

## Research on the electrochemical mechanisms of tribo-corrosion damage at the lubricant/metal interface under high dynamic load conditions

Xu Wang, Zehua Dong\*

(*School of Chemistry and Chemical Engineering, Huazhong University of Science and Technology, Wuhan, Hubei 430074, China. E-mail: [zehua.dong@gmail.com](mailto:zehua.dong@gmail.com)*)

China's offshore wind energy reserves are substantial, with the world's leading offshore wind power installed capacity. However, offshore wind power installations are predominantly located in coastal areas with high humidity and salt spray, where wind power facilities are exposed to the marine atmospheric environment for extended periods. This exposure leads to contamination of lubricants, accelerating the aging and deterioration of the lubricant, thereby hastening the wear and corrosion of bearings and gear workpieces. The synergistic effect of wear-resistant materials in mechanical and chemical media significantly reduces their service life, and gearbox failures or damage due to unit downtime are not uncommon. Friction and wear-induced corrosion have become key issues affecting the safe operation of offshore wind power, necessitating a deeper understanding of lubricant failure mechanisms and the friction and corrosion mechanisms of bearing materials in oil-phase media. This knowledge aids in the formulation of reasonable preventive measures and the regular replacement of lubricants.

Zeng et al. investigated the corrosion behavior of M50 steel in brine-contaminated lubricating oil by immersing the steel in such lubricants and comprehensively characterizing localized corrosion areas on its surface. However, their study was conducted under static conditions, neglecting the synergistic effects of friction and corrosion in actual operating conditions, and it lacked an in-situ characterization method to understand the tribo-corrosion mechanisms of rolling bearings. Electrochemical methods, with their fast response speed, low cost, and ability to obtain data quantitatively at regular intervals, are advantageous. However, due to the lower conductivity in oil-phase systems compared to aqueous media, electrochemical signals are weaker, and specialized device and method designs are often required. Yu et al. developed a ball-disc mini-traction tester and utilized a ball-disc two-electrode electrochemical testing system to analyze the oil film at different rotational speeds, establishing the capacitive and impedance behavior and the relationship between impedance and oil film thickness. Nonetheless, the non-ideal two-electrode system used in their method is limited to electrochemical testing of pure oil phases and poses a risk of short-circuiting in brine-contaminated system.

In this work, we designed a tribo-electrochemical device, as shown in Figure (a), for the study of tribo-corrosion process of steel in brine-contaminated lubricants. The electrochemical impedance spectroscopy results, as depicted in Figure (b), indicate that during the tribo-corrosion process, a water-in-oil emulsion is formed, reducing the corrosivity and increasing the capacitive loop over time. Conversely, when the tribo-corrosion process ceases, brine water deposition leads to increased corrosivity and a decrease in the capacitive radius over time in Figure (c).

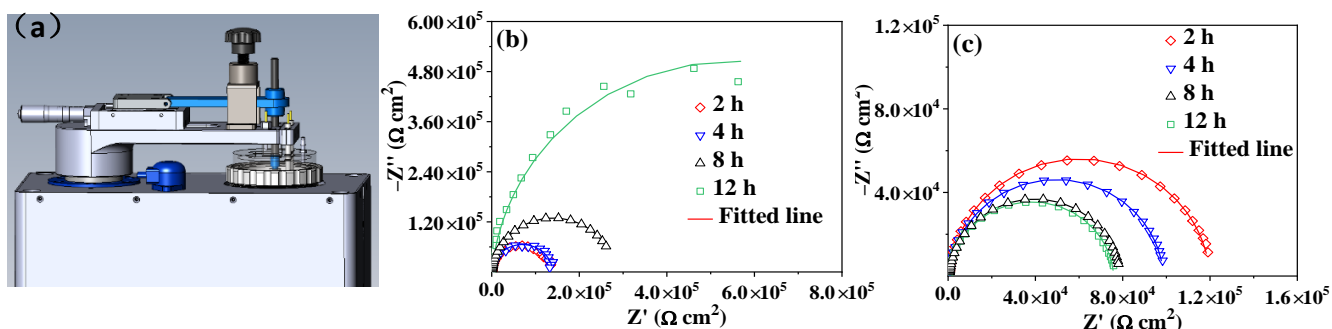


Figure: (a) Schematic diagram of the tribo-electrochemical test device, Nyquist diagram of PAO oil with 0.5% (v/v) NaCl solution added (15 N-100 rpm) under (b)dynamic and (c) static conditions