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Externally Pressurized Bearing (EPB) — The Bearing of the 21st Century

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Throughout my career, I've tried to ensure that the solutions that we offer to our customers clearly exceed expectations. A large part of our future success will be based on our ability to not only meet customer expectations, but to exceed them.

When we state that the Bently **Externally Pressurized Bearing (EPB)** is **THE** bearing of the 21st Century and the most important development in bearing technology in the last 100 years, I'm well aware that such a statement is a paradigm shift in technology. This paradigm shift requires innovation on our part with regard to how we bring the EPB to the marketplace. We all are working to a new "high bar" of expectation and performance.

However, as I observe the results to date, both in terms of internal research as well as external customer commitment, I am convinced that the EPB will revolutionize the way machinery in managed.

What is EPB technology? Simply stated, it is a fully lubricated, "high" pressure fluid (gas or liquid) bearing. It exhibits all of the positive attributes of hydrostatic, hydronamic, rolling element, and magnetic bearings without any of the adverse drawbacks of those technologies.

The features and advantages of the EPB are numerous and we'll review them later on in this article. However, in order to fully appreciate the EPB, a brief review of other bearing technologies is appropriate. A detailed discussion of the EPB can also be found in my book, *Fundamentals of Rotating Machinery Diagnostics*.

FLUID FILM BEARINGS

Fluid film bearings have historically been the choice of machinery designers for high-speed turbomachinery. In particular, this has been true where large load carrying capacity is required. An early problem with such bearings, however, was fluid induced instabilities originating from the circumferential flow of the lubricant in the bearing. Fluid induced instabilities were observed as both rigid body (whirl) and flexible (whip) modes. Early observations of fluid induced instabilities date back to the early 1920's when machinery designers were "pushing the envelope" in terms of machinery operating speed.

Early research published by Harrison in 1919 [11] was inappropriately interpreted by the rotordynamic community of the day. Those interpretations concluded that pressurization and full 360º lubrication would lead to instability within the bearings. While the combination of full lubrication and *inadequate* pressurization can exacerbate fluid induced instability (as is the case with a traditional *hydronamic* fluid film bearing where the dynamics of the shaft rotating inside of the bearing provide for internal (inadequate) pressurization of the bearing), this is not true for the EPB which operates with full 360º lubrication at *high* pressure.

Those mis-interpretations of Harrison's work gave rise to "conventional wisdom" of the day that suggested that bearings should never be fully lubricated or supplied with a lubricant at a pressure in excess of approximately 25 psig.

This thought process effectively stopped researchers from experimenting with the application of higher pressure bearings and full lubrication on turbomachinery applications. This belief has, unfortunately, been accepted as reality around the world with very few exceptions. The result is that in today’s world, virtually every fluid film bearing in a turbomachinery application uses partial lubrication at low supply pressures.

Previous and on-going research at Bently Pressurized Bearing Company has led us to a conclusion that is exactly opposite to the “conventional wisdom” regarding fluid film bearings. By properly pressurizing a fully lubricated bearing, (EPB), the bearing will exhibit characteristics that are far superior to traditional fluid film bearing designs which employ partial lubrication and low pressurization.

The EPB’s characteristics can be adjusted in the field to optimize performance. The EPB has far superior stiffness and damping properties as compared to a traditional fluid film (hydronamic) bearing. External pressurization of the EPB promotes axial flow of the fluid along the longitudinal axis of the bearing, thus reducing the circumferential flow of the fluid in the bearing and increasing the stability margin. Unlike the traditional fluid film bearing whose stiffness and damping properties are directly related to how close the shaft operates in relationship to the bearing wall (eccentricity ratio), the EPB can operate at essentially zero eccentricity ratio and a low attitude angle and still exhibit high stiffness and damping properties.

The “conventional wisdom” of the last century which dictated the use of partial lubrication and minimized pressurization did not eliminate the problem of fluid induced instabilities. Bearing instabilities continued to be a significant problem for machine designers and users. Partial lubrication and low pressurization are merely attempts to keep the lubricant from being “dragged” into motion around the circumference of the shaft – thus limiting the circumferential flow of the fluid. Because partial lubrication at low pressurization did not always work, other technologies evolved. Hence the rise of geometry modifications to the simple hydronamic bearing including “pressure dams”, “lobed bearings”, “elliptical bearings”, “off set halves bearings”, and “tilt pad bearings”. All of these designs had one thing in common – to alter the lubricant’s (fluid’s) circumferential flow path in an attempt to prevent fluid induced instabilities (whirl and whip) from occurring.

What the designer (and end users) soon realized was that none of these geometries would eliminate the problem entirely. Furthermore, the use of mechanical “obstacles” to disrupt the fluid flow path led to greater fluid drag and subsequent frictional and mechanical losses in the bearings themselves.

Today, fluid induced instabilities are far from being “solved”. Figure 1 is a histogram of machinery malfunctions as identified from our over 40 years of studying machinery behavior. You will note that, historically, fluid induced instabilities rank 5th overall at 6.4% of the problems encountered in the field.

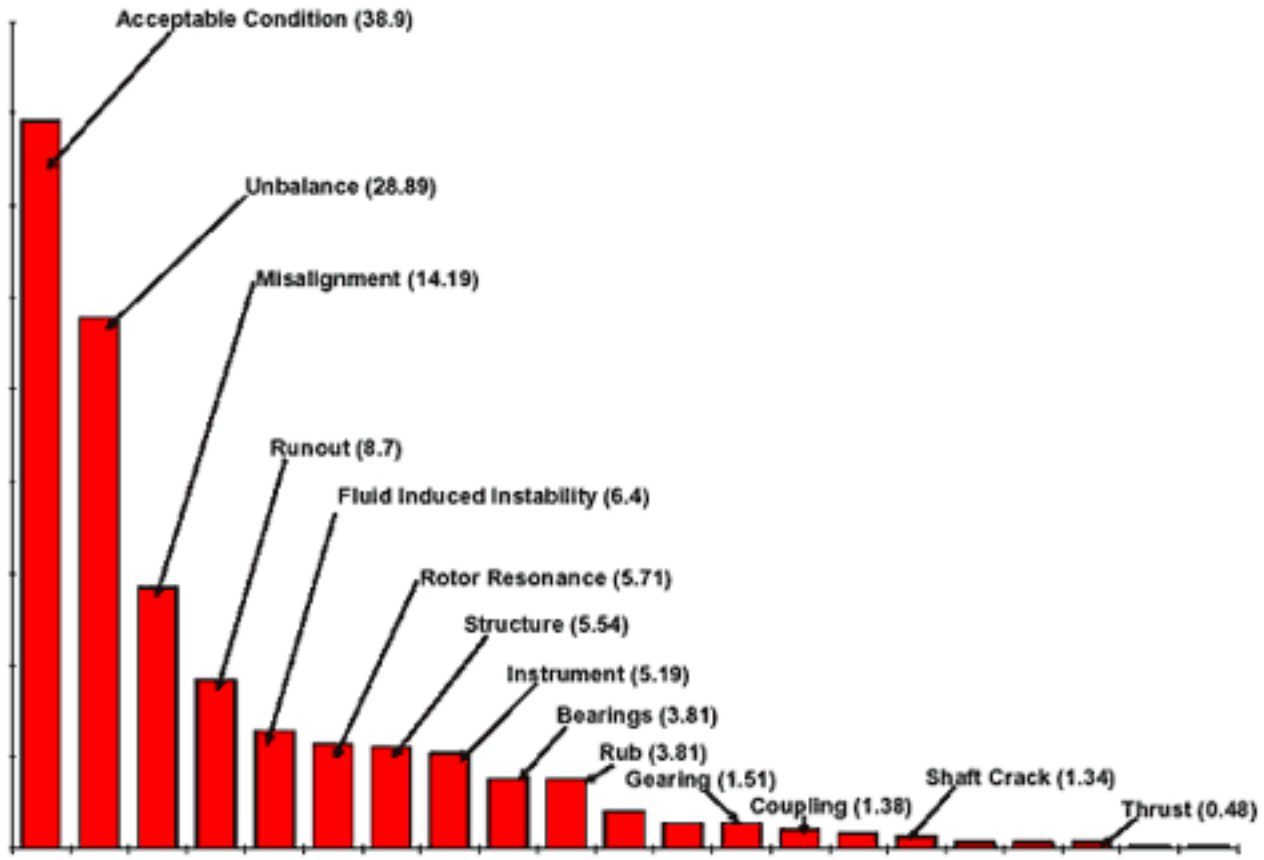

Figure 1

As an aside, I've often heard people state that "Fluid induced instabilities are impossible in our machines because we have tilt pad bearings". Actually, fluid induced instabilities are not impossible in tilt pad bearings. We have observed fluid induced instabilities in tilt pad bearings in the field on many occasions. One must remember that these bearings will encompass a close toleranced, "oil control ring" on each end of the bearing housing itself. Although short in axial length, these oil control rings can themselves act as small, simple, hydronamic bearings where a rotating cylinder (shaft) is rotating inside of a stationary cylinder (oil control rings). The circumferential flow of lubricant around the oil control rings can give rise to fluid induced instabilities.

LUBRICANT CONSIDERATIONS

Almost, without exception, the typical hydronamic bearing employed in most turbomachinery today uses some form of petroleum based lubricating oil. The EPB can certainly operate with conventional lubricants; however, it can also operate with other incompressible fluids (water for example) as well as a variety of compressible fluids and gasses (air or any process gas). Consequently, numerous possibilities present themselves to choose a fluid not based solely on its lubricating properties but also for its compatibility with the process and surrounding environment.

As we have presented the EPB to our customers, a frequently asked question has been "What pressure ranges can we accommodate?". Often the customer wants to know what we mean by "high pressure". To date, we have found that most machines can be addressed with EPB technology using pressure ranges less than 1000 psig. Our primary concern with extremely high internal bearing pressures is that the fluid velocities through the bearing orifices could potentially become large enough to begin to cut or erode the shaft or bearing. Therefore, our design methodology has been very conservative in this area.

Another advantage of the EPB design is that its fully lubricated design reduces foaming. Unlike partially lubricated bearings, it is more difficult for air to become entrained in the lubricant and create foaming.

ROTORDYNAMIC MACHINERY MANAGEMENT

Until now, the rotordynamic properties of a machine were something that the end user simply had to "live with". Making deliberate changes to the machine's rotordynamic characteristics meant at least two things:

1. Removing the machine from service.
2. Physical modifications to the geometry of bearings, seals, blades, rotor, or support structures.

With EPB technology, machines can now have *adjustable* rotordynamic characteristics while "on-line". In other words, the end user can make adjustments to the machine without removing the unit from service and physically modifying the rotor and associated components.

EPB technology allows for independent adjustment of both bearing stiffness and damping characteristics while in operation by varying either the external supply pressure (stiffness) the supply temperature (damping) or both.

There are numerous reasons why adjusting rotordynamic characteristics on-line are both useful and important. I'll just name a few here:

1. Complex machines that cannot be fully modeled on the drawing board. Often, this results in machines whose true rotordynamic characteristics are not known until the machine is installed in the field. Unfortunately, at that point, field modifications are both costly and not easily accommodated.
2. Machines whose rotordynamic characteristics change over time.
3. Malfunctions for which short-term corrective action can be taken by adjusting the machine's rotordynamic characteristics while waiting for a more opportune time to open the machine and perform maintenance.
4. Uprated and / or upgraded turbomachinery where the revised design has changed the rotordynamic characteristics of the machine. The ability to compensate for these changes with adjustable bearing characteristics is highly desirable.

CONCLUSIONS

What started as a search for a more stable fluid film bearing has resulted in a design that has exceeded even my expectations. In this article, I've described EPB technology and its numerous benefits. I've compared the EPB to the traditional hydronamic (fluid film) bearing. In last month's newsletter I discussed *"WHY MAGNETIC BEARINGS HAVE PROBLEMS"* and the advantages of EPB technology over magnetic bearings. In both cases, I've described the numerous benefits of the EPB over those technologies.

I'd be delighted to hear from you with your questions or with applications that you think might benefit from EPB technology.

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