Renewable and Sustainable Energy Reviews 53 (2016) 779–791

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Rheological behaviour of nanofluids: A review

Anuj Kumar Sharma [a,*], Arun Kumar Tiwari [b], Amit Rai Dixit [a]

[a] Department of Mechanical Engineering, Indian School of Mines, Dhanbad 826004, India
[b] Department of Mechanical Engineering, Institute of Engineering & Technology, GLA University, Mathura 281406, India

ARTICLE INFO

Article history:
Received 1 October 2014
Received in revised form
30 June 2015
Accepted 17 September 2015

Keywords:
Nanofluids
Nanoparticles
Rheological behaviour
Newtonian
Non-Newtonian
Viscosity
Pressure drop

ABSTRACT

A colloidal mixture of nanometre-sized (< 100 nm) metallic and non-metallic particles in conventional fluid is called nanofluid. Nanofluids are considered to be potential heat transfer fluids because of their superior thermal and tribological properties. In recent period, nanofluids have been the focus of attention of the researchers. This paper presents a summary of a number of important research works that have been published on rheological behaviour of nanofluids. This review article not only discusses the influence of particle shape and shear rate range on rheological behaviour of nanofluids but also studies other factors affecting the rheological behaviour. These other factors include nanoparticle type, volumetric concentration in different base fluids, addition of surfactant and externally applied magnetic field. From the literature review, it has been found that particle shape, its concentration, shear rate range, surfactant and magnetic field significantly affect the rheological behaviour of any nanofluid. It has been observed that nanofluids containing spherical nanoparticles are more likely to exhibit Newtonian behaviour and those containing nanotubes show non-Newtonian flow behaviour. Furthermore, nanofluids show Newtonian behaviour at low shear rate values while behave as non-Newtonian fluid at high shear rate values. Authors have also identified the inadequacies in the research works so far which require further investigations.

© 2015 Elsevier Ltd. All rights reserved.

Contents

1. Introduction . . . 779
2. Rheological behaviour of nanofluids . . . 786
   2.1. Newtonian and non-Newtonian behaviour of nanofluids . . . 786
   2.2. Rheological behaviour of ferrofluids . . . 786
   2.3. Effect of surfactants on rheological behaviour of nanofluids . . . 786
3. Conclusions . . . 786
4. Recommendations for future work . . . 789
References . . . 789

1. Introduction

Conventional fluids, such as, mineral oils, have excellent lubrication properties but poor thermal properties that restrict their use as coolants in industrial applications. Nowadays a number of methods are available to enhance the heat transfer rate of any conventional fluid. One such method may be the addition of small-sized solid particles (millimetre and micrometre) in conventional fluid that can improve its thermal properties. But use of these fluids has shown serious problems such as clogging, high erosion, pressure drop in pipelines and poor stability of

Abbreviations: ASCH, Al_2O_3–SiO_2 clay hybrid; BCA, 2-Butoxyethylacetate; CA, Diethylene glycol monethyl ether acetate; CMC, Carboxy methyl cellulose; CNT, Carbon nanotube; DEG, Diethylene glycol; EG, Ethylene glycol; GNP, Graphene nanoplatelets; HTPB, Hydranxy terminated polybutadiene; ITO, Indium Tin Oxide; ICH, Iron oxide clay hybrid; MWCNT, Multi walled carbon nanotube; PG, Propylene glycol; PPG, Poly propylene glycol; PSi, Poly siloxane; TNT, Titanate nanotube

* Corresponding author. Tel.: +91 9711037075; fax: +91 5422368157
E-mail address: sharmaanuj79@gmail.com (A.K. Sharma).

http://dx.doi.org/10.1016/j.rser.2015.09.033
1364-0321/© 2015 Elsevier Ltd. All rights reserved.

suspension. About a decade ago, nanometre-sized particles replaced these milli- and micro-sized particles in the suspension, leading to the development of a new class of fluids called 'nanofluids'. These nanofluids have a number of advantages, such as, better stability, greater thermal conductivity and lower pressure drop compared to the base fluid. Also, use of these nanofluids has shown a remarkable improvement of performance parameters in machining, such as, milling [1–8], grinding [9–18], drilling [19] and turning [20–23] of various metals and their alloys. Sharma et al. [24] reviewed the literature available on nanofluid application in various machining processes as cutting fluid and observed that nanofluid improved machining performance significantly.

Nanofluids are colloidal mixtures of nanometre-sized particles (1–100 nm) in a base fluid. The nanoparticles can be metallic, non-metallic, oxide, carbide, ceramics, carbonic, mixture of different nanoparticles (hybrid nanoparticles) and even nanoscale liquid droplets. The base fluid may be a low viscous liquid like water, refrigerant or a high viscous liquid like ethylene glycol, mineral oil or a mixture of different types of liquids (EG+water, water-+propylene glycol etc.). The term 'nanofluid' was first coined by Dr. Stephen Choi (Energy Technology Division, Argonne National Laboratory, USA) in 1995 [25]. However, there was an earlier and independent report by Masuda et al. [26] which dealt with the similar subject. At the initial stage, research on nanofluids was mainly conducted at Argonne National Laboratory, USA. At this stage, the key area of research was thermal conductivity under macroscopically static conditions. Few researchers have observed in their investigations that addition of nanoparticles in conventional fluids remarkably enhanced their thermal conductivity [27–39,139–141] in comparison to the base fluids. Saidur et al. [40] observed that the thermal conductivity of nanofluids increased with the increase of particle volumetric concentration in base fluid. The mixing of nanoparticles with base fluid may alter the thermo-physical properties of fluids as the nanoparticles possess higher thermal conductivity than base fluids [25,41]. However, various experiments have shown that the increase of thermal conductivity might be offset by an increase of viscosity and noticed a little penalty in pressure drop [42–45]. Tiwari et al. [46,47] observed that an increase of nanoparticle volume concentration increased the viscosity and density of fluid, which, in turn, caused a pressure drop, and hence, increased the pumping power. Increment of shear viscosity of nanofluids as a function of nanoparticle concentration can also be seen in Fig. 1. Vajjha and Das [48] observed that increase of nanoparticle loading in the base fluid increased viscosity and density significantly. They observed an increment of ~91% in viscosity and ~13.9% in density at 6 vol% Al_2O_3/EG+water (60:40) nanofluid. They also found that at a given temperature, all three nanofluids at 2 vol% (CuO, Al_2O_3 and SiO_2) required less pumping power than the base fluid. However, CuO nanofluid required more pumping power than the base fluid at a higher volumetric concentration (>3 vol%). This can be well explained by Fig. 2. Thus, an increase of viscosity may incur a penalty in pressure drop and rise in pumping power. Hence, viscosity of nanofluids can play a vital role in selection of the nanofluid for a particular application.

The pressure drop in any fluid is also affected by Reynolds number. A few researchers [49–55] have observed that an increase of Reynolds number of any fluid flow increased its pressure drop. Moreover, as shown in Fig. 3, there is a small increase in pressure drop with the increasing particle volume concentrations. In the present paper, however, the review is restricted to summarizing the effects of nanoparticle type, shape, shear rate range and volumetric concentration on rheological flow behaviour. Furthermore, the rheological behaviour of a nanofluid can also give an idea of viscosity variation with shear rate. The detailed rheological analysis of nanofluids [62–135] is sufficient to explain that they can exhibit either or both Newtonian and non-Newtonian behaviours. This behaviour depends on various factors such as nanoparticle shape [28,56–57], size [64], nanoparticle concentration [58–60], nanoparticle structure [61], surfactants [70,75,77–78,80,83,104–106,112,116,125,128], shear rate range [70,96,114] and even magnetic field [125–135]. Furthermore, Wang et al. [137] reviewed literature available on rheology of nanofluids and found Brownian motion and nanoparticle aggregation to be the major mechanisms for rheological properties of nanofluids. The rheological behaviour of nanofluid, being an important factor in its application, might be helpful in understanding the viscosity profile

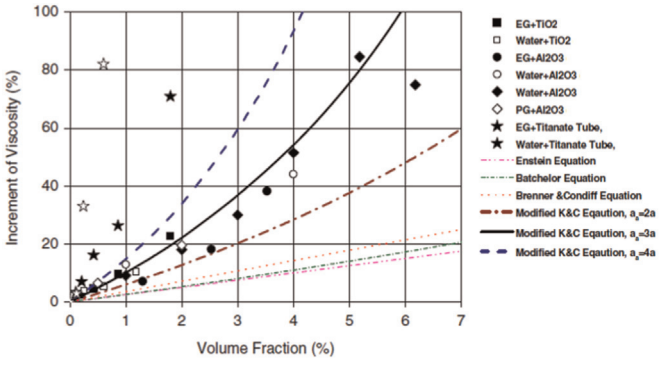

Fig. 1. Shear viscosity of nanofluids as a function of nanoparticle concentration [57].

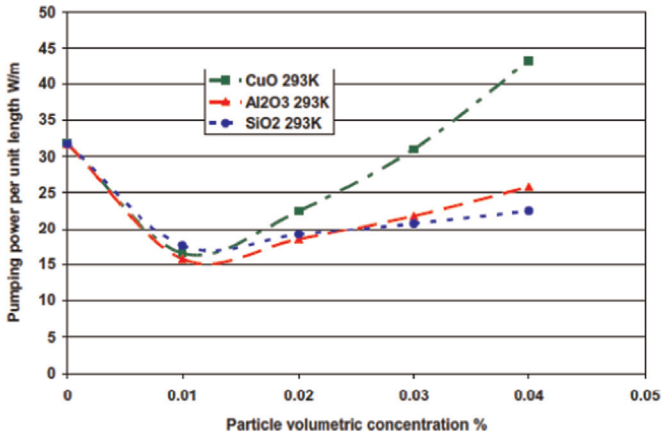

Fig. 2. Pumping power versus particle volume concentration [48].

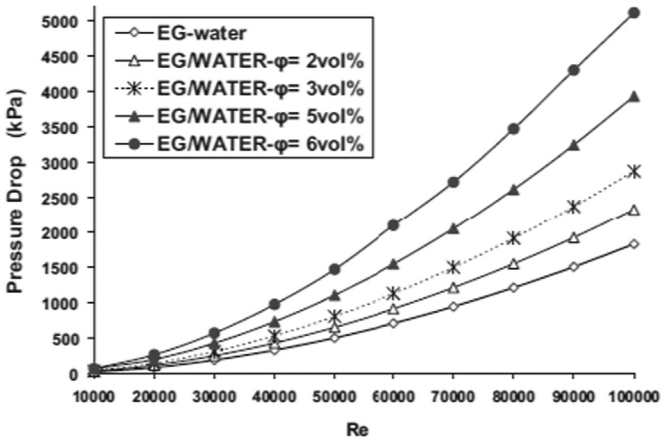

Fig. 3. Variation of pressure drop versus Reynolds number for different particle volumetric concentrations [53].

Download English Version:

https://daneshyari.com/en/article/8115607

Download Persian Version:

https://daneshyari.com/article/8115607

Daneshyari.com