Spherical Roller Bearings and Overhung Fans.

A case history in condition monitoring, root cause analysis, and design.

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Background

BlueScope Steel's Western Port Works is a steel processing facility that converts steel slabs into metal coated and painted strip.

Centrifugal fans are a common element in each stage of the processing, and many of these are of the overhung type. Our overhung fans were typically supported by spherical roller bearings mounted in plummer blocks.

These fans have given us many problems over the years, with the 2 Hot Strip Mill Combustion Blowers receiving much attention. This is due to the fact that these blowers had many failures, but also because they are at the beginning of the first process and therefore can have an impact on the rest of the plant.

These fans are driven by 600kW, 6.6kV motors that are direct coupled to the fan shaft.

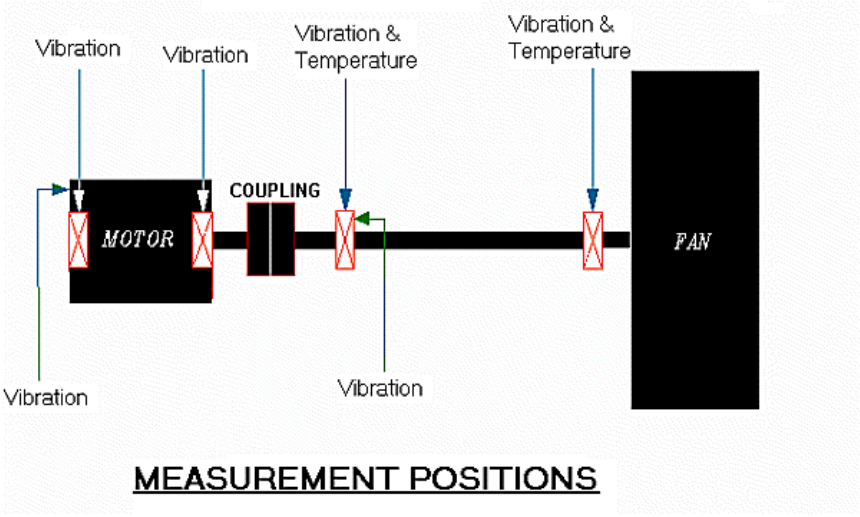
On average we would experience a bearing failure every 2 years. This would impact our Uptime through the initial process stoppage (4 hrs) and subsequent slow running (48 hrs).

In order to try and prevent theses failures we were conducting vibration monitoring on a 28 day cycle. This did not prevent the failures, so we halved our monitoring period to 14 days. And yet we still found ourselves looking at the smoking ruins of bearings, so we were unable to determine the root cause. Despite the fact that the root cause was unknown, we went ahead and installed a "better" bearing anyway. This did not help.

We asked our bearing supplier at that time to have their engineering department do the calculations and comment on the suitability of the bearings and their arrangement. They gave it all a green light. Yet the failures continued. It got to the point where we had a failure only 2 days after noticing a very small change in the vibration.

It became clear to us that in order to get to the bottom of the problem, we would need to retrieve one of these bearings with a defect in it before it failed catastrophically.

Our solution was to install an online vibration monitoring system. Our approach was to measure radial vibration at each bearing, and axial vibration on each shaft. We also measured temperature at each of the fan bearings as a safety net. We didn't want another flaming wreck.



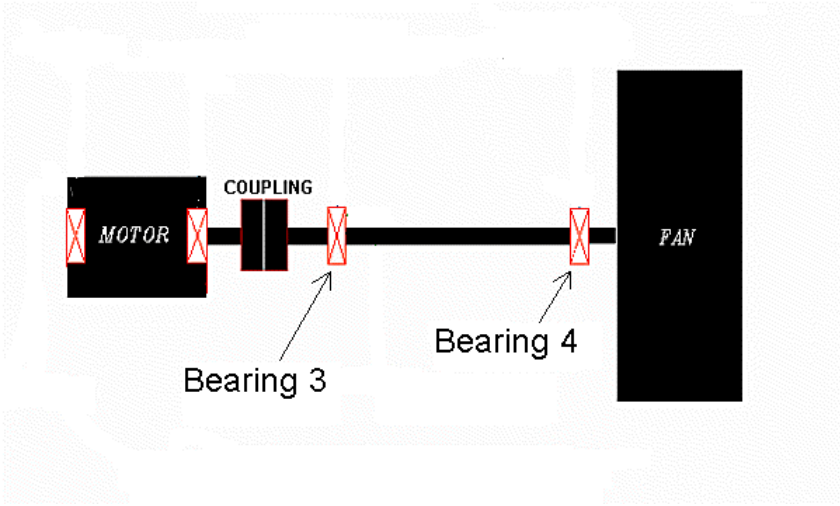
MEASUREMENT POSITIONS

In due course the monitoring system detected deterioration in the condition of one of the bearings. Deterioration was evident from an increase in the amplitude of the acceleration and demodulation parameters. This bearing was removed before it failed and the root cause investigation finally made some headway.

Examination of the bearing showed that only one row of rolling elements was taking any load. There were also signs of deterioration in the cage.
With the help of our new bearing supplier we came to understand why we were seeing these symptoms, what the root cause of the problem was, and how to fix it. The bottom line is that spherical roller bearings in plummer blocks are not a good solution for overhung fans.

Explanation

Before we get to the explanation of why this is so, ask yourself whether the fixed bearing in the diagram opposite should be bearing number 3 or bearing number 4.



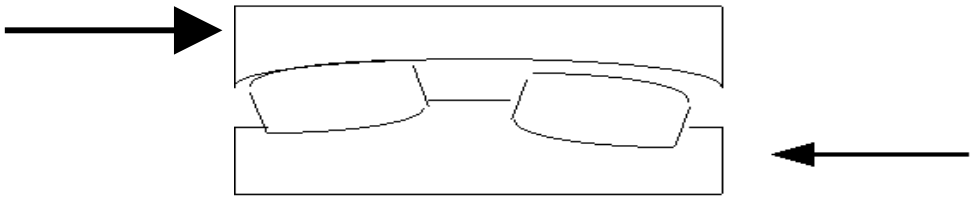
Make up your mind before you continue reading.

For spherical roller bearings to achieve their design life, they must have a radial load that is several times the axial load. Consult your manufacturers catalogue for the actual value for each bearing, but typically the maximum ratio of radial to axial load is around 3:1.

The problem is that overhung fans generate a relatively high axial load, because of the pressure drop across the impeller, while having a relatively low radial load.

Calculations showed that these 2 fans (and subsequently many others across our plant) were not meeting this radial to axial load ratio requirement. Note that this requirement only applies to the fixed bearing, as the floating bearing will not be taking axial load.

When this ratio is not met, the axial load displaces the inner race relative to the outer race, as shown below.



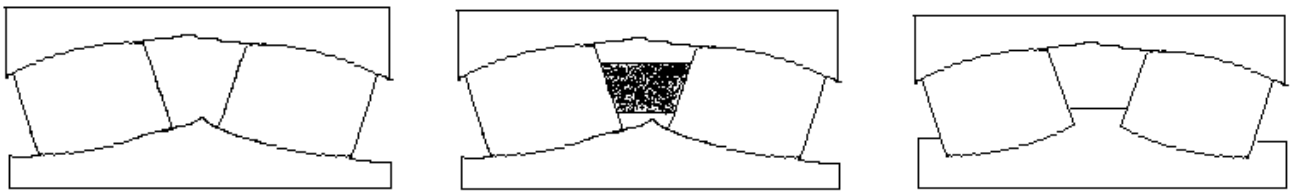
When this happens, the row of rolling elements at the drive end of the fixed bearing loses contact with the outer race. This deprives these rolling elements of the guidance normally afforded by the outer race. These rolling elements are then free to move around in their cage pockets, causing wear and ultimate failure of the cage. The end result is a flaming wreck.

The severity of the problem depends upon the actual value of the axial to radial load ratio, as well as the internal configuration of the bearing.

There are a number of different internal configurations available. My experience is that while none of them provide a real solution, the configuration shown on the left is the least satisfactory, while the one on the right is the most satisfactory.

<u>Solutions</u>

1. Choose a bearing with an internal configuration that provides good roller guidance.



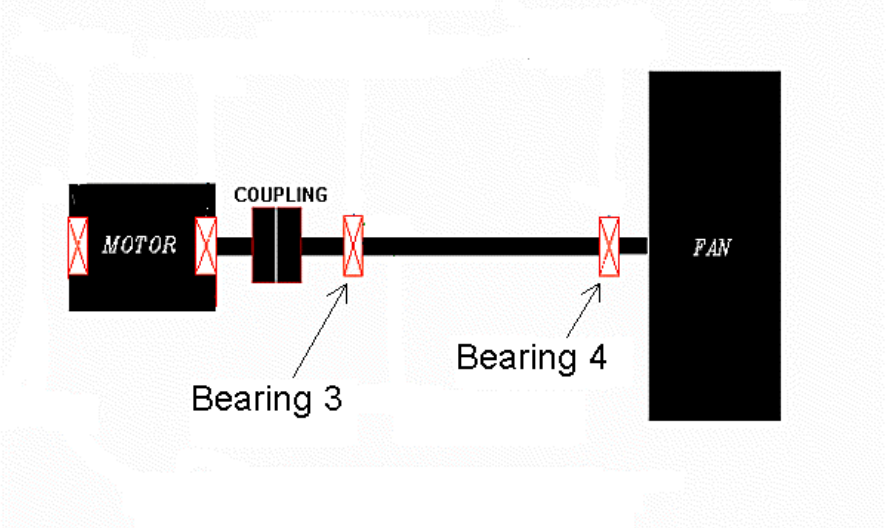
2. Lock the bearing with the highest radial load.

We often lock the wrong bearing because of misguided attempts to share the radial and axial loads, thinking that this is good for the bearing life. But as your bearing catalogue shows, spherical roller bearings do not like predominantly axial loads.

Another reason we sometimes lock the wrong bearing is because of misguided concerns about axial expansion of the shaft. Axial expansion of the shaft is inconsequential here.

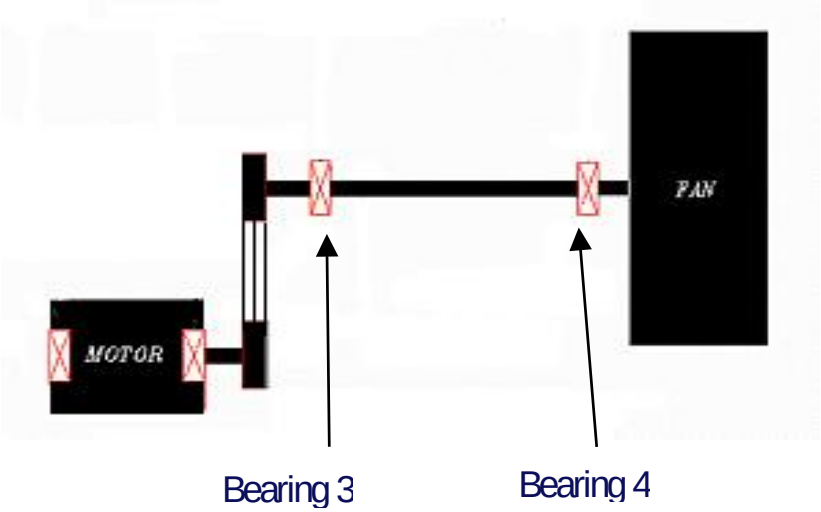
So which bearing should be the fixed bearing for a direct coupled arrangement?

The answer is Bearing 4, as it will have the highest radial load.



And which bearing should be the fixed bearing in the belt drive configuration shown?

The answer is bearing 3, as it will have the highest radial load.

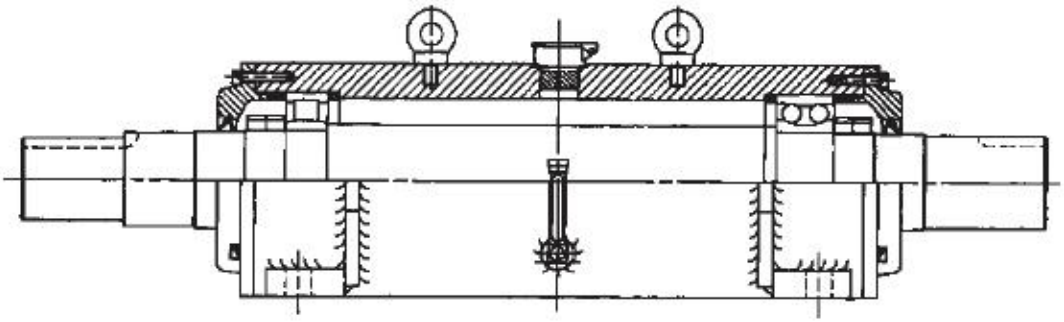


Now, if you can't achieve the correct radial to axial load ratio

OR

if you are still having failures,

then the answer is to install a single line bored housing with 2 non self aligning bearings.
The SKF catalogue even says that these housings were developed for overhung fan applications.



This arrangement may have an angular contact bearing and a cylindrical roller bearing as shown, or, as in our case study, an angular contact bearing and a ball bearing.

In addition to solving the fundamental design issue, this arrangement has the advantage that the housing is very easily sealed to facilitate oil lubrication and oil condition monitoring.

The disadvantages are that this is a more expensive arrangement, and it takes more effort to replace the bearings. However, these are more than offset by the fact that downtime costs will be eliminated and you won't have to replace the bearings!

The other important thing to remember here is that, like everything else, you have to install the housing properly. You must ensure that there is no soft foot when the housing is installed otherwise the bearings will be stressed and rapid failure will result.

Results

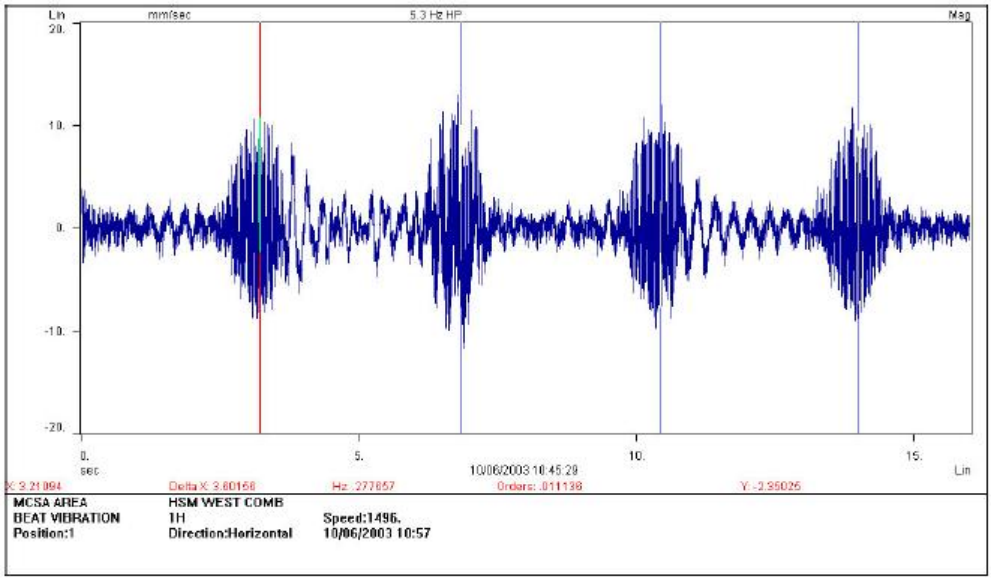
There have been no bearing failures since the new housing arrangement was installed over 7 years ago. Provided we look after the lubrication, we expect that these bearings will run for many years yet.

We have experienced the same level of improvement on a number of other fans around the site.

This particular fan was failing bearings every 3 months, on average. It has had only 1 failure since the new arrangement was installed many years ago, and this failure was as a result of a seal problem.

An added bonus from the installation of the permanent monitoring system was that it also detected deterioration in the rotor condition on both blowers at different times in later years.

The initial symptom in both cases was a step change in the overall vibration that fluctuated in amplitude. The symptoms on the east blower were unusual in that the vibration was in the axial direction rather than the more typical radial direction. Investigations showed that the vibration was being modulated at the Pole Pass Frequency. This indicated a rotor problem.



Motor Current

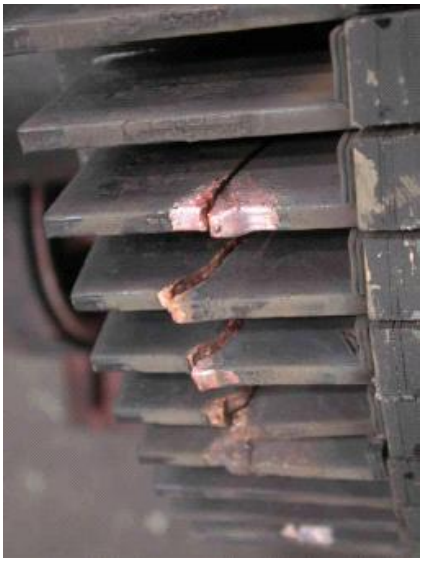
Signature Analysis on the East blower showed no indication of a fault.

However, we knew that the blower was lightly loaded and that this would affect the analysis. So we went ahead with plans to replace the motor. Once we had identified rotor problems, we issued instructions that the blower was not to be turned off, as the rotor was unlikely to withstand the forces it would be subjected to during restarting.

These actions also gave us time to procure the new motor from South America, and to install a monorail to facilitate the motor change. The damaged motor was then replaced during a scheduled down period. The old motor was found to have cracks in 70 of 74 rotor bars.

Motor Current Signature Analysis on the West blower showed an amplitude difference between the 50 Hz peak and the first lower pole pass frequency sideband of 41dB.

This suggested that we were likely to have 2 broken rotor bars or problems with high resistance joints. However, because of the low current level and our experience with the East blower, we felt it likely that the problem would be significantly worse. And so it proved to be. 10 bars were broken and all of the remainder were cracked.



Close

The installation of a permanent vibration monitoring system not only solved a chronic reliability problem, it also had some unexpected flow on benefits. We learned a lot about bearings and overhung fans, and were able to apply these learnings to solve other fan reliability issues around the site. We also had a couple of major wins where we prevented the catastrophic failure of two 600kw motors. Lead time for the supply of new motors is approximately 15 weeks.

Savings to date from avoiding bearing and rotor failures amounts to several million dollars.