A Sensitivity analysis of planetary- and high speed shaft bearing loads in Wind turbines
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Abstract
Long downtime periods burden the economic efficiency of wind turbines (WT). 60% of all downtime periods are caused by gearbox failures and most of them are caused by bearing outages [1]. Planetary and high speed shaft bearing failures are responsible for more than 70% of these bearing outages [2]. The causes for these failures are frequently dynamical mechanical loads at the bearing stages. This shows that the dynamic loads at these bearing stages are yet not sufficiently well known. To analyse the influences on bearing loads at the planetary and high speed shaft stage, a sensitivity analysis with varying loads at the hub flange for pitch, yaw, drive torque and thrust is done. As additional factors different bearing clearances and shaft stiffnesses were considered. The results show, that the drive torque at the hub flange has the main influence on value, amplitude and frequency of the bearing loads of all examined factors. Further, the influence of pitch torque according the load distribution at the planetary stage is demonstrated.

Methods
The sensitivity analysis is based on a validated MBS-model which was developed at the Center for Wind Power Drives (CWD) [3]. During the first step, simulations were done to gain loads at the hub flange of the WT for real wind loads including special events such as gusts, fault ride through and emergency-stops (Figure 1:1 → 2 and Figure 2). Values, amplitudes and frequencies of the maximum hub flange loads were identified. Based on these results, the resulting bearing loads at the planetary and HSS stage were calculated with a sensitivity analysis (2 → 3). Using the detailed bearing loads and the slice model as calculation method [4], the pressure distribution along the inner and outer ring was determined (3 → 4).

Figure 1: Approach to sensitivity analysis

Results
Figure 3 shows the used Force-Elements inside the SIMPACK-Model to identify the detailed planetary bearing loads. The impact of different loads at the hub flange to radial bearing loads at the planet are presented in effect diagrams (Figure 4 and 5). Main impact on radial bearing loads has the drive torque. An increasing amplitude of the pitch torque shifts the mean of radial bearing loads at the planet from the rotor side bearing to the generator side bearing. For the shown reference model in Figure 6, the mean value of resulting bearing load is varying by 6.7% for the position at GS1, 2% at GS2, 1.5% at RS3 and 4% at RS4, depending on the load amplitude of pitch torque. Reducing half of the bearing clearance at the planetary carrier leads to less variation of resulting bearing loads by different load cases. Also reducing half of the bearing clearance of the planet leads again to a slightly higher variation of resulting bearing loads at RS1 and GS4. For all simulations with varied bearing clearance the pressure distributions at the inner ring of the planet bearings were always the highest when the radial bearing clearances of the planetary carrier and planet were halved (Figure 7).

Conclusions
The resulting bearing loads are mainly influenced by the drive torque concerning their value, amplitude and frequency. Pitch torque has an impact on the bearing pressure distribution at the planetary stage. To achieve realistic load cases for the real size planetary and HSS test rig inside the project WT-Bearing Center/NRW, the results will be used to analyse field data of WT and for further load simulations of WT.

References

Figure 2: Identification of main shaft loads

Figure 3: Force-Elements of planetary bearings inside the SIMPACK-Model

Figure 4: Planet bearing loads by static load input

Figure 5: Planet bearing loads by dynamic load input

Figure 6: Comparison of planetary bearing loads with different settings of Mpitch and different bearing clearances inside the model

Figure 7: Pressure distribution at planetary bearing for Mdrive torque = 1600 kNm, Mpitch = 500 kNm, Myaw = 200 kNm

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