Numerical Study of Convective Heat Transfer of Nanofluids: A Review
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Abstract:
The recent development of nanotechnology led to the concept of using suspended nanoparticles in heat transfer fluids to improve the heat transfer coefficient of the base fluids. Specifically, numerical studies are reviewed in this study to get a clear view and detailed summary of the influence of several parameters such as type of nanoparticle and host liquid, particle volume concentration, particle size, particle shape, Brownian diffusion and thermophoresis effect on hydrodynamic and thermal characteristics of convective heat transfer using nanofluids. In addition, the paper provides detailed information about the most of commonly-used correlations which are utilized to predict the effective thermophysical properties of nanofluids. Finally, the main aim upon which the present work is based is to give a comprehensive review on different CFD approaches employed in numerical simulation of nanofluid flow, address the pros and cons of each approach, and find the suitable technique which gives more credible results as compared to experimental results.

I. INTRODUCTION:
Over the last few years, energy consumption has increased drastically; therefore, scientists have developed new energy saving strategies to overcome the threat of energy shortage [1]. Heat exchangers are widely used in industrial systems in the field of energy conservation, conversion and recovery. Thus, it is obvious that providing more efficient heat exchanging systems can mitigate the energy concerns considerably. 1.1. The rise of compact thermal devices Better heat removal can be achieved by decreasing the area to volume ratio of thermal devices which is one of the most important factors in thermal design [2]. This idea motivated Tuckerman and Pease [3] to propose microchannel heat sink (MCHS) about two decades ago. After that, many researches [4–6] proved the effectiveness of using micro-channel heat exchangers for thermal enhancement purposes. Lately, due to the advancement of micro fabrication technology, microchannels and microtubes are manufactured and utilized in industries such as microelectronics, aerospace, biomedical, robotics, telecommunications and automotive [7]. The main reasons for development of miniaturized and light weight heat exchangers are given as follows:

- Space and size limitations.
- Energy and material savings.
- Ease of unit handling.
- Growing need for heat transfer augmentation with increasing energy demands.
- Cooling requirement of microscale and microelectronic devices.

II. TWO-PHASE APPROACH:
Generally speaking, nanofluids are by nature two-phase fluids; therefore one can expect that they probably have some features of solid–liquid mixture. For this reason, the theory of classical two phase flows has been applied for nanofluids. In the two-phase approach, the nanoparticle and the base fluid are considered as two different phases with different velocities and temperatures and the assumption of zero slip velocity between the fluid and particles is no longer valid [78]. This is due to gravity, friction between the fluid and solid particles, Brownian motion, Brownian diffusion, sedimentation and dispersion. Because the two-phase approach considers the movement between the solid and fluid molecule, it may get realistic results. Although this model describes an understanding of the functions of both liquid phase and solid phase in the heat transfer process, it needs a long time for computation and a high performance computer. The two-phase approach is categorized in two general models: Eulerian-Eulerian and Lagrangian-Eulerian.

III. LATTICE BOLTZMANN METHOD (LBM):
In spite of using traditional CFD approaches, Lattice Boltzmann Method (LBM) (or thermal lattice Boltzmann methods (TLBM) has exhibited some attractiveness during recent years in simulating the nanofluid flow and their heat transfer behavior. LBM solves the Boltzmann equation to simulate the flow instead of solving the Navier-Stokes equations. In LBM simulations, two different forms are utilized more than others: Typical D2Q9 (two-dimensional and nine-velocity) square and D3Q19 (three-dimensional and 19-velocity) cube lattice structures [283]. In addition, this method may present some well-known advantages such as simple and efficient implementation for parallel coding, the uniform algorithm for multiphase flows, and easiness in dealing with complex geometries [284]. Xuan and Yao [285] first proposed LBM for simulating flow and energy transport processes inside the nano-fluid, considering the effective forces on flow like gravity, buoyancy, Brownian, and the interactive force among nanoparticles. LBM has been widely exploited for natural and mixed convections [82, 83, 286–289], and to a smaller extent for forced convection [290–293]. The obtained results from these studies are in accordance with the available numerical results which are based on the conventional CFD methods. However, to our knowledge, the researchers who adopted LBM did not bring any code validation according to the experimentally conducted nanofluid works in order to assess
the accuracy of LBM for nanofluids. Therefore, further researches might be necessary in this area to see to what extent LBM gives reliable results for nanofluid simulation.

IV. CONCLUSION:

The present article comprehensively reviews the convective heat transfer of nanofluids from the numerical point of view. From the observed numerical results it is evidently seen that nanofluids can improve the heat transfer capability of conventional heat transfer fluids significantly due to the existence of highly conductive dispersed nanoparticles in the host liquid. Not only does the increase of nanoparticle volume concentration bring about an increasing trend in forced convective heat transfer of nanofluids, also it increases the pressure drop slightly, which is widely expressed by most numerical works. In contrast, among the experiments and simulations there are some inconsistencies about the influence of particle concentration on the variation of heat transfer in natural convection which is attributed to improper selection of CFD modeling and effective viscosity correlation for nanofluids as well as ignoring their non-Newtonian rheology in the numerical simulations.

V. REFERENCES:


