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Traditionally, oil lubricated Babbitt bearings have been used in hydro turbine guide bearing applications. However, increasingly stringent water pollution regulations have caused companies to find alternative solutions of removing as much oil and grease as possible from their hydro plants.

The emergence of modern water lubricated composite and plastic bearing materials has made it possible to eliminate the need for oil lubricated bearings, easing regulatory compliance. At the same time, safety issues have also been found to favour water lubricated bearings. The reasoning behind this concern is that in most units with a conventional oil bearing, the shaft seal or packing box is positioned beneath the bearing in a location designated as a confined space. This means that the ability to adjust the seal or perform routine maintenance is extremely limited, especially when the unit is operating.

In this paper, we shall examine further the benefits of converting to water lubricated turbine bearings and provide examples of successful conversion cases. We shall also cover the steps involved in such conversion projects and consider the various factors influencing the change from oil to water lubrication.

Location of Components in a Vertical Francis Turbine
Advantages of water lubrication

Recent advancements in composite material properties have enabled water lubricated hydro turbine guide bearings to become a viable alternative to conventional oil lubricated Babbitt bearings.

The most notable advantage of this development is the easing of the environmental impact. By eliminating oil from the turbine pit, the risk of oil leaks and spills is diminished. Babbitt bearings are either self-lubricated, by means of partial submersion in the oil bath, or there is forced oil lubrication involving piping, pumps, and a reservoir. Even when following best practices for bearing maintenance, the potential for an environmental hazard occurring has always to be considered.

Oil lines can leak, and spills can occur during draining and filling operations. Furthermore, storing oil in the powerhouse typically requires containment measures and environmental precautions. When oil spills cause contamination of the waterway, the obligatory clean-up tasks can be time-consuming and costly.

The use of water lubrication eliminates this environmental risk, whilst also providing maintenance free operation. With water lubricated bearings, the water acts not only as a lubricant, but also as a cooling agent and as an effective means for flushing away abrasives.
Extensive experience in shipping and power generating industries across the globe.

As part of the global Wärtsilä Group, Wärtsilä Seals & Bearings has accumulated years of experience in developing solutions for the world’s shipping and power generating industries. The company has successfully completed a number of projects involving converting oil lubricated guide bearings to water lubricated solutions. Below are three case study examples of such projects.
Case Study: Loup River Power District

Background: In 2015, Wärtsilä Seals & Bearings was approached by the Loup River Power District, based in the state of Nebraska, USA to investigate a particular operational challenge at the company’s Monroe plant. Operation of the plant’s three 7.8 MW turbines was being adversely affected by repeated problems with the shaft seals and oil lubricated guide bearings. These problems were causing excessive maintenance costs and frequent costly downtime of the turbines. The Wärtsilä team agreed to investigate and make recommendations for overcoming these problems.

The analysis:

The challenges to be faced were essentially:

a) Failures due to the liner grooving;

b) Water ingress into the oil lubricated guide bearings;

And c) the downtime to the turbines directly related to a) and b).

Wärtsilä’s Hydro & Industrial consulting engineers liaised closely with the plant’s maintenance supervisors in order to fully understand the issues being faced. It was decided to initially focus on repairing one turbine only, in order to assess the effectiveness of the solution proposed and to overcome any issues arising during installation of the proposed solution.
The Wärtsilä solution:

After due consideration and coordination with the plant’s maintenance team, Wärtsilä proposed that the existing seal and oil lubricated bearing be replaced with an integrated water lubricated seal and bearing package. The proposal included the fabrication of a new integrated walkway.

The bearing housing was manufactured using Wärtsilä’s latest structural composite material. This material notably reduces the weight, while at the same time removing the need for corrosion protection. It also eases installation and improves serviceability.

The proposed offering included specialist services to support the on-site maintenance team throughout the conversion process.
The outcome:
The conversion of the turbine’s lower guide bearings from oil to water lubrication resulted in significant operational improvements and notable benefits. These included:

- Improved environmental sustainability
- Reduced component costs
- Reduced component weight, thanks to the use of Wärtsilä’s composite housing material
- Improved serviceability, thanks to easier access to the seal for maintenance, and to the bearing shells for in-situ replacement
- Greatly improved service life
- Reduced service costs
- Reduced turbine downtime

Conclusion:
Following six months of trouble-free operation, the conversion was deemed to be completely successful. Loup River Power District then contracted Wärtsilä to convert the Monroe plant’s other two turbines in a similar fashion.

The water source was switched to the canal system feeding the power plant. This was deemed necessary in order to supply the bearings with sufficient cooling flush. However, since the quality of the canal water is poor, the scope of supply was expanded to include a Water Quality System (WQS).

Wärtsilä successfully delivered a complete package, including the seals, the bearings, and the conversion services.
Case Study:
Ngoi Phat Hydro Electric Power

Background:
The Ngoi Phat hydro-electric power plant in Vietnam was experiencing transition line failures during the country’s rainy season. This was causing a runaway condition in which the bearing pressure head was 5.5 bar, as opposed to the rated pressure of 4.2 bar, and the speed was 28.37 metres per second at the bearing surface, when the rated speed was 16.7 metres per second. Whereas such a runaway condition normally occurs once a year for a 15-minute duration, in this case it was happening more frequently because of the transmission line failures.

The analysis:
An oil to water lubricated bearing and seal conversion was required.
Technical solution: Wärtsilä supplied a shaft, having a diameter of Ø425 fitted with a liner. The accepted diametrical bearing clearance was between 0.64 and 0.79 mm based on Wärtsilä’s REsafe material formula. For lubrication, the minimum flow requirement was determined to be 64 litres per minute, based on the shaft diameter.

A calculation was carried out to determine the level of heat generated in the bearing due to load and speed. This was calculated to be 2.3°C at 750 rpm (16.7 m/sec) and 6.4 °C at 1275 rpm (28.37 m/sec). The actual coolant flow delivered to account for the increased heat generation at maximum speed and load conditions was 74 litres per minute. The Stribeck Curve Theory states that hydrodynamic operation occurs once a critical speed has been reached. In this case, friction drops to less than 0.01 and Wärtsilä’s in-house testing and service experience supports the theory that hydrodynamic operation is not affected by an increase in speed. There is a marginal increase in friction as the speed increases because of the increase in fluid film shear.

Fig. 7 Oil lubricated bearing in a horizontal Kaplan machine
Conclusion:
A risk analysis was carried out to justify the conversion. Wärtsilä determined that the bearing should not be adversely affected by the turbine operating at close to its rated speed. The company has had a bearing operating in similar conditions for two years without any performance issues arising. Furthermore, while a small increase in friction and heat will occur over and above what is normally experienced with similar bearings running at lower speeds, the increase in heat generation has been accounted for in the cooling flush flow calculations. The bearing pressure is within the accepted range.

The Wärtsilä REsafe composite material used has an exceptionally low wear rate of 4x10⁻⁷ mm³/Nm. The hydrodynamic bearings can last for many years if correctly aligned with the shaft, and with a good quality water supply delivered at a suitable flow rate.
Case Study: La Tzintre power plant

Background:
Wärtsilä was requested to liaise with the technical staff at a pilot facility of the La Tzintre power plant in Charmey, Switzerland. The project involved carrying out the necessary investigations into developing a bespoke combined water lubricated bearing and shaft sealing system. In order to do this, it was necessary for the Wärtsilä team to fully understand the installation, its operating parameters, and details of the problems occurring with the existing set-up.

The analysis:
Due to the location of the bearing and seal assembly in the turbine, and the space constraints identified, a lightweight solution was deemed to be necessary. A water lubricated composite bearing with an overwound structural composite housing and an integrated PSE type mechanical seal was proposed. The seal and bearing assemblies were designed as fully split components to facilitate installation with the shaft in-situ.

The Wärtsilä Solution:
The project commenced in May 2014, and the proposed system was installed over a two-week period in September of that year. Initial trials showed a significant improvement in running performance over the original white metal arrangement. The system has continued to operate successfully without any performance issues arising.
Steps required for converting to water lubrication

Before carrying out an oil to water lubricated bearing conversion, there are some key points that should be considered:

1. The configuration of the turbine head cover must be considered, since the location of the shaft seal will be moved from below the oil bearing to above the water bearing.

2. All composite bearings require a non-corrosive shaft journal. This is typically accomplished by adding a stainless steel sleeve to the shaft.

3. A water lubrication system needs to provide ample quantities of clean water to the bearing and shaft seal. The standard means of meeting this requirement is a self-contained filtration unit with redundant pumps, automatic self-cleaning filters, and instrumentation for monitoring the flow rates. Alarms and unit shutdown control features are common since a water lubricated bearing will fail quickly without adequate cooling.

Conclusion

It can be safely assumed with the development of composite and plastic bearing materials now well established, water lubrication of the bearings is entirely viable. Indeed, water lubrication presents credible advantages, most notably in avoiding possible non-compliance with environmental regulations.

Wärtsilä Seals & Bearings has demonstrated its capabilities in consulting with customers on possible oil to water conversions, and in designing and carrying out such conversion projects. By offering complete package solutions, from initial investigation to final installation and post-installation monitoring, Wärtsilä acts as a complete lifecycle provider for this service. In so doing, we can work directly with the customer and oversee the project to ensure its successful outcome.
Wärtsilä Seals & Bearings in brief

Wärtsilä provides integrated seals and bearings systems, packages and products that offer lifecycle efficiency, reduced risks through reliability and are environmentally sustainable.

As a truly global organisation, Wärtsilä has a broad product and services portfolio covering the whole lifecycle of the vessel. Looking ahead, Wärtsilä’s continuing development and technological leadership can ensure customers an environmentally sound solution that always complies with the latest regulations.