Paper for AWTEC 2018

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

[#]*SKF GmbH Germany*

Gunnar-Wester-Str. 12

97421 Schweinfurt, Germany

matthias.hofmann@skf.com

Keywords:
Tidal stream turbine, drive train, bearing, seal, gearbox, engineering, calculation

I. Introduction

A correct drive train design is the foundation for a later reliable and robust horizontal tidal stream turbine. Bearings, sea water seal, gearbox, generator, etc. are key products and its prober selection and design is of extremely high importance. Engineering & application knowledge from similar ship propeller shaft and wind turbine applications is very helpful to re-use learning and reduce technical risks.

II. Abstract

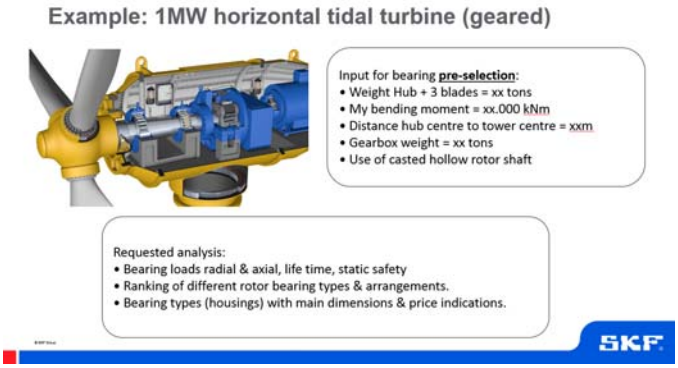
The presentation illustrates a case study what is helpful for turbine designers to get more component understanding during work out and comparison of different turbine concepts. Derived from existing wind turbines and upcoming tidal turbine, it indicates suitable rotor bearing concepts for a new geared turbine in the 1MW range.

Basic engineering working steps from first load analysis to the selection of shaft, bearing, seal, coupling, gearbox, generator and lubricant are pictured. Explanation of specific rotor bearing selection criteria's according different standards and further application specific needs are part of the presentation. Different turbine layouts are compared in different technical and commercial aspects.

The aim of the presentation is to inform and share existing drive train knowledge, re-use and further improve it. 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 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 .

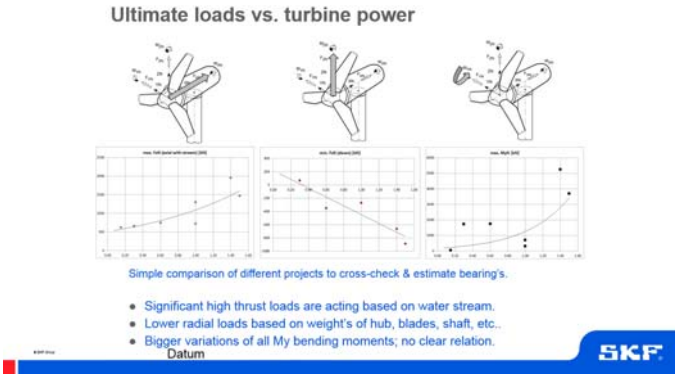
Case study: 1MW horizontal tidal stream turbine (geared)

Tidal stream turbines are located in the harshest Ocean environment as swimming platform or sub-sea grounded machines. The machine principle is based on a 2- or 3-bladed hub design, horizontal low speed rotor shaft and following gearbox/generator. During an early turbine design concept phase, first input parameters are often specified to pre-select the main components used at drive line shaft.



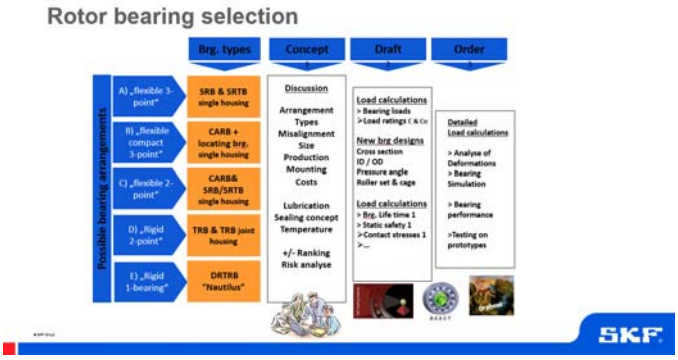
Slide 1: Example 1MW turbine design

The software "Tidal bladed" from DNV-GL seems to be the upcoming tool to simulate tidal stream operational and ultimate loads acting at the blade hub. This complex load simulations are used for further load reductions to handle and calculate bearing radial and axial loads. This load calculations forms the base for a first selection about bearing types & arrangements. Most relevant for the bearing selection according SKF experience is the thrust loads Fx produced by the ocean tidal water stream. Radial bearing loads Fz in vertical position. Often seen extreme high bending moments My who can result in bearing misalignment and edge loading inside the bearings.



Slide 2: Fx, Fz and My hub loads

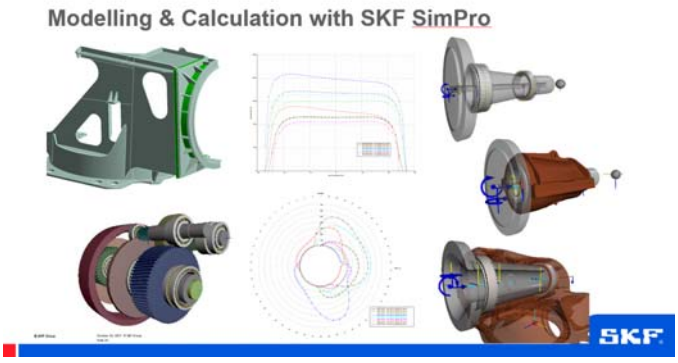
For a 1MW turbine a wider range of suitable bearing arrangements and drive train designs is possible. During the concept phase different designs A, B, C, D, E, etc. builds the base for SKF to select the most promising technical solutions based on individual customer wishes and experiences with designs before. There are different criteria's to consider by a stepwise increase of the engineering level during the project. At a later project stage, more advanced engineering software is used to work out bearing performance in detail and ensure a reliable running.



Slide 3: Bearing selection chart

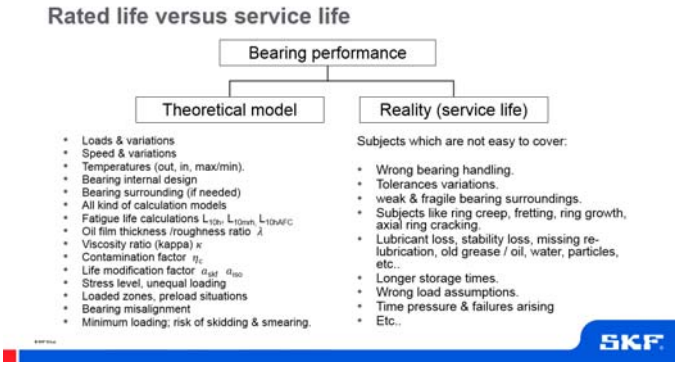
The tidal turbine and especially bearings are stressed in this new application under water. It's a challenge for the industry to develop reliable products and lubricants for an area where access to nacelles is limited and only short term experiences is partly available. There are today extreme high expectations about bearing performance and fulfilment of calculated life time. Many influencing factors, like lubricant and its contaminations, can be considered in advanced bearing calculation software tools.

There are also high efforts needed to do flexible FE calculations to optimise bearing surroundings like housing and nacelle body design. The presentation shows how this shapes bearing loads zones and stress distributions inside the bearing roller to race contact.



Slide 4: Modelling & calculation

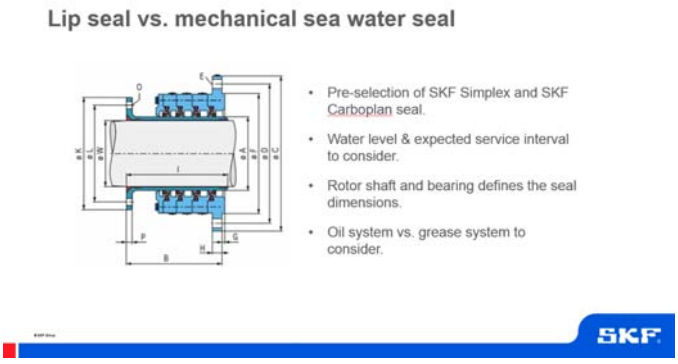
The presentation likes to inform also about limitations and often seen subjects on daily base which can negative effect the bearing life time. Learnings SKF made over the years in other segments like wind industry.



Slide 5: Bearing selection chart

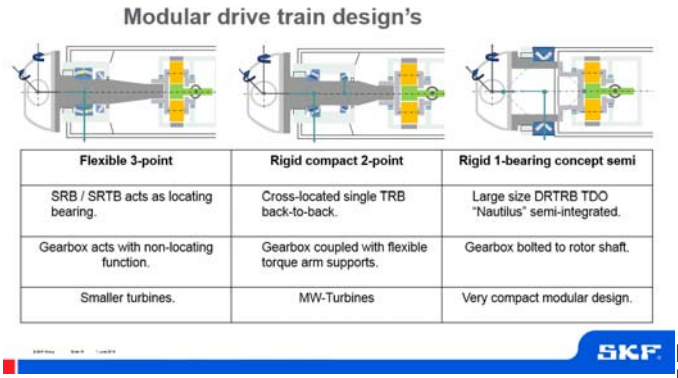
Between rotating blade hub and turbine nacelle, a complex sea water seal is needed to prevent water entry into the bearing system and its lubricant. Strength calculations of the rotor shaft in combination with the rotor bearing size selection builds the base to select the needed seal size.

Existing SKF ship propeller seals from type Simplex and Carboplan can be selected according applications conditions like water pressure and expected service interval



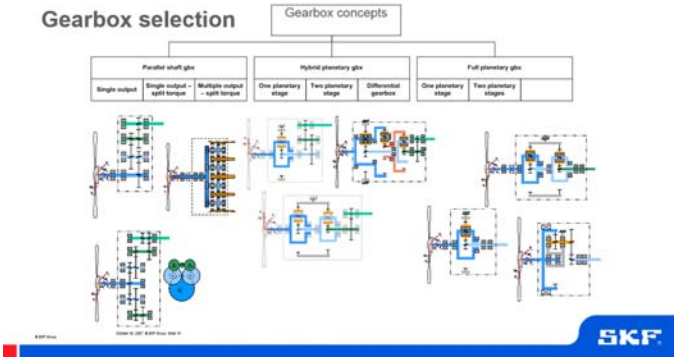
Slide 6: SKF Marine lip seal vs. mechanical seal

The presentations indicates different modular gearbox arrangements installed inside the turbine nacelle and fixed to the end of rotor shaft. The gearbox mounts and decoupling elements plays a dominant role to ensure that only drive torque Mx enters the gearbox input shaft and generator. All parasitic hub loads should be transferred via the bearings to the turbine mainframe. Pros- and cons of different design versions are pictured and explained.



Slide 7: Different geared drive train design's

There are various gearbox designs existing like parallel shaft and planetary designs or a combination of it. Most relevant concepts are introduced by principle sketches to get an overview about gear stages, possible ratios and bearing arrangements inside the box.



Slide 8: Gearbox types & selection

As an example, the gearbox planet wheel application of a 1MW gearbox is selected to inform about the way how this bearings and arrangements are calculated and designed. Learnings from the wind industry and its best bearing solutions today.

Slide 9: Gearbox planet wheel application

REFERENCES

[1] M. Hofmann, Senior Application Engineer, SKF GmbH Germany 2018

[2] M. Baumann, Business Development Manager, SKF GmbH, Germany 2018