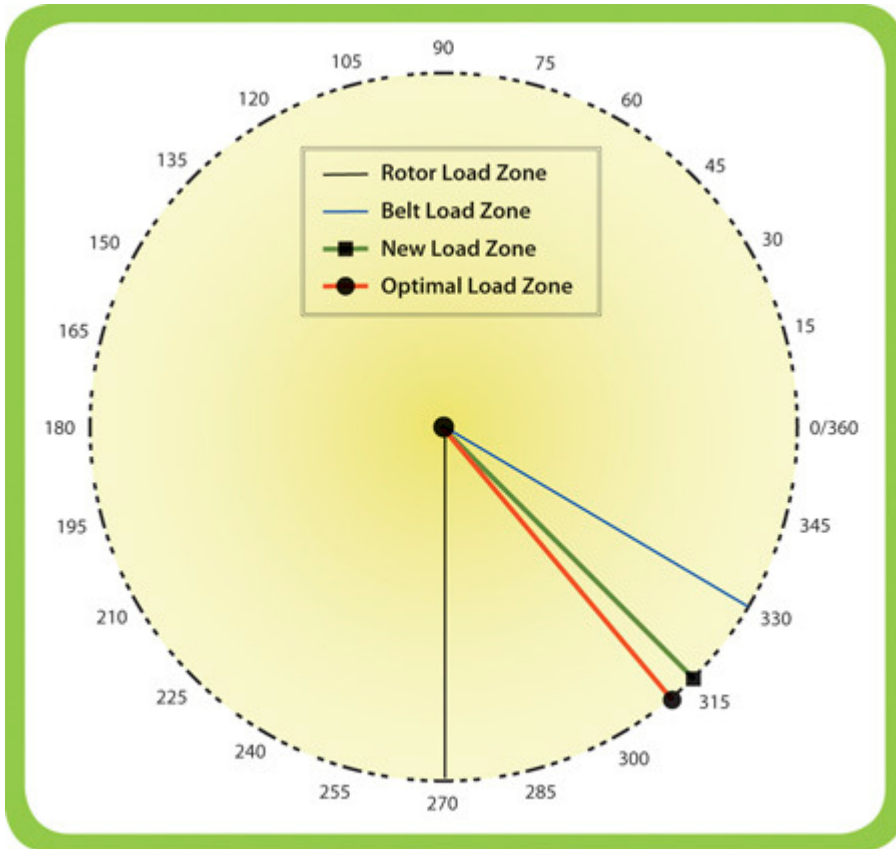


Figure 4 - Three Load Zones on Bearing

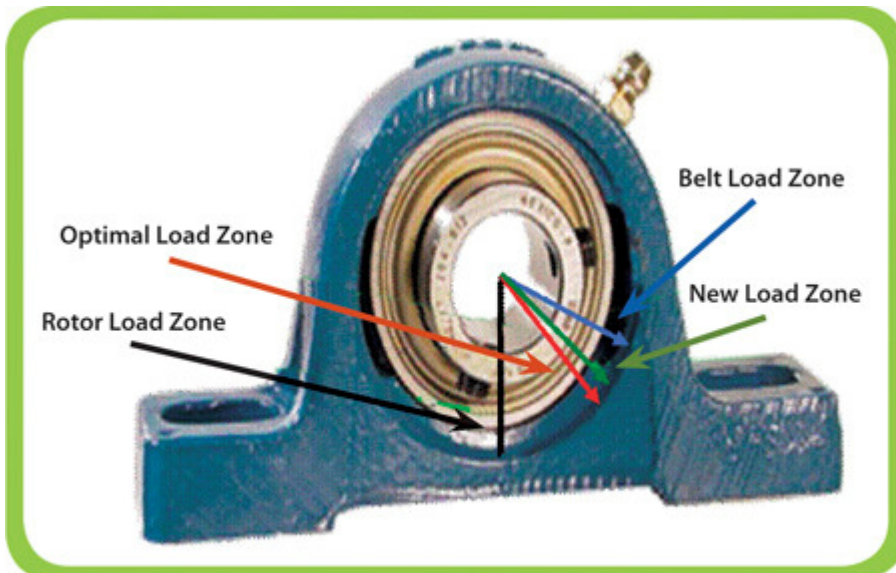


Figure 5 - Visual Representation of Bearing Load Zones

Going Forward

The Bearing Life Reduction Calculator has successfully quantified the importance of accurate belt tension, but it has also significantly improved awareness regarding precision maintenance on site, specifically for power transmission drives. By combining the successes

with the aforementioned air handling unit and the Bearing Life Reduction Calculator, precision maintenance techniques are proliferating and culture is shifting to focus on the I-P interval of the I-P-F curve (see Figure 6). Precision maintenance practices regarding belt tensioning have been introduced to all of the maintenance teams and the technicians are eager to begin using the new tools to help reduce bearing failures caused by overloading. Precision maintenance is the best strategy to use to increase site reliability because it increases the time from installation to a potential failure as demonstrated in the I-P-F curve. By increasing the I-P time interval, site reliability will increase and production will be able to function with less failures and downtime.

Additionally, the increased awareness about precision maintenance due to the Bearing Life Reduction Calculator has reached upper level management. Based on the adverse effects of improperly tensioned belts, management suggested training of all maintenance technicians in precision maintenance techniques involving power transmission drives. Precision maintenance technique training for maintenance personnel in power transmission drives will not only increase bearing life, but system life will increase as well. By expanding the knowledge and experience of those who work on the equipment, asset health will improve, and, ultimately, the bottom line will increase.

Figure 6

The I-P-F curve represented in Figure 6 shows asset health as time progresses. Implementation of precision maintenance techniques at the time of installation will lead to prolonged equipment life and possibly reduce the risk of failure entirely. In order to effectively succeed in extending equipment life, precision maintenance techniques must be used in multiple areas. Belts must be tensioned properly and thoroughly inspected and sheaves must be accurately inspected and aligned at installation. Practicing these precision maintenance techniques will greatly increase the I-P interval, effectively expanding equipment life for the least cost to the company.

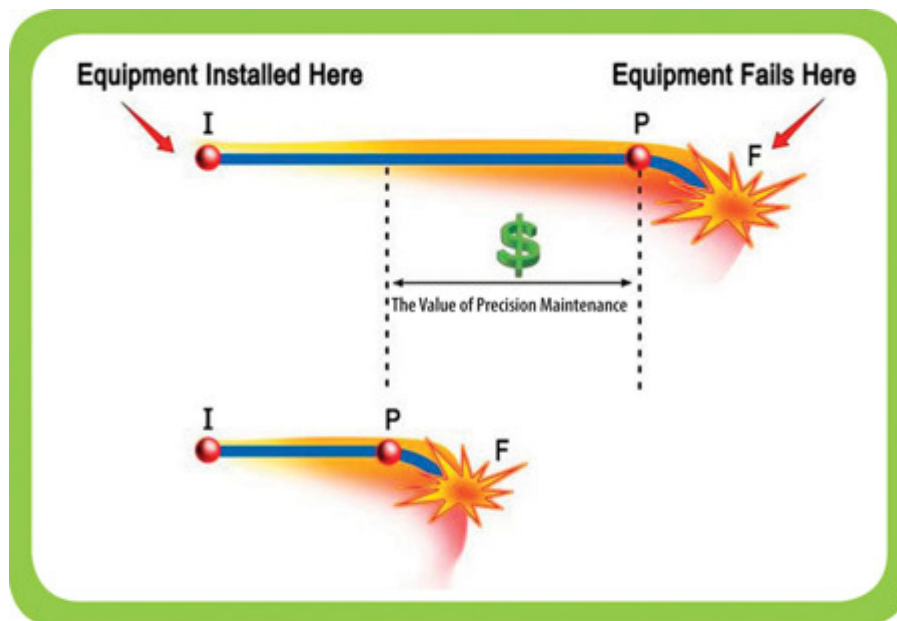


Figure 6 - The I-F-P Curve illustrating the value of Precision Maintenance.

Summary

As stated previously, one of the most common causes associated with premature bearing failure is excessive loading caused by belt over tension. Using the Bearing Life Reduction Calculator to quantify the effects of over tensioned belts will help illustrate the importance of precision maintenance practices and their effects on Asset Health. Not only will technicians perform better in the field by using the appropriate tools and procedures, but equipment reliability will be improved by implementing simple tasks centered on precision maintenance practices. As inconsequential as belt tension may seem, over tensioned belts have drastic negative effects on an entire system and even contribute to environmental harm. Using precision maintenance techniques on belts and other aspects of power transmission drives will greatly increase reliability at any manufacturing plant.

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