International Journal of Surface Engineering and Interdisciplinary Materials Science
Volume 5 • Issue 2 • July-December 2017

Design and Testing of a Jet-Impingement Instrument to Study Surface-Modification Effects by Nanofluids

Gustavo J. Molina, Department of Mechanical Engineering, Georgia Southern University, Statesboro, GA, USA
Fnu Aktaruzzaman, Department of Mechanical Engineering, Georgia Southern University, Statesboro, GA, USA
Valentin Soloiu, Department of Mechanical Engineering, Georgia Southern University, Statesboro, GA, USA
Mosfequr Rahman, Department of Mechanical Engineering, Georgia Southern University, Statesboro, GA, USA

ABSTRACT

The growing research interest on nanofluids, the suspensions of nano-size powders in ordinary fluids with enhanced cooling properties, has led the authors to study surface modifications (i.e., possible erosion-corrosion effects) from nanofluid interactions with typical heat-exchanger materials. This article discusses existing instruments and the rationale for designing a new ad-hoc test rig using jet-impingement at speeds from 3.5 m/s to 35 m/s. Preliminary tests used typical nanofluids—2% volume alumina-nanopowder in water—which were jet-impinged at 15.5 m/s speed on aluminum and copper specimens. The instrument, methodologies and assessment tools proved to be appropriate to test for the nanofluid interactions with material surfaces. The studied surface modifications, which were assessed by roughness measurements, weighing for removed-material, and optical-microscopy, suggest that addition of nano-powders can lead to patterns of erosion-corrosion that are substantially different than those typically obtained from base fluids.

KEYWORDS

Corrosive Wear, Erosion Test, Erosive Wear, Nanofluid, Tribo-Corrosion,

DOI: 10.4018/IJSEIMS.2017070104

INTRODUCTION

Nanofluids are colloidal suspensions of nano-size-powders (1 nm to 100 nm) in a base fluid that are studied for their potential as enhanced alternatives to ordinary cooling fluids. The first reference to nanofluid enhanced heat-transport properties were reported by Masuda et al (1993) and Choi et al (1995). Since then nanofluids have evolved (Singh, 2008) as typically mixtures of solid metal nano-particles (as alumina, silica, titanium dioxide and copper oxide of up to 5% of nanoparticles), of carbides and nitrides, and of carbon nanotubes or nanofibers in cooling fluids (as water, and its solutions with alcohols). Nanofluids are predicted to have higher thermal conductivity and heat transfer coefficient than those of the base fluids, because of the solids much larger thermal conductivity, and of nanoparticles much larger surface-to-volume ratio and higher mobility (Yu, 2008). Therefore, nanofluids are a promising alternative as coolants for critical-cooling systems, as advanced nuclear systems (Buongiorno, 2006), large engine radiators, and microchip cooling (Wong, 2010). For instance, a computational simulation of ideal nanofluid cooling in a Cummins 500hp diesel engine showed that radiator size could be reduced by 5% (Saripella, 2007). Recently M'hamed et al (2016) reported experimental increases of up to 196% for maximum heat transfer coefficient by a 0.5% nanoparticle volume concentration of multi-walled carbon nanotubes in water/ethylene glycol coolant in an actual radiator system.

However, many concerns remain about the practical applications of nanofluids, mainly because of their potential corrosion-erosion effects on cooling-system material surfaces. Addition of solid particles in flowing fluids is known to lead to higher erosion rates on conduit materials, but the effect of adding smaller size ones, as nanoparticles (1nm-100nm) are largely unknown. Use of nanofluids instead of conventional cooling fluids requires a better understanding of their likely wear/erosion and corrosion effects. Solid-contact models (derived from contact-mechanics theory) are not appropriate to assess the erosion rates from multiple particles which occur in actual application purposes. Early work on the study of multiple macroscopic-particle impact and erosion was carried out by Brainard and Salik (1980) for annealed copper and aluminum erosion produced by both single- and multiple-particle impacts of 3.2-millimeter-diameter steel balls in air at up to 140 m/s; their results agreed with findings of Cousens and Hutchings (1983). Rao and Buckley (1983) investigated erosion and morphology of 6061-T6511 aluminum alloy when treated by normal impingement-jets of a mix of spherical glass beads and angular crushed-glass particles. They showed that the time evolution for gas-jet erosion involved an "incubation period", an acceleration-deceleration period, and a final steady state period, and they correlated the length of incubation and acceleration periods with decreasing particle impact-velocity.

The work of Gee and Hutchings (2002) describes the four common "dry-type" erosion test systems (e.g., gas jet; centrifugal accelerator; wind tunnel; and whirling arm tests) and includes a discussion on the important variables (as particle impact velocity, particle impact angle, particle size, shape and material, and ambient temperature). The ASTM G76 - 07: "Standard Test Method for Conducting Erosion Tests by Solid Particle Impingement Using Gas Jets" (ASTM, 2007) covers testing of material loss by solid particle impingement with gas-carrier jet-type erosion equipment. There is abundant data from these particle-in-gas-jet erosion tests of metals (including

17 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage: www.igi-global.com/article/design-and-testing-of-a-jet-impingement-instrument-to-study-surface-modification-effects-by-nanofluids/192114

Related Content

EDM Process Parameters Optimization for Al-TiO2 Nano Composite
Arvind Kumar Dixitand Richa Awasthi (2015). *International Journal of Materials Forming and Machining Processes (pp. 17-30).*
www.irma-international.org/article/edm-process-parameters-optimization-for-al-tio2-nano-composite/130696

Corrosion Behaviour of Metallic Biomaterials in Physiological Environments
Rakesh Pani, Rasmi Ranjan Beheraand Sudesna Roy (2023). *Handbook of Research on Corrosion Sciences and Engineering (pp. 246-273).*
www.irma-international.org/chapter/corrosion-behaviour-of-metallic-biomaterials-in-physiological-environments/323402

Fabrication and Tribological Properties of Al-Si/B4C Metal Matrix Composites
Sadineni Rama Rao, G. Padmanabhanand P.V. Chandra Shekar Rao (2014). *International Journal of Surface Engineering and Interdisciplinary Materials Science (pp. 74-84).*
www.irma-international.org/article/fabrication-and-tribological-properties-of-al-sib4c-metal-matrix-composites/113284

Hardness of Duplex Treated Stainless Steel: Influence of the Architecture and Composition of Films
Umm-i-Kalsoom, Nisar Ali, Narjis Begum, Ali Hussnainand Riaz Ahmad (2018). *Production, Properties, and Applications of High Temperature Coatings (pp. 447-466).*
www.irma-international.org/chapter/hardness-of-duplex-treated-stainless-steel/196378

Virtual Environments in Materials Science and Engineering: The Students' Opinion

D. Vergara, M. Lorenzoand M.P. Rubio (2017). *Materials Science and Engineering: Concepts, Methodologies, Tools, and Applications (pp. 1465-1483).*
www.irma-international.org/chapter/virtual-environments-in-materials-science-and-engineering/175748