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Heat transfer augmentation by nano-fluids and Spiral Spring insert in Double Tube Heat Exchanger – A numerical exploration

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ABSTRACT

The efficiency of the most of the thermal devices can be improved by increasing the heat transfer. Some process industries like power plant, automobile demand the heat transfer augmentation in either heating or cooling or evaporation on the devices like air conditioning, radiators, refrigerators, condensers etc. The available methods can be classified in to two category namely passive and active techniques. The objective of the research to improve the heat transfer in double pipe heat exchanger by passive techniques. The fluid mediums like water, titanium dioxide nano-fluid, Beryllium oxide or beryllia nano-fluid, zinc oxide nano-fluid and copper oxide nano-fluids are considered for analysis with the aim of increasing the thermal conductivity of fluid medium. The Spiral Spring insert used for offering the flow resistance and spread the fluid to surface to enhance the heat transfer. The numerical study is investigating the thermal and flow fields utilizing various types of nano-fluids with Spiral Spring insert in the double pipe heat exchanger. The Finite volume method employed for solve the continuity, momentum and energy equations the ANSYS 15.0 employed for conducting the numerical analysis.

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1. Introduction

The heat transfer amplification is primary importance in the heat exchangers. The Nanofluids are kind of heat transfer fluid which has suspension of nanoparticles on its base fluid. [1] experimentally examined the nanofluids applications in Micro Electro-Mechanical Systems, that is the Al_2O_3 nanofluid and SiO_2 nanofluid applications in the microchannels and reported that the SiO_2 nanofluid perform better in heat transfer enhancement than Al_2O_3 nanofluid. The heat transfer proportional to nanoparticle concentration. [2] studied the performance of nanofluids which flow in an elliptic annulus. The base fluid was ethylene glycol and the nanoparticles are SiO_2 Al_2O_3, ZnO, and CuO and concluded that the ethylene glycol and SiO_2 nanofluid perform better in heat transfer enhancement than other nanofluids. The nanoparticle concentration increases the Nu. [3] reported that the water and ethylene glycol are employed as base fluid for the nanofluids for heat transfer applications. [4] reviewed the role and thermo physical properties of hybrid nanofluids. In hybrid nanofluids two different nanoparticles will be included with the conventional fluids like water or ethylene glycol to prepare them. [5] numerically explored the heat transfer performance in a heat exchanger and reported he interesting results like the decrease of size of nanoparticles improves the optimal particle loading, increase of average temperature of Heat Transfer Fluid increase the heat transfer, increase of hot pipes increases the total Nu and location of the pipe influencing more. [6] Investigated about base fluid hybridization for a solar thermal system of the parabolic trough collectors and recommended that the 60% of ethylene glycol with 40% water yielded high pressure drop penalty than pure water. [7] numerically studied on annular concentric pipe with TiO_2, Al_2O_3 and CuO – water based nanofluids. The nanofluids, expansion ratio and volume fraction were varied 3 levels, the heat flux also varied. The highest total improvement of 49% augmentation with Al_2O_3-water based nanofluid. The numerical results were shown good agreement with experimental results. [8] reviewed and reported about the CNT based nanofluids that the lower the pumping power the higher the heat transfer coefficient can be achieved by use of CNT nano fluid than other nanofluids for heat transfer augmentation. [9]

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numerically studied the effect of concentration of Al_2O_3-water nanofluid in the circular-tube banks with staggered arrangement and reported that the maximum concentration 5% performed well at Re range from 100 to 600. [10] studied numerically about flow of water based CuO, TiO_2 and Al_2O_3 nanfluid the intensification heat transfer under the higher Re (Turbulent) in the straight square channel and reported that when concentration in nanofluids increases, the wall shear stress. Among three nanofluid the water based CuO outperformed significantly. The results agreed with 10% deviation with other literatures. But this paper numerically analyzing the effect of using twisted tape with rectangular cut on its rib, insert placed in a circular double pipe heat exchanger on the thermal and flow fields utilizing various types of nanofluids.

2. Materials and methods

2.1. Double tube

The Double Tube Heat Exchanger (DTHE) is considered here with unit length. The cooling tube material is steel. Its inner tube inner diameter 50.83 mm and outer tube outer diameter is 76.20 mm. the length of the tube is 1000 mm. The 3D modeled tube is shown in Fig. 1.

2.2. Twisted tape

The Fig. 2 shows the 3D modeled trapezoidal cut twisted tape (TCTT) and its various parameters: Tape length 998 mm, in which the twist Length 355 mm, tape width is 49.3 mm and the twist angle is 500°. The Spiral Spring width 49.3 mm and rod insert diameter of 10 mm, Fins diameter of 3 mm and the total length of 998 mm.

The combination of the Twisted Tape and Double tube is shown in Fig. 3. The Mesh image of the double heat exchanger with twisted tape insert is shown in Fig. 4. The ANSYS FLUENT software version 15.0 is used for this numerical investigation. The boundary conditions were assigned and the model is meshed. The governing equations were solved through a segregated, implicit solver option. The first order upwind discrimination scheme was used for the energy, momentum, and turbulence parameters and the second order pressure interpolation scheme and SIMPLE pressure–velocity coupling were implemented. A residual root-mean-square (RMS) target value of 10^{-4} (10^{-6} for energy equation) was defined for the CFD simulations. The inlet and outlet temperatures were 300 K and 348.15 K respectively. The experiments carried out with the done for Reynolds number of 1000, 2000, 3000, 5000 and 10,000. The pressure based and absolute velocity formulation at steady time solver type was assigned. The Realizable k-epsilon energy equation is used at uniform inlet temperature in the viscous model. As per [4], gravitational force is included in the fluid medium. The flow of hot fluid and flow of cold fluids are in the inner and outer tube respectively

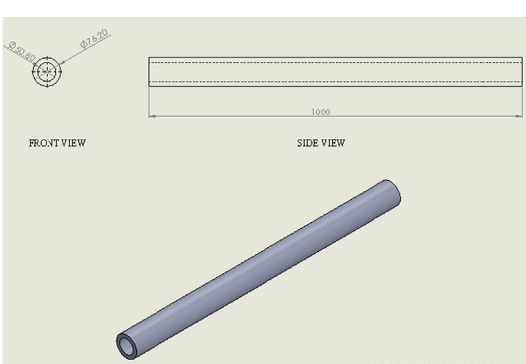

Fig. 1. 3D Model of Double Tube.

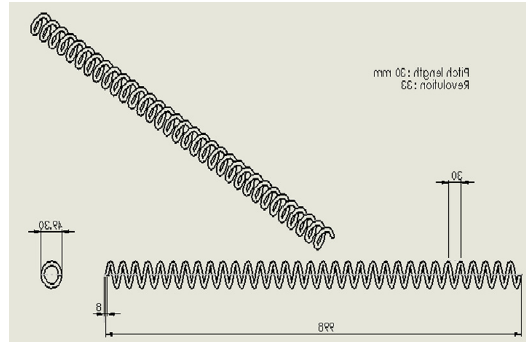

Fig. 2. 3D Model of Spring insert.

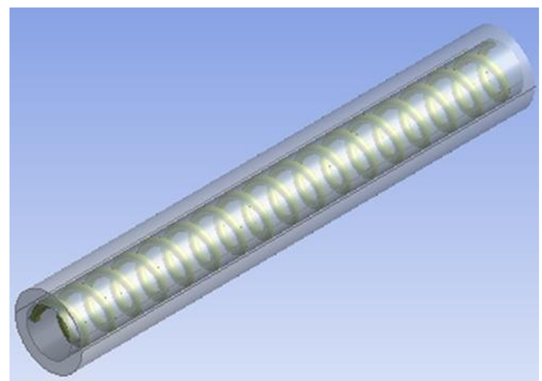

Fig. 3. 3D model of DTHE with a Spring inserts.

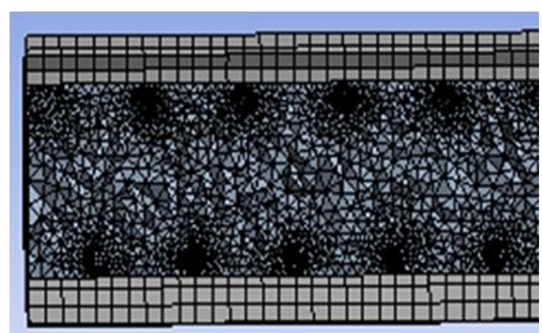

Fig. 4. Messing of DTHE with a Spring inserts.

2.3. Thermal performance factor

The thermal performance factor (TPF) can be defined as a ratio between the enhanced heat transfers to the increased friction. Mathematically termed as η. This factor is a measures of performance of effectiveness of the passive techniques which adapted for heart transfer enhancement. Here the notation 't' for with twisted tape insert and the notation 'p' for (Plain) without twisted tube.. The ratio of Nusselt numbers (Nu) of a case tube with twisted tape insert to plain tube case is called as enhanced heat transfer. Similarly the increase of friction is the ratio of friction in the twisted tape insert case to plain tube case.

The set up simulated with desired Reynolds numbers for both the case plain and twisted tape insert cases and also with different

Table 1
Thermal performance and Friction of nano-fluids with respect to Reynolds Number.

Reynolds number		1000	2000	3000	5000	10,000
Plain Water	Nu	41.5802	61.2302	92.1154	175.4577	278.9941
	f	0.2011	0.1388	0.0814	0.0535	0.0225
TiO_2	Nu	90.392	102.0394	137.2577	207.157	356.0451
	f	0.2042	0.1476	0.1255	0.1057	0.0845
BeO	Nu	67.8122	99.9431	135.6761	204.6472	350.8753
	f	0.2012	0.152	0.1296	0.1093	0.0873
ZnO	Nu	65.1267	97.386	131.8694	201.0138	341.3365
	f	0.2167	0.1325	0.1211	0.1147	0.0911
CuO	Nu	61.3796	79.0837	127.7398	200.406	341.508
	f	0.2199	0.1612	0.1315	0.1169	0.0927

Table 2
Thermal performance factor for nano-fluids with respect to Reynolds Number.

Reynolds number	Thermal performance factor, η			
	TiO_2	BeO	ZnO	CuO
1000	1.8790	1.7952	1.6587	1.5578
2000	1.8669	1.7580	1.7985	1.6015
3000	1.2898	1.2612	1.4236	1.2547
5000	0.9407	0.9190	0.8884	0.8800
10,000	0.8209	0.8001	0.7675	0.7635

Table 3
Heat transfer rate with fluid medium.

Reynolds number	Heat Transfer Rate (W)				
	Plain Water	TiO_2	BeO	ZnO	CuO
1000	5240.1409	5077.623	5170.091	5209.202	5260.965
2000	10857.2856	10563.77	10709.42	10735.2	10816.77
3000	16550.7954	16126.25	16328.31	16341.83	16458.94
5000	27911.645	27194.74	27290.18	27307.43	27487.17
10,000	55133.965	53891.72	54386.77	54176.35	54441.54

fluid medium like plain water, titanium dioxide nano-fluid, Beryllium oxide or beryllia nano-fluid, zinc oxide nano fluid and copper oxide nano-fluid. The observed thermal performance (Nusselt number) and friction factors with respect to flow (Reynolds number) are furnished in the Table 1. The calculated thermal performance factor (η) furnished in the Table 2. The heat transfer rates with respect to fluid medium at various flow conditions are presented in Table 3.

3. Results and discussions

The velocity, temperature, pressure and the turbulence kinetic energy profiles are observed and demonstrated in the graphs from

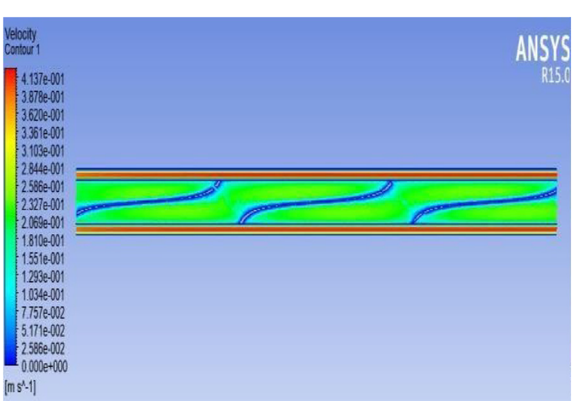

Fig. 5. Velocity Profile of DTHE with Spring insert.

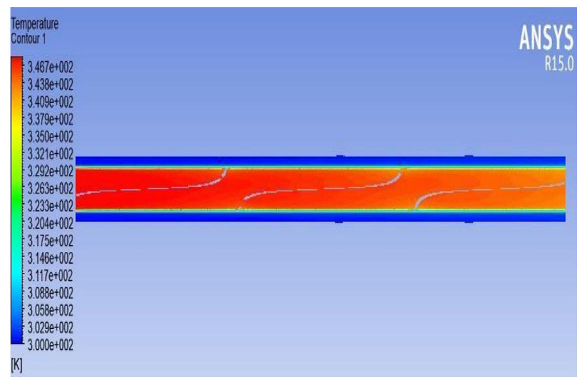

Fig. 6. Temperature Profile of DTHE with Spring insert.

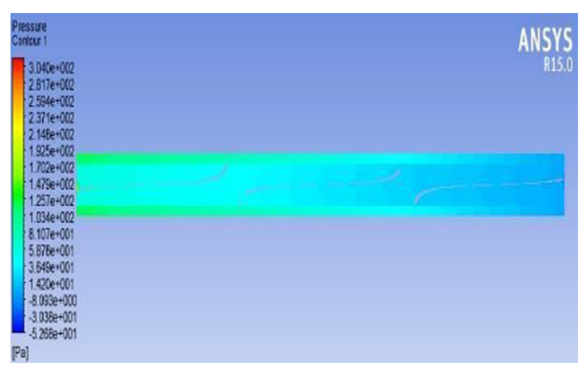

Fig. 7. Pressure Profile of DTHE with Spring insert.

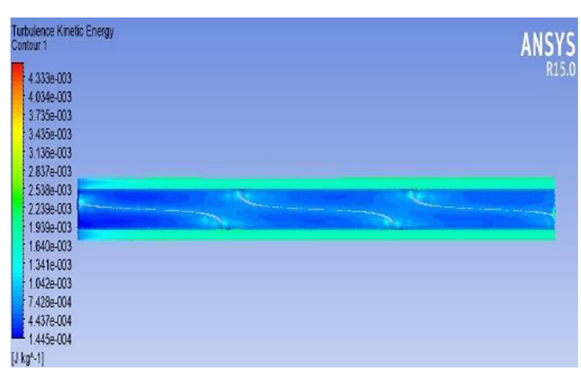

Fig. 8. Turbulence Kinetic Energy Profile of DTHE.

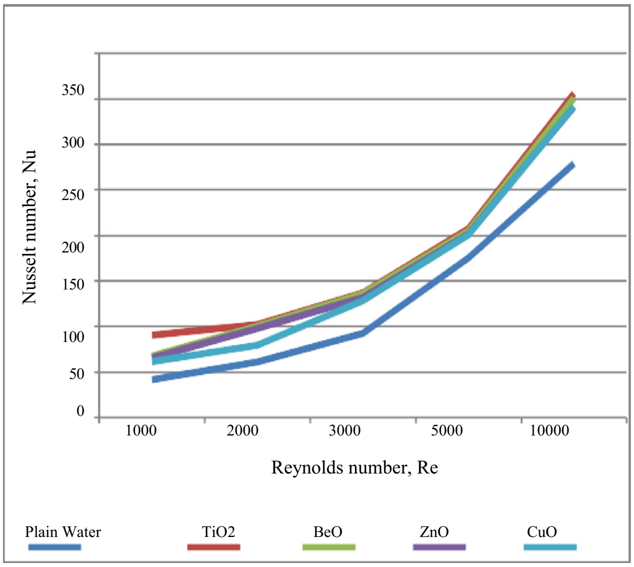

Fig. 9. Thermal Performance of Nano-Fluids & Water.

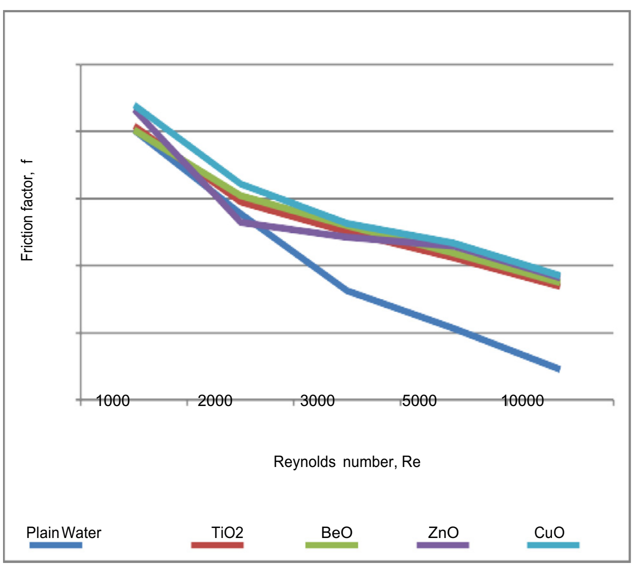

Fig. 10. The friction factor for Nano-Fluids & Water.

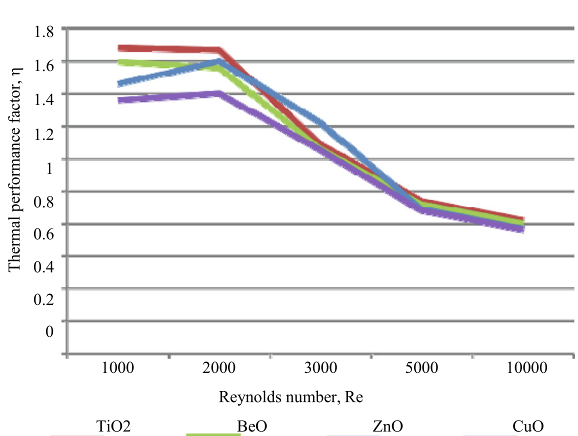

Fig. 11. Thermal performance factors for Nano-Fluids.

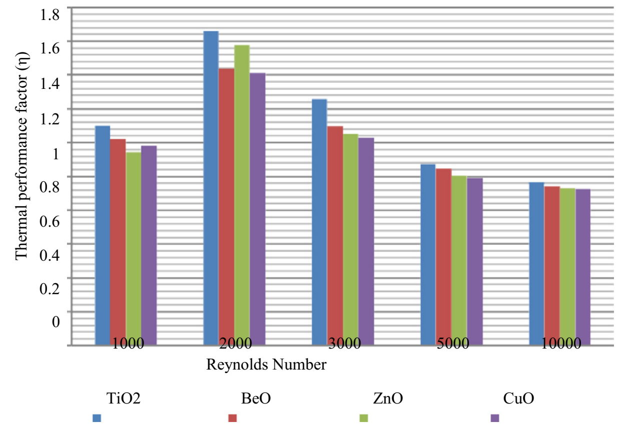

Fig. 12. Comparative Thermal performance factor.

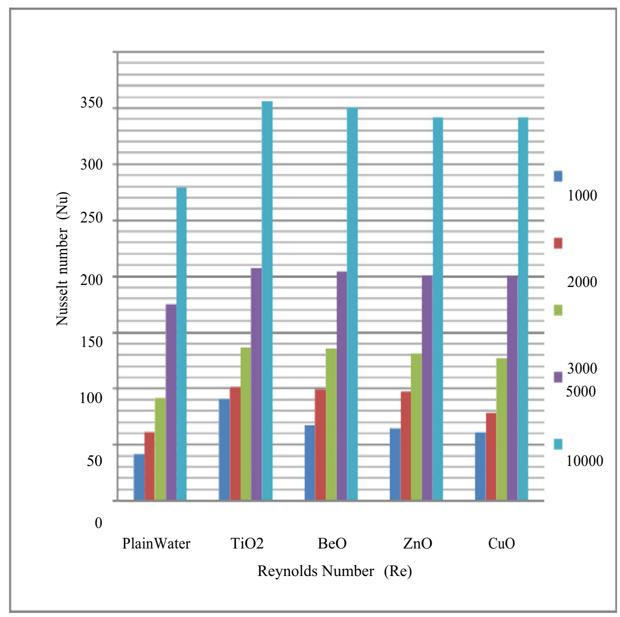

Fig. 13. Nu Vs Re for Nanofluids.

the Figs. 5–8 for the respective parameters in order, for set up of tube with special twisted tape insert.

The Fig. 9 shows the thermal performance of various fluid medium in the DTHE with the Spring insert at various flow conditions. The plain water, TiO_2 Nanofluid, BeO Nanofluid, ZnO Nanofluid and CuO nanofluid considered in which the increase of Reynolds Number increases the heat transfer performance. The flow varies at five level. The thermal performance of TiO_2 Nano fluid in the experimental setup found superior performance in the entire range of flow considered (Refer Figs. 9 and 13). The other nano-fluids performances are: BeO nano-fluid, ZnO nanofluid, and CuO Nanofluid in descending order. The friction factor not increased significantly by use of nanofluids (Refer Figs. 10 and 14). The thermal performance factor is directly proportionate to thermal performance. Hence use of nano powders yielded significant performance factors, in which the TiO_2 Nano fluid outperforms (Refer Figs. 11 and 12).

4. Conclusion

The heat transfer analysis of the twisted tape heat exchanger is carried out by the various Reynolds number regions of 1000, 2000, 3000, 5000 and 10,000 the pressure drop is increased in the

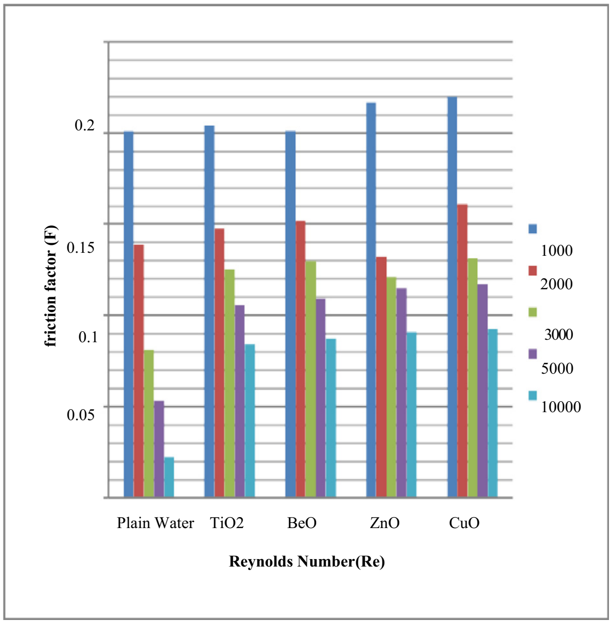

Fig. 14. Friction factor vs Re for anofluids.

twisted tape heat exchanger with increase in Reynolds number, as well as heat transfer rate. Figs. 9 and 13 presents the variation of Nusselt number with Reynolds number for the tube equipped with trapezoidal cut twisted tape. For all cases, the Nusselt number increases with increasing Reynolds number. This is primarily attributed to the increase of turbulent intensity as Reynolds number increases, leading to an amplification of convective heat transfer. At the given Reynolds number, the Nusselt numbers for the tube with trapezoidal cut twisted tape is considerably higher than those for the tube with no inserts. In common, the twisted tape with trapezoidal cut generates the swirl flow, which is responsible for a better fluid mixing. This action is directly related to heat transfer improvement. Figs. 10 and 14 present the variation of friction factor with Reynolds number for the tube equipped with various inserts. For all cases, the friction factor decreases with increasing Reynolds number. This is primarily attributed to increase of the velocity of the fluids, leading to reduction of thermal boundary layer and reduced friction factor. As seen, the thermal performance factor tends to decrease with the rise of Reynolds number, for most of the cases. The thermal performance factors of nano-fluids are consistently larger than unity and significantly higher than inserts with plain water. This reveals the advantage of using nano-fluids over the plain water, in viewpoint of energy saving. Thermal performance factor of 1.879 achieved in laminar flow by use of TiO_2 Nano fluid. Similarly other nano-fluids fluids also performed well that is the thermal performance factor 1.795 obtained by use of BeO nano-fluid, 1.798 by means of ZnO Nanofluid and 1.601 through CuO Nano-fluid medium. TiO_2 Nano fluid is a right choice for the entire range of flow tested.

References

[1] James Bowers, Hui Cao, Geng Qiao, Qi Li, Yulong Ding, Flow and heat transfer behaviour of nanofluids in microchannels, Prog. Nat. Sci.: Mater. Int. 28 (2) (2018) 225–234.

[2] H.K. Dawood, H.A. Mohammed, Nor Azwadi Che Sidik, K.M. Munisamy, Omer A. Alawi, Heat transfer augmentation in concentric elliptic annular by ethylene glycol based nanofluids, Int. Commun. Heat Mass Transfer 82 (2017) 29–39.

[3] W.H. Azmi, K. Abdul Hamid, N.A. Usri, Rizalman Mamat, K.V. Sharma, Heat transfer augmentation of ethylene glycol: water nanofluids and applications — a review, Int. Commun. Heat Mass Transfer 75 (2016) 13–23.

[4] Gabriela Huminic, Angel Huminic, Hybrid nanofluids for heat transfer applications – a state-of-the-art review, Int. J. Heat Mass Transf. 125 (2018) 82–103.

[5] Faroogh Garoosi, Faraz Hoseininejad, Mohammad Mehdi Rashidi, Numerical study of heat transfer performance of nanofluids in a heat exchanger, Appl. Therm. Eng. 105 (2016) 436–455.

[6] Alina Adriana Minea, Wael M. El-Maghlany, Influence of hybrid nanofluids on the performance of parabolic trough collectors in solar thermal systems: recent findings and numerical comparison, Renewable Energy 120 (2018) 350–364.

[7] Hussein Togun, S.N. Kazi, A. Badarudin, Turbulent heat transfer to separation nanofluid flow in annular concentric pipe, Int. J. Therm. Sci. 117 (2017) 14–25.

[8] Muhammad Noor Afiq Witri Muhammad Yazid, Nor Azwadi Che Sidik, Wira Jazair Yahya, Heat and mass transfer characteristics of carbon nanotube nanofluids: a review', Renew. Sustain. Energy Rev. 80 (2017) 914–941.

[9] M.A. Ahmed, M.M. Yaseen, M.Z. Yusoff, Numerical study of convective heat transfer from tube bank in cross flow using nanofluid, Case Stud. Therm. Eng. 10 (2017) 560–569.

[10] M.Kh. Abdolbaqi, C.S.N. Azwadi, R. Mamat, Heat transfer augmentation in the straight channel by using nanofluids, Case Stud. Therm. Eng. 3 (2014) 59–67.

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