Erosion-Corrosion Wear of Heat-Exchanger Materials by Water/Ethylene-Glycol/Alumina Nanofluids

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ABSTRACT

Nanofluids are suspensions of nanoparticles in ordinary coolants, but their tribological effects on heat-exchanger materials are unknown. Previous research has explored wear from distilled-water-base nanofluids only, while most engine-coolants are alcohol solutions in water. This article presents testing of aluminum and copper by jet impingement of 50%-ethylene-glycol in water solution and of its 2%-alumina nanofluid. The effects are investigated of nanoparticle addition on the anticorrosion protection provided by ethylene glycol. The observed modifications showed that ethylene-glycol in water nanofluid led to wear patterns that were different than those obtained with the base-fluid; nanoalumina addition enhanced erosion and corrosion on aluminum and copper. Comparing the effects of ethylene glycol and its nanofluid solutions to those from same tests performed with distilled-water and its nanofluid suggests that nanopowders can substantially enhance wear by decreasing the anticorrosion action of ethylene glycol by a synergetic mechanism of erosion-corrosion

KEYWORDS


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INTRODUCTION

Nanofluids are nanoparticle-in-liquid suspensions (of up to 5% of nanoparticles, of size between 10 to 100 nm) that are mainly studied for their abnormal thermal transport properties (Younes, 2015). Metal oxides nanoparticles (as alumina, copper oxides, silicon oxide, silicon carbide and titanium oxide) show higher thermal conductivity, very large surface to volume ratio, and higher mobility. It is believed these nanoparticle features give enhanced heat-transfer properties when added to ordinary cooling fluids (Eastman, 2001). Potential nanofluid applications are in cooling of power and nuclear systems, engine radiators, microchips, grind operations (Withanara, 2013) and as heat-exchange fluids for solar collectors (Hussein, 2017). But there is little knowledge of the possible long-term tribological impact (i.e., enhanced erosion, wear and corrosion effects) on heat-exchanger materials if nanofluids are to be used to replace traditional coolants. This study aims to elucidate the tribological effects on typical materials of a nanofluid of 2%-nanoalumina added to a traditional coolant, the 50% ethylene glycol in water. This research work is, to the author’s extent of knowledge, the first comprehensive tribology study of ethylene-glycol coolant nanofluids.

BACKGROUND

Early research on nanofluid tribology was conducted by Roubort et al (2008) and by Singh (2009) at the US Dept. of Energy. Their works suggested that no significant surface changes would occur to aluminum 3003 samples when jet-impacted for 750 hours by the tested nanofluid. They employed the nanofluids of SiC-in-water, and of Cu- and Al-oxides in ethylene- and trichloroethylene-glycol with 2%-added nanopowders. Test velocities were of 8 to 9 m/s and impact angle of 30°; the extrapolation of that limited material-removal data would predict an erosion rate as low as 0.065 milligrams/year if such nanofluids were employed in vehicle-radiators.

Nguyen et al (2008) later found, however, that a significant total mass-loss can be obtained from aluminum specimens subjected for 180 hours to a 9.6m/s jet-impingement of a 5% alumina-in-water nanofluid. Celata et al (2011, 2014) tested the jet-impingement effects on aluminum, copper, and stainless steel by the nanofluids of TiO2, Al2O3, and ZrO2 (each at 9% concentration) in distilled water. They compared the measured material-removal rates (by profilometer scanning) to those obtained when the same materials were impacted by water-only jets. Significant material-removal differences were measured on aluminum targets for the TiO2, Al2O3, and ZrO2 nanofluids, while for copper such surface modifications occurred only when treated with the ZrO2 nanofluid. They observed no differences in material removal for stainless steel. Those test strongly suggested that nanofluids impact on aluminum and copper surfaces could lead to higher erosion rates than those obtained by distilled water only. George et al (2014) presented the erosion effects on aluminum and cast iron of a 0.1%-TiO2 in distilled water nanofluid. They conducted tests for up to 10 hours of jet-impingement at 5m/s and 10m/s and for varied impingement angles. They
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