Review of Performance Characteristics of Shell and Tube Heat Exchanger with Different Nanofluids

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Abstract— **This review focuses on the enhancement of performance of shell and tube heat exchanger working on nanofluids which helps in improvising various parameters namely thermo physical properties, heat transfer performance, and possible reduction of effective area of the shell and tube heat exchanger. Using different nanofluids like Al_2O_3, CuO, Graphene, etc performance of shell and tube heat exchanger is optimized and investigated for various constructional aspects. The review shows that the Nusselt number increases with increase in the concentration of Al_2O_3. The heat transfer coefficient also increases for increase in volume concentration of Al_2O_3. The review also shows that the combination of cylindrical shaped nanoparticles and 20^o baffles angle gives the best results for increment in overall heat transfer coefficient and heat transfer rate and in minimization of entropy generation. As the concentration of grapheme increases the heat transfer coefficient increases substantially. With the increase in volume concentration of CuO from 0.05% to 0.3%, the thermal conductivity of CuO nanofluid increases from 3.07% to 10.55% compared to that of distilled water.**

Keywords— **Shell and Tube Heat Exchanger, Nanofluids, Nusselt number, Nanoparticles, Baffle, Overall Heat Transfer coefficient, Heat Transfer Rate, Thermal Conductivity.**

I. INTRODUCTION

Shell and tube exchangers are most commonly used heat exchange equipment in thermal engineering. In Shell and tube heat exchanger one fluid flows through tube i.e. tube side and other flows through shell i.e. shell side in which both the fluids are at different temperatures. Heat transfer takes place between the two fluids. The design of shell and tube heat exchanger is based on various parameters such as fluid flow condition, tube side and shell side temperature, pressure drop, mass flow rates etc. Baffles and fins are one of the key design elements which act as a secondary surface to increase the efficient heat transfer area and transfer heat to fluid to strength the efficiency heat exchanger.

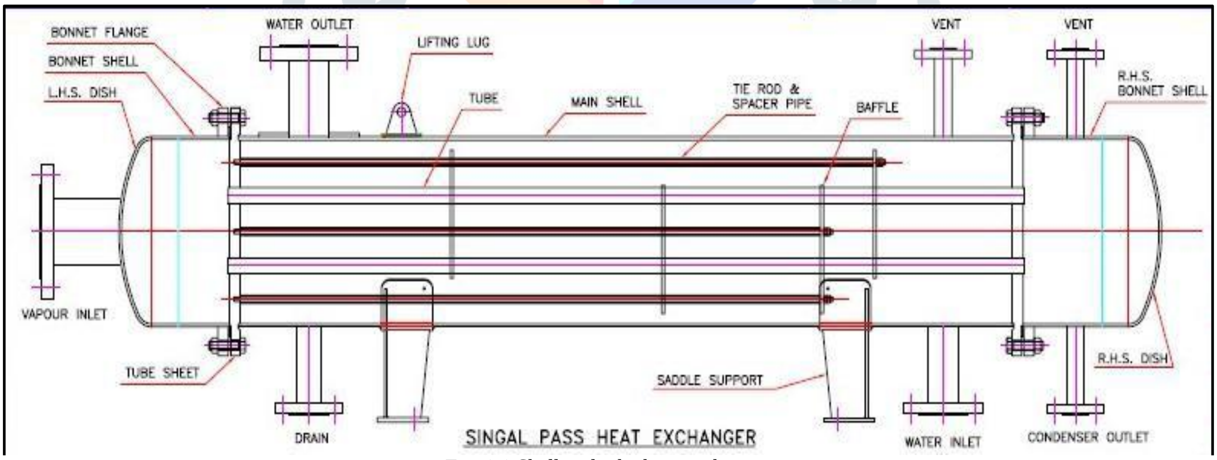

Fig. 1.1 Shell and tube heat exchanger

Nanoparticles used in nanofluids are typically made up of oxides, metals, carbides or carbon nanotubes. Common base fluids used are water, ethylene glycol and oil. Nanofluids have essential properties to enhance the performance of shell and tube heat exchanger. Discovering a suitable nanofluid for improving heat transfer properties and high thermal conductivity becomes a serial challenge, therefore it is essential to use adequate amount of nanoparticles and nanofluid. For example, alumina–water nanofluid at 6 vol% can increase the heat transfer coefficient in the entrance and fully developed regions by 17% and 27%, respectively, when compared with pure water. The heat transfer coefficient of zirconia–water nanofluid increases by approximately 2% in the entrance region and 3% in the fully developed region at 1.32 vol%. For nanofluids containing 0.5 wt% CNTs, the maximum enhancement is over 350% at Re = 800, and the maximum enhancement occurs at an axial distance of approximately 110 times of tube diameter[5]. The basic properties of few nanofluids are mentioned in the table given below.

Substance	Density (kg/m^3)	Specific heat (J/kg-K)	Conductivity (W/m-K)
Al_2O_3	4000	880	30
Copper	8920	390	401
Water	998	4190	0.58
Ethylene Glycol	1110	2470	0.258

Table. 1.1 Properties of nanofluids

II. LITERATURE REVIEW

K. Somasekhar et al, done the modelling of a multi pass shell and tube heat exchanger with 3 tubes by using CATIA and meshing on ICEM CFD software, simulations were carried out by using CFD-FLUENT software. The CFD-FLUENT software was used to found out the pressure drop and heat transfer characteristics of Al_2O_3-water nanofluid and distilled water as a base fluid under turbulent flow condition. This simulation results were compared with experimental results. [1]

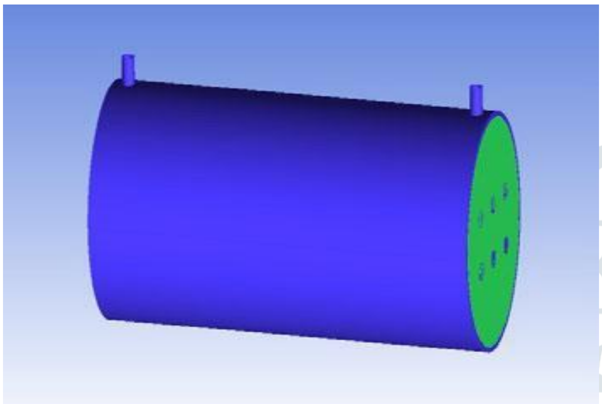

Fig. 2.1 Geometric model of shell and tube heat exchanger

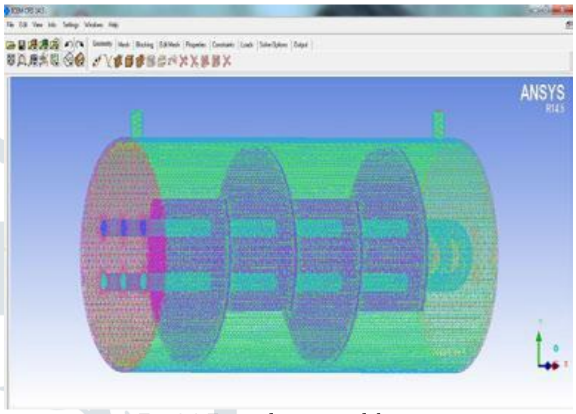

Fig. 2.2 Finite element models

Ramtin Barzegarian et al, assessed the effect of Al2O3-water nanofluid on thermal performance of a commercial shell and tube heat exchanger with segmental baffles. Al_2O_3-gamma nanoparticles with 15 nm mean diameter (99.5% purity) and Sodium Dodecyl Benzene Sulphonate (SDBS) as surfactant are used to make aqueous (Al_2O_3) nanofluid at three various volume fractions of nanoparticles (φ =0.03, 0.14 and 0.3%). The effect of some parameters hot working fluid such as Reynolds number and volume concentration of nanoparticles on heat transfer characteristics, friction factor and thermal performance factor of a shell and tube heat exchanger under laminar flow regime was investigated. [2]

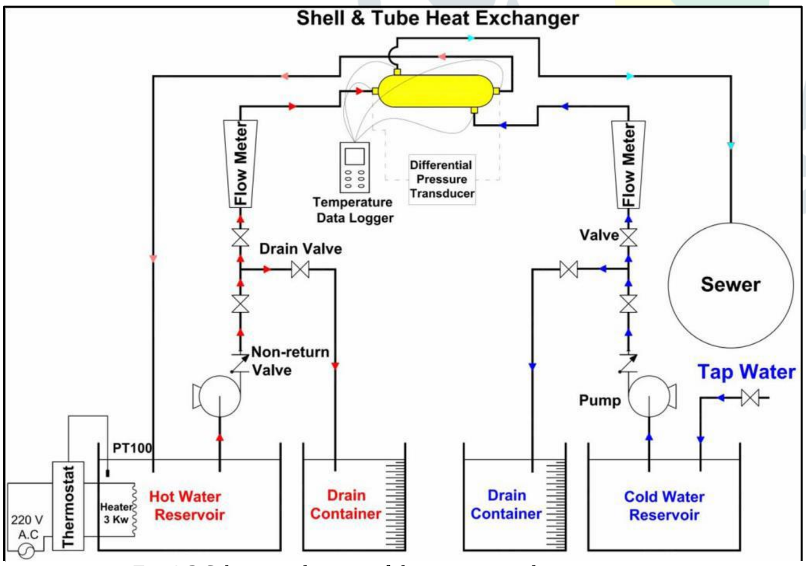

Fig. 2.3 Schematic diagram of the experimental apparatus.

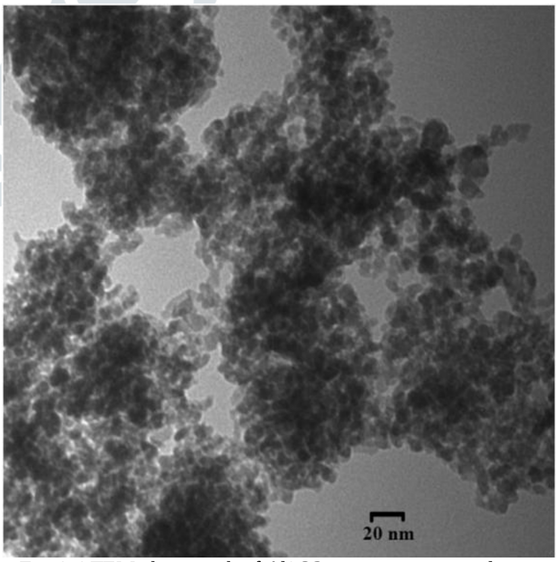

Fig. 2.4 TEM photograph of Al2O3-gamma nanoparticles

M.M. Elias et al, studied the effect of shapes of nanoparticles (cylindrical, bricks, blades and platelets) on the overall heat transfer coefficient, heat transfer rate and entropy generation of shell and tube heat exchanger along with different angles of baffles and a segmental baffle. The experiment is performed with different concentrations of nanoparticles in Boehmite alumina (c-AlOOH).[3]

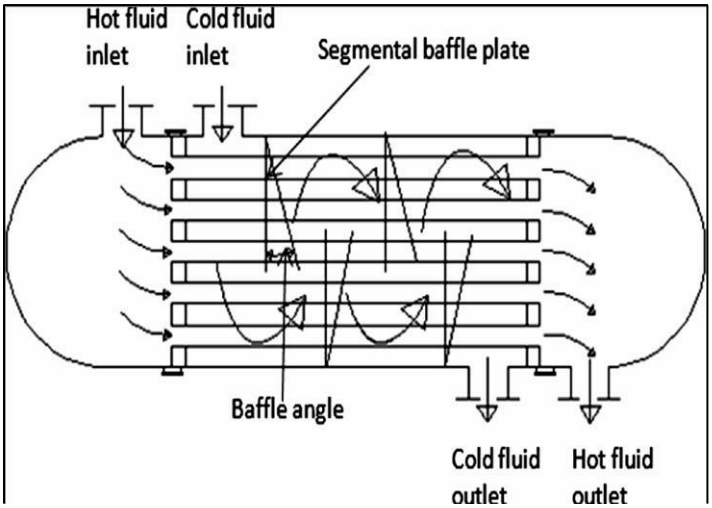

Fig. 2.5 Shell and tube heat exchanger with baffle angle

L. Godson et al, had investigated the heat transfer characteristics of silver/water nanofluid in a shell and tube heat exchanger. The results were found out for Reynold's number varying between 5000 to 25000, whereas the heat flux between 800 W/m^2 and particle volume concentrations of 0.01%, 0.03%, and 0.04%. By the use of above values of Reynold's number, heat flux and particle volume concentration the influence of the mass flow rate, inlet temperature and the volume concentration on LMTD, effectiveness, convective heat transfer coefficient and the pressure drop were investigated. [4]

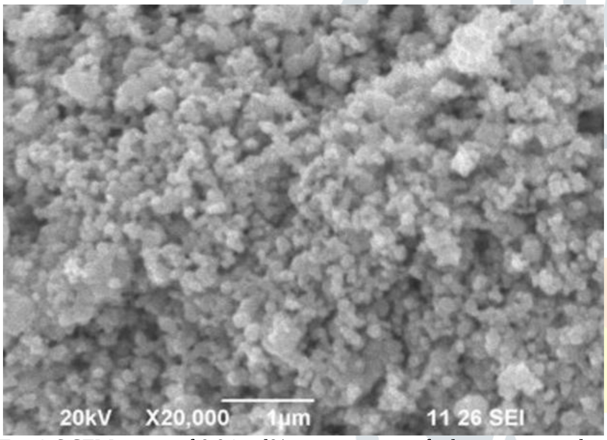

Fig. 2.6 SEM image of 0.04 vol% concentration of silver nanoparticles.

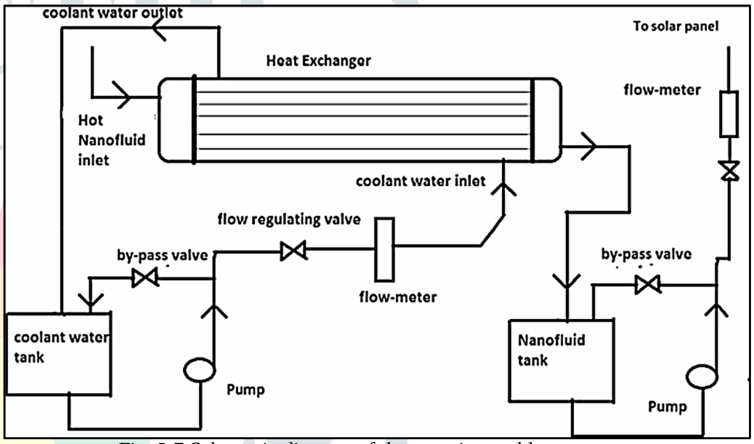

Fig. 2.7 Schematic diagram of the experimental layout.

Specification	Shell	Tube
Material	Stainless Steel	Copper
Outer Diameter (mm)	200	6
Inner Diameter (mm)	150	4
Length	700	700
Number of Tubes	-	25

Table. 2.1 Specifications of the shell and tube heat exchanger.

Ahmad Ghozatloo et al, investigated development of higher convective heat transfer characteristics of graphene nanofluids through the shell and tube heat exchanger under laminar flow. Graphene nano sheets were prepared by CVD method and their morphology was investigated by SEM and Raman spectroscopy. The convective heat transfer coefficients of graphene nanofluids based on water in the entrance region and under laminar conditions have been measured. Also the effect of temperature and concentration on convective heat transfer coefficients of graphene nanofluids has been discussed. [5]

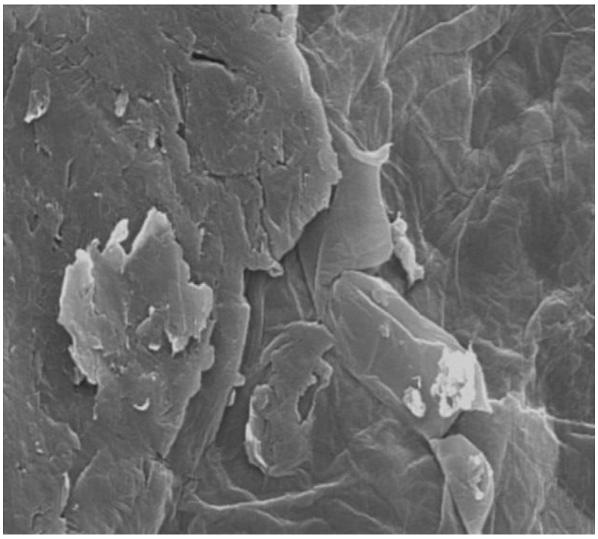

Fig. 2.8 SEM image of graphene.

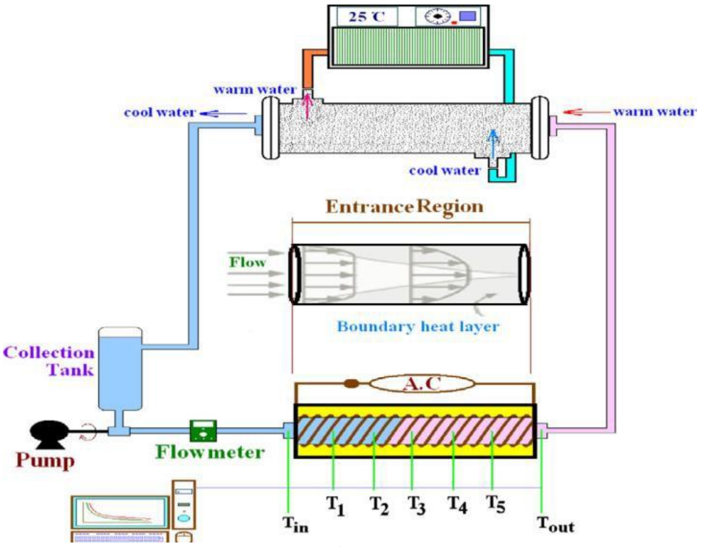

Fig. 2.9 Schematic of the experimental set up.

Z. Said et al, performed the optimization of shell and tube heat exchangers. An improvement in heat exchanger efficiency was achieved by maintaining lower overall cost and energy consumption. The stability, thermo physical properties, heat transfer performance, and possible reduction in area of shell and tube heat exchanger with CuO/water nanofluid was investigated. The Eco Audit CES Edu pack software was used to carry out the life cycle analysis for the total energy, CO2 emissions and the cost over the life (25 years) of the baseline. The results showed that the proposed new system is economically viable and environmentally friendly.[6]

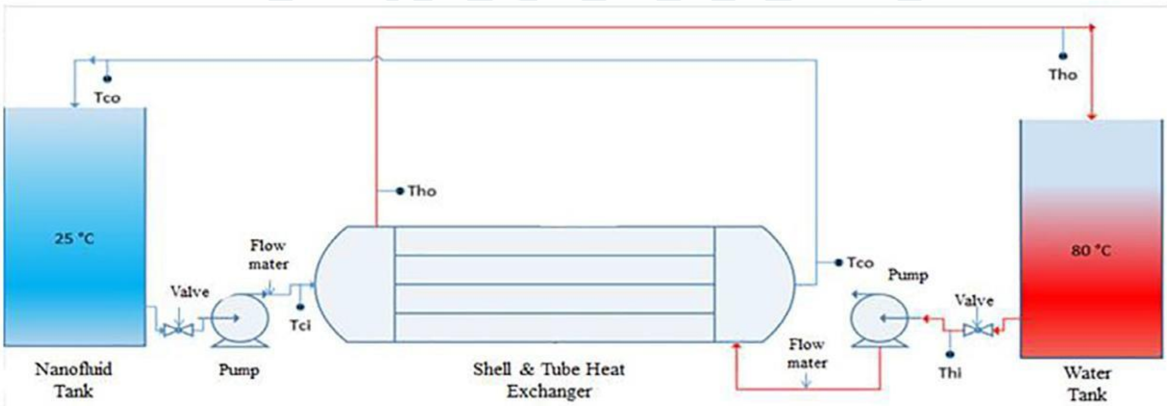

Fig. 2.10 Schematic diagram of the experimental setup

III. Performance Characteristics

The Tube side cold fluid temperature increases when compared with Distilled water for 2% volume concentration Al2O3-water nanofluid is observed to be 2.4 K for Pe=60000. The increase in Tube side hot fluid temperature for 0.3%, 0.5%, 0.75%, 1%, 2% volume concentrations of Al2O3-water nanofluid is found to be 0.5K, 1K, 1.5K, 1.9K, 2.4K respectively. The Nusselt number increase for 0.3%, 0.5%, 0.75%, 1%, 2% volume concentrations of Al2O3-water nanofluid is found to be 0.55%, 2.65%, 4.05%, 5.58%, 7.54% respectively.[1]

Physical Properties	Distilled water as a cooling medium	Al2O3- Water nano fluid as a cooling medium at Pe=60000, 2% volume fraction	% Enhancement Or % Reduction
Over heat transfer coefficient U_i (W/m^2K)	347	356.2	2.65% enhancement
Nusselt number	71.6	77	7.54% enhancement

Table. 3.1 Comparison of CFD simulated results of cooling mediums

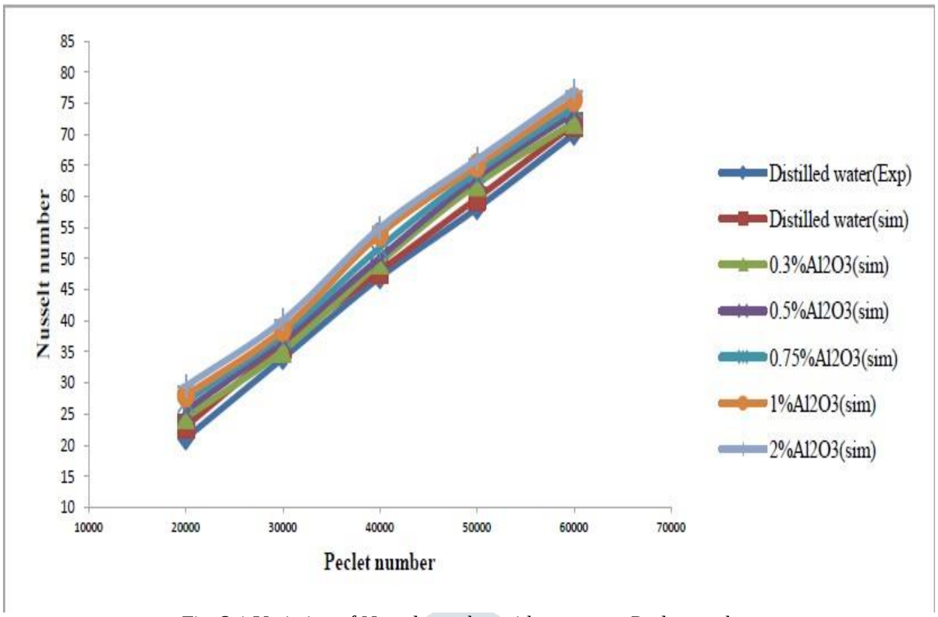

Fig. 3.1 Variation of Nusselt number with respect to Peclet number

The Nusselt number of hot working fluid augments with enhancement of Reynolds number and at a specific Reynolds number, the Nusselt number enhances as the nanoparticles volume concentration increases. The maximum enhancement of nanofluid Nusselt number at 0.03, 0.14 and 0.3% volume concentration of particles are specified about 9.7, 20.9 and 29.8%, respectively and also it is clearly seen that the maximum enhancement of nanofluid Nusselt number at 0.14 and 0.3 vol% have occurred at the highest tested Reynolds number.[2]

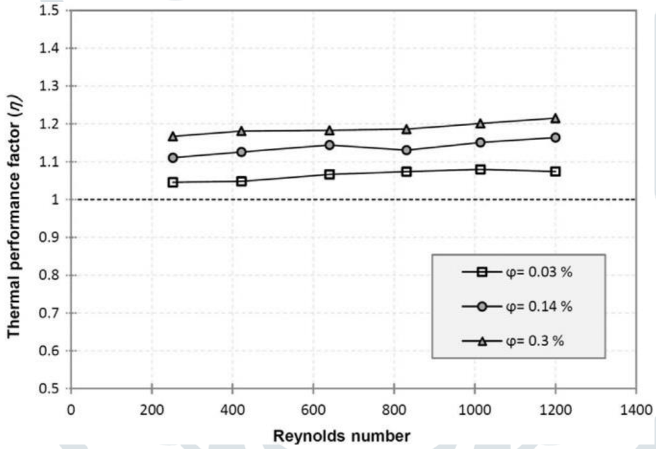

Fig. 3.2 Comparison between the thermal performance factor of nanofluid at different nanoparticles vol% in the shell and tube heat exchanger

Effect of Shape of Nanoparticles and Baffle Angle on Overall Heat Transfer Coefficient and Heat Transfer Rate

I. All shapes shows better results with 20° baffle angle than others.
II. For all baffle angles, cylindrical shaped nanoparticles gives best results.
III. Blades and platelets shaped nanoparticles gives almost same results.[3]

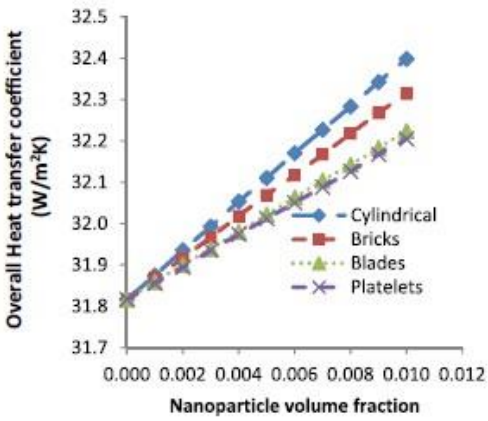

Fig. 3.3 Effect of nanoparticle shapes on overall heat transfer coefficient at segmental baffle

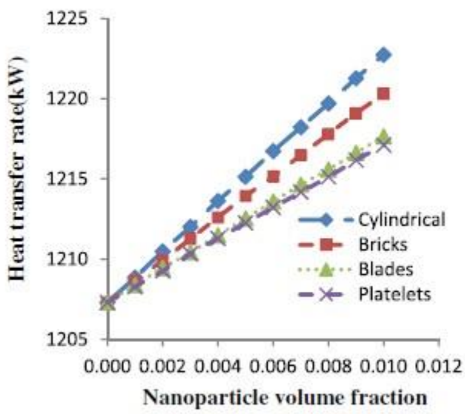

Fig. 3.4 Effect of different nanoparticle shapes on heat transfer rate at segmental baffle

Effect of Shape of Nanoparticles and Baffle Angle on Entropy Generation

I. Entropy generation is highest for 20^o baffle angle and lowest for 50^o baffle angle.

II. Minimization rate of entropy generation is highest for cylindrical shape and lowest for platelets shaped nanoparticles.[3]

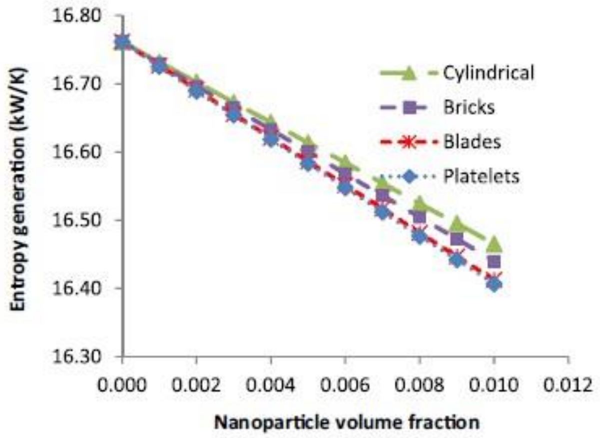

Fig. 3.5 Effect of different nanoparticle shapes on entropy generation at segmental baffle

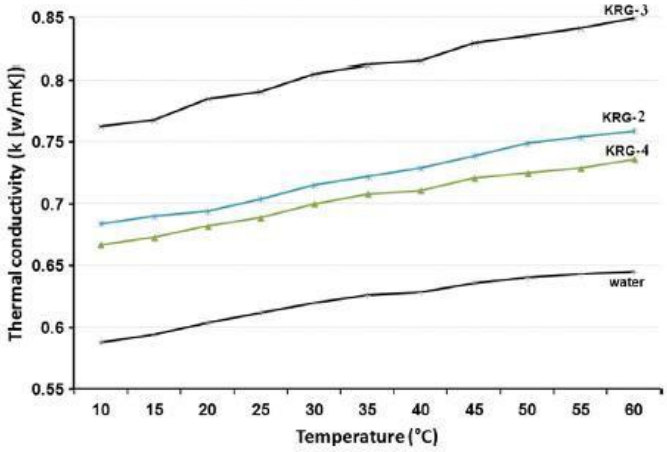

Fig. 3.6 Effect of temperature on heat transfer coefficient

Thermal conductivity of the samples increases with increase in concentration of samples and temperature. The effect of graphene on thermal conductivity of nanofluids is much more than heat transfer coefficient of nanofluids and this effect increases with increasing the concentration of graphene. This matter is related to the difference of thermal conductivity and heat transfer coefficient which respectively are static properties and dynamic properties. The thermal conductivity of graphene nanofluids at 25 ^{O}C increased by 15.0%, 29.2 and 12.6 at 0.05, 0.075 and 0.1 wt%, respectively. [5]

Increasing the temperature and concentration of nanofluids, average heat transfer coefficient will increase. By increasing the temperature from 25 to 38 ^{O}C, 13.1% increase in the convective heat transfer of 0.1 wt% graphene nanofluids was observed. The effect of graphene concentration in water at higher temperatures was more noticeable. By increasing the concentration of graphene from 0.025 wt% to 0.1 wt%, the heat transfer coefficient of grapheme nanofluids increased by 15.3% at 25 ^{O}C, whereas at 38 ^{O}C, an enhancement of 23.9% on heat transfer coefficient was occurred. [5]

IV. CONCLUSION

The review study showed that the effective cooling of shell and tube heat exchanger was better with Al_2O_3-water nanofluid than distilled water. The CuO nanofluid has higher thermal conductivity and effectiveness which results in better heat transfer rate, higher heat transfer coefficient and lowers the energy consumption. The combination of cylindrical shaped nanoparticles and 20^o baffles angle gives the best results for increment in overall heat transfer coefficient and heat transfer rate and in minimization of entropy generation. The percentage increase in heat transfer coefficient for 0.01%, 0.03% and 0.04% vol% of silver-water nanofluid are 9.2%, 10.87% and 12.4% respectively. The effect of graphene on thermal conductivity of nanofluids is much more than heat transfer coefficient of nanofluids and this effect increases with increasing the concentration of graphene.

V. REFERENCES

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