CHARACTERIZATION, EXPERIMENTAL AND SIMULATION OF HEAT TRANSFER PERFORMANCE FOR Al_2O_3-TiO_2-SiO_2 TERNARY NANOFLUID WITH INSERTS

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Penyelidikan pemindahan haba telah mendapat perhatian yang ketara sejak sekian lama dan telah ditemui dalam pelbagai aplikasi, termasuk peranti elektronik penyejukan, sistem pembuatan dan sistem tenaga suria. Dalam beberapa tahun kebelakangan ini, cecair nano dan sisipan telah digunakan untuk meningkatkan lagi prestasi pemindahan haba untuk teknik pasif dengan kaedah kompaun. Walau bagaimanapun, terdapat kajian terhad mengenai cecair nano terner dengan gegelung dawai dan pita berpintal. Bendalir nano ternari dianggap kerana kelebihannya dalam mengatasi kelemahan kestabilan cecair nano mono dan binari. Sementara itu, gegelung dawai dan pita berpintal digunakan dalam kajian ini kerana ia memberikan peningkatan pemindahan haba maksimum dengan penalti geseran paling sedikit di antara sisipan. Oleh itu, kajian ini bertujuan untuk mencirikan dan menilai sifat termofizikal, prestasi pemindahan haba, dan faktor prestasi terma (TPF) bagi cecair nano terner Al_2O_3-TiO_2-SiO_2 dengan gegelung dawai dan pita berpintal di bawah keadaan eksperimen dan simulasi. Bendalir nano ternari pada mulanya dirumus menggunakan nisbah komposisi optimum 20:16:64 mengikut peratus isipadu. Bendalir nano kemudiannya disediakan dalam pelbagai kepekatan isipadu antara 0.5 hingga 3.0%. Kestabilan cecair nano terner telah disiasat menggunakan kaedah kualitatif dan kuantitatif. Kekonduksian terma dan kelikatan dinamik cecair nano ternary diukur dengan Penganalisis Sifat Terma KD2 Pro dan Rheometer Brookfield LVDV III. Perpindahan haba perolakan paksa eksperimen telah dijalankan menggunakan persediaan yang direka. Kerja eksperimen telah dijalankan untuk julat luas nombor Reynolds dari 2,300 hingga 12,000 pada suhu pukal 70 °C. Eksperimen telah dilakukan pada keadaan sempadan fluks haba malar untuk aliran dalam tiub biasa dengan sisipan gegelung dawai ($0.83 \leq P/D \leq 2.50$) dan dengan pita berpintal ($2.0 \leq H/D \leq 5.0$). Model simulasi cecair nano terner dibangunkan untuk tiub biasa, gegelung dawai dan pita berpintal dan disahkan menggunakan analisis kebebasan grid. Simulasi dilakukan menggunakan Computational Fluid Dynamics (CFD) dengan model k-ε piawai untuk menentukan corak aliran, taburan suhu, pemindahan haba dan faktor geseran cecair nano terner di bawah keadaan eksperimen yang sama tetapi pada bilangan Reynolds yang lebih tinggi iaitu lebih daripada 12,000. Bendalir nano terner telah disahkan dalam keadaan kestabilan yang sangat baik dengan potensi zeta tinggi sehingga 63.72 mV. Peningkatan kekonduksian terma tertinggi sebanyak 24.8% diperolehi untuk cecair nano terner pada kepekatan isipadu 3.0%. Kepekatan isipadu 3.0% juga menunjukkan kelikatan tertinggi pada semua suhu. Berdasarkan eksperimen, peningkatan pemindahan haba maksimum untuk cecair nano terner dalam tiub biasa, dengan gegelung dawai (P/D-0.83) dan pita berpintal (H/D-2.0), telah dicapai sebanyak 3.0% kepekatan isipadu sehingga 21.46%, 199.23% dan 225.35%, masing-masing. Bendalir nano ternary dengan pita berpintal meningkatkan TPF sehingga 3.22 pada kepekatan isipadu 3.0%, jauh lebih tinggi daripada keadaan tiub biasa dan gegelung dawai. Simulasi semasa untuk cecair nano terner dengan tiub biasa, gegelung dawai dan pita berpintal secara berkesan boleh meramalkan nombor Nusselt dan faktor geseran dengan persetujuan yang baik antara simulasi dengan ANSYS dan data eksperimen. Kesimpulannya, cecair nano terner Al_2O_3-TiO_2-SiO_2 meningkatkan sifat dan meningkatkan prestasi pemindahan haba dengan gegelung dawai dan pita berpintal. Bendalir nano terner pada kepekatan isipadu 3.0% dengan pita terpintal pada H/D = 2.0 disyorkan untuk aplikasi pemindahan haba seperti penukar haba dan sistem penyejukan automotif untuk menyediakan TPF tertinggi.

ABSTRACT

Heat transfer research has received significant attention for a long time and has been found in various applications, including cooling electronic devices, manufacturing systems, and solar energy systems. In recent years, nanofluids and inserts have been used to boost further the heat transfer performance for passive techniques with the compound method. However, there has been limited research on ternary nanofluids with a wire coil and twisted tape. The ternary nanofluids are considered due to their advantages in overcoming the stability drawback of mono and binary nanofluids. Meanwhile, the wire coil and twisted tape are used in the present study because they provide maximum heat transfer enhancement with the least friction penalty among the inserts. Therefore, this study aims to characterize and evaluate the thermo-physical properties, heat transfer performance, and thermal performance factor (TPF) of Al_2O_3-TiO_2-SiO_2 ternary nanofluids with a wire coil and twisted tape under experimental and simulation conditions. The ternary nanofluids were initially formulated using the optimum composition ratio of 20:16:64 by volume percent. The nanofluids were then prepared in various volume concentrations ranging from 0.5 to 3.0%. The stability of the ternary nanofluid was investigated using qualitative and quantitative methods. Thermal conductivity and dynamic viscosity of ternary nanofluids were measured with KD2 Pro Thermal Properties Analyzer and Brookfield LVDV III Rheometer. Experimental forced convection heat transfer was carried out using a fabricated setup. The experimental work was undertaken for a wide range of Reynolds numbers from 2,300 to 12,000 at bulk temperature of 70 °C. Experiments were performed at constant heat flux boundary conditions for flow in plain tubes with wire coil inserts ($0.83 \leq P/D \leq 2.50$) and with twisted tape ($2.0 \leq H/D \leq 5.0$). Simulation models of ternary nanofluids are developed for a plain tube, wire coil and twisted tape and validated using grid independence analysis. Simulations were performed using Computational Fluid Dynamics (CFD) with standard k-ε model to determine the flow pattern, temperature distribution, and heat transfer and friction factor of ternary nanofluids under similar experimental conditions but at higher Reynolds number of more than 12,000. The ternary nanofluids were confirmed under excellent stability conditions with a high zeta potential of up to 63.72 mV. The highest thermal conductivity enhancement of 24.8% was obtained for ternary nanofluids at 3.0% volume concentration. The 3.0% volume concentration also shows the highest viscosity at all temperatures. Based on experimental, the maximum heat transfer improvement for ternary nanofluids in a plain tube, with wire coil (P/D-0.83) and twisted tape (H/D-2.0), was attained by 3.0% volume concentration of up to 21.46%, 199.23% and 225.35%, respectively. The ternary nanofluids with twisted tape improve the TPF by up to 3.22 at 3.0% volume concentration, significantly higher than plain tube and wire coil conditions. The present simulation for ternary nanofluids with plain tube, wire coil and twisted tape can effectively predict the Nusselt number and friction factor with a good agreement between the simulation with ANSYS and experimental data. In conclusion, the Al_2O_3-TiO_2-SiO_2 ternary nanofluids enhanced the properties and improved the heat transfer performance with a wire coil and twisted tape. The ternary nanofluids at 3.0% volume concentration with twisted tape at H/D = 2.0 were recommended for heat transfer application such as heat exchanger and automotive cooling system to provide with the highest TPF.

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