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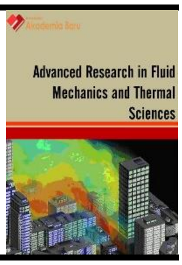

Effect of Impregnate Nanocellulose With Ethylene Glycol for Car Radiator Application

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ABSTRACT

One of the efforts to increase the effectiveness of radiator is by adding nanocellulose in radiator coolant. Furthermore, the percentage of nanocellulose plays an important role to make sure that the amount of heat transfer can be increased by increasing the percentage of nanocellulose. The nanocellulose is used in this experiment as the nanoparticles. Radiator was modelled using One-Dimensional simulation software to predict the performance characteristics and effectiveness of the radiator with addition of nanoparticles. Besides that, method of using micro channels and fins to extend the cooling rate of a radiator ended up being a traditional technology which already reached to its maximum limit. Moreover, Heat transfer coefficient of cellulose nanofluids can be increased by increasing the size of the radiator. Increase in size of radiator may enhance better and help to increase the rate of heat transfer. In addition, it clearly states that when the flow rate of the coolant or working fluid in the radiator cooling system increase the rate of heat transfer also is increases.

1. Introduction

An engine coolant is a fluid which flows through the engine and prevents it from overheating by transferring the heat generated by the engine to other components that either make use of it or dissipate it. Besides that, a feature of an ideal coolant entails a low viscosity, high thermal capacity, has chemical inertness and is low-cost [1]. Further, it should neither cause nor promote corrosion of the cooling system. The most common coolant is water. Its high heat capacity and low cost makes it a suitable heat-transfer medium [2, 3]. It is usually used with additives, like corrosion inhibitors and antifreeze. Antifreeze, a solution of a suitable organic chemical (most often ethylene glycol, diethylene glycol, or propylene glycol in water, is used when the water-based coolant has to

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withstand temperatures below 0 °C, or when its boiling point has to be raised. In radiator, force convectional is the important thing that can be considered. The examples of convectional heat transfer fluids are nanofluid, water, glycerol, Ethylene Glycol and minerals oil [4-6]. These base fluids have been used widely in automotive radiators and these fluids recently have very low thermal conductivities. In advance, in the last decade, many researches have been done regarding to the study of enhancement of the convective heat transfer performance in nanoparticles [7, 8]. All of these transfer fluids play an important role in many industrial sectors such as air-conditioning, transportation, microelectronics, power generation and chemical production [9, 10]. Although different systems have been connected to upgrade their heat transfer abilities, their execution is regularly constrained by their low thermal conductivities which impede the execution improvement and smallness of heat exchanges [11]. According Naraki *et al.* [12], the experimental under laminar flow in a car radiator shows that the overall heat transfer coefficient with nanoparticles absolutely more than the base fluid. There was experimentally studied from for forced convection heat transfer of Fe2O3 and CuO nanofluids in car radiator [13]. As the result from the research, the overall heat transfer coefficient is increase but the inlet temperature of liquid is decrease. In a study of [6], one of the strategies to increase the heat transfer in car radiator is by using nanofluid because it is the new innovation that can be obtained by dispersing nanoparticles on the base fluids [14]. In the best condition, the heat transfer coefficient upgrade of around 55% contrasted with the base liquid was recorded [15]. Utilizing distinctive fin sorts and micro channels, various tube embeds, or harsh surfaces demonstrate a few efforts made for expand [12]. Besides that, in their researchers found that expanding the fluid circulation rate can enhance the heat transfer execution while the fluid inlet temperature to the radiator has next to zero impact [8, 16]. Nanofluid researched in the present work with low concentration improved the heat transfer rate up to 37% in examination with base liquid [17, 18]. In additions, Nanoparticles, the added substances of nanofluid, play a critical part in changing the thermal transport properties of nanofluid additionally they change the liquid attributes since thermal conductivity of the particles is higher than standard liquids [19, 20]. Some studies also were made on effects of variable mass flow rate of the coolant in the radiator, the rate of flow is controlled by the pump voltage for experimental and speed for the simulation. The main focus of the paper is to analyse the radiator in one dimensional. In fact, nanosubstance can be categorized into nanoparticle, nanorod, nanowire, nanosheet and nanotube. Each category is differentiated by its physical appearance such as size, shape and aspect ratio. Thus, variation in physical appearance produces different amount of thermophysical enhancement. The selected type of nanosubstance and base fluid plays a major role in thermophysical property enhancement. Experiment conducted by reveals that nanoparticle in sphere size enhances thermal conductivity better than cylinder shaped nanoparticle. It can be best explained by variation of surface area to volume ratio among type of nanosubstance. Thus, nanoparticle with high surface area produces better thermal conductivity enhancement.

2. Material and Method

2.1 Nanofluid Preparation

There are few criteria that need to be finalized before the preparation of the nanocellulose which concentration volume are, required volume of nanofluid and amount of cellulose to be mix with the nanofluid. 0.5% of volume concentration sample was chosen to run in the one-dimensional test. During normal operation of a radiator in an automotive engine, the radiator cooling fluid is prepared with mixture of water and Ethylene Glycol with certain percentage which comprises the total volume of the radiator. For an instance, assuming the volume of the radiator is 1 litre, and the mixing ratio is set to be 50:50. Thus, the mixture of the cooling fluid in the radiator will be 500ml of water (50%) and 500ml of Ethylene Glycol (50%). As proposed in this research, the volume of the radiator used is 4 litres and the agreed mixing ratio is 60:40 whereby 60% of total volume of radiator will be Ethylene Glycol while the rest 40% will be water. Therefore, the required volume of nanofluid is 3.9L prepared for 0.5% volume concentration. Later, distilled water has to be poured in the 1L beaker according to the ratio which is 40% of the total solution which is 368ml. Furthermore, distilled water should be poured first because it has the lowest density value compared to Ethylene Glycol and the cellulose. Then, followed by 60% of Ethylene Glycol at 552ml. Next, the nanocellulose must be dispersed in the base fluid of distilled water and Ethylene Glycol using syringe at required volume which is 70ml. On the other hand, the experiment was conducted 4 times since the beaker used is 1L and the quantity needed is less than 4L. For next step, the beaker is placed on top of a magnetic stirrer and a magnet is dropped into the beaker which will play its role in mixing the mixture. Besides, the speed of the magnetic stirrer is set at appropriate speed so that the nanofluid will not splash out of the beaker. The stirring process was carried out for 30 minutes to ensure the nanocellulose is fully diffused into the distilled water and Ethylene Glycol. After that, the solution will be placed for sonication bath for 2 hours at the temperature of 50^{O}C.

2.2 Thermal Conductivity Measurement

The thermal conductivity of the nanofluid is measured with thermal property analyzer which uses the transient line heat source to detect the thermal properties of the liquid. The thermal analyzer model is KD2 Pro as shown in Figure 1. The range of the measurement for this equipment is 0.2 W/m.K to 2.0 W/m.K. KS-1 sensors is used to measure the thermal conductivity of liquids. Besides that, thermal conductivity is an important criterion which determines the heat conductivity rate of a fluid [21]. Metal have higher thermal conductivity compared to liquids. The main reason of adding nanocellulose into distilled water and Ethylene Glycol is to evaluate its thermal conductivity and heat diffusivity ability and its differences at 0.5% volume concentration at ratio 60:40 (EG:W). Thermal diffusivity represents how fast a fluid can diffuse heat through it. The larger the thermal diffusivity, the faster the propagation of heat through a fluid. Although water which is readily available coolant might be relevant to be used as radiator coolant but water takes longer period of time to release the heat which is absorbed from the radiator to the surrounding [22]. This is the factor which makes water to be a poor radiator coolant compared to cellulose nanofluid [23].

Fig. 1. KD2 Pro used to measure the thermal conductivity of nanofluid

2.3 Viscosity Measurements

The viscosity of the nanofluid is measured by using viscometer as shown in Figure 2. Before measuring the viscosity of nanofluid, the viscometer is validated with measurement of distil water at room temperature. The measured viscosity of nanofluid is validated by using Eq. (1). In addition, the regression equation can be used to predict the viscosity of nanofluid. Another important criterion is the viscosity where it describes the internal friction of a moving fluid. Nanocellulose have greater viscosity compared to water and Ethylene Glycol. Mixture of nanocellulose with distilled water and Ethylene Glycol can increase the level of viscosity of the content compared to ordinary available coolant which contains only water and ethylene glycol [24].

$$\frac{\mu_{nf}}{\mu_w} = C_1\left[\left(1+\frac{\varphi}{100}\right)^{11.3}\left(1+\frac{T_{nf}}{70}\right)^{-0.038}\left(1+\frac{d_p}{170}\right)^{-0.061}\right] \quad (1)$$

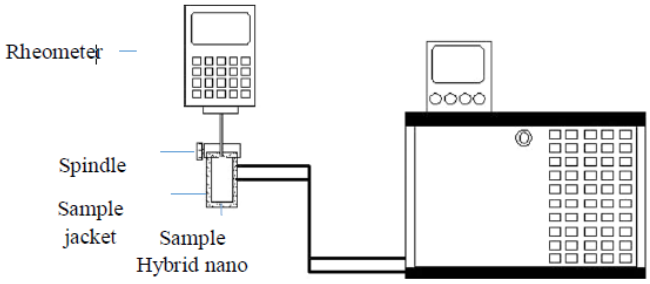

Fig. 2. Viscosity measurement with Brookfield Rheometer

3. Result and Discussion

3.1 Stability of Nanofluid

Stability test also performed for 0.1%, 0.5%, 0.9% and 1.3% of volume concentration for ratio 50:50 (EG:W) nanofluid to determine its shelf life and storage condition of the nanofluid. The ratio of 50:50 (EG:W) was chosen for the stability test because the amount of water and Ethylene Glycol is even with the mixture of nanocellulose. The sample was kept in a dry place for about 2 months to observe for any changes in the nanofluid. In fact, from Figure 3 shows that there is no sedimentation take place after 2 months shows that the condition of nanofluid is good.

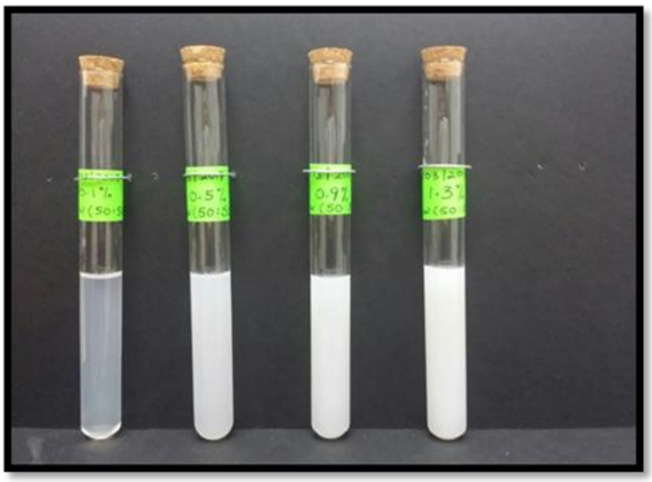

Fig. 3. Stability test for nanofluid of ratio 50:50 (EG:W)

3.2 Simulation Data Compare to Experimental Data

Comparison of temperature is shown in Figure 4 and 5. The trend is similar with increment in temperature as the pump speed is increased. The simulation data can capture more points and its values agree to the experimental data by ±3 °Moreover, Figure 4 represent the data achieve from the one-dimensional analysis which is in case setup template, the case setup was created with different parameter for the radiator before it can run and develop result. The case setup is set up to 10 cases with different engine speed. The engine speed is started from 500 rpm and ended with 5000 rpm with the increment of 500 rpm for each case. Then, Figure 5 shows the data accomplish from the experimental of the test rig. Once the target is reached for the 80°C for nanocelluose, the valve will be opened to let the nanofluid flows into the pump. Later, the radiator fan and the pump adaptors are switched on. Then, the nanofluid is let to be flown and circulate the system. Readings of the temperature from data acquisition at the both inlet and outlet of the radiator together with the temperature at the radiator flat tubes are taken. Lastly, the set-up of test rig turned off.

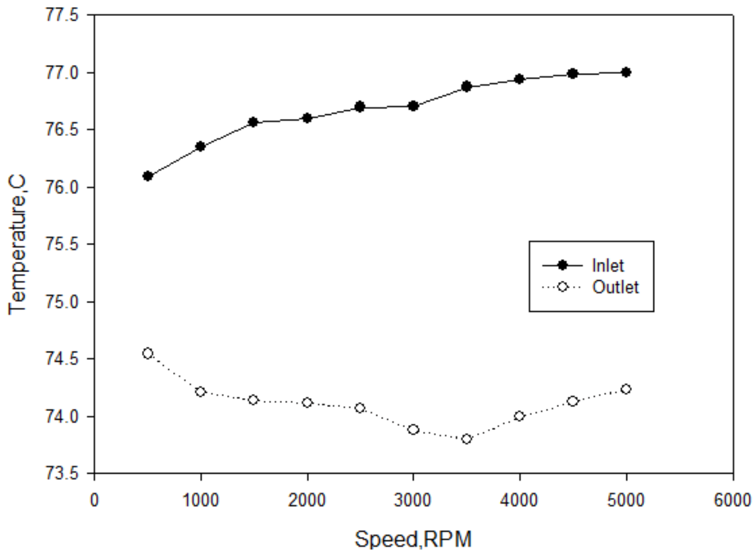

Fig. 4. Speed versus temperature from simulation

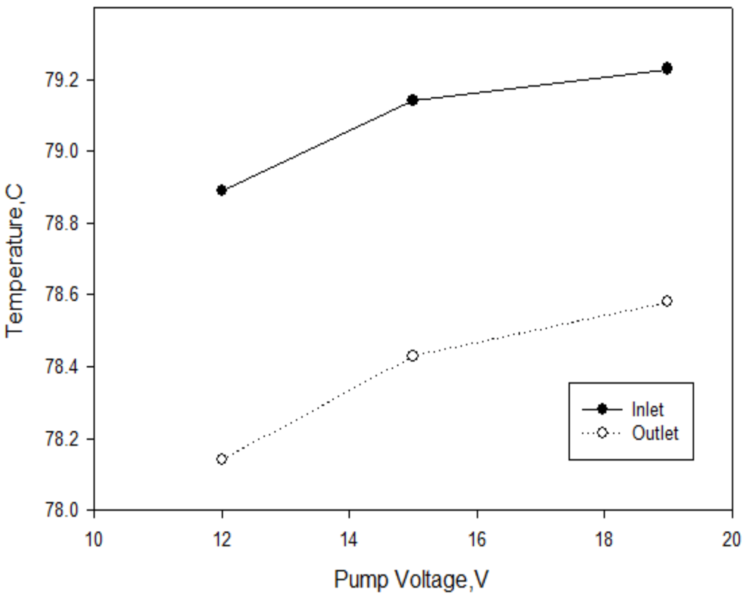

Fig. 5. Pump voltage versus temperature from experimental

The flow rate of the coolant or working fluid in the radiator cooling system increase the rate of heat transfer also is increases as shown in Figure 6 and 7. This is because at higher flow rate the more scrubbing action will occur at the surface of the radiator flat tubes, thus more heat energy will be transferred from coolant to radiator flat tube by the mean of conduction [25]. Nevertheless, there is limit of the flow rate of the coolant is applicable in car cooling system. As the flow rate exceed the limit of the flow rate, the aeration or erosion on the radiator flat tube and foaming of coolant inside the system will likely to happen which is to be avoided. The relation is similar increment in heat transfer rates, the experimental is in proportional value however the experimental values are generally lower as compared to the simulation, this may occur as the simulation is considering ideal conditions which is not captured in real life [26].

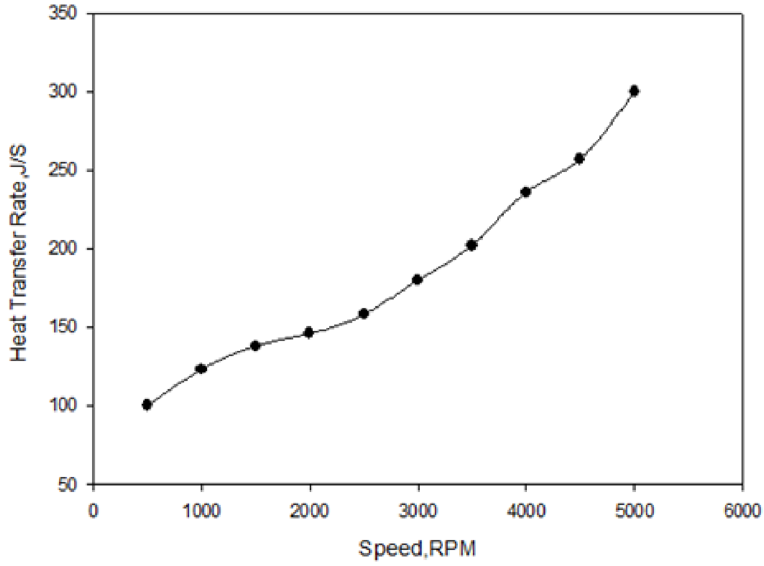

Fig. 6. Relationship between heat transfer and speed from simulation

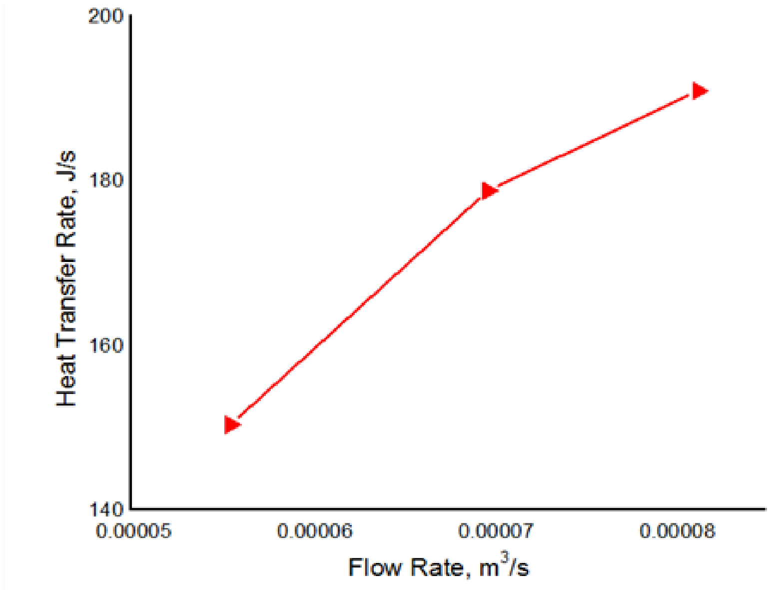

Fig. 7. Relationship between flow rate and heat transfer from experimental

For the consideration of engineering application, it is essential to investigate the temperature drop of nanofluids in addition to the heat transfer enhancement features [27]. The effect of thermal gradient for temperature drop system or also knows as temperature loss along the radiator fins was included additional investigation. This is because at higher flow rate the more scrubbing action will occur at the surface of the radiator flat tubes, thus more heat energy will be transferred from coolant to radiator flat tube by the mean of conduction [28]. Other than that, there is limit of flow rate of the coolant is applicable in car cooling system.

4. Conclusion

Based on the experimental data obtained through simulation and experimental , it is proven facts that the application of nanocellulose with Ethylene Glycol for car radiator application shows a better thermal absorbing efficiency compared to distilled water. 0.5% of volume concentration nanofluid of ratio 60:40 (EG:W) displays a better rate of heat transfer compared to distilled water. Thermal conductivity test shows that compared to Ethylene Glycol, cellulose nanofluids have better thermal conductivity. The highest thermal conductivity is possessed by 0.5% cellulose nanofluids is at 0.519 W/m.°C while the lowest thermal conductivity at 0.497 is owned by cellulose nanofluids of 0.1% volume concentration at ratio 60:40 (EG:W). Moreover, Heat transfer coefficient of cellulose nanofluids can be increased by increasing the size of the radiator. Increase in size of radiator may enhance better and help to increase the rate of heat transfer. In addition, it clearly states that when the flow rate of the coolant or working fluid in the radiator cooling system increase the rate of heat transfer also is increases. This is because at higher flow rate the more scrubbing action will occur at the surface of the radiator flat tubes, thus more heat energy will be transferred from coolant to radiator flat tube by the mean of conduction. Nevertheless, there is limit of the flow rate of the coolant is applicable in car cooling system. As the flow rate exceed the limit of the flow rate, the aeration or erosion on the radiator flat tube and foaming of coolant inside the system will likely to happen which is need to be avoided. This is because it can reduce the efficiency of the radiator. Therefore, improvement can be done by increasing the size of radiator where the cellulose nanofluid can help to transfer more heat from the system.

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References
[1] Gao, Xunan, Bojan Savic, and Roland Baar. "A Numerical Procedure to Model Heat Transfer in Radial Turbines for Automotive Engines." *Applied Thermal Engineering* 153, (2019): 678-691.
[2] George, Mathew, A. K. Pandey, Nasrudin Abd Rahim, V. V. Tyagi, Syed Shahabuddin, and R. Saidur. "Concentrated photovoltaic thermal systems: A component-by-component view on the developments in the design, heat transfer medium and applications." *Energy Conversion and Management* 186 (2019): 15-41.
[3] Pu, Wenhao, Ning Yang, Chen Yue, Shuang Bai, and Yitung Chen. "Simulation on direct contact heat transfer in gas-molten salt bubble column for high temperature solar thermal storage." *International Communications in Heat and Mass Transfer* 104 (2019): 51-59.
[4] Xu, H. J., Z. B. Xing, F. Q. Wang, and Z. M. Cheng. "Review on heat conduction, heat convection, thermal radiation and phase change heat transfer of nanofluids in porous media: Fundamentals and applications." *Chemical Engineering Science* 195, (2018): 462-483.
[5] Lei, Gang, Weirong Li, and Qingzhi Wen. "The convective heat transfer of fractal porous media under stress condition." *International Journal of Thermal Sciences* 137 (2019): 55-63.
[6] Chakraborty, Pranay, Tengfei Ma, Lei Cao, and Yan Wang. "Significantly enhanced convective heat transfer through surface modification in nanochannels." *International Journal of Heat and Mass Transfer* 136 (2019): 702-708.

[7] Sajid, Muhammad Usman, and Hafiz Muhammad Ali. "Recent advances in application of nanofluids in heat transfer devices: a critical review." *Renewable and Sustainable Energy Reviews*103 (2019): 556-592.
[8] Huminic, Gabriela, and Angel Huminic. "Heat transfer capability of the hybrid nanofluids for heat transfer applications." *Journal of Molecular Liquids* 272 (2018): 857-870.
[9] Qi, Cong, Maoni Liu, Guiqing Wang, Yuhang Pan, and Lin Liang. "Experimental research on stabilities, thermophysical properties and heat transfer enhancement of nanofluids in heat exchanger systems." *Chinese Journal of Chemical Engineering* 26, no. 12 (2018): 2420-2430.
[10] Bondareva, Nadezhda S., Bernardo Buonomo, Oronzio Manca, and Mikhail A. Sheremet. "Heat transfer inside cooling system based on phase change material with alumina nanoparticles." *Applied Thermal Engineering* 144 (2018): 972-981.
[11] Ji, Pengfei, and Yuwen Zhang. "First-principles molecular dynamics investigation of the atomic-scale energy transport: From heat conduction to thermal radiation." *International Journal of Heat and Mass Transfer* 60 (2013): 69-80.
[12] Naraki, M., S. M. Peyghambarzadeh, S. H. Hashemabadi, and Y. Vermahmoudi. "Parametric study of overall heat transfer coefficient of CuO/water nanofluids in a car radiator." *International Journal of Thermal Sciences* 66 (2013): 82-90.
[13] Peyghambarzadeh, S. M., S. H. Hashemabadi, M. Naraki, and Y. Vermahmoudi. "Experimental study of overall heat transfer coefficient in the application of dilute nanofluids in the car radiator." *Applied Thermal Engineering* 52, no. 1 (2013): 8-16.
[14] Subhedar, Dattatraya G., Bharat M. Ramani, and Akhilesh Gupta. "Experimental investigation of heat transfer potential of Al2O3/Water-Mono Ethylene Glycol nanofluids as a car radiator coolant." *Case Studies in Thermal Engineering* 11 (2018): 26-34.
[15] Ahmed, Siraj Ali, Mehmet Ozkaymak, Adnan Sözen, Tayfun Menlik, and Abdulkarim Fahed. "Improving car radiator performance by using TiO2-water nanofluid." *Engineering science and technology, an international journal* 21, no. 5 (2018): 996-1005.
[16] Delavari, Vahid, and Seyed Hassan Hashemabadi. "CFD simulation of heat transfer enhancement of Al2O3/water and Al2O3/ethylene glycol nanofluids in a car radiator." *Applied thermal engineering* 73, no. 1 (2014): 380-390.
[17] Goudarzi, K., and H. Jamali. "Heat transfer enhancement of Al2O3-EG nanofluid in a car radiator with wire coil inserts." *Applied Thermal Engineering* 118 (2017): 510-517.
[18] Hussein, Adnan M., H. K. Dawood, R. A. Bakara, and K. Kadirgamaa. "Numerical study on turbulent forced convective heat transfer using nanofluids TiO2 in an automotive cooling system." *Case Studies in Thermal Engineering* 9 (2017): 72-78.
[19] Subudhi S, Kumar A. "Application of Nanofluids for Radiator Cooling. Reference Module in Materials Science and Materials Engineering." *Elsevier*; (2019).
[20] Mohammadpoor, M., S. Sabbaghi, M. M. Zerafat, and Z. Manafi. "Investigating heat transfer properties of copper nanofluid in ethylene glycol synthesized through single and two-step routes." *International Journal of Refrigeration* 99 (2019): 243-250.
[21] Taheran, Ehsan, and Kourosh Javaherdeh. "Experimental investigation on the effect of inlet swirl generator on heat transfer and pressure drop of non-Newtonian nanofluid." *Applied Thermal Engineering* 147 (2019): 551-561.
[22] Raja, M., R. Vijayan, P. Dineshkumar, and M. Venkatesan. "Review on nanofluids characterization, heat transfer characteristics and applications." *Renewable and sustainable energy reviews* 64 (2016): 163-173.
[23] Sundar, L. Syam, and Manoj K. Singh. "Convective heat transfer and friction factor correlations of nanofluid in a tube and with inserts: a review." *Renewable and Sustainable Energy Reviews* 20 (2013): 23-35.
[24] Mahian, Omid, Lioua Kolsi, Mohammad Amani, Patrice Estellé, Goodarz Ahmadi, Clement Kleinstreuer, Jeffrey S. Marshall et al. "Recent advances in modeling and simulation of nanofluid flows-part II: applications." *Physics reports* (2018).
[25] Ali, Hafiz Muhammad, Hassan Ali, Hassan Liaquat, Hafiz Talha Bin Maqsood, and Malik Ahmed Nadir. "Experimental investigation of convective heat transfer augmentation for car radiator using ZnO–water nanofluids." *Energy* 84 (2015): 317-324.
[26] Mukkamala, Yagnavalkya. "Contemporary trends in thermo-hydraulic testing and modeling of automotive radiators deploying nano-coolants and aerodynamically efficient air-side fins." *Renewable and Sustainable Energy Reviews* 76 (2017): 1208-1229.
[27] Ganvir, R. B., P. V. Walke, and V. M. Kriplani. "Heat transfer characteristics in nanofluid—a review." *Renewable and Sustainable Energy Reviews* 75 (2017): 451-460.
[28] Hong Wei Xian, Nor Azwadi Che Sidik, M'hamed Beriache. "Heat Transfer Performance of Hybrid Nanofluid as Nanocoolant in Automobile Radiator System. " *Journal of Advanced Research Design* 51, no. 1 (2018): 14-25.