ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

Heat Transfer Characteristics and Exergy Analysis of Nanofluid

[1]Kanthimathi Tumuluri,

[1]Assistant professor, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram Green Fields Guntur Dt., Andhra Pradesh, 522302, India

[2]Sai Kumar V,

[2]Student, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram Green Fields Guntur Dt., Andhra Pradesh, 522302, India

[2]Prasad Y D M V

[2]Student, Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram Green Fields Guntur Dt., Andhra Pradesh, 522302, India

Abstract

Nanofluids offer better heat transfer characteristics when compared to conventional heat transfer fluids. In the present work, analysis of heat transfer characteristics and entropy generation of two different nanofluids is carried out experimentally. Iron oxide (Fe_3O_4) and silicon carbide (SiC) nanoparticles are suspended in base fluid Distilled water (DW) in the volume fractions ranging from 0.02 to 0.08%. The thermophysical properties and the heat transfer characteristics of the nanofluids are determined experimentally under turbulent flow conditions. Thermal and frictional entropy generation are determined along with entropy generation ratio (EGR) for the nanofluids. Results reveal that the increase in the volume fraction of nanoparticles resulted in the enhancement of thermal conductivity, viscosity, and density while specific heat decreased. The heat transfer coefficient and Nusselt number of the nanofluids increased with the increase in volume fraction of nanoparticles. Maximum enhancement of 13.96% and 6.58% in heat transfer coefficient and Nusselt number for Fe_3O_4 while 22.37% and 0.11% for SiC at 0.08% volume faction is observed. Thermal entropy generation decrease while the frictional entropy generation increased with the increase in volume fraction. The Entropy Generation Ratio (EGR) of the nanofluids decreased with the increase in volume fraction and flow rate, indicating the advantage of using nanofluid over conventional base fluids. A maximum decrease of 0.44% & 0.18% in EGR for Fe_3O_4 and SiC is obtained for 0.08% volume fraction. .

ISSN PRINT 2319 1775 Online 2320 7876

Research paper © 2012 IJFANS. All Rights Reserved, UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

Keywords: Entropy generation ratio, nanofluid, volume fraction, heat transfer characteristics

1. Introduction

There has been a significant increase in global energy consumption in recent years. The efficient and appropriate use of energy is crucial. For an efficient energy savings, it is essential to improve the performance of the thermal equipment such heat exchangers, solar thermal collectors, freezers, heat pipes, and others. Single phase fluids can be utilized as heat transfer fluids in the majority of the thermal devices previously described. These days, a variety of research have used heat transfer and effectiveness enhancement strategies. Both the systems active and passive strategies can be used to increase heat transmission. While the passive technique does not require any additional power sources, the active method does require an additional energy device or process. The passive method creates turbulence inside the fluid flow without modification of the geometry. One of passive method is to enhance the heat transfer characteristics of the working fluid by spiking it with the nanometer size particles called nanoparticles. There are various types of nanofluids, they are metallic, non-metallic and Ceramics. The variety of nanofluids which are available in the market are Al_2O_3,SiC ,CuO, Fe_3O_4. Suspension of nanoparticles inside the fluid increases the thermal conductivity of the fluid due to the Brownian motion of the particles and the interaction of the particles inside the fluid. In order to avoid the sedimentation of the particles will change the characteristics of the fluid. Other method to attain the stability of nanofluid is adjusting the PH of the solution. Sundar et al. [1] also found an enhanced thermal conductivity enhancement for Fe_3O_4/water nanofluid. He et al. [2] numerically studied the performance efficiency coefficient of CuO/water nanofluid in a tube under the Reynolds number ranging from 3000 to 36,000 and in the volume concentrations ranging from 1 to 4 %. They observed that, the maximum performance efficiency coefficient in the tube with one twisted tape is 2.18 (for the two-phase model, Re = 36,000 and u = 4 %), while for a tube with two twisted tapes under the same conditions, it is 2.04. Gavili et al. [3] observed thermal conductivity enhancement of 200 % at / = 5.0 % of Fe_3O_4/ water nanofluid. Sundar et al. [4] have observed an enhanced knf for 50:50 % water (W)/ethylene glycol (EG) mixture based Al2O3 and CuO nanofluids. Liu et al. [5] seen knf raise of 22.4 % at 0.5 % of EG/CuO nanofluid. An innovative way for enhancing the

ISSN PRINT 2319 1775 Online 2320 7876

Research paper © 2012 IJFANS. All Rights Reserved, UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

thermal conductivity of fluids is to add nanomaterial to the fluids as presented by Choi [6]. These so-called nanofluids can be used for energy transportation and are affected by the type and properties of their nanoparticles. A number of recent experiments on nanofluids have indicated dramatic improvements in the effective static thermal conductivity of these fluids compared to their base fluids. Zamzamian et al. [7] investigated the heat transfer performance of Al2O3/ethylene glycol and CuO/ethylene glycol nanofluids in a plate heat exchanger and described that, the heat transfer coefficient increased with temperature and vol.% of nanoparticle. Heat transfer capacity is required to rise to meet the rising demand of energy density and this can be accomplished by using fluid with higher thermophysical properties. Nanometer sized solid particles suspended in the advanced heat transfer fluids are called 'nanofluids' which was invented by Choi [8].Mare et al.[9] experimentally compared the thermal performances of γAl2O3/water and CNTs/water nanofluids in plate heat exchangers with each other and found a greater heat transfer coefficient for nanofluids compared to water. Kwon et al. [10] analyzed the heat transfer performance and pressure drop of Al2O3 and ZnO nanofluids in a plate heat exchanger. Their investigation concluded that the performance of the plate heat exchanger at a given flow rate did not increase with the nanofluid. Singh et al. [11] carried out the study of entropy generation due to flow and heat transfer in nanofluids. They concluded that it will be beneficial to use Alumina– water NFs in conventional channel with laminar flow and microchannels with turbulent flow. Wright et al. [12] studied the thermal conductivity behavior of single wall carbon nanotubes coated by Ni nanoparticles suspended in water. Helical and straight tubes were compared by Prabhanjan et al. [13]. The results showed that a helical coil heat exchanger increases the heat transfer coefficient and the temperature rise of fluid depends on the coil geometry and the flow rate. An innovative technique to improve the heat transfer is using the nano-scale particles in the base fluid. Fluids with nanoparticles suspended in them are called Nanofluids [14]. Khan et al. [15] explored analysis of heat and mass transfer in three- dimensional nanofluids flowing on a linear stretching sheet under convective wall conditions and thermal radiations. It was deduced that heat and mass transfer rates enhance with the stretching parameter. Karimia and Yousefi [16] developed a density model by considering an experimental data of Al2O3/40:60 % W/EG, SnO2/40:60 % W/EG, ZnO/40:60 % W/EG and CuO/water using artificial neural network. Earlier studies show increased thermophysical al properties with larger particles volume

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

loadings compared to base fluid. The analysis of heat transfer coefficient h_{nf} of nanofluids is an important parameter. Kumar et al. [17] experimentally and numerically studied tube in tube helical heat exchanger in turbulent regime. The predicted Nusselt number and friction factor were compared with relations proposed by other researchers. Although the boundary conditions were different the results were reasonably in good agreement. Haghshenas et al. [18] examined the plate and concentric tube heat exchangers by using ZnO/water nanofluids as the hot stream at a constant mass flow rate, and concluded that the heat transfer coefficients of nanofluids were much higher than those of the distilled water. Chawhan et al. [19] observed an overall heat transfer coefficient of 2727.38 W/m2 K for 0.1 % of Ag-TiO2/water hybrid nanofluid and for water, but whereas, the overall heat transfer coefficient is 1211.71 W/m2 K at a Re of 3480, respectively.

In the present Study Fe_3O_4 and SiC nanoparticles are suspended in the base fluid DW in the volume fractions of 0.02, 0.04, 0.06 and 0.08%. The heat transfer characteristics, thermal, frictional entropy and entropy generation ratio were determined for the prepared nanofluids

2. Design/Methods/Modelling

The Fe_3O_4, SiC nanoparticles are mixed in Distilled water (DW) in the volume fractions of 0.02%, 0.04%, 0.06% and 0.08%. Surfactant is not used in the preparation of nanofluid as its presence affects the original properties of nanofluids. The weight of nanoparticles to be mixed in each base fluid is evaluated using Eq. (1), where ϕ is the particle concentration by volume of the nanofluid.

$$\phi = \frac{\frac{m_{np}}{\rho_{np}}}{\left(\frac{m_{np}}{\rho_{np}} + \frac{m_{bf}}{\rho_{bf}}\right)} \times 100 \qquad (1)$$

Nanofluids are prepared using two step method and the thermophysical properties like density, Specific heat , viscosity and thermal conductivity are determined experimentally. The heat transfer characteristics are determined using a double pipe heat exchanger under turbulent conditions. The instrumentation used for the determination of properties and heat transfer characteristics is given in Kanthimathi et al. [20]. Thermal Entropy Generation of the nanofluid is obtained by Equ.2

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

$S_{g.th} = (Qh^2/(Nu\pi kT_iT_o))$ (2)

Frictional Entropy Generation of the nanofluid is obtained by Equ. 3

$S_{f.th} = ((8fM^3L)/(\rho 2\pi 2D5_i(T_o - T_i)))\ln(T_o/T_i)$ (3)

Where f is friction factor of the nanofluid is obtained by Equ. 4

$f = (\Delta p)/((L/D_i)(\rho v^2/2))$ (4)

Entropy Generation Ratio of the nanofluid is obtained by Equ. 5

$$EGR = S_{gtot(hf)}/S_{gtot(bf)} \quad (5)$$

3. Results and Discussion

The density, Specific heat, viscosity and thermal conductivity of the Fe3O4 and SiC nanofluids with DW base fluid are represented in Figures 1, 2, 3, 4.

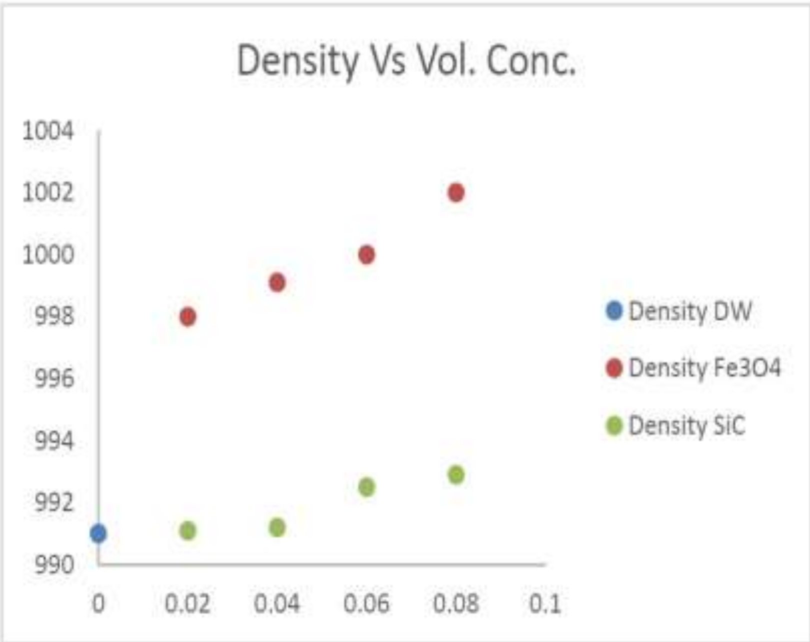

Figure 1. Density of Fe_3O_4/DW and SiC/DW Naonofluids

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

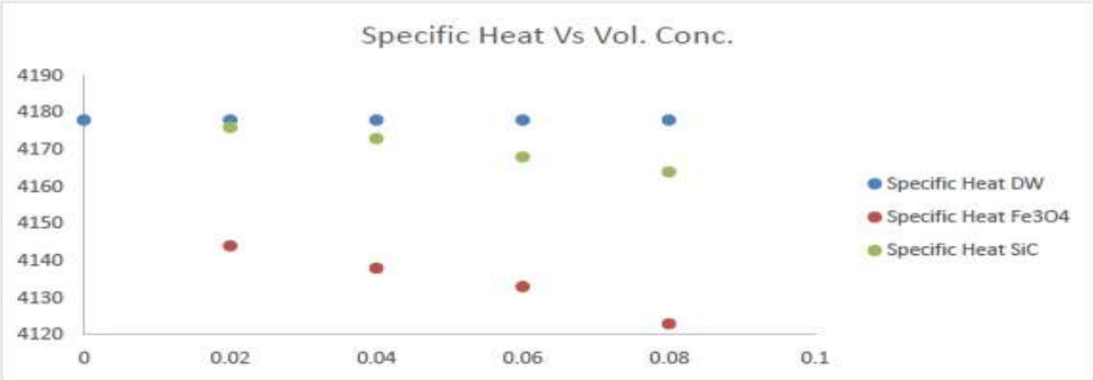

Figure 2. Specific heat of Fe_3O_4/DW and SiC/DW Nanofluids

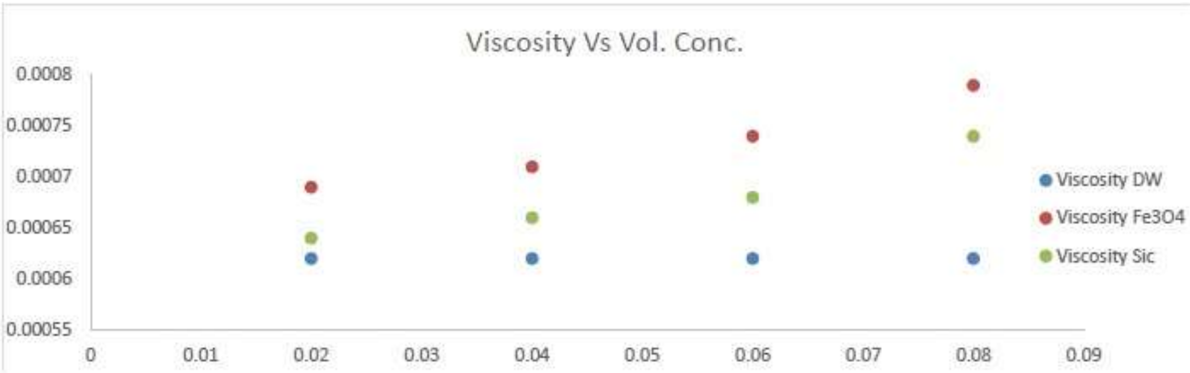

Figure 3. Viscosity of Fe_3O_4/DW and SiC/DW Nanofluids

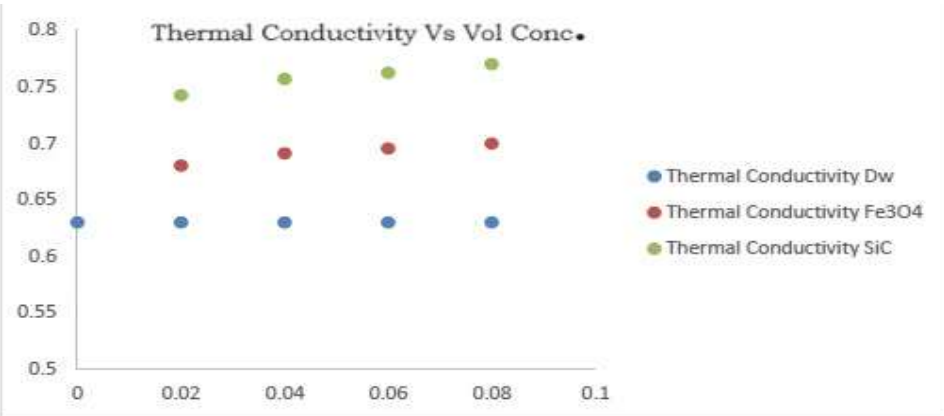

Figure 4. Thermal Conductivity of Fe_3O_4/DW and SiC/DW Nanofluids

The Percentage increase in the density of Fe_3O_4/DW nanofluid is 0.7 to 1.1 % and SiC/DW 0.01 to 0.1% whaen compared with base fluid DW for the volume fraction ranging from 0.02 to 0.08%.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

The decrease percentage of specific heat for Fe_3O_4/DW nanofluid is 0.8 to 1.3% and that of SiC/DW nanofluid is 0.04 to 0.3% when compared with base fluid for volume fraction ranging from 0.02 to 0.08%.

The percentage increase in the viscosity of Fe_3O_4/DW nanofluid is 17.87 to 22.23% and that of SiC/DW nanofluid is 7.9 to 11.07% for volume fraction ranging from 0.02 to 0.08% when compared with the base fluid.

The percentage increase in the thermal conductivity of Fe_3O_4/DW nanofluid is 7.95 to 11.07% and that of SiC/DW nanofluid is 17.87 to 22.23% for volume fraction ranging from 0.02 to 0.08% when compared with the base fluid.

The heat transfer characteristics of Fe_3O_4/DW and SiC/DW nanofluids are represented in Figures 6 & 7.

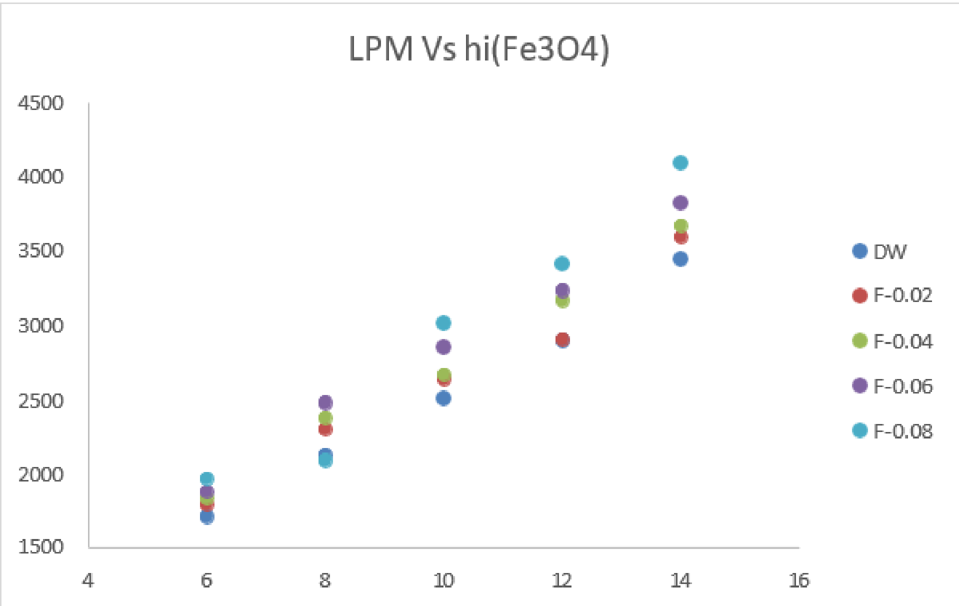

Figure 5. Heat transfer coefficient of Fe_3O_4/DW nanofluid Vs Flow rate

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

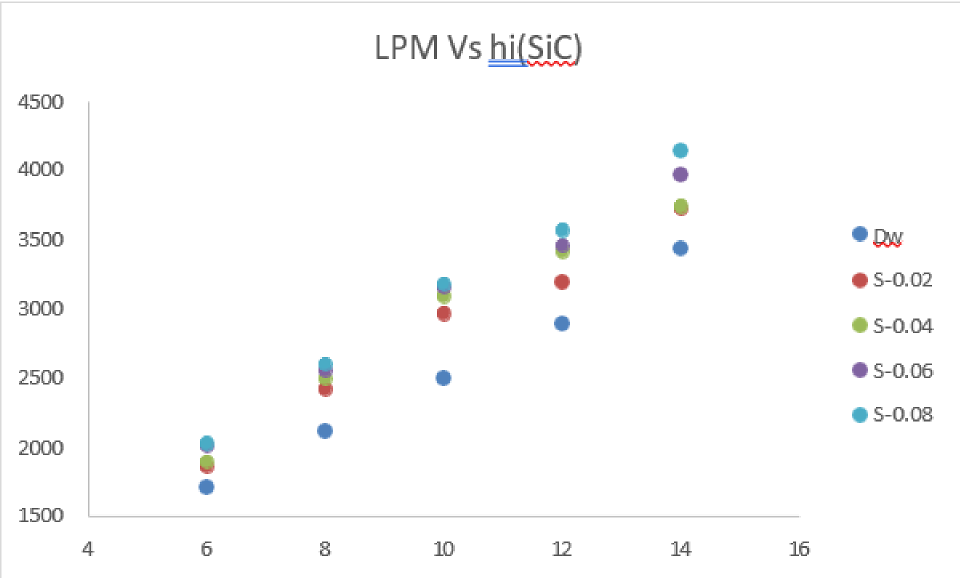

Figure 6. Heat transfer coefficient of SiC/DW nanofluid Vs Flow rate

The average Percentage enhancement in the heat transfer coefficient for Fe_3O_4 nanofluid varied from 4.54 to 13.96% as the volume concentration increased from 0.02 to 0.08%. The average Percentage enhancement in the heat transfer coefficient for Fe_3O_4 nanofluid varied from 12.00 to 22.37% as the volume concentration increased from 0.02 to 0.08%. The variation of thermal entropy generation with Reynolds number for Fe_3O_4/DW and SiC/DW nanofluid is shown in Figures 7 & 8.

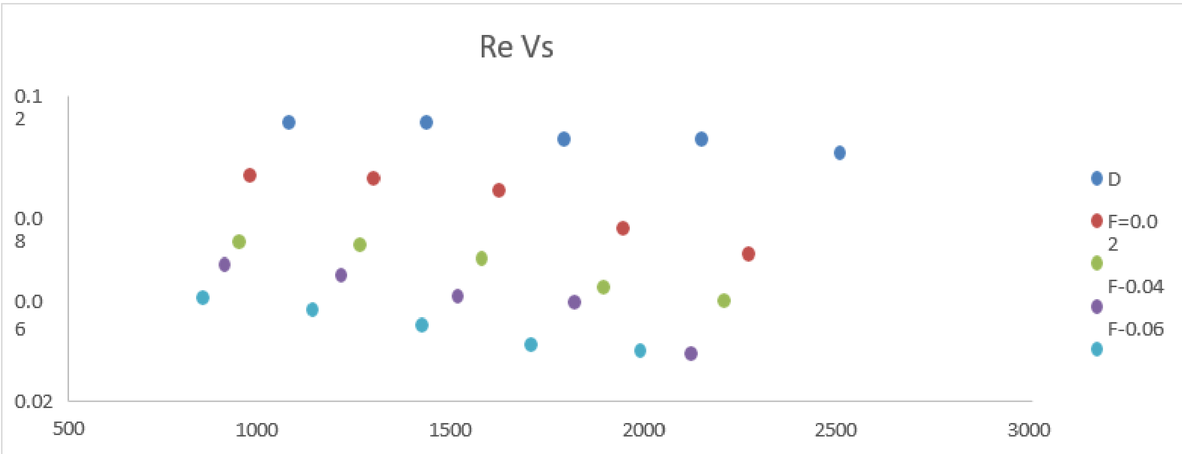

Figure 7. Thermal Entropy generation Vs Reynolds Number for Fe_3O_4/DW nanofluid

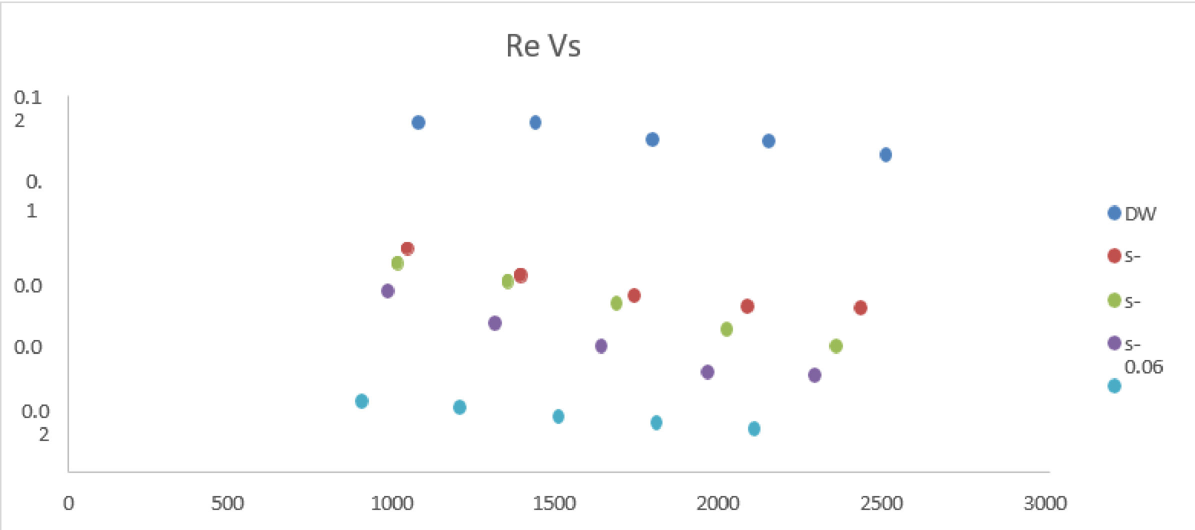

Figure 7. Thermal Entropy generation Vs Reynolds Number for SiC/DW nanofluid

The average thermal entropy generation decreased from 21.71% at 0.02% to 58.71% at 0.08% volume concentration for Fe_3O_4 nanofluids. The average thermal entropy generation decreased from 45.06% at 0.02% to 83.23% at 0.08% volume concentration for SiC nanofluids. Figures 8, 9, 10 & 11 represent the frictional entropy generation and Entropy generation ratio of Fe3O4, SiC nanofluids with respect to Reynolds number.

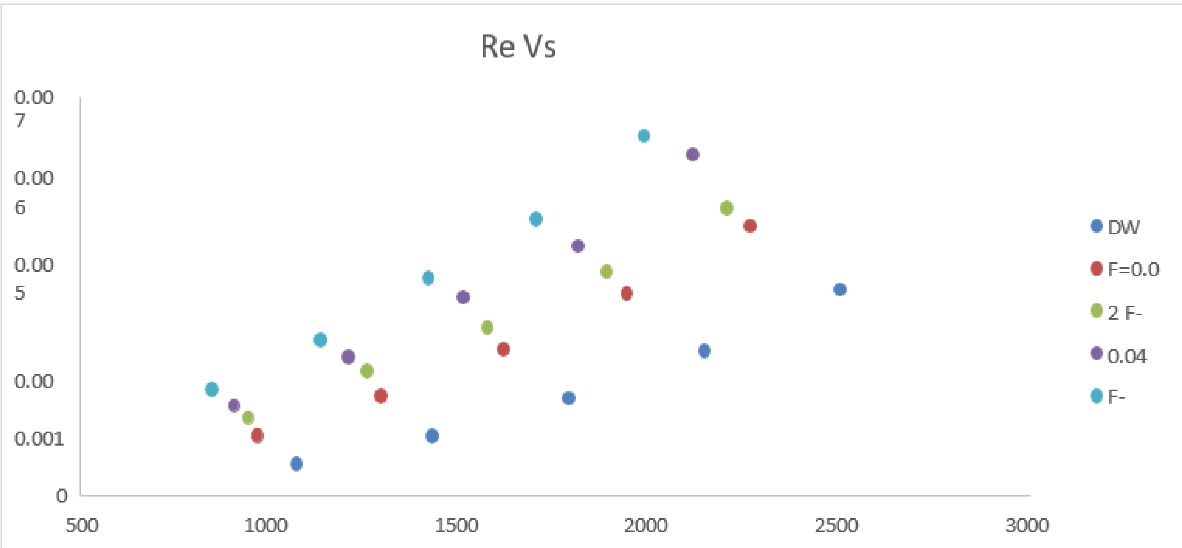

Figure 8. Frictional Entropy generation Vs Reynolds Number for Fe_3O_4/DW nanofluid

ISSN PRINT 2319 1775 Online 2320 7876

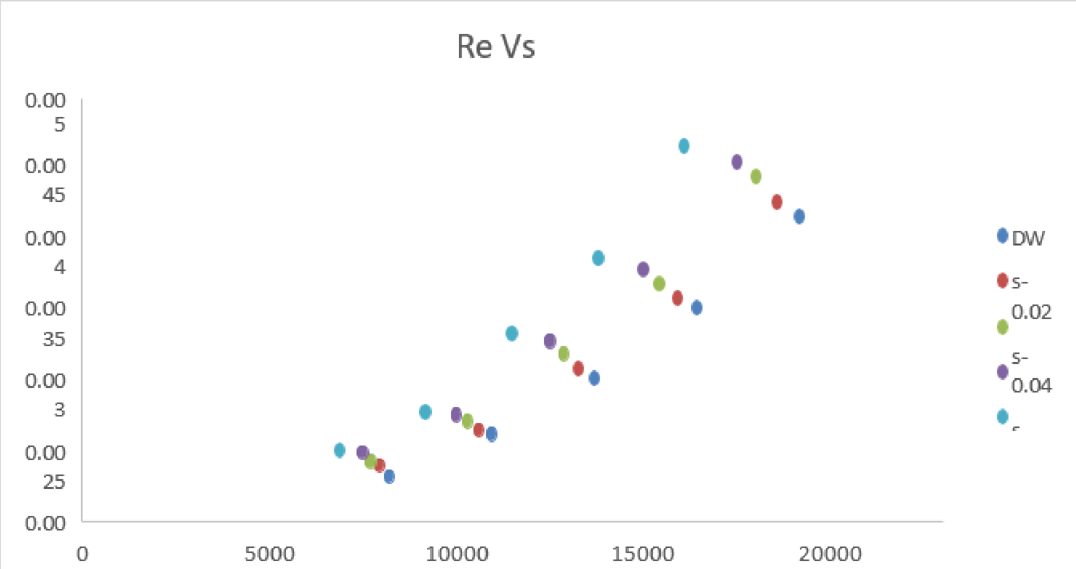

Figure 9. Frictional Entropy generation Vs Reynolds Number for SiC/DW nanofluid

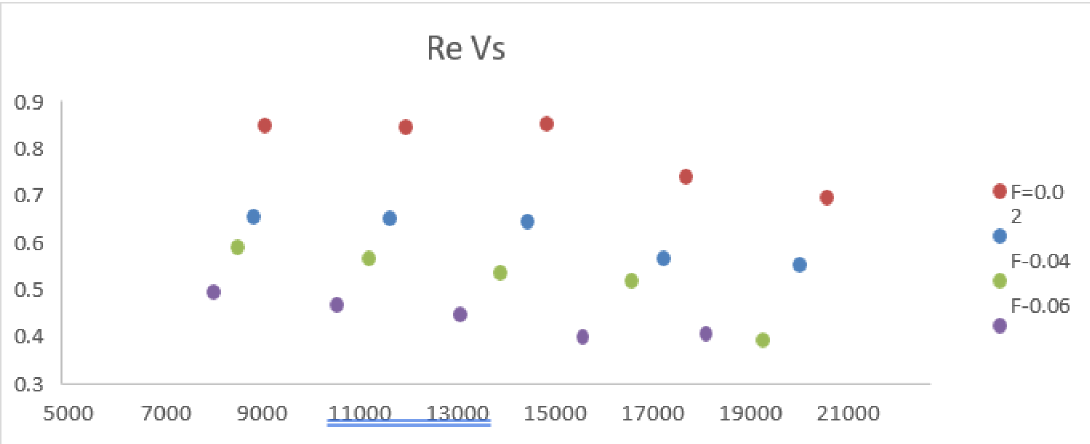

Figure 10. Entropy Generation ratio (EGR) for Fe_3O_4/DW nanofluid

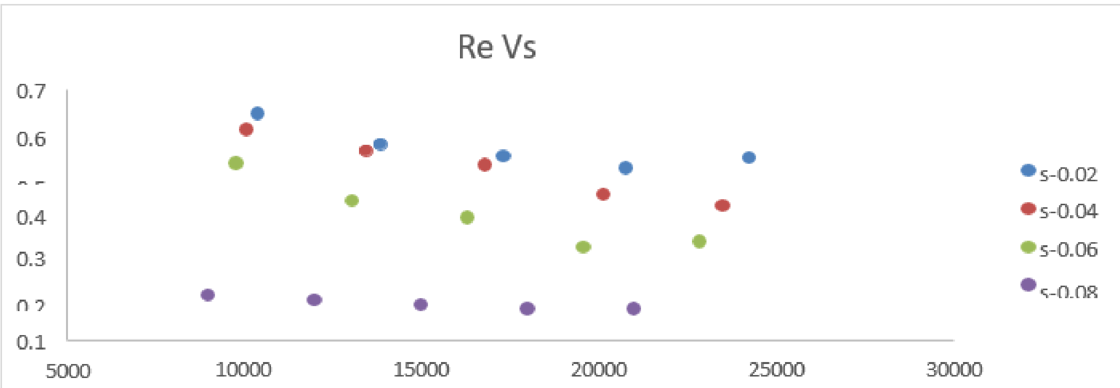

Figure 11. Entropy Generation ratio (EGR) for SiC/DW nanofluid

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

The average frictional entropy generation increased from 56.78% at 0.02% volume concentration to 139.39% at 0.08% volume concentration for Fe_3O_4 nanofluids. The average frictional entropy generation increased from 9.23% at 0.02% volume concentration to 31.42% at 0.08% volume concentration for SiC nanofluids. The entropy generation ratio is decreased from 0.84% at 0.02% volume concentration to 0.055% at 0.08% volume concentration for Fe_3O_4 nanofluid and from 0.64% at 0.02% volume concentration to 0.20% at 0.08% volume concentration.

4. Conclusion

Fe_3O_4 and SiC nano particles are suspended in base fluid distilled water at 0.02,0.04,0.06, and 0.08% volume concentration, Thermophysical properties, heat transfer characteristics & entropy generation parameters are analyzed.

- Thermal conductivity & viscosity density of nano fluids increased with volume concentration.
- SiC nano fluids exhibited higher enchantment in Tc& lower increase in viscosity when compared to Fe_3O_4.
- Enhancement in heat transfer coefficient of Sic nano fluids is higher than Fe_3O_4 nano fluids.
- Thermal entropy generation was observed to be less for Sic nano fluids compared to Fe_3O_4 .
- Frictional entropy generation was higher for Fe_3O_4 nano fluids than SiC.
- EGR was observed to decrease with increase into Reynolds number. EGR of Sic is less when compared to Fe_3O_4.

From the obtained results it is evident that nano fluids enhance the heat transfer characteristics of base fluids. SiC nano fluids proved to be better heat transfer fluids when compared to Fe_3O_4.

References

1. Sundar LS, Singh MK, Sousa ACM. Investigation of thermal conductivity and viscosity of Fe_3O_4 nanofluid for heat transfer applications. Int Commu Heat and Mass Transfer 2013;44:7–14.

2. He W, Toghraie D, Lotfipour A, Pourfattah F, Karimipour A, Afrand M. Effect of twisted-tape inserts and nanofluid on flow field and heat transfer characteristics in a tube. Int Commu Heat and Mass Transfer 2010;110:104440.
3. Gavili A, Zabihi F, Isfahani TD, Sabbaghzadeh J. The thermal conductivity of water base ferrofluids under magnetic field. Exp Thermal and Fluid Sci 2012;41:94–8.
4. Sundar LS, Farooky MH, Sarada SN, Singh MK. Experimental thermal conductivity of ethylene glycol and water mixture based low volume concentration of Al2O3 and CuO nanofluids. Int Commu Heat and Mass Transfer 2013;41:41–6.
5. Liu M-S, Lin M-C-C, Huang I-T, Wang C-C. Enhancement of thermal conductivity with CuO for nanofluids. Chem Eng Technology 2006;29:73–7. Kole M, Dey TK. Effect of aggregation on the viscosity of copper oxide gear oil nanofluids. Int J Thermal Science 2011;50:1741–7.
6. S.U.S. Choi, Enhancing thermal conductivity of fluids with nanoparticles, Developments and Applications of Non-Newtonian Flows 231 (1995) 99–105.
7. A. Zamzamian, S.N. Oskouie, A. Doosthoseini, A. Joneidi, M. Pazouki, Experimental investigation of forced convective heat transfer coefficient in nanofluids of Al2O3/EG and CuO/EG in a double pipe and plate heat exchangers under turbulent flow, Exp. Thermal Fluid Sci. 35 (3) (2011) 495–502.
8. S. Choi, Enhancing thermal conductivity of fluids with nanoparticles, in:H.P.W.D.A. Siginer (Ed.), Developments Applications of Non-Newtonian Flows,ASME, New York, 1995, pp. 99–105.
9. T. Maré, S. Halelfadl, O. Sow, P. Estellé, S. Duret, F. Bazantay, Comparison of the ther mal performances of two nanofluids at low temperature in a plate heat exchanger, Exp. Thermal Fluid Sci. 35 (8) (2011) 1535–1543.
10. Y. Kwon, D. Kim, C. Li, J. Lee, D. Hong, J. Lee, S. Lee, Y. Cho, S. Kim, Heat transfer and pressure drop characteristics of nanofluids in a plate heat exchanger, J. Nanosci. Nanotechnol. 11 (7) (2011) 5769–5774.
11. Pawan K. Singh, K.B. Anoop, T. Sundararajan, Sarit K. Das, "Entropy generation due to flow and heat transfer in nanofluids", Int. J. of Heat and Mass Transfer 53 (2010) 4757-4767.
12. B. Wright, D. Thomas, H. Hong, L. Groven, J. Puszynski, E. Duke, X. Ye, S. Jin,

ISSN PRINT 2319 1775 Online 2320 7876

Research paper © 2012 IJFANS. All Rights Reserved, UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

Magnetic field enhanced thermal conductivity in heat transfer nanofluids containing Ni coated single wall carbon nanotubes, Applied PhySiC s Letters 91 (2007) 173116.

13. D.G. Prabhanjan, G.S.V. Ragbavan, T.J. Kennic, Comparison of heat transfer rates between a straight tube heat exchanger and helically coiled heat ex changer, international communication heat and mass transfer 29 (2) (2002) 185–191.
14. S.U.S. Choi, enhancing thermal conductivity of fluids with nanoparticles, Proceed ings of the 1995 ASME International Mechanical Engineering Congress and Exposi tion San Francisco, CA, USA, 1995.
15. Khan, A.S.; Nie, Y.; Shah, Z.; Dawar, A.; Khan, W.; Islam, S. Three- Dimensional Nanofluid Flow with Heat and Mass Transfer Analysis over a Linear Stretching Surface with Convective Boundary Conditions. Appl. Sci.2018, 8, 2244.
16. Karimia H, Yousefi F. Application of artificial neural network–genetic algorithm (ANN–GA) to correlation of density in nanofluids. Fluid Phase Equilib 2012;336:79– 83.
17. V. Kumar, B. Faizee, M. Mridha, K.D.P. Nigam, Numerical studies of a tube-in-tube helically coiled heat exchanger, Chemical Engineering and Processing 47 (12) (2008) 2287–2295.
18. F.M. Haghshenas, M.R. Talaie, S. Nasr, Numerical and experimental investigation of heat transfer of ZnO/water nanofluid in the concentric tube and plate heat exchangers, Therm. Sci. 15 (1) (2011) 183–194.