WHITEPAPER

IMPROVING THE RELIABILITY AND EFFICIENCY OF KAPLAN TURBINES FOR HYDROPOWER WITH ENGINEERED POLYMER SEALS

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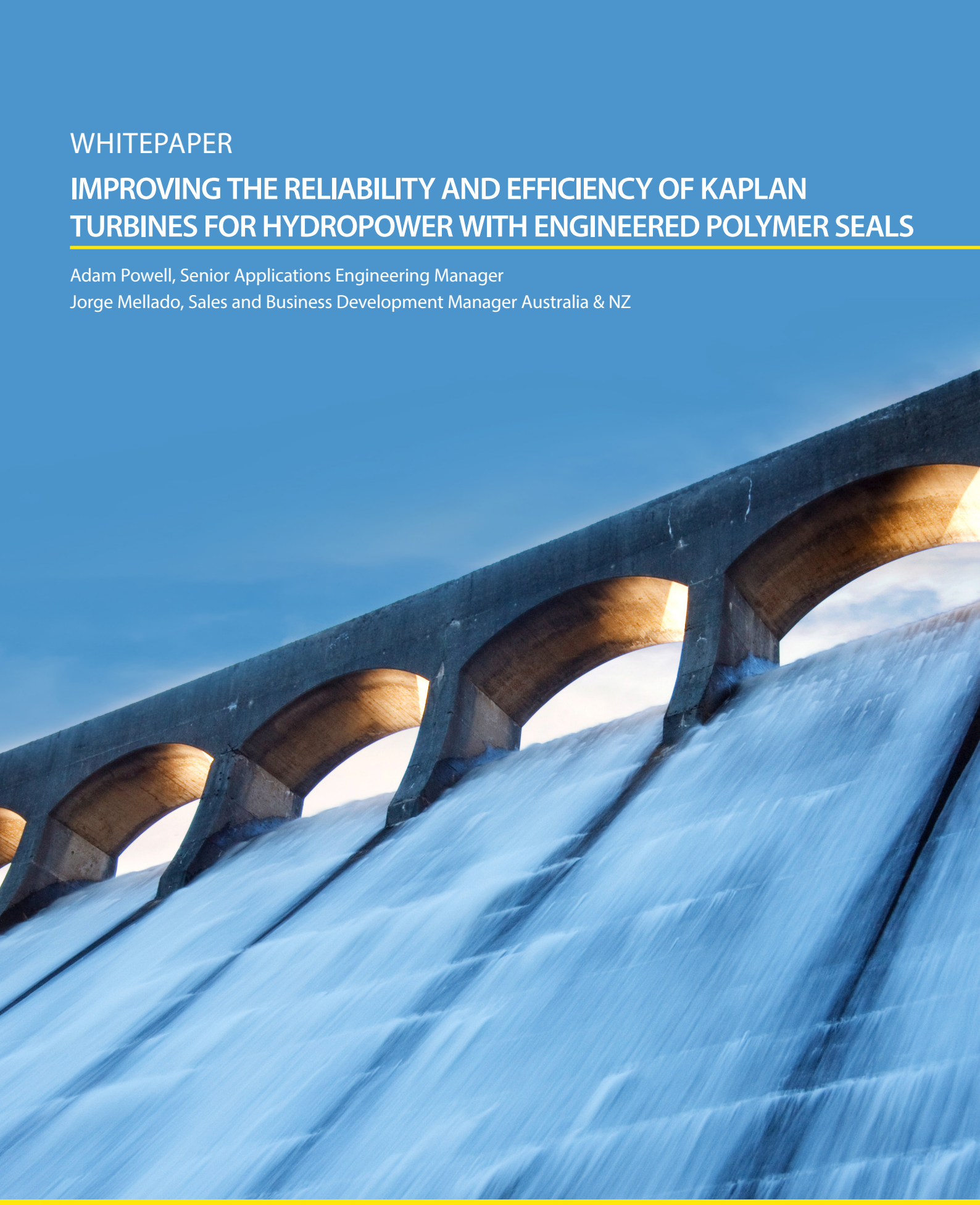

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1.0 INTRODUCTION

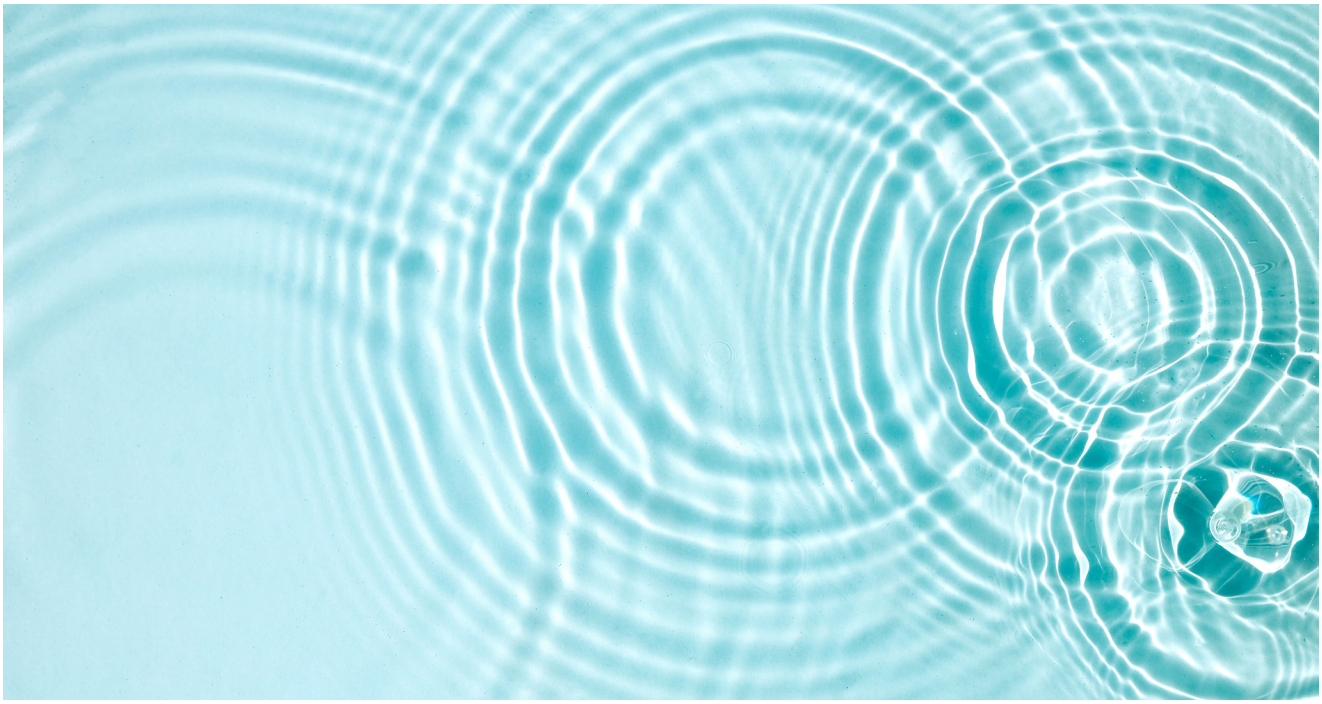
As one of the world's cleanest sources of electricity, hydropower is an important part of the renewable energy mix.

With many organisations and governments around the world now focused on drawing energy from more environmentally friendly energy sources, hydropower tops the list as a cost-effective and sustainable option. Another reason it stands out is its storage capacity and versatility to be able to ramp up and provide additional supply quickly.

Hydropower plant shutdowns are rare and equipment overhauls can stretch over a decade. Plants operate with heavy-duty hydraulics, under difficult conditions in a harsh environment that is also conducive to erosion and corrosion. The components are often heavy, with difficult access for maintenance equipment or to check on or apply seals. Operators need high-performance products that can withstand these elements and still deliver efficiently.

To gain the highest efficiency and return from hydropower investments, operators need to ensure they have smart sealing solutions in place that are cost-effective, reliable and minimise downtime. Some original manufacturers however still provide rubber-based seals despite the availability of more advanced materials like polyurethane that display better performance over time.

Ensuring the right sealing solutions are in place can help to reduce any leakage of water or oil and address environmental concerns about operations at hydroelectric power plants. Engineered polymer seals can provide a more effective seal and have properties that deliver major benefits back to hydropower operators, including less unplanned downtime and faster maintenance schedules.



2.0 DISCUSSION

2.1 Hydropower, the world's renewable energy workhorse

As part of the overall electricity mix, hydropower makes up 17% of global electricity generation, the third largest after coal and natural gas. When it comes to renewable energy though, hydropower represents almost half of all low-carbon energy generation.

Hydropower really is the renewable energy workhorse for environmentally friendly and cost-effective energy generation. According to the International Energy Agency[1], we've only tapped into half of its full potential around the globe.

While hydropower technology is known as an environmentally friendly, pollution-free choice for energy generation, there are still environmental risks around the presence of petroleum-based oil. These environmental concerns are enhanced with Kaplan turbines, some of the most complex hydraulic and pneumatic systems at a hydropower plant.

The oil is used to help equalise pressure with the outside water pressure and protect the turbine hub. It is also used to lubricate internal mechanisms and moving components and assists hydraulics to the runner blade pitch control servo motor. A high volume of oil is often required and without the right care or sealing solution, the oil could escape into the water system.

These concerns are leading to the design of more eco-friendly turbines that try to reduce the amount of oil used in the system. Other designs seek to switch petroleum-based oils for water or biodegradable fluids, or switch to pneumatic or electric servo motors and self-lubricated bearings.

However, there are many existing turbines that will still be in use for decades to come. For these, the focus on addressing environmental concerns is on mitigating the risk of oil leakage that could cause downstream pollution.

2.2 The flexibility of Kaplan turbines

A Kaplan turbine is a propellor type of turbine that is commonly used throughout the hydropower industry for power production with a water head range of between 2 and 75 metres. Designed by Victor Kaplan in 1913, he based his design on the principles behind the Francis turbine. Kaplan added automatically adjusted propeller blades with automatically adjusted wicket gates to achieve efficiency over a wide range of flow and water levels.

Kaplan turbines can be vertically oriented or are also known as bulb turbines when horizontally oriented. They work across a broad range of flow conditions and have a typical output range from 0.1 to 200 MW. Due to their operational flexibility, they can be found in hydropower plants of all sizes and are most commonly used in run-of-river power stations.

2.3 Sealing challenges for the Hydropower industry

There are many sealing challenges to overcome that are directly or indirectly associated with the equipment used to generate hydropower.

These include:

- **Environmental Impact** – Designing a leak-free sealing system for Kaplan blade runner seals is attainable. Achieving this requires the incorporation of a positive sealing system, capable of maintaining oil within the hub while keeping water out until the next planned maintenance is scheduled.
- **Bearing wear** – Bearing wear will naturally occur over time and one solution is to design a sealing system capable of offsetting common issues associated with blade droop. This requires sealing device designers to combine materials expertise and design geometry to develop a sealing solution.
- **Equipment variation** – Without global sealing specifications for OEMs to follow, variations do exist between types of equipment and turbine design expertise is not the same as sealing system design expertise. As a result, sealing device manufacturers are challenged to develop a range of sealing geometries to accommodate various designs. The best way to factor this in is to gather actual equipment dimensions as these can change from the original specification after years of use.
- **Equipment condition** – Both the dynamic and static surface finishes will directly impact the seal performance as these are in direct contact with the sealing device. To optimise the performance of the replacement sealing system, work closely with a seal supplier to ensure any surface finish upgrades meet the capabilities of the replacement sealing system.
- **Installation and replacement** – Ensure there are detailed instructions available and review these carefully before installation. The sealing component is a critical area where poor planning can lead to extended downtime and significant profit loss.
- **Knowledgeable service** – Working with an experienced, proven sealing device specialist is critical to avoid installation problems that can cost considerable time and money to fix.

The right choice of advanced materials and the design of the solution can help address some of these challenges by improving the average time between repairs, simplifying installation, reducing maintenance costs, minimising downtime and positively impacting the environment.

2.4 Choosing the right material for hydropower applications

For over 130 years, Chesterton®, a world leader in industry sealing solutions has continued to provide innovative and reliable seals for its customers in operations worldwide. The company developed AWC-800, a proprietary thermoset polymer material for seals that outperforms rubber-based materials and is well-suited to the hydropower industry.

Compared with rubber, polyurethane has improved abrasion resistance, cut and tear resistance, higher load bearing, ozone resistance, harder durometer, radiation resistance and solvent resistance. Polyurethane has a higher tensile strength compared with rubber as well as a lower coefficient of friction, minimising wear on equipment and enhancing the life of a seal.

2.5 Improving the design of seal solutions

While the choice of material can extend the life of a seal solution, its design can also play a critical role in reducing downtime and the time spent on maintenance. It has been proven that a split seal configuration can provide outstanding performance in new and existing Kaplan turbine equipment as replacement seals for blade runners.

The back-to-back approach is a bi-directional seal system that keeps oil in the hub and excludes water. The geometry of the seals can be changed for different equipment dimensions.

The static side of the seal is achieved by stacking the seals and applying axial compression using the gland plates of the equipment. The seals are slightly oversized in the axial direction to provide compression and provide static sealing to keep the seals secure. In most Kaplan turbine seal installations, seals need to be split to eliminate the requirement to remove the turbine blade.

Chesterton 10K Split Interlock Seals are made with advanced AWC-800 polymers that outperform

rubber-based seals provided by OEMs. The interlocking design of the split seal allows the seal to be maintained during blade adjustments. This makes it much easier and safer to install and access for maintenance, without the need for much heavier equipment and reduces the potential for contamination downstream.

2.6 Applications across Kaplan turbines

There are several areas within the turbines where sealing solutions based on AWC-800 can be used to achieve greater efficiency and reliability.

RUNNER BLADES

Runner blades are the most important part of a reaction turbine in a power generator. They convert hydraulic energy to mechanical energy. The exposure to the load of the water pressure makes it the most vulnerable component.

Both water and oil leakage are a concern in runner blades and ensuring an effective seal is critical. Oil leakage can cause downstream pollution and environmental concerns. This can lead to unscheduled downtime to identify the source and remedy the issue. Water leakage can lead to corrosion and the foaming of oil which in turn adds wear.

WICKET GATES

Wicket Gates or Guide Vanes control and direct the flow of water to the turbine runner. Wicket Gates have hydraulic seals on each end to protect the bearings. OEM seal solutions for Wicket Gates generate high friction on the shafts of the Guide Vanes. This leads to wear and grooving on the shafts, shorter seal service life, high motion torque and high force and overload on the servo motors. Seal solutions from Chesterton are made from AWC-800 polymers which have excellent abrasion and hydrolysis resistance, making them a superior choice over rubber-based seals.

SERVO MOTORS

Servo motors actuate the Wicket Gates which control the flow of water through to the turbines. Oil leakage is particularly a concern here with older technology rag and rubber. Chesterton sealing solutions include a bearing band, stack set technology made from AWC-800 materials and a wiper to reduce the potential for oil leakage.

3.0 CONCLUSION

Hydropower is an important source of renewable energy around the world. Maximising the efficiency and reliability of the performance and operation of turbines at hydroelectric power plants is crucial to hydropower remaining an environmentally friendly and cost-effective solution.

Designing the right sealing solutions and having these in place for turbines drives higher efficiency and reliability. Choosing advanced polymer seals over OEM rubber seals and implementing smarter and proven designs for sealing solutions not only improves the design life of seals but also reduces costly downtime as well.

4.0 WANT TO KNOW MORE?

Visit Chesterton Customseal to discover more about Engineered Polymer Seals and solutions for the hydropower industry, or send your enquiry to enquiries_apac@chesterton.com and speak to one of our experts to discover the right sealing solution for your business.

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SOURCES

[1] IEA (2021), Hydropower Special Market Report, IEA, Paris https://www.iea.org/reports/hydropower-special-market-report, License: CC BY 4.0