Abstract for AWTEC 2018

M. Hofmann[#1], M. Baumann[*2]

[#]SKF GmbH Germany
11th floor, Gunnar-Wester Str. 12, 97421 Schweinfurt, Germany
[2]Michael.Baumann@skf.com

I. Keywords

Sealing of the rotor shaft – One of the biggest challenges for tidal stream turbine device developers.

II. Abstract

The presentation covers typical customer requirements of rotor shaft seal applications, informs about key selection parameters and what the appropriate rotor shaft seal technology will be for shallow and deep water tidal turbine rotor shaft applications.

The rotor shaft sealing is one of the most critical components in tidal stream turbine drive trains as it ensures that lubricants inside the rotor shaft bearings will be separated from the seawater and ensures likewise that sea water is kept out of the nacelle. Hence, the right seal technology is vital for the overall robustness, reliability and cost competitiveness of a tidal stream turbine. The presentation introduces common tidal stream turbine drive train designs, focuses on rotor shaft sealing technologies for different installation depths with its respective merits and demerits.

When designing the drive train, a design and engineering working process should be followed which will be discussed during the presentation. Frequently asked questions about respective seal types, application parameters and decisive selection criteria will be answered in order to give a hands-on guide to select the most suitable seal technology for tidal stream turbine designers. In addition, it explains what conditions will mainly influence the performance and lifetime of a rotor shaft seal solution in a tidal stream turbine.

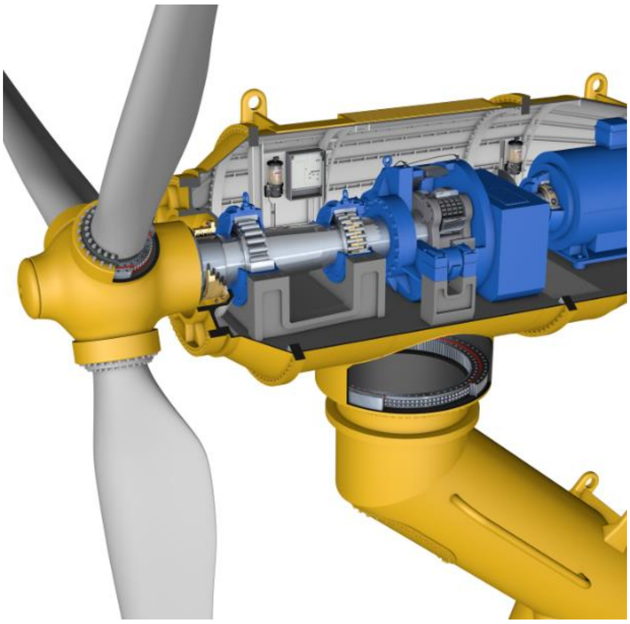


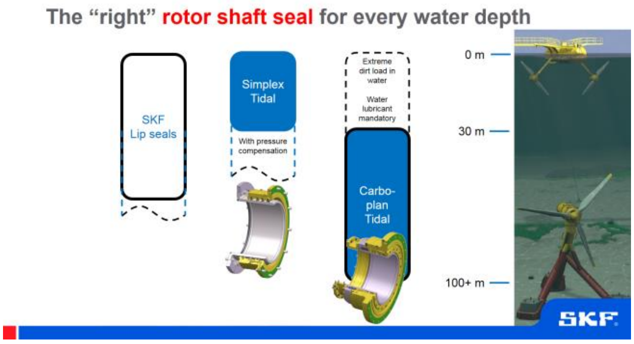
Fig. 1 Example drive train of an tidal stream turbine

The content of this presentation is derived from practical experience from various advanced tidal stream turbine projects in Europe, North America and Asia. SKF, who is one of the global leaders in the bearing and seal industry, is engaged with most advanced tidal stream turbine manufacturers from the early prototype phase. This involves drive train design, engineering, manufacturing, as well as validation and testing. SKF makes use of its extensive track record in rotating underwater shaft sealing technologies in Marine applications.

Fig. 2 Exemplary rotor shaft seal solutions

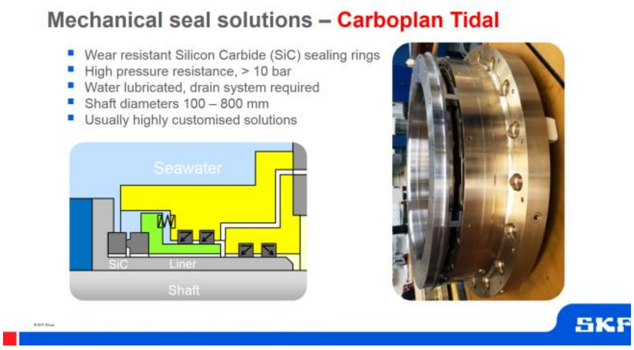
For long-term viability of the tidal energy sector it is absolutely critical to become cost competitive to established renewable energy technologies. To achieve lowest possible levelised cost of energy (LCoE), asset reliability, availability and maintainability are key factors that will mainly influence this goal. Therefore, key mechanical components such as rotor shaft bearings and seals need to be fit for purpose for operating in harsh sea water environments and maintenance intervals of up to 5 years. For this reason it is essential to select the right rotor shaft seal for every water depth and installation site.

SKF Marine differentiates tidal stream turbine rotor shaft seals between deep sea applications with high water pressures starting from 3 bar which equals an installation depth of 30 meters up to 10 bar or more which equals an installation depth of 100 meters, and seals for shallow water applications ranging from several meters up to 30 meters of water depth, *see slide 7*.



Slide 7: The "right" rotor shaft seal for every water depth

For the first application range, mechanical seal solutions are typically provided such as the SKF Marine Carboplan Tidal seal, *see slide 8*. This contains wear resistant silicon carbide (SiC) sealing rings, a shaft liner, back-up sealing rings and a sealing housing. This is a water lubricated seal solution which does not require any further lubricants or an active lubrication supply. For potential ingress of sea water, it is combined with a drain system and is available for shaft diameters between 100 and 800 mm. Each seal is usually a highly customised design.

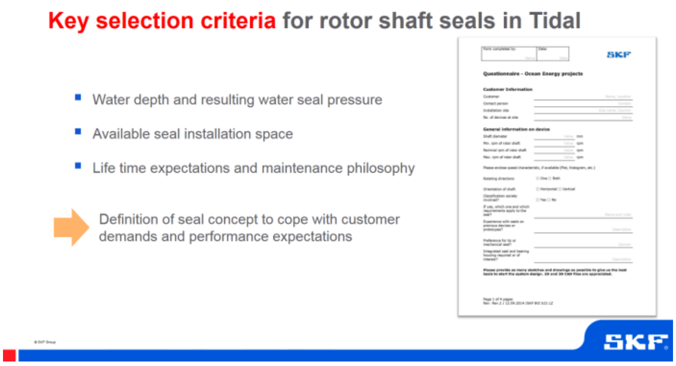


Slide 8: Mechanical seal solutions

In case of shallow water applications, lip seals are used such as the SKF Simplex Tidal, *see slide 9*.
These seal systems generally consist of lip seals which are fixed in a seal housing and which are running on a seal liner. These lip seals are available in a compact and modular design for simplistic handling and installation, are grease or oil lubricated, but more sensitive against particles such as sand or dirt as mechanical seals. The lip seals are designed for easy maintenance and repairs. For this reason, the sealing rings can be split and the bonding procedure of the lip seal itself during maintenance and repairs is well-proven.

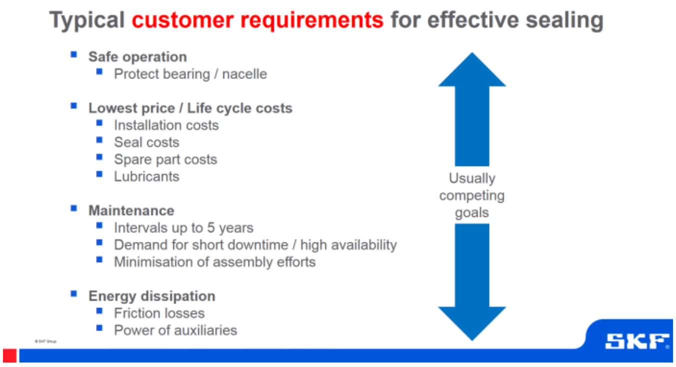
Slide 9: Lip seal solutions

When designing a tidal stream turbine rotor shaft seal, a typical customer request starts with answering questions about key selection criteria, *see slide 10*. Where will the turbine and seal solution be operated, which water depth and resulting seal pressure need to be considered, what will be the available installation space, what are the seal life time expectations and what is the expected maintenance philosophy. These are some examples which are key drivers of defining the most suitable seal concept. These answers will also help to categorise the seal request and leads the way for more detailed seal design discussions.



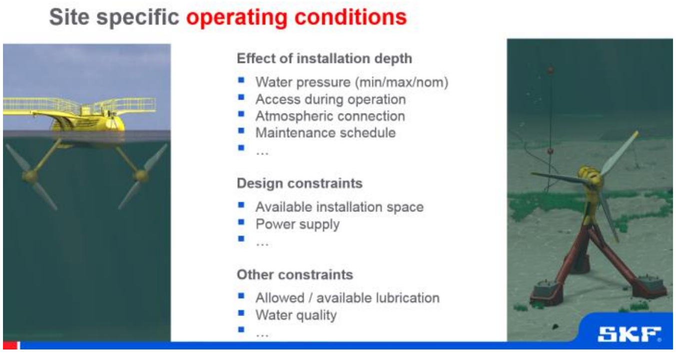
Slide 10: Key selection criteria for rotor shaft seals in Tidal

Typical seal customer requirements are listed in *slide 11*. The key requirement and function which each seal solution has to fulfil is a *safe operation* for at least a pre-defined maintenance interval which in tidal is up to 5 years. The inside of the nacelle need to be protected against the ingress of sea water, contaminants or marine growth which are aquatic and aggressively trying to enter the turbine over time. Equally, the sea water environment needs to be protected from leaking lubricants potentially coming from the rotor shaft bearings or from the seal system itself. These customer needs are followed by another key requirement, the attainment of the *lowest possible life cycle costs* which includes Capital and Operational Expenditures (CAPEX and OPEX) of the seal.
CAPEX are heavily depending on the overall seal type which will be used in the application e.g. (mechanical vs. lip seal) and required periphery components such as lubrication or drainage systems and commissioning services. OPEX of the seal are mainly depending on *maintenance* costs during service intervals such as seal inspection, replacement of worn components, spare parts and other repair costs. In order to minimise these maintenance costs, there is generally a strong demand for short downtimes. This includes the minimisation of assembly efforts which already need to be considered during the design phase of the seal and an efficient spare part management to ensure that required spare parts will be available when they are needed, at the right time and location. Another important customer requirement which need to be considered is the intended *energy dissipation* of the respective seal solution as friction losses as well as power of auxiliaries systems, which can result in considerable amount of power and yield losses over time of a tidal stream turbine. In summary, most of these customer requirements are in competition with each other and typically a compromise with the customer need to be found.



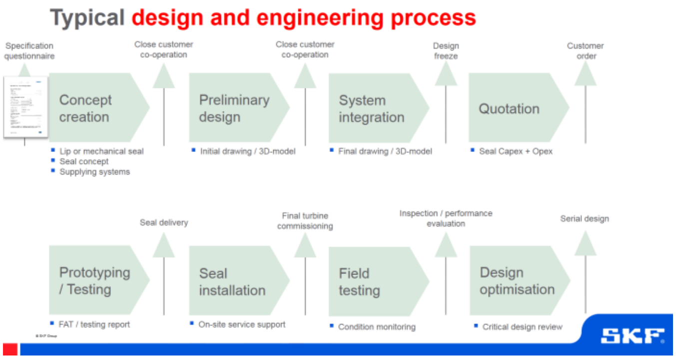
Slide 11: Typical customer requirements

As tidal streams are very location specific, the turbine operating conditions of respective installation sites can vary significantly and thereby influence the operating conditions and selection parameters of the seals, *see slide 12.*
For example, the installation depth and occurring wave height defines the min./max./nom. water pressure which the seal has to cope with. Depending on, if it will be a near or offshore installation site, the access during operation of the turbine might be very limited which will demand for highest seal reliability during maintenance intervals and also influence planned maintenance schedules. The overall turbine design which is customised to certain operating conditions provides typically further design constraints such as available installation space of the turbine nacelle or available power supply.



Slide 12: Site specific operating conditions

In order to select the right seal for each customer application, to ensure a smooth design and engineering process, and in order to manage customer expectations, the following process flow diagram provides an insight of individual design steps, *see slide 13*.



Slide 13: Typical design and engineering process

When the specification questionnaire is answered by the customer, *the initial concept will be elaborated* with key decisions to be made e.g. should a lip or mechanical seal concept be considered, how should the overall seal system be built-up and what auxiliary systems will be required. These items will be discussed and elaborated in close customer co-operation. If clarity and agreement on the main design points exists, *the preliminary design*, including initial 3D-CAD model and 2D customer drawing will be provided for further technical discussions. If further design details at this stage are clear and agreed, the final drawings will be elaborated with a following jointly agreed design freeze. Afterwards the quotation can be prepared with an expected subsequent customer purchase order. Typically in this phase, prototype and factory acceptance tests will be discussed and agreed in parallel. This is followed by the seal delivery, seal installation and commissioning, before the seal can be finally field tested in its environment it was ultimately designed and engineered for. After the defined trial testing period, the inspection is an essential part to evaluate the seal performance in order to optimise the seal solution further for serial production and deployment.

Quick, easy and proven maintenance concepts play a vital role of the overall seal concept from the beginning of the design process, *see slide 14*. For these reasons there are standard concepts available from the marine sector which can be transferred to tidal.

Typical seal features for example are lip seals which can be split and bonded during maintenance. These design features will be completed by a worldwide network of qualified service stations from SKF Marine which provide 24/7 maintenance and emergency availability.

As the ocean energy market is still in an emerging phase, there is currently a great focus on prototype validation to prove technical concepts to make them fit for commercial deployment. SKF Marine is heavily engaged in advanced developments and provides technical and service support from first prototypes to serial products.

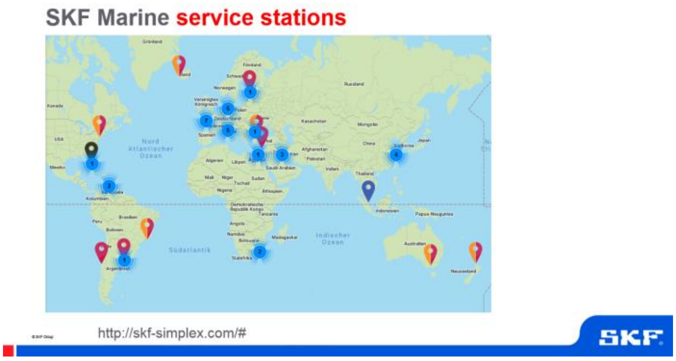
Slide 14: Maintenance concepts

In doing so, testing is a vital part of developing and optimising technologies further. At SKF Marine Hamburg, 9 test rigs are available for dynamic seal testing and seal sizes up to 1030 mm, *see slide 15*. Currently there is one seal test rig dedicated for tidal stream turbine applications for shaft diameters between 400 to 800 mm. Single components and complete lip or mechanical seal systems can be tested. Also long-term factory acceptance tests between 1000 and 2000 hours are possible. In addition, a Simplan test rig for evaluating ceramic materials for mechanical seals can be used.

In order to simulate typical tidal stream load site velocity profiles, a continuous motor speed control is available.

Slide 15: SKF Marine seal test facility

SKF Marine accompanies a tidal stream turbine throughout its entire life cycle with professional planning, regular maintenance, emergency services and quality spare parts. The comprehensive service for Simplex and Carboplan Tidal seals, ensures that a tidal stream turbine is optimally equipped and maintained for increased uptime. Our worldwide service station network is shown on *slide 16.*



Slide 16: SKF Marine service stations

REFERENCES

[1] M. Hofmann, Senior Application Engineer, SKF GmbH Germany, 2018
[2] M. Baumann, Business Development Manager, SKF GmbH Germany, 2018