Free Contact Angles in Pitch Bearings and their Impact on Contact and Stress Conditions

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Introduction

The pitch bearing, which connects the hub and the blades, allows the required oscillating movements of the blade. During the service life of about 20 years of a turbine the pitch bearing is loaded dynamically. In a double row four-point contact bearing, which is often used for this application [1], the described loads lead to radial and axial displacements between the inner and outer ring [2]. These displacements lead to contact angles which vary from the mounted contact angle which is given by the supplier of the bearing [3]. This divergent angles are called free contact angles. For a four-point contact bearing the mounted contact angle is $45°$. Deviations from the mounted contact angle can lead to reduced fatigue life of the bearing and increased wear arising from the modified contact behavior. Under axial loads and bending moments the contact area shift perpendicular to the rolling direction. In the worst case the contact area get truncated from the geometry of the bearing, which leads to concentrated and comparatively high stresses. The international standard for fatigue life of bearings *DIN ISO 281* [4] only uses the mounted contact angle for the calculation of bearings. Furthermore there are no results about how the free contact angles differ from the mounted contact angle in a pitch bearing of a modern wind turbine. This paper shows how the free contact angles of a double row four-point contact bearing of a modern wind turbine behaves during the service life and the effects on contact angle variations to the stress distribution.

Approach

In order to analyse the free contact angles during the service life different reference models are used, which are designed in close cooperation to the industry. The reference, state of the art wind turbine IWT 7,5 MW [5] uses modern blades and an individual pitch controller. Furthermore, the hub, blades and pitch bearings are completely designed.

Bearing geometry:

D_{pw}	*Pitch diameter*	*3900 mm*
D_w	*Ball diameter*	*60 mm*
α	*Mounted contact angle*	*45 °*
Z	*Number of balls per row*	*165*
r	*Number of rows*	*2*
$C_a(\alpha = 45°)$	*Dynamic axial loading*	*2400 kN*

The loads are calculated with the software *HAWC2* [6] and follow the provisions of *DIN ISO 61400* [7]. A few chosen design load cases are implemented in a FE-Model, to show the effects on the stress distributions.

Main body of abstract

The load dependent free contact angle α^0 can be solved numerically by the following equations (1) and (2) [3]:

$$\sin\alpha = \frac{\sin\alpha^0+\overline{\delta_r}+\Re_i\cdot\bar{\theta}\cdot\cos\psi}{\sqrt{\left[\left(\sin\alpha^0+\overline{\delta_a}+\Re_i\cdot\bar{\theta}\cdot\cos\psi\right)^2+\left(\cos\alpha^0+\overline{\delta_r}\cdot\cos\psi\right)^2\right]}} \quad (1)$$

$$\cos\alpha = \frac{\cos\alpha^0+\overline{\delta_r}\cdot\cos\psi}{\sqrt{\left[\left(\sin\alpha^0+\overline{\delta_a}+\Re_i\cdot\bar{\theta}\cdot\cos\psi\right)^2+\left(\cos\alpha^0+\overline{\delta_r}\cdot\cos\psi\right)^2\right]}} \quad (2)$$

With:

α	*Mounted contact angle*	rad
α^0	*Free contact angle*	rad
$\overline{\delta_a}$	*Annual axial Deflection*	mm
$\overline{\delta_r}$	*Annual radial deflection*	mm
ψ	*Annual angular spacing between rollers*	rad
$\bar{\theta}$	*Annual bearing misalignment angle*	rad
$\Re_i$	*Ring radius to neutral axis*	mm

All values can be determined by the given loads and reference models. Thus, an algorithm calculates the free contact angle for each discrete time step of the bearing load range. A global FE-Model of the pitch bearing shows the influence of the free contact angle on the contact area. Furthermore, differences between the numerical approach, with the assumption of ideal stiffness behavior of the components, and the FE-Model, which consider the stiffness, can be demonstrated.

Conclusion

The paper shows that the free contact angle α^0 varies from the mounted contact angle α during the service life of the turbine. Most of the time the deviations between α^0 and α are below *10*°. During extreme loads the free contact angle is greater than *65*° which lead to a truncated contact area. The investigation shows that the calculation of the dynamic loading C varies when the free contact angle α^0 is used. In such cases, according *to DIN ISO 281* [4] the radial loading C_r shall be used. Furthermore, the FE-Analyses shows the occurrence of critical stress distributions.

Learning objectives

To calculate the bearing life according to *DIN ISO 281* it would be useful to use the free contact angle. It should be discussed if other bearing geometries can weaken the deviations between free contact angle and mounted contact angle. Thus, the critical load cases should be analyzed in detail to study their impact on different damage mechanisms and the bearing life.

References

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