Fresh thinking brings breakthrough sealing solution for main bearings

As wind energy moves to larger, lighter turbines in harsh and remote locations, its specialty in large-diameter, custom seals, alongside a reputation for reliability, is making System Seals a player of note in this growing space.

Systemwind is the company's offering for the wind sector. According to Sales Director Sean Hensey, it represents 'fresh thinking' in wind seal technology. 'Our thinking is around 'how can we eliminate grease and oil leaks from a wind turbine main bearing? How can we reduce maintenance, downtime and the cost of ownership, no matter where in the world a turbine is located?' And we are finding solutions.'

Central to Systemwind is the VORTEX main bearing seal for grease-lubricated applications. Originally designed for 1.5 MW onshore turbine main bearing applications back in 2012, it has now become the main bearing seal of choice for large offshore turbines, sealing bearings up to 4.5 m diameter. This revolutionary seal has proven itself in over 10,000 turbines worldwide, eliminating main bearing leaks in all applications, from small onshore turbines to the largest offshore operations. The novel pumping effect of the seal ensures any potential leakage is trapped between the seal lips and pumped back towards the bearing.

New VORTEX PLUS for oil and grease-lubricated bearings

Launched at this year's Husum Wind fair in September, the next-generation VORTEX PLUS was originally conceived specifically for oil-lubricated bearings but has been adapted for grease-lubrication also.

It features pressure-activated seal lips which can accommodate pressures up to 1 bar. With the lowest seal lip seal force in the industry, it boasts lower torque, while service life is extended because it operates at a lower lip temperature. It also seals flushing fluids during the bearing production process. 'This new seal is answering a real customer need,' says Sean. 'Not least among those operators who are keen to move to oil-lubricated bearings because of the perceived longer life they offer.'

Sealing solutions explained

Traditional rotary lip seals have been employed in turbine bearing applications with varying degrees of success, with limitations including the seal's ability to follow radial shaft deflections, and lack of redundancy in the event of leaks. Their design is based on achieving a specific lip sealing force, based on a number of modes of action, including total contact stress, stress distribution at the lip, and micro and macro pumping mechanisms. The total stress is a function of radial force created from stretching the seal over the shaft, flexural forces associated with bending the seal in the hinge region, and forces created from the installed spring, usually a garter spring, or a finger spring for larger diameter applications.

A major disadvantage of this design is that any fluid leaking past the lip surface results in a permanent loss of lubricant. Further, lip seals are highly sensitive to surface finish requirements; even minor imperfections to the shaft surface can lead to a permanent leak path. Finally, due to the minimally energised nature of lip seals and the viscoelastic nature of elastomers, in order to combat hysteresis effects and the reduced ability to follow radial deflections, either 'heavy' seal designs are required, or springs are needed to compensate. These result in higher seal forces and accelerated wear. As bearing sizes increase, in particular for offshore applications, and the application conditions become more challenging, a more robust seal design, operating on a different mechanical paradigm, is called for.

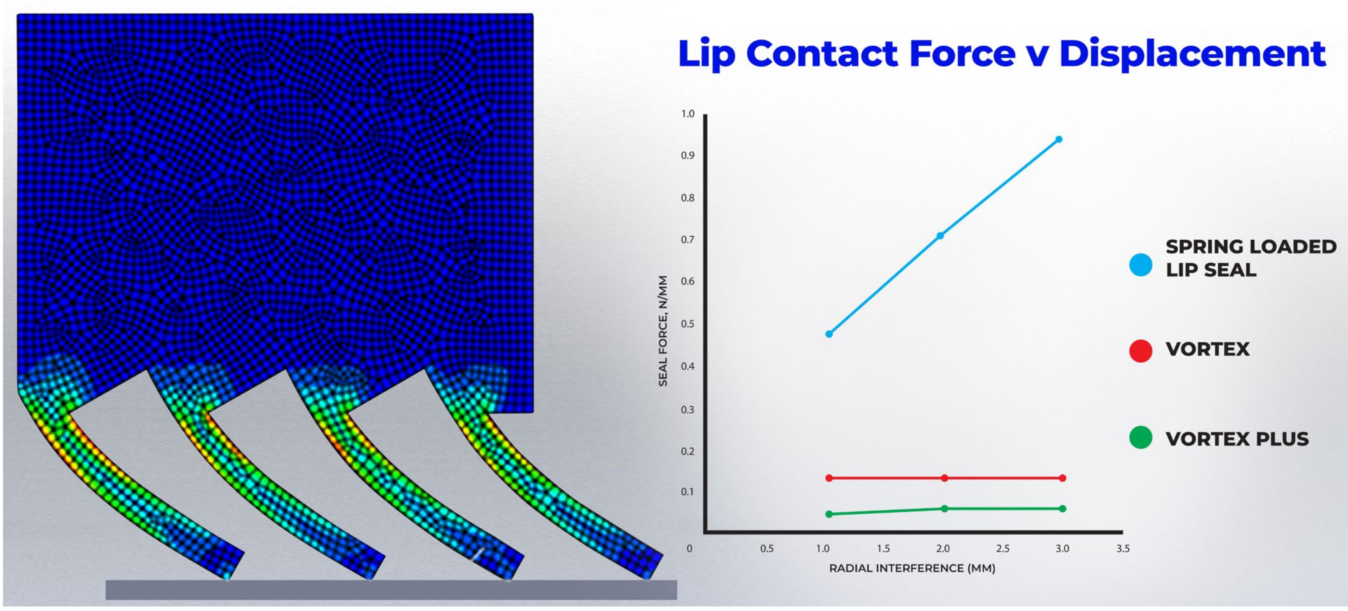
VORTEX seal design: operation and advantages

The original VORTEX seal, designed for grease-lubricated bearings, incorporates a continuous helical blade, similar to a screw pump blade, with an entry/exit zone on the grease side of the seal. The final pass of the helix terminates at an endless fixed wiper lip on the outboard side of the bearing.

Unlike traditional rotary grease seals, which rely on micro pumping and contact barrier pressure to prevent lubricant leaks, the helical nature of the seal prevents leaks by utilising an angled channel which serves to screw-pump the lubricant back into the bearing; as grease is introduced into the seal, the angle of the blade, the pitch of the screw helix, and the rotational speed and diameter of the system, among other variables, control the rate at which grease is moved through the seal and returned towards the bearing. Although very little grease makes its way from the reservoir to the outermost path of the helix, most is

Sean Hensey

The VORTEX corkscrew-style seal has proven itself in over 10,000 turbines over the past decade



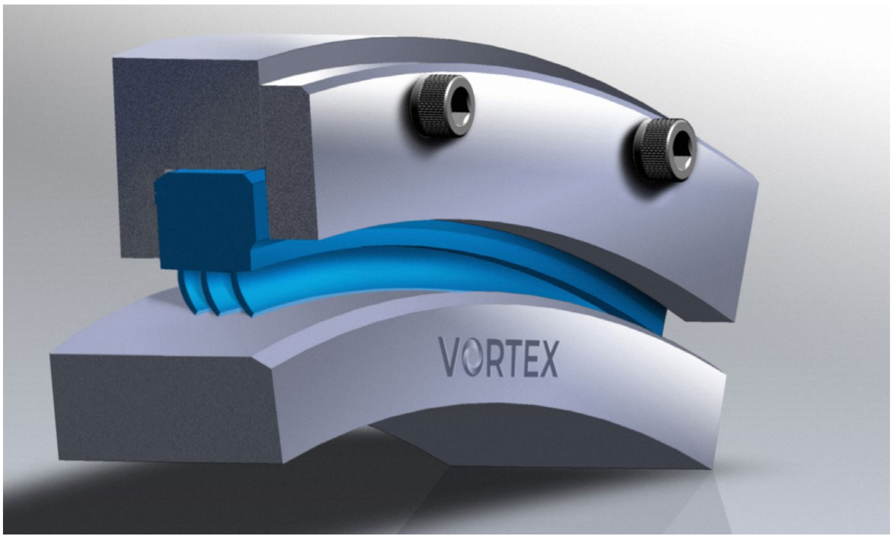
Unlike traditional lip seals, VORTEX maintains a constant seal force across a range of deflections

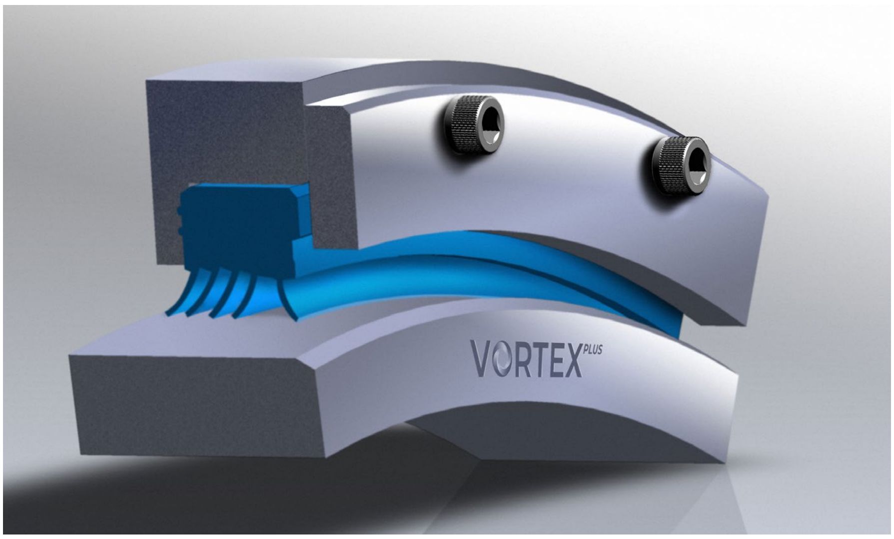
retained in the first pass or two, such grease is pumped back into the bearing or grease source, with the rotation of the seal or the bearing.

How is this pumping effect different from that of the traditional lip seal? Consider the combined effects of bearing diameter and rpm on linear velocity in conjunction with the effect of the grease's viscosity. As the bearing rotates, grease adheres to the seal running surface and rotates with the bearing. Thus, the grease itself has a velocity relative to the stationary VORTEX blades. Under pressure, grease also migrates axially from the source bearing towards the seal. As the grease comes in contact with the surface, due to the pitch of the lips and the relative velocity of the grease, the grease is driven axially back towards the source. Since the axial rate of return is a function of rotational velocity and pitch, the lip characteristics can be designed or modified to accommodate a wide range of application limits.

Whereas the traditional lip seal relies primarily on sealing contact pressure, with its mode of pumping similar to a positive displacement piston, VORTEX relies primarily on screw pumping while relegating sealing due to contact pressure to a secondary role.

Compared to traditional lip seals, the seal force generated for the seal is significantly lower per lip. For example, one industry standard lip seal for wind applications gives seal forces as high as 0.9 N/mm, while another lighter version results in a max of 0.2 N/mm. VORTEX maintains a constant seal force of 0.12 N/mm per lip over the entire tolerance range of deflection (for this example), or 0.36 N/mm for a 3-lip helix.





VORTEX and VORTEX PLUS in installed state. Note that the latter dust wiper still faces outward to prevent ingress

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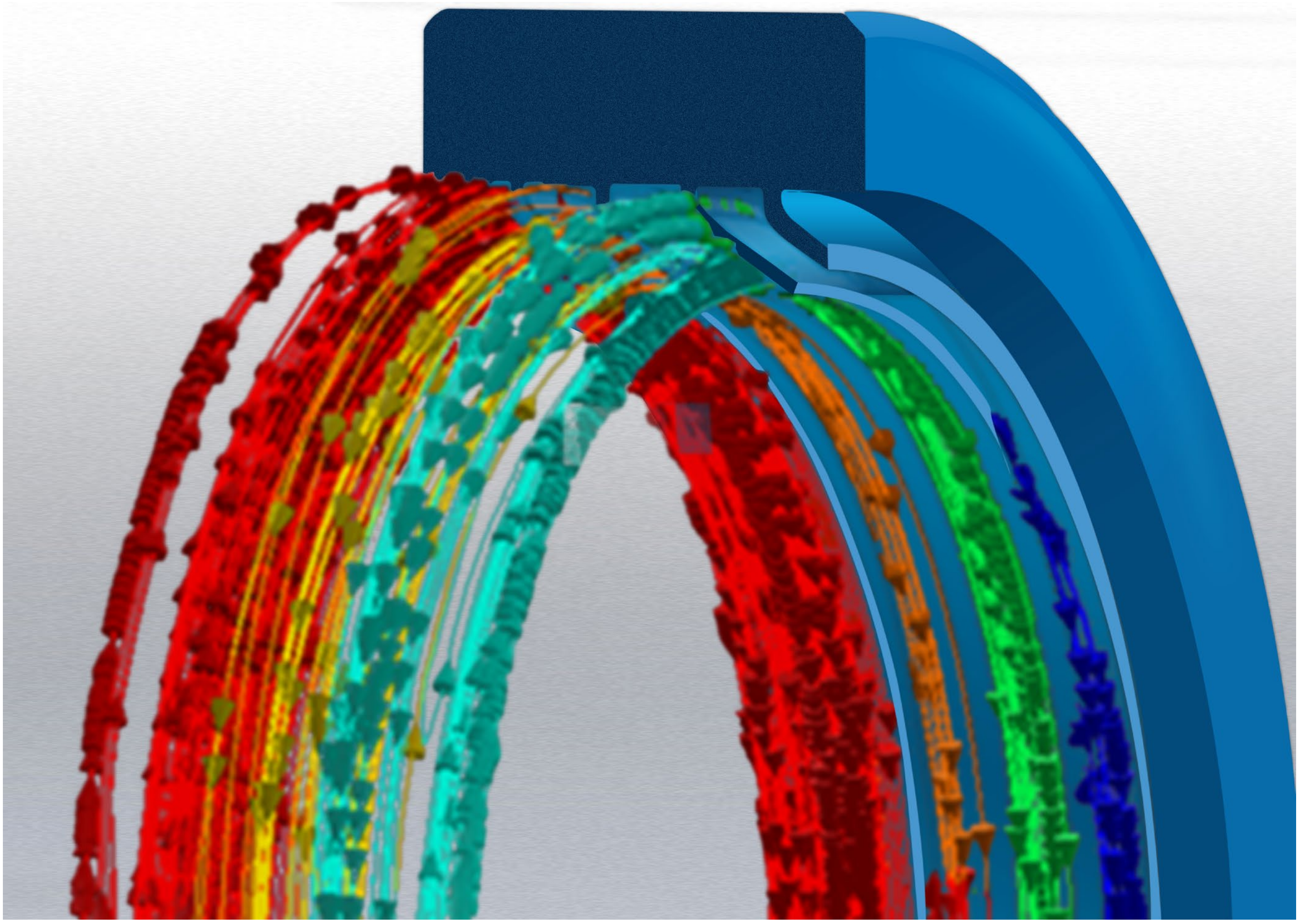

Computational Fluid Dynamics (CFD) was used in design of the VORTEX seal range

Both finite element analysis (FEA) and dynamic testing, in which the seal lip is stroked +/- 2.0 mm at 0.7 Hz up to 1,000,000 cycles, show the force generated by the VORTEX lip is relatively constant throughout the stroke, whereas the traditional lip seal generates a displacement-dependent force.

Pressure retention and the motivation for VORTEX PLUS

Standard installation for VORTEX results in outward facing lips, with pressure applied to the convex side. Under typical grease applications, the lip stiffness is sufficient to ensure no leaking. However, in cases of applied head pressure of oil in fully flooded bearings, outward facing lips have a pressure retention limit, beyond which leaking will occur. Thus, VORTEX PLUS was developed specifically for oil applications. This next-generation seal incorporates inward facing, or inverted, lips which are manufactured to a predetermined angle to aid in installation and further reduce seal force.

Because the system was originally designed for fully-flooded oil-filled bearings, some exceeding 4 m in diameter, it was necessary to understand its pressure, velocity, and flow characteristics. Computational Fluid Dynamics (CFD) models were built to study the effects of size, channel dimensions and number, pitch, and viscosity on flow characteristics. Additionally, analytical models and physical testing showed a high degree of correlation with the CFD simulations, when adjusted for the non-Newtonian nature of gear oils. As a result, System Seals can now predict the pressure, flow rates, and velocity fields for a given VORTEX design.

In addition to the ability to seal against pressure, VORTEX PLUS has the added benefit of even lower lip contact force leading to reduced torque and lower operating temperature.

'Engineer to engineer'

These are the products of a distinctive engineering philosophy that has characterised seal specialist System Seals since its foundation in the early 1990s. Problem-solving 'engineer to engineer' has been a hallmark of the company from the start and has continued with its embrace of wind technology in recent years. Every VORTEX seal is designed for a unique bearing application, either for an OEM application or to retrofit an existing bearing in the aftermarket.

'Our senior team members are very much engineers at heart and we're happiest at the table with client engineers finding technical solutions to customer-specific problems. It's our DNA, if you will. The innovative products you see in our portfolio are the direct results of this collaborative approach to our work.' concludes Sean.

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