Electrical Conductivity of Nanoparticle-Enhanced Fluids

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Research on nanoparticle-enhanced fluids' electrical conductivity is at its beginning at this moment and the augmentation mechanisms are not fully understood. Basically, the mechanisms for increasing the electrical conductivity are described as electric double layer influence and increased particles' conductance. Another idea that has resulted from state of the art is that the stability of nanofluids can be described with the help of electrical conductivity tests, but more coordinated research is needed. Concluding, this analysis has shown that a lot of research work is needed in the field of nanofluids' electrical characterization and specific applications.

nanofluids electrical conductivity

History

Heat-exchange processes are of major importance for almost all industrial processes, and thus their efficiency is of paramount significance. In the last few decades, a new class of heat-transfer fluids was developed and intensively studied, namely nanoparticle-enhanced fluids. This new class of fluids actually consists of regular heat-transfer fluids enhanced with solid nanoparticles, generally termed as nanofluids. As base fluids, both conventional and non-conventional fluids were considered, and a few examples are: water, ethylene glycol, oils, ionic liquids, basic lubricants and also molten salts. On the other hand, nanoparticles consist of metals, oxides, carbon nanotubes, graphene and several composites. The combination of these two phases (i.e., liquid and solid nanoparticles) raised a lot of interest in the published literature also due to their intrinsic applications in heat exchangers used for different industries as: automobile (i.e., car radiator), coolers, radiators, refrigerators, in the oil and gas industries (i.e., cooling and preheating of fluids), solar collectors, electronic industries, aeronautics etc [[1],[2]].

Development and applications

Nevertheless, unlike the properties of regular mixtures that can be predicted very easily by averaging the properties of the pure phases, the thermophysical properties of nanofluids do not respect this rule, as was outlined intensively in the open literature [[1],[2],[3],[4],[5],[6],[7],[8],[9],[10],[11],[12]] .

If the electrical conductivity is considered, this author believes that this is a less studied property, even if it is of tremendous relevance for several industrial applications. For example, commonly, fluids are poor conductors of electricity while several liquids (as for example: mercury, sea water, molten metals, electrolytes) are good conductors. In the last few years, an abundant consideration was received by the study of conducting fluids, especially because of their numerous applications in engineering, as for example: plasma jet, controlled thermo-nuclear reactor, shock tubes, pumps, magneto hydrodynamic generators [[13],[14],[15],[16]]. Many gaps still exist in the science describing the flow of electrically conducting fluids and such gaps are most frequent with regard to magneto hydrodynamic (MHD) subjects like flows of inhomogeneous and multiphase fluids (i.e., nanofluids) and turbulent flows [[13]].

Application

On the other hand, as one of the most relevant applications of nanofluids is electronic cooling, the increased electrical conductivity over the base fluid constitutes a major advantage [[15]], especially when it is coupled with higher thermal conductivity. Consequently, Pordanjani et al. [[1]] recommended in their comprehensive review the use of nanoparticles in heat exchangers under the influence of electrical fields, and thus the investigation of electrical behavior of nanofluids is of major importance.

Conclusion

A complex review was performed on electrical conductivity results. Even if the other nanofluids' properties received greater attention (see thermal conductivity, viscosity, specific heat), studies on electrical conductivity can also offer valuable information about these new fluids' behaviour in different real-life applications.

Some of the conclusions that can be derived from the state of the art are summarized as follows:

1. Electrical conductivity, together with zeta potential, can be a good tool to evaluate the nanofluid stability; more precisely, the increase in electrical conductivity is attributed to a better suspension stability. Alternatively, a reduction in electrical conductivity suggest a poor stability and this property can be measured also at a certain time distance to check the long-term stability of a nanofluid.

2. Electrical conductivity depends on base liquid type and polarity.

3. Electrical conductivity is influenced by the addition of surfactants.

4. Electrical conductivity was found to increase with temperature upsurge; however, its variation with nanoparticle concentration is not fully described and understood, results being somewhat contradictory (i.e. most authors found an increase with concentration, but there are studies that contradict this hypothesis).

5. The increase in electrical conductivity was found to be mainly determined by three causes: surface conductance of nanoparticles; electrical double layer development, liquid polarity.

6. The Maxwell model cannot describe properly the variation in electrical conductivity when nanoparticles are added to the base fluid (i.e. it under predicts the experimental values), as well as other classical theoretical models.

7. Only few equations for estimating electrical conductivity are present in the open literature, most being linear correlations.

8. None of the reviewed studies discussed about the preferred application of manufactured nanofluids, based on their electrical conductivity performance.

As a general conclusion, it was noticed that even if the research on nanofluids started a couple of decades ago, the majority of electrical conductivity studies are limited to nanofluids based on water, EG and few W-EG mixtures. Other base fluids studies are scattered and a solid conclusion cannot be ruled out yet. Another observation, this time in regard to ionic liquid-enhanced nanofluids (NEIL), is that no studies are available to date in the open literature in regard to their electrical behaviour, even if the manufacture of these NEILs was firstly noticed about 8 years ago.

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