The Hidden Cost of Incomplete Hydrodynamic Bearing Maintenance

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Introduction

Reliability and maintenance engineers can improve uptime and save money on both long-term maintenance and downtime costs by properly diagnosing and correcting bearing vibration issues when they exceed their acceptable limits. This requires inspecting the housing as well as the liner for wear, and replacing them as a pair when the housing is worn, so that wear-in between the mating surfaces can occur. Without proper contact between the housing and liner, fretting damage will drastically reduce the life expectancy of the liner. Although the upfront cost is greater, the investment required for complete pillow block replacement versus the cost of replacing the liner alone, which is the most common maintenance practice, should be compared in order to expose the hidden cost of incomplete hydrodynamic bearing maintenance.

Vibration

Any industrial fan in operation has inherent vibrations that manifest themselves at the bearings. These vibrations and their amplitudes are indicative of the health of the fan assembly, and can indicate when servicing is required based upon the many standards that have been published concerning acceptable levels of vibration. Therefore, vibration monitoring is essential for proper operation and adequate understanding of the fan performance; however, even with all the vibration monitoring in place, there is still ambiguity as to the cause of the vibrations.

Before an entire fan refurbishing is planned, it is a common maintenance practice to service the unit and its components to optimize the fan performance and to complete corrective actions for the issues that have developed. Unfortunately, during the stress and time-sensitive nature of outages, planned or unplanned, the predominant corrective action of hydrodynamic bearing maintenance when vibration levels have exceeded their limits is to replace the liner (insert) of the bearing, and to leave the housing untouched and uninspected (Fig. 1).

The liner is frequently misdiagnosed as the sole contributor of fan bearing problems, as it is the component that not only supports the shaft but also requires replacement once the clearance within the liner increases beyond an acceptable limit, which can cause excessive vibration. However, this is an incomplete framework of the source of bearing problems. The amount of contact between the spherical seats of the housing and liner is an often overlooked source of bearing problems. When the contact between these two components is significantly worn, the result will be excessive vibration that can easily be misdiagnosed as excessive clearance in the liner (liner failure). However, replacing the liner will not fix this problem. It may provide a vibration reduction for a very short period of time, but the fan vibration will continue to reoccur, often more aggressively than before, since the other sources of vibration remain unchecked and uncorrected. The consequence of leaving unchecked vibrations in the system is the acceleration of fretting damage that will continue to occur to both the housing and liner, even after a new liner is replaced into the original housing.

Fretting Damage

When two properly machined surfaces in contact and are loaded against each other, there will be a period of run-in wear that occurs until they are suitably conformed to each other, similar to purchasing a new pair of shoes and letting them break-in for a few weeks before they fit most comfortably. However, over time, as proven with shoes, permanent wear damage occurs on the loaded and contacting surfaces, in a process of material removal. As the wear progresses, small amplitude oscillatory movements will begin to occur between the mating surfaces, which is the process of fretting, and is the result of external vibrations in the system (Waterhouse, 1992). Normally, this is a very slow process to develop in a new pillow block (liner and housing pair) since the components wear in together. However, when a new liner is placed into an older housing that has had years of deformation and material removal from operating in conjunction with the previous liner, there is no opportunity for the two surfaces to wear in together. Since the older housing surface cannot conform to the newly machined liner surface, the process of fretting will begin immediately and rapidly progress in severity on both the liner and housing; the only solution that will solve this problem is to replace the entire pillow

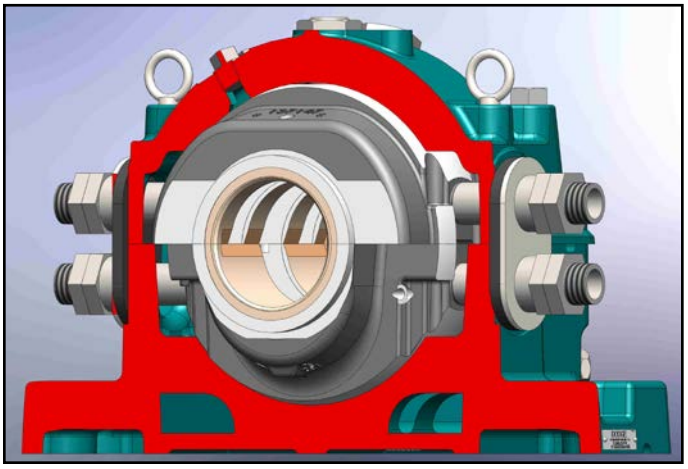

Figure 1 Cutaway view of a pillow block assembly showing the liner, which is commonly serviced, and the housing, which is commonly neglected of service. (Courtesy of Dodge)

Figure 2 A new liner installed into an old housing failed after ~1 to 1½ years of operation and caused an unexpected fan shutdown due to high vibration levels. The deep pitting and fretting corrosion caused by improper seating of the liner in the housing can be clearly seen.

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block and allow the mating surfaces to wear in together as designed.

Performing bearing liner maintenance but neglecting the housing damage from wear and fretting corrosion could consign a new bearing liner to ~1–2 years of life before high vibration issues develop and potentially cause fan shutdown times, which is ~1/10th of the intended life of the liner with proper maintenance and servicing. In an actual example from the field (Fig. 2), a distributor reported: "The customer replaced the liner assembly with a new one approximately 1 to 1½ years ago because of high fan vibration. The fan is again out of service for high vibration". However, this customer is not unique in this situation of replacing a new liner into an old housing as a standard maintenance procedure and achieving sub-satisfactory results that do not prolong equipment life or reduce unscheduled downtimes due to high vibration levels.

To further demonstrate the common occurrence of this problem, additional pictures from customers across the United States have been included that show the distinguishing marks of fretting corrosion (irregular dark-colored patterns and cavities) along both the liner sphere and spherical seats of the housing (Fig. 3-4).

The purpose of addressing this issue is to dispel the notion that liner repair or replacement is the single most important corrective action in hydrodynamic bearing maintenance when vibration levels are too high. Instead, the entire bearing pillow block assembly should be perceived as a unit of interdependent components that, for proper operation and life expectancy, must cohesively work together. When one of the components is significantly worn out, the entire pillow block should be replaced to alleviate the impending fretting that will occur from a liner that is improperly retained in the housing. However, the issue then becomes a matter of "unjustifiable cost", which is a more grievous misconception than the original problem of resolving fan vibration issues with liner replacement alone.

Figure 3 Three separate liners that have failed due to high fan vibration levels and show the fretting corrosion marks along their spherical seats.

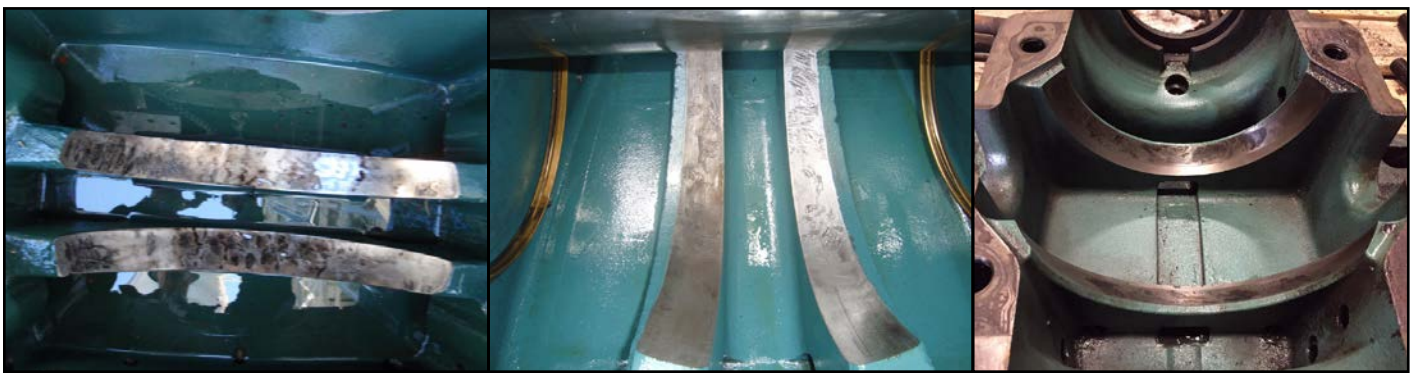

Figure 4 Three separate housings that have been pulled from service due to high fan vibration levels and exhibit the characteristic fretting marks caused by improper contact and retention of the liner within the housing.

Cost of Replacement vs. Expected Life

Durability is one of the many advantages of hydrodynamic bearings. Due to hydrodynamic lubrication, the only wear that should occur between the shaft and the liner takes place at start-up and shutdown. With proper oil care and maintenance, hydrodynamic bearings can theoretically run forever. It's for this reason, among many others, that end users and OEMs will make the financial investment for a hydrodynamic bearing rather than a spherical roller bearing. However, because of the rugged construction and many advantages of hydrodynamic bearings, it is well known that they are not inexpensive. That is why the financial case must be considered for proper bearing servicing versus low-cost servicing1 as it pertains to the life of the fan assembly.

In a pillow block assembly from a general manufacturer, the cost of the liner comprises approximately 72% of the entire cost of the pillow block. In a fictitious scenario2 where two customers (Customer A, Customer B) install a new fan with new hydrodynamic bearings that cost $10k at the same time, the cost comparison of two maintenance strategies over a twenty year period clearly demonstrates the value of proper maintenance and servicing (Table 1).

Although this scenario is fictitious, the general financial and life expectancy patterns it showcases is consistent with real applications, and the difference between the two methods becomes exceedingly more drastic as time continues, especially when downtime losses are considered. The reality is that the short-term financial investment required to replace the pillow block at the time of bearing servicing is more than compensated for by the longevity of the bearing. When considered from the perspective of the life of the fan, it is the frequency of servicing and the associated downtime costs that are significantly more expensive than the less frequent pillow block replacement costs. Therefore, the best financial investment that a customer can make is to take advantage of the life the bearings were designed for and save the money that would be spent on more frequent maintenance and liner replacement.

Conclusion

Improving uptime, reducing the frequency of required maintenance, and saving money are the target objectives of nearly every maintenance and reliability engineer. These targets can be most effectively accomplished by investing in the bearing equipment as designed by the manufacturer. Shortcutting proper housing maintenance will save marginal dollars at the time of servicing and cost exceedingly more in future repairs. The best method to properly keep hydrodynamic bearings running for the long durations that they're designed for is to consider the liner and housing as an interdependent pair. The ability of the housing and liner to wear-in together is critical to eliminating the fretting corrosion that will otherwise develop and gradually promote fan vibrations that are sure to exceed the limits. **PTE**

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Table 1 Fictitious 20-year financial comparison of two maintenance strategies

	Customer A				Customer B			
	Maintenance Course: Replace liner when fan vibration exceeds limits				**Maintenance Course:** Replace housing and liner pair when fan vibration exceeds limits			
	New Fan Installation - New Bearings				**New Fan Installation - New Bearings**			
	Housing Age	**Maintenance**	**Cost**	**Total investment**	**Housing Age**	**Maintenance**	**Cost**	**Total investment**
	0 years	None	$0	0	0 years	None	$0	0
	10 years of service				**10 years of service**			
	10 years	Replace Liner	$7,200	$7,200	10 years	Replace Pillow Block	$10,000	$10,000
Hidden Cost of Partial Bearing Replacment	**5 years of service**							
	15 years	Replace Liner	$7,200	$14,400				
	3 years of service							
	18 years	Replace Liner	$7,200	$21,600				
	2 years of service				**10 years of service**			
	20 years	Replace Pillow Block	$10,000	**$31,600**	10 years	Replace Pillow Block	$10,000	**$20,000**