Small-scale test of ball-on-curved surface contact to study fretting wear of wind turbine blade pitch bearings

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Abstract. This paper presents an experimental study of the development of a small-scale testing of ball-on-curved surface contact to investigate fretting wear damage under similar conditions of that of large-scale wind turbine blade pitch bearings. Coefficient of friction, fretting loops and wear depths under various levels of the maximum contact pressure, oscillation amplitude, with dry and lubricated conditions, are investigated.

Introduction

Blade pitch bearings are one of the critical components of large wind turbines (WTs) installed in offshore wind farms. In order to maximise energy production and to control loads induced on WT components and supporting structures, modern WT blades employ active individual pitch controls, which produce small and repetitive movements between rolling element and raceway contact surfaces of the bearing. For a 6-MW wind turbine, the diameter of a blade pitch bearing is about 6 meters to support a turbine blade of about 75 meters long. Operational maintenance, failure inspection and replacement of such large bearings in an offshore environment are extremely costly. Understanding blade bearing failure modes under WT operational conditions is important to develop the predictive maintenance strategy and to prolong the service life of blade pitch bearings, ultimately to reduce the cost of offshore wind energy.

Blade pitch bearings can be constantly subjected to oscillating movements of small and variable amplitudes. Under small oscillating movements, oscillation wear damage in the form of false brinelling and fretting corrosion have been identified as one of the critical field failure modes of the raceways of large WT blade pitch bearings. Key operating parameters associated with this failure mode of the bearing include the maximum contact pressure, oscillation amplitude, lubrication, and cycles to failure. Full-scale testing of such large bearings is very costly. Small-scale testing under similar conditions to large bearing operations provides an alternative experimental method to investigate blade bearing damage development. In this study, a small-scale test of ball-on-curved surface is developed to represent the contact and operating conditions of a WT blade pitch bearing and to evaluate frictional behaviour and wear damage accumulation.

Experimental Method and Results

The experiment of a ball in contact with a curved surface is developed to represent rolling element-raceway contact of a blade pitch bearing. Fig. 1 shows a specimen with grooves in diameter of 12 mm in contact with the ball in diameter of 9.5 mm. To represent the operating conditions of large-scale pitch bearings, oscillation amplitudes are determined by mapping the slipping ratio (X/2b) of that of the pitch bearings. Tests under different contact loads are designed to investigate the effect of the maximum contact pressure, in the range of the pitch bearings, on wear damage accumulation. Tests are conducted on Bruker's Universal Mechanical Tester (UMT). The ball is held in a ball-holder while the specimen is subjected to oscillating movements, and both dry and lubricated tests are conducted. Alicona InfiniteFocus-SL is used to capture the profile of the worn groove surface to measure the wear depth and volume after tests. Figs. 2, 3, and 4 show measured fretting loops and wear depths under different loading and oscillation conditions, with and without lubricant.

Conclusion

- Under a lower contact load of 200 N and small oscillating amplitude of 0.2 mm, the partial slip regime is observed while the amplitude of 0.4, 0.6 and 0.8 mm produce the gross slip regime.
- The partial slip regime under small amplitude oscillations leads to an increased coefficient of frication. The application of lubrication has shown to reduce the average coefficient of friction, from 0.152 to 0.1.
- The contact load tested has a more noticeable effect on wear depth compared to the effect of lubrication. Wear volume increases with the contact load, oscillating amplitude and the number of tested cycles.

Acknowledgements

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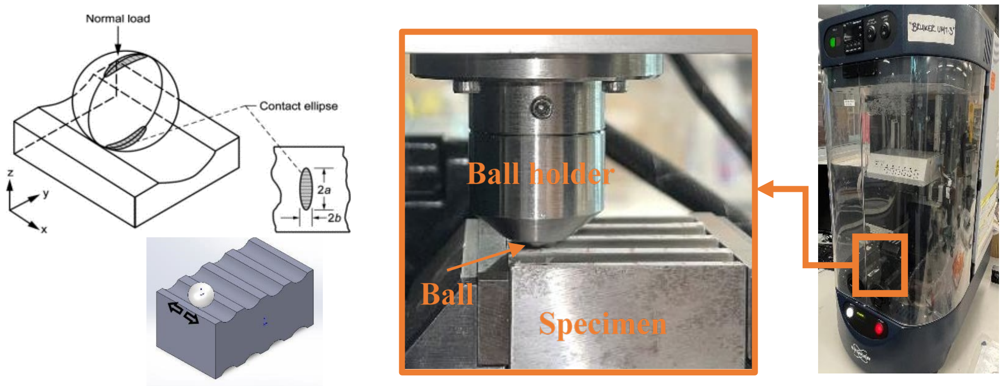

Fig.1 Ball-on-curved surface contact and test setup on Bruker's Universal Mechanical Tester

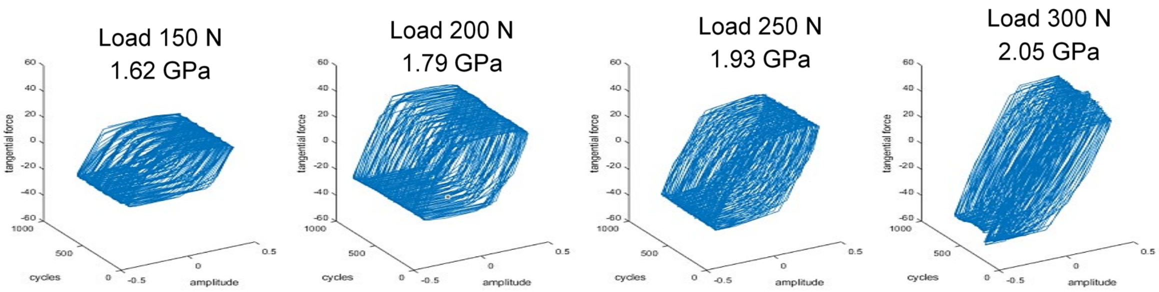

Fig. 2 Measured fretting loops under different contact loads (amplitude 0.4mm, dry, 1000 cycles).

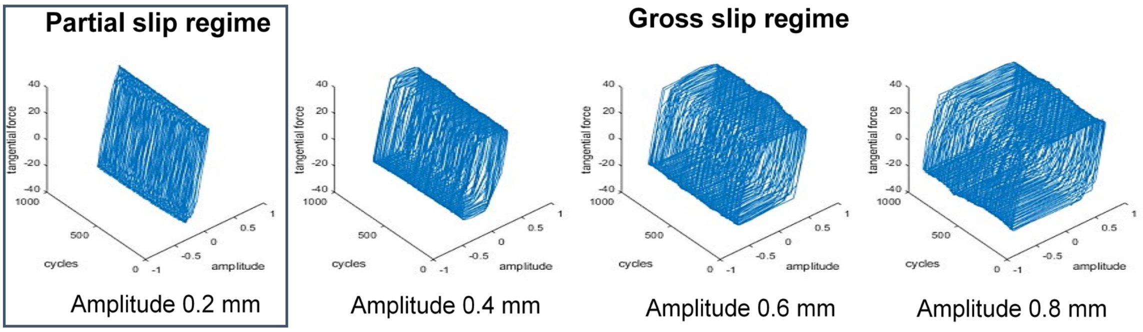

Fig. 3 Measured fretting loops under different oscillating amplitudes (Load 200N, dry, 1000 cycles).

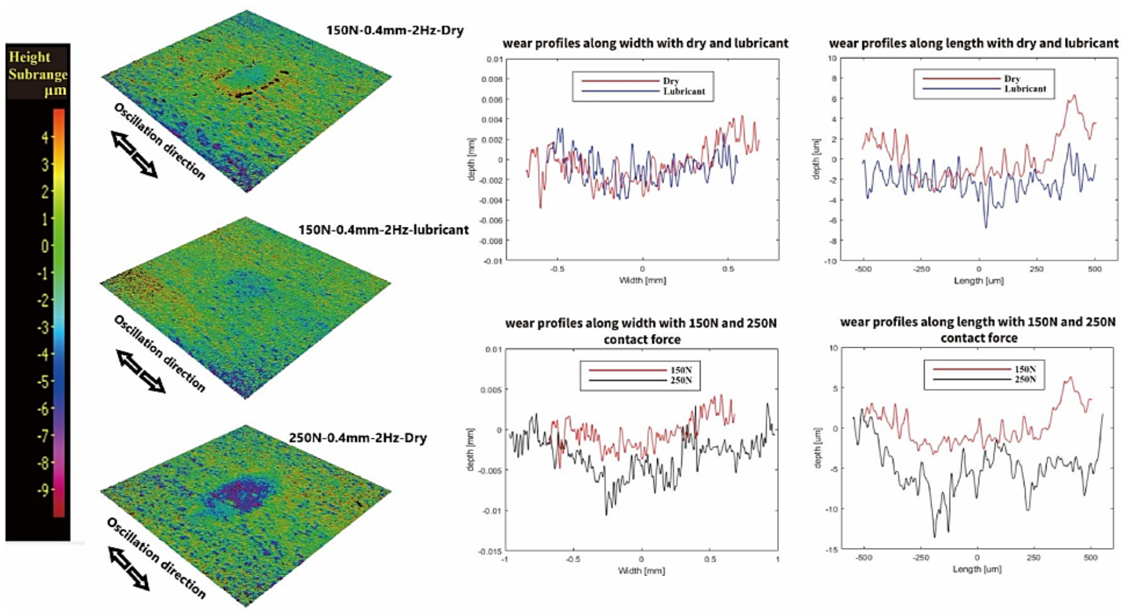

Fig. 4 Measured wear profiles under load 150 N and 250 N, dry and lubricated by SKF Lithium (1000 cycles).