Fatigue and Wear in Rolling and Sliding Contacts

The REWIND project was conceptualized to "perform strategic research at the highest level in the field of material-manufacturing-properties-performance of metallic components in the rotor and drive train in large wind turbines, with the ultimate aim of enhancing the reliability and arriving at an improved life expectancy prediction of such components." One of the focus areas of the REWIND project is to study the failure of the main bearings in a wind turbine and suggest improvements to improve their lifetime. This PhD project is focused on two areas: Lubrication and rolling contact fatigue. The main bearing supports the main shaft, which connects the rotor to the gearbox. The main bearing is a rolling element bearing containing spherical rolling elements. The loads on a main bearing are very high, which leads to a lubrication regime called elastohydrodynamic lubrication (EHL). Under the EHL regime, the pressures in the lubricant are large enough to elastically deform contacting surfaces. EHL usually occurs between the inner ring and the rolling element because the non-conformal contact leads to a high interfacial pressure. The EHL film thickness is very small, usually less than 1 micrometer. It is intended to increase the film thickness, so as to ensure there is no contact between the roller and the raceway. Under lower loads (loads less than EHL loads) it has been observed that axial grooves help to increase the film thickness at certain optimum operating conditions. It is believed that these grooves act as reservoirs of lubricant and can emit excess lubricant to increase the film thickness. However, the performance of these grooved surfaces has not been studied under EHL loads. So in this Ph.D. project, rolling-sliding, lubricated tests are performed to study the tribological behaviour of axially grooved rings under EHL loads. Multigrid models simulating the rolling of a single grooved surface against an infinite half-plane are coded. The results from this model are used to explain certain experimental results. The results show that under EHL loads, the grooves do not appear to prove beneficial in improving the film thickness. They might improve the film thickness at certain optimum running conditions, but it is tough to ascertain what those conditions are. The main bearings also undergo rolling contact fatigue failure. The main bearing experiences premature fatigue failure in both onshore and offshore wind turbines. Their failure is characterized by the formation of nanosized ferrite grains called white etching areas (WEAs). These grains surround the fatigue cracks and turn white when etched with Nital. Hence they are named White Etching Areas. It has also been proven in past studies that under high temperatures and pressures, lubricants can react with a fresh steel surface to decompose and generate hydrogen gas. So it is assumed that hydrogen is generated when the lubricant in a main bearing reacts with the steel surface. This hydrogen then enters the steel surface and causes embrittlement. To study the fatigue failure of these bearings, it was decided to replicate these failures in the lab. So a test rig was built to conduct lubricated RCF tests on 100Cr6 bearing steel rings. The loads applied were similar to those experienced by the main bearing in a wind turbine. Hydrogen is infused into the steel ring by immersing the ring in a solution of aqueous ammonium thiocyanate. The tests are then run until the rings crack. Once the rings have cracked, they are etched and observed under a microscope. The results show that White Etching Cracks (WECs) can be simulated using the test rig. The main bearings are usually press-fit onto the main shaft to ensure a tight fit between the inner ring and the shaft. This press-fit introduces a tensile hoop stress and a compressive radial stress on the inner ring. To simulate this on the test rig, the steel ring specimens are press fit onto the shaft introducing tensile hoop stresses. The effect of two values of tensile hoop stress on the fatigue life of the bearing is studied. It is observed that the fatigue life decreases as the tensile hoop stress is increased.

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