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Development of a database of heat transfer properties of nanofluids

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Abstract: This work presents the need for a standardized reporting and a database of experimental heat transfer data of nanofluids, that allow evaluating the consistency of published data in the field, and support the development of predictive general models for the heat transfer behavior of nanofluids. The first attempts to build a comprehensive database of experimental heat transfer data of nanofluids are introduced, and the main challenges for the collection of the data are enumerated. The objective is to collect experimental data published in the scientific literature and consolidate a standardized database where data can be quickly searched by base fluid, nanoparticle type, heat transfer configuration or operation ranges, and be ready for its use by researches and engineers for the analysis and simulation of nanofluids as heat transfer fluids.

Background: Evaluating the suitability of the use of nanofluids as heat transfer or working fluids requires knowledge of their heat transfer behavior over a wide range of operating conditions, or instead, models that are able to predict their heat transfer features with sufficient accuracy. Although the most widely used general heat transfer correlations have a theoretical basis, most of today's developed heat transfer correlations are empirical or semi-empirical, and require large amounts of experimental data as a basis for their development.

The rapid growth of the number of publications in the field of heat transfer of nanofluids has provided a large number of experimental data of heat transfer experiments with different types of nanofluids and configurations. Following this, several reviews that discuss heat transfer of nanofluids have been published, being 15 of them published only during 2018. Some of these review works focus on providing a general overview of the published research on experimental heat transfer of nanofluids, while others focus on specific types of nanofluids, or even configurations. For instance, Moreira et al. [1] and Choi et al. [2] present general reviews of the heat transfer applications of nanofluids in which the increase or decrease of heat transfer is generally pointed out for each reviewed publication. Yang and Du [3] presented an equivalent analysis of the heat transfer enhancement, but dedicated only to nanofluids containing TiO_2 nanoparticles.

Though the published reviewed works provide a good overview of the publications available for specific nanofluid types, or heat transfer configurations, it is detected that they do not provide a clear view on whether data for similar systems measured by different authors are consistent, or if large deviations in the measured enhancement exist. For example, Sajid and Ali [4] reviewed recent experiments on heat transfer of nanofluids and provided a general view of the maximum achieved enhancement depending on the nanoparticle type. However this presentation of the data does not provide insight on the presence of outliers in the measurements or the consistency of datasets. In this regard, it has been pointed out that inconsistencies exist among different studies on heat transfer of nanofluids, which indicates that the impact of different factors in these processes is still not understood [5]. A database collecting experimental heat transfer data of nanofluids would allow the quick comparison of values from different sources and systems, as well as the detection of outliers or major inconsistencies. However, to the best of our knowledge, such a database is missing.

This work aims at developing a database of published experimental heat transfer data of nanofluids, as well as suggesting a standard for future data reporting in the field of nanofluids' heat transfer, therefore facilitating the data analysis and comparison. The database will consider nanofluids formed by a base fluid and a single type of nanoparticle. The data collected in the database will cover diverse flow conditions (e.g. vertical or horizontal flow, pool boiling) and geometries (e.g. tubes, plates), as well as different pressure, temperature and mass flow rate ranges. A quality control of the compiled data will be carried out, in order to avoid potential typographical errors and to spot significant outliers.

The database will be the base for the development, validation and improvement of reliable heat transfer correlations for nanofluids, as well as to provide a consistent indication on the relative level of heat transfer enhancement for different fluids and nanoparticle combinations, and heat transfer conditions. Moreover, defining a standard for the reporting of heat transfer data for nanofluids will increase the impact of credibility of future experimental data, thus ensuring their benefit for the scientific community.

Discussion and Results:

The collection of heat transfer data poses a significant challenge due to the large number of factors influencing the heat transfer phenomena (e.g. geometry, flow, media), and the diverse ways of reporting empirical data in the scientific literature (e.g. heat transfer coefficients, Nusselt numbers, or their ratios with respect to a reference fluid). This challenge increases when analyzing data of nanofluids' experiments, not only due to the addition of the nanofluids' properties, but because of the systematic inaccuracies that have been observed in the recent literature. Some of these inaccuracies are enumerated as follows: i) in most of the cases, heat transfer parameters are presented graphically in the form of plots and, normally, no access to the raw data is possible; ii) a great number of the works present heat transfer data in the form of ratios with respect to the base fluid behavior, being the reference data missing; iii) in many cases basic information about the nanofluid properties is missing (e.g. nanoparticles size, shape); iv) in some cases surfactants are used but this information is not provided or the substance is reported as unknown.

In order to standardize the existing published empirical data, and provide a base for comparison of different studies, data needs to be treated and converted. Non-dimensional magnitudes (such as the Nusselt number Nu or Péclet number Pe) are collected from the analyzed publications or calculated, if data is reported in their dimensional form. Predicted thermophysical properties for each nanofluid are used for the data conversion. All the calculated values will be built in the database and are clearly indicated.

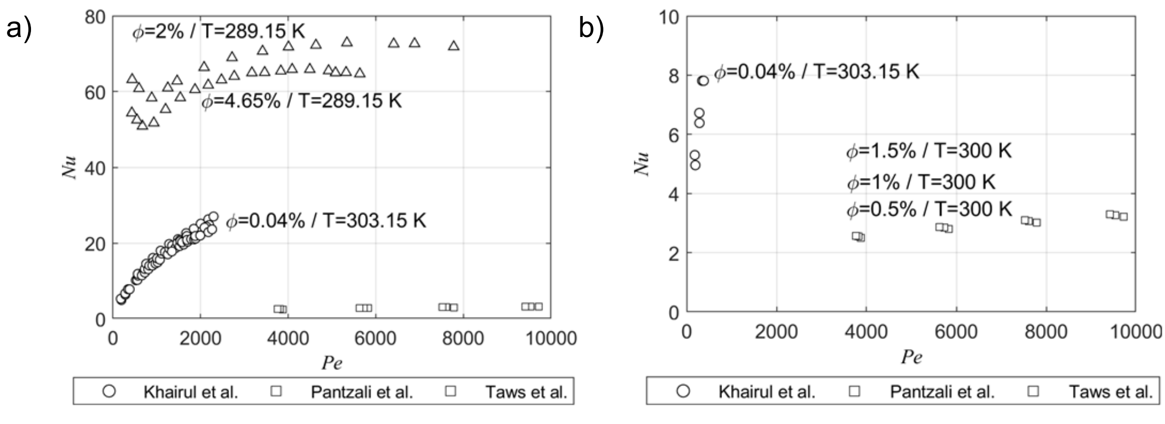

Figure 1. Comparison of heat transfer data for water+CuO nanofluids in plate heat exchangers [6–8]**. Volume fraction ϕ and temperature are indicated if given.**

Fig. 1 shows an example of comparison of heat transfer data for water+CuO nanofluids in plate heat exchangers from different sources. Thanks to the data treatment, the reported values of different magnitudes can be compared in terms of the Nu and Pe. It can be seen that, for the higher volume fractions, the heat transferred for ϕ=2% is greater than for ϕ=4%, contrary to what is expected. For lower ϕ, values from different sources seem to agree, although differences with particle concentration are negligible.

As the database expands, it will be applied to assess the prediction performance of heat transfer correlations independently, as they are commonly derived based on limited sets of experimental data or for specific types of nanofluids.

Summary/Conclusions: The uncertainty imposed by a great number of experimental heat transfer studies on nanofluids and the observed variety of heat transfer enhancement makes it necessary the development of a database of experimental heat transfer data of nanofluids and the definition of a standard for data reporting. The database will be used for development of new heat transfer correlations, and the assessment of the existing data. This work is supported by the European Union's Horizon 2020 research and innovation programme with a Marie Skłodowska-Curie Fellowship under grant agreement No 704201 with the project NanoORC (www.nanoorc.mek.dtu.dk).

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