James Walker®

REINVENTING THE SEAL

An innovative sealing solution for large diameter rotary sealing applications in the wind industry

Time to re-invent the seal

Background

Over recent years wind turbines have made significant increases in size as operators and OEMs seek to optimise the costs of power generation by building fewer, larger, more efficient turbines. Whilst these will produce substantially more energy than they take to produce, install and maintain, larger units present significant challenges.

In mechanical terms, an increase in size means an increase in the loads generated throughout the equipment in turn leading to more stress being imposed on virtually every component in the system, but particularly on rotating and transmission components.

Seal performance

Elastomeric rotary lip seals of the type used to seal bearings and rotating shafts follow a long-established seal design that has changed little over the years and is now being required to achieve new levels of performance at a reduced cost. With loads on the main shaft of a large wind turbine being high enough to cause flexing and distortion of bearings, it falls to the seal to cope with any eccentricity of movement whilst still performing its intended duties of preventing the escape of lubricant or the ingress of contamination.

Lip seals were also originally designed to work with oil as a lubricant, their sealing principle relying on the sealing lip running on a thin film of oil on the surface of the shaft. In modern wind turbines however, the vast majority of bearings now use high-performance greases for lubrication, bringing a whole new dynamic to the operation of the bearing seal.

With turbines now expected to achieve a working life of 20 years plus and the industry driving to achieve higher load capacities, there is a demand for components to offer efficiency benefits in addition to long life.

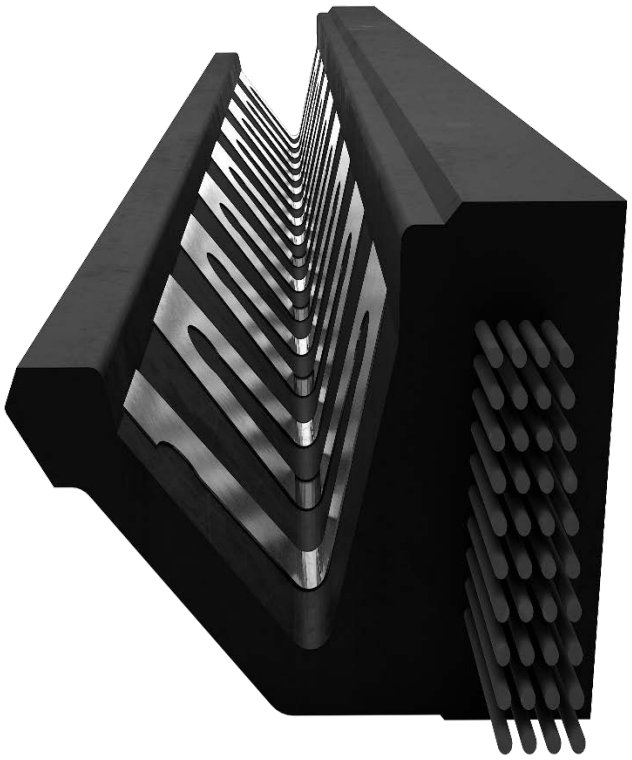
In line with the aim of improving load factors* and reducing overall generating costs, all elements of a turbine are being brought under close cost scrutiny, forcing the whole supply chain to seek ways of taking cost down whilst also delivering the improvements in performance demanded by increasingly harsh operating environments and the increase in turbine size.

Faced with these growing challenges, James Walker decided to take a close look at every element of the large diameter lip seals required for the wind industry and see what could be done to meet current and future needs. Nothing was off-limits.

**The ratio of the amount electricity actually produced by a windfarm or turbine, compared to its theoretical potential.*

Seal lip design

Radial lip seals have been successfully used since the 1940's to seal lubricated systems but they were originally designed around the use of oil as the lubricating medium, whereas modern wind turbines use high-performance grease. The non-Newtonian fluid behaviour of grease places different challenges on the seal / shaft interface, requiring a different sealing concept compared with traditional lubricating oils. In collaboration with customers in the wind industry using detailed Finite Element Analysis (FEA) modelling and in-house dynamic testing, James Walker redesigned the existing seal lip to optimise performance for grease media.



Spring assistance

The larger the seal / shaft diameter the more difficult it becomes to maintain an even lip pressure on the shaft – a task made even more difficult when higher degrees of eccentricity of shaft rotation are added into the mix due to the forces generated in large modern turbines.

Springs are commonly used to help retain lip – shaft contact, a helical or 'garter' spring being the traditional format. For larger diameter seals, especially in situations where eccentricity or runout is present in operation, garter springs can provide less consistent force around the whole seal circumference. What is required under these conditions is a more adaptive assistance that can accommodate fluctuations and still maintain a consistent lip load at all points around the surface of the shaft.

Extending the FEA modelling and in-house testing of the lip design, James Walker engineers identified that a 'finger' spring would provide the necessary assistance required to accommodate eccentricity / deflection and maintain a constant / linear lip load at all points on the shaft. The modelling also allowed the engineers to refine the spring design, optimising it for the material and diameter of the seal. The resulting design is a spring securely bonded into the seal profile with each individual 'finger' operating independently to accommodate deflection and maintain a consistent load on the circumference of the shaft.

Seal materials

Having optimised the sealing element, the focus moved onto the backing material and how to create a suitably robust 'hoop' without the complications of metallic or fabric based options. James Walker's lip seal design has traditionally been a separate lip element moulded to a backing of multi-ply, elastomer-proofed fabric. This provides excellent 'hoop strength' and torsional rigidity, with the seals being manufactured to an interference fit within the housing. This design ensures that the elastomeric lip has the benefit of being in compression on the shaft.

A fabric construction has drawbacks however, particularly that it uses a lot of solvents and plastics during its manufacture which has a negative impact on our environment. James Walker began the search for an alternative design that would not only be ideal for larger diameter products but also allow simplification of the manufacturing process, reduction of environmental impact and provide overall performance benefits whilst not increasing the cost of manufacture.

The result of a comprehensive programme of experimentation and testing is a new innovative rubber / glass fibre composite material in which the glass strands are aligned circumferentially, providing enhanced dimensional stability yet retaining full flexibility that makes a large diameter seal of this construction easier to fit into its housing.

Testing the concept

Each new element of the seal design was initially developed and validated using FEA. After this 'virtual' phase, test regimes were developed to assess the performance envelope of each individual component against customer expectations before complete seals were manufactured and subjected to in-house testing on a new large diameter rotary test rig specifically commissioned for this project. Following successful in-house testing, seals were supplied to key OEM customers in the wind industry for further exhaustive testing.

Finger springs were tested to assess any risks of the spring failing or becoming de-bonded from the body of the seal over a regime of more than 7 million cycles – in a simulation of actual service. By the end of this test no issues that would affect seal performance had been observed and there was no significant change in lip load exhibited by the seal samples. This provided confidence that eccentric running would not have a negative effect on seal performance, even over extended periods of time.

Due to the sizes of seal required for the next generation of turbines, the joining capability of the new glass-elastomer material was also fully tested through a comprehensive regime of twist and flex motions. The conclusion drawn from these results was that the new material provides a strong homogenous bond across the area of the join, equal to or better than that observed with any alternative backing constructions.

Complete seals have been tested internally on James Walker rotary test rigs initially at 405mm diameter and then on a newly commissioned test rig specifically developed for this project, which allows testing of seals up to 1.1m diameter. The bespoke rig logs temperature, pressure, speed, torque and leakage as well as being capable of configuration to test up to 5mm offset, a tilt of up to 2 degrees or up to 3mm eccentricity. The tilting operations can be configured to be constant or cyclical, allowing real life operational conditions to be accurately simulated.

Throughout this project James Walker has been working in partnership with a number of OEMs seeking to test factors such as seal rotation in the housing, lip load, leakage performance and life expectancy.

Product development and validation testing has all been carried out in-house at the James Walker centre of excellence for elastomeric materials in the UK. Further real-life simulation testing was then carried out by OEMs using commercially produced seals on full-size housing / shaft / bearing set-ups.

The developed solution has demonstrated excellent capabilities in terms of maintaining shaft contact and preventing leakage or the ingress of contaminants, even when faced with eccentric running or extreme shaft deflection.

A new manufacturing process

New designs and new material combinations mean the process for manufacturing the new glass-backed product is cleaner and greener, particularly in terms of reducing material wastage and a reduction of nearly 98% in solvent usage. Reducing the environmental impact of manufacture is seen as a significant benefit for an essential product being used in the production of green energy.

The new manufacturing process also offers the chance to increase automation when compared with the traditional manufacturing methods and makes manufacture more easily repeatable, which in turn contributes to improvements in dimensional accuracy as well as providing consistent joins of the highest quality due to excellent compatibility with our mould and mould joining techniques.

With this new rotary lip seal design initially being focused on wind turbine applications, the business has now developed a dedicated production cell to optimise the solution for the requirements of OEM partners.

Marginal gains can provide significant benefits

By breaking the existing Walkersele down into its 'constituent parts' and making small but significant improvements in each of these areas, James Walker has taken an already successful and proven product and pushed it to deliver new levels of reliability and performance to meet customer demands.

James Walker Worldwide

Australia
T: +61 2 9721 9500
E: sales.jwau@jameswalker.biz

Belgium
T: +32 3 820 79 00
E: sales.be@jameswalker.biz

Brazil
T: +55 11 4392 7360
E: sales.br@jameswalker.biz

China
T: +86 21 6876 9351
E: sales.cn@jameswalker.biz

France
T: +33 437 49 74 80
E: sales.fr@jameswalker.biz

Germany
T: +49 4038 60810
E: sales.de@jameswalker.biz

India
T: +91 224 0808080
E: sales.in@jameswalker.biz

Ireland
T: +353 214 323626
E: sales.ie@jameswalker.biz

Italy
T: +39 2 2578308
E: sales.it@jameswalker.biz

Middle East
T: +971 481 78888
E: sales.jwme@jameswalker.biz

Netherlands
T: +31 186 633111
E: sales.nl@jameswalker.biz

New Zealand
T: +64 9 272 1599
E: sales.nz@jameswalker.biz

Norway
T: +47 22 75 75 00
E: sales.no@jameswalker.biz

Singapore
T: +65 6715 6300
E: sales.sg@jameswalker.biz

South Africa
T: +27 31 304 0770
E: sales.za@jameswalker.biz

Spain & Portugal
T: +34 94 447 00 99
E: sales.es@jameswalker.biz

UK
T: +44 1270 536000
E: sales.uk@jameswalker.biz

USA
T: +1 708 754 4020
E: sales.jwna.us@jameswalker.biz

James Walker Sealing Products & Services Ltd

Registered Office: Lion House, Oriental Road,
Woking, Surrey GU22 8AP, United Kingdom.

Reg no: 00264191 England

James Walker

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