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Sub-micron dispersions of sand in water prepared by stirred bead milling and ultrasonication: A potential coolant

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ABSTRACT

Sub-micron dispersions of 'sand in water' have been prepared by stirred bead milling of the micron-sized sand particles, followed by probe ultrasonication. The dependence of dispersion viscosity and thermal conductivity on particle volume concentration has been studied. The influence of ultrasonication on the above transport properties has also been investigated. An estimated 4% and 10% increase in heat transfer coefficient may be obtained under turbulent and laminar flow conditions respectively by utilizing these dispersions as coolants. Further experimental studies in heat exchangers are required to ascertain the suitability of these dispersions for cooling applications.

1. Introduction

Heat exchangers form integral part of food, pharmaceutical, mineral, power and petrochemical industries. These are used for preheating of raw materials, cooling of reaction products, recovery of heat from exhaust hot streams etc. Water is the most widely used coolant for majority of cooling applications. The potential of improving the thermal conductivity of liquids through addition of solid particles was realized in late 19th century, following which several theoretical and experimental studies were carried out using millimeter/micrometer sized particles as additives [1]. Such suspensions tend to settle quickly rendering them unsuitable for real time applications. Settling can be avoided through the use of particles in the nanometer range such that the effect of gravity is less. One of the results of such an attempt is nanofluids which are colloidal dispersions of nanoparticles in a liquid [2]. Enhancement in thermal conductivity has been observed due to addition of nanoparticles to common coolants and compilation of such thermal conductivity data is available in literature [3–9].

Compared to numerous studies and reviews on the thermal conductivity of nanofluids, studies on viscosity of nanofluids are less. This could probably be attributed to the fact that the most intended application of nanofluids is in thermal management where thermal conductivity enhancement is considered to be more important. Nanofluids may be prepared by either one-step method or two-step method [7]. In one-step method, nanoparticles are produced and dispersed simultaneously into a base fluid [7]. Two-step methods involve preparation of nanoparticles as the first step, followed by their dispersion in a base fluid as the second step [7].

The important characteristics of a nanofluid for heat transfer application are (i) enhanced thermal conductivity (ii) reproducible enhancement in thermal conductivity (iii) colloidal stability during heating and cooling operations and (iv) low penalty on pressure drop. Hence any colloidal dispersion with the above characteristics may also be used as coolants. This work is an attempt to develop such sub-micron dispersions from sand through stirred bead milling, providing a variant of two-step method. A comparison of transport properties (thermal conductivity and viscosity) of these dispersions with that of nanofluids has been made to explore the suitability of these dispersions for heat transfer applications. To the best of author's knowledge, transport properties of sub-micron dispersions of sand in water produced by stirred bead milling for the purpose of use as coolant have not been reported. An assessment of potential enhancement in heat transfer coefficient for laminar and turbulent flows has been performed using few available correlations and the transport property data measured.

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