EROSION-CORROSION OF HEAT-EXCHANGER MATERIALS BY WATER/ETHYLENE-GLYCOL/ALUMINA NANOFLUIDS

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ABSTRACT

The tribological effects of nanofluids, the suspensions of nanoparticles in ordinary coolants, on heat-exchanger materials are largely unknown. Previous research explored wear on heat-exchanger materials from distilled-water-base nanofluids only, while most engine-coolants are alcohol solutions in water. In this research work the authors tested of aluminum and copper by jet impingement of 50%-ethylene-glycol in water solution and of its 2%-alumina nanofluid. The observed modifications showed that such nanofluid led to wear patterns that were different than those obtained with the base-fluid. Same tests also were performed with distilled water and its nanofluid as references. The results suggests that nanopowders can substantially enhance wear by decreasing the anticorrosion action of ethylene glycol by a synergetic mechanism of erosion-corrosion.

NEW TEST INSTRUMENTS TO ASSESS TRIBOLOGICAL EFFECTS OF NANOFLUIDS

Previous research by the authors [1-2] showed that long test times and a wide range of jet speeds were needed to investigate tribological effects of nanofluids by jet-impingement; the authors first developed a new multiple nozzle test-rig [3]. Figure 1 shows a schematics and a photograph of the first developed test rig. This instrument comprises eight nozzles of same dimension. On the lower jet-speed (3.5 m/s) side, each one is fed by a pump, while in the higher jet-speed (5-35 m/s) side all nozzles are fed by a high pressure centrifugal impeller pump; full instrument specification were presented in [3]. Tested fluid is recirculated by the instrument pump during each test. Further instrument specification are presented in [3]. The author's also developed a new through-flow test-rig, shown in Figure 1 (right image), which resembles the typical fluid/material interaction in pipe-type heat-exchangers, because the specimen surfaces are placed parallel to the fluid-flow and inside a conduct. Figure 2 shows schematics and photograph of the through-flow test rig. The instrument is fed by a recirculation pump (of 1m/s-speed flow). Further instrument specifications are presented in [4].

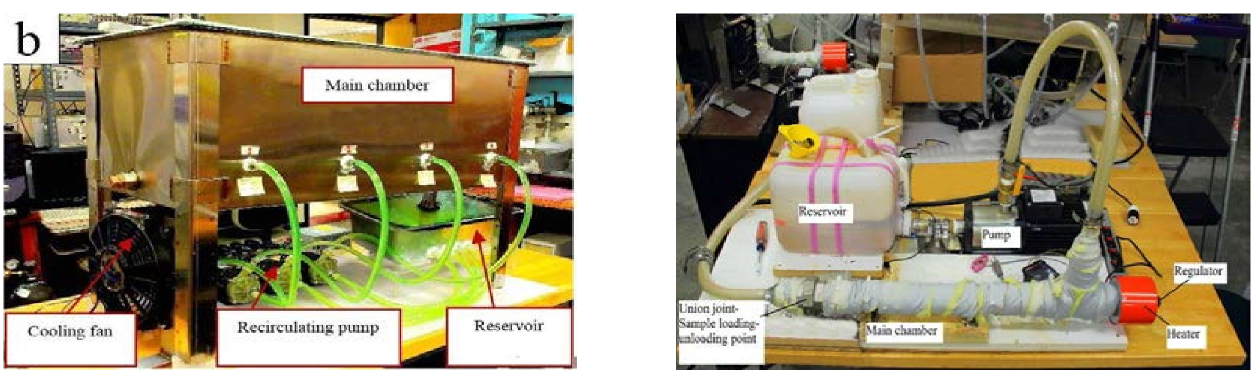

Figure 1. Jet-impingement (left image) and through-flow test-rig (right image) for testing of nanofluids effects [3-4]

METHODOLOGY AND SELECTED EXPERIMENTAL RESULTS

Results obtained by the use of the developed jet-impingement rig and of the through-flow rig were presented and discussed by the authors in [3-4], results here are extensively presented and discussed in [5]. The tests employed either distilled water or a mixture of ethylene glycol in water as reference fluids, and the nanofluid suspensions obtained by adding a 2% volume of alumina nanoparticles in those reference fluids. Jet-impingement tests were carried out for 3, 7, 14, 28, 56, 112, 240, 312 and 408 hours for each of the two fluids (while in the sequence of 3 to 112 hours for through-flow tests), for constant distance from nozzle to target of 1 inch (25.4mm). Materials were copper 110 and 3003-T3 aluminum alloys (polished to a Ra roughness not greater than 5 μinch).

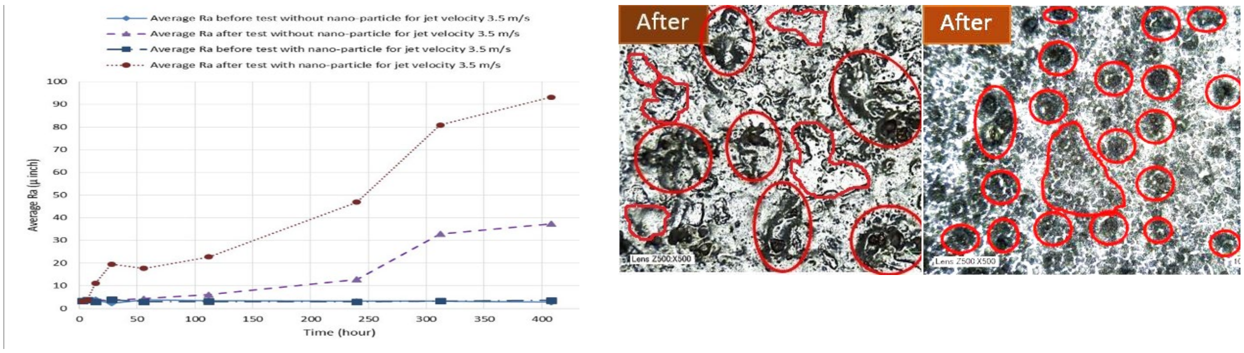

Figure 2. Jet-impingement tests: Ra roughness for 3003-T3 aluminum before and after 3, 7, 14, 28, 56, 112, 240, 312 and 408 hour-treatments with distilled water, and with its nanofluid of 2% nano-alumina and optical microscopy images (Magnif:5000X) for 408 hour-test (left image: after test with nanofluid; right image: distilled water only) . Jet-speed speed 3.5m/s.

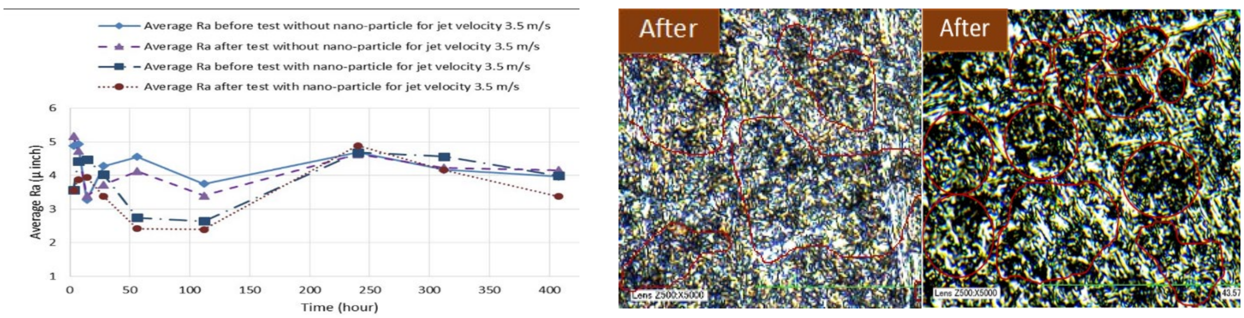

Figure 3. Jet-impingement tests: Ra roughness for 3003-T3 aluminum before and after 3, 7, 14, 28, 56, 112, 240, 312 and 408 hours with 50/50% Ethylene Glycol in water (EG/w), and with its nanofluid of 2% nano-alumina and optical microscopy images (Magnif:5000X) for 408 hour-test (left image: after test with EE/w nanofluid; right image: EG/w). Jet-speed speed 3.5m/s.

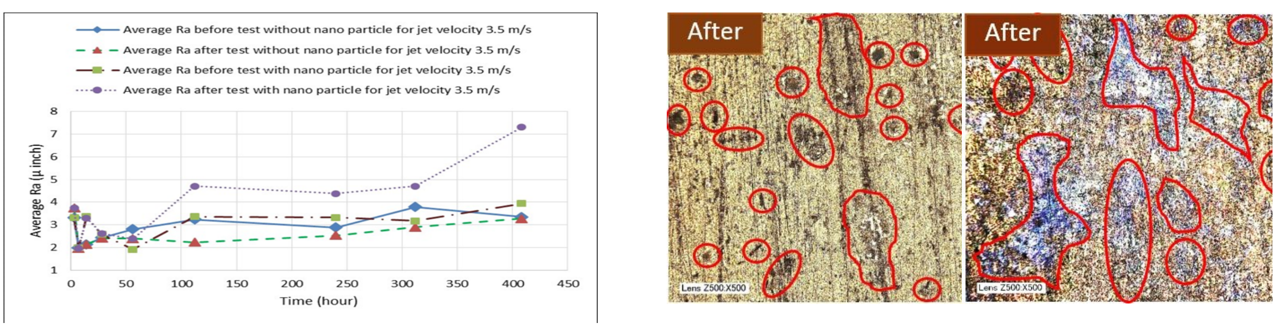

Figure 4: Average Ra for copper 110 after 3, 7, 14, 28, 56, 112 and 408 hour-treatments with distilled water, and its nanofluid of 2% nano-alumina, and optical microscopy images (Magnif.:500X) before and after test of 408 hour-test (left image: after test with nanofluid; right image: distilled water only). Flow speed 3.5 m/s.

Figures 2 to 4 present typical results from jet-impingement tests; assessment was carried out by pre- and post-test roughness measurements, optical microscopy observations, and weight-change (non-significant) measurements. While significant roughness changes and differences were observed on aluminum for distilled water and for its nanofluid (in Figure 2), roughness changes were non-significant (in Figure 3) for 50/50%

Ethylene Glycol in water (EG/w), or its nanofluid of 2% nano-alumina. But optical microscopy revealed in both Figures 2 and 3 that significant surface erosion occurred for all of the tested fluids. Similar results (but for lower level of surface modification for same fluids and test durations) occurred for copper specimens in Figure 4.

DISCUSSION AND CONCLUSIONS

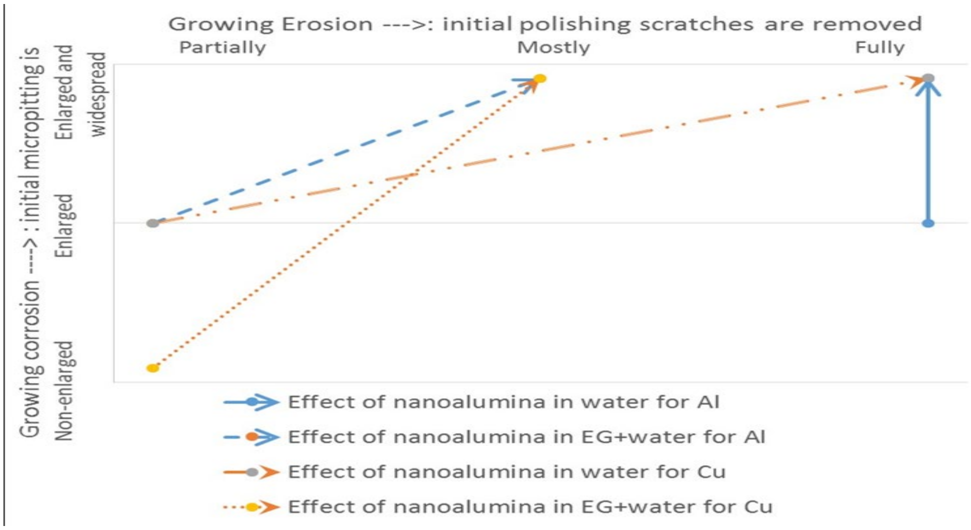

Figure 5. Evolution of erosion and corrosion effects (as assessed, respectively, by microscopy-image removal of initial polishing-scratches and enhancement of initial micro-pitting) from 2%-nanoalumina addition in each coolant fluid (water and 50% ethylene glycol in water) jet-impinged on aluminum 3003-T3 and copper alloy110.

The erosion-corrosion plot of Figure 18 graphically summarizes the observed evolution for both erosion and corrosion effects (as assessed, respectively, by removal of initial polishing-scratches, and by enlargement of initial micro-pitting) from the actions of each fluid as compared to those of each corresponding nanofluid, on both aluminum and copper; each arrow graphs the changes observed for the erosion and corrosion effect, where the initial point of arrow represents the effects of base-fluid (without nanoparticles), and each end of arrow corresponds to the effects of 2%-alumina nanofluid. Figure 5 reveals that addition of nano-alumina may increase corrosion in all cases (e.g., for the two jet-impinged fluids on the two materials), and that such increases were particularly noticeable in the case of copper subjected to the nanofluid of EG/w. Erosion of aluminum is high when treated with distilled water and with its nanofluid, while grows from moderate to medium erosion when nano-alumina is added to the EG/w fluid. Erosion of copper is moderate when tested for both base fluids, but it is enhanced when nanofluids are used (by growing from moderate to medium erosion when nanoalumina is added to distilled water, and by increasing to high erosion when the nanopowder is added to EG/w).

The designed test-rigs and surface assessment techniques showed appropriate to obtain significant results in reasonable times. The effects of nanofluids where studied in tests for two materials (Al and Cu), and for water, and water plus Ethylene Glycol, and its nanofluids of 2% of alumina nanopowder. Results suggest significant erosion and wear effects from nanofluid action, as compared to those effects from the reference fluids.

References

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