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Unvealing tribocorrosion mechanisms in CO2 anoxic environments: Insights from carbon steels and corrosion-resistant alloys

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Tribocorrosion in CO2 in anoxic environments remains poorly understood, despite its relevance in critical sectors such as oil and gas, geothermal energy, and carbon capture and storage (CCS). While CO2 corrosion mechanisms of metals have been widely researched over the past decades, the additional influence of sliding motion on surface degradation and tribocorrosion wear has received limited attention. Most of the existing studies dealing with CO2 tribocorrosion focus on erosion-corrosion due to particle impingement, while the effects of tribological loading in CO2-saturated media remain largely unaddressed.

The present work reveals the degradation mechanisms induced by sliding motion in CO2-containing aqueous environments, focusing on low-carbon steels, corrosion-resistant alloys, and Ni-based coatings. In case of low-alloyed carbon steels, CO2 corrosion leads to the formation of iron carbonate scales that partially protect the substrate by limiting diffusion of CO2. However, sliding disrupts this scale, producing the formation of a complex microstructure characterized by the presence of nanocrystalline grains, localized corrosion and compacted corrosion products. This microstructure ultimately leads to crack propagation and delamination. In corrosion-resistant alloys, sliding causes a cathodic shift in open circuit potential (OCP), indicating depassivation by rupture of the passive film, whereas in Ni-based cermets coatings the OCP remains stable suggesting no changes in electrochemical properties of the wear track. Surprisingly, Ni–P coatings show under sliding a potential shift towards anodic values, suggesting ennoblement of the wear scar.

These findings highlight the complex interplay between electrochemical and mechanical processes in CO2 anoxic environments. Standardized testing approaches based on either wear or corrosion alone may lead to misleading material selection. A more integrated tribocorrosion approach is essential to ensure long-term performance and safety.

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