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Numerical Analysis on Convective Heat Transfer Enhancement by Using Ferrofluid

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Abstract: Ferrofluidconsist of nanoparticles of magnetic material. They to external magnetic field and become highly magnetic in the presence of same. Due to this property of ferrofluid, it is being used in many applications like energy harvesting, heat exchanger, electronic cooling, seal, lubrication and damping. Thermophysical properties of ferrofluid can be controlled by varying externally applied magnetic field. Addition of ferrofluid into base liquid, under the action of externally applied magnetic field, increases heat transfer rate. This paper focuses on enhancement in convective heat transfer due to addition of ferrous material in base liquid under the effect of externally applied magnetic field. As intensity of externally applied magnetic field will increase, convective heat transfer rate also increases.
Keywords: Ferrofluid, Convective heat transfer, External Magnetic Field, Thermophysical Properties

I. INTRODUCTION

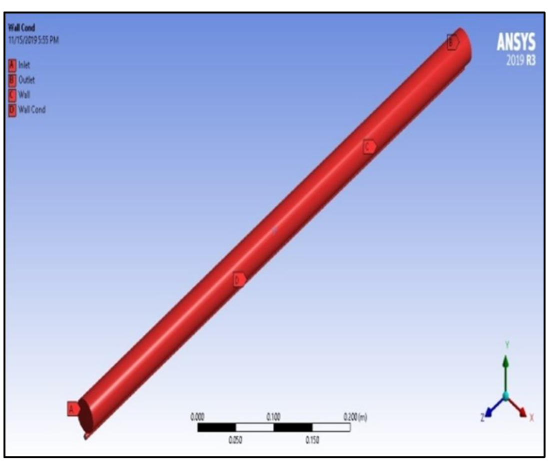
Ferrofluid are colloidal liquids made of nanoscale ferromagnetic, or ferrimagnetic, particles suspended in a carrier fluid (usually an organic solvent or water). Its important property is, though it is liquid still responds to externally applied magnetic field and become highly magnetic in the presence of same. Every nano particle is coated with a surfactant to restrain clustering. In the absence of an externally applied field, ferrofluid usually do not retain magnetization. In the absence of external magnetic field, magnetic dipoles of ferrofluid remains randomly oriented, but when magnetic field will be applied externally on ferrofluid, its magnetic dipole gets oriented in a same direction as that of externally applied magnetic field. It indicates that ferrofluid responds to externally applied magnetic field. Due to this property, use of ferrofluid is widened in many applications like convective heat transfer, electronic cooling, seal, lubricant and damping. By applying external magnetic field ferrofluid's thermophysical properties can be controlled, which will enhance the convective heat transfer rate and thus performance of equipment, using ferrofluid as a working medium.

Aursand et al. (2016) investigated use of thermo magnetically pumped ferrofluid to enhance performance of natural convection cooling system. Experimentation results revealed thermomagnetic driving force is significant compared to natural convection in single phase. Bozhko et al. (2004) investigated the interplay of buoyancy and thermo-magnetic convection mechanisms in a horizontal fluid layer heated from one wide side and cooled from another in the presence of external uniform transversal magnetic field. Influence of gravitational settling of magnetic particles and their aggregates on heat transfer and convection instability was studied. Chaudhary et al. (2012) investigated self-pumping magnetic cooling effect so as to eliminate use of mechanical pump to circulate working fluid. Gavili et al. (2012) carried experimental investigation on thermal conductivity of ferrofluid under the influence of magnetic field. Experimental results indicated that thermal conductivity of ferrofluid is a function of intensity of magnetic field. Ghasemian et al. (2015) numerically studied laminar forced convection heat transfer of water based ferrofluid in a mini channel in the presence of constant and alternating magnetic fields. The heat transfer enhancement due to the magnetic field was more significant at lower Reynolds numbers. Goharkhah et al. (2014) investigated numerically, forced convective heat transfer of water based Fe_3O_4 nanofluid (ferrofluid) in the presence of an alternating non-uniform magnetic field. Experimental results, as compared with zero magnetic field case, showed that the heat transfer enhancement increases with the Reynolds number. Goharkhah et al. [2015] experimentally investigated the effects of constant and alternating magnetic field on the laminar forced convective heat transfer of ferrofluid in a heated tube. Results indicated that in the absence of a magnetic field, ferrofluid improves convective heat transfer as compared to DI- water. Goharkhah et al. (2016) experimentally investigated laminar forced convective heat transfer of ferrofluid under the effect of external magnetic field. . It was observed that the convective heat transfer has a direct relation with the Reynolds number and ferrofluid concentration. Jafari et al. (2008) studied heat transfer phenomena in a kerosene based ferrofluid. The flow behaviour was investigated. When magnetic field is perpendicular to the temperature gradient, the heat transfer will increase more compared to the case with magnetic field parallel to temperature gradient. Krichler et al.(2013) proposed two methods to calculate thermal conductivity of ferrofluid, hot wire technique and hot plate technique. In hot wire technique, line heat source is used. In hot plate technique, plane heat source is used.

Hot wire technique is mainly used for liquid specimen and hot plate technique for solid specimen. Lajvardi et al. (2016) investigated experimentally convective heat transfer of ferrofluid flowing through a heated copper tube in the presence of magnetic field. Effect of various orders of magnetic field, concentration of magnetic nanoparticles and magnet position on heat transfer enhancement was investigated. Li et al. (2009) investigated experimentally convective heat transfer features of the aqueous magnetic fluid flow under the influence of an external magnetic field. The experimental results showed that the external magnetic field is a vital factor that affects the convective heat transfer performances of the magnetic fluids and the control of heat transfer processes of a magnetic fluid flow is possible by applying an external magnetic field. Mohammadi et al.(2016) carried experimental investigation on four-turn pulsating heat pipe (PHP)At higher charging ratio, better thermal performance was obtained in the presence of magnetic field. Mojumder et al.(2016) numerically analyzed magneto-hydrodynamic convection in a half-moon shaped cavity filled with ferrofluid. Numerical simulation was carried out for a wide range of Rayleigh number It was observed that increment of magnetic field reduces the heat transfer rate, whereas increment of heater distance augments the heat transfer rate significantly. Mehrali et al. (2016)proposed ecofriendly approach to generate a graphene-based nanofluid. A novel mode of graphene oxide reduction through functionalization with polyphenol extracted from redwine was introduced. Present study indicated that, red wine can be prosperously utilized to prepare W-r GO nanofluid. Sheikholeslami et al.(2016) analyzed ferrofluid convective heat transfer in a sinusoidal cold wall cavity under the effect of external magnetic field. Impact of magnetic field on hydrothermal behavior of nanofluid in a cavity with sinusoidal cold wall was investigated. Sundar et al.(2013) carried experimental investigation on effective thermal conductivity and viscosity of ferrofluid. It was observed that thermal conductivity and viscosity of nanofluid, both are function of particle volume concentration and temperature. Xuan et al.(2011) investigated thermomagnetic convection over natural convection for electronic cooling application. It was observed thermomagnetic convection strongly depends upon temperature difference. At higher temperature difference, thermomagnetic convection effect is remarkably higher.

II. METHODOLOGY

Ansys 2019 R3 was used for simulation and analysis. Single Tube arrangement is modeled as shown in fig.1. Tube was modeled with consideration of, inner diameter of tube, d_i = 25mm and outer diameter of tube, d_o = 28 mm. Length of the tube is L= 700 mm. Meshing is done with the help of ICEM CFD for Fluent 2019 R3. Meshing is done as a Mesh Report Nodes158776Elements145000. Flow arrangement was considered in order to obtain the maximum advantage for a given configuration. In order to understand the comparison of Tubes with and without application of Magnetic Field single tube model is used. In this model convective heat transfer is allowed from single tube to the free stream air, at a temperature of 298K. This arrangement is made in Fluent, Magnetic Field is applied with the help MHD module in the Fluent Addon-Model. Magnetic Induction type is selected for application of external magnetic field at outer periphery of the Ferrofluid pipe, Conductor is provided for provision of External magnetic field with electric potential. The local convective heat transfer is measured at both, with and without magnetic field. The effect of constant magnetic field on convective heat transfer for water based magnetic nanoparticles *(Fe_3O_4)* is studied experimentally. Reynolds number range of 250-800 is studied to understand the effect on heat transfer augmentation. External magnetic field intensity is kept constant at B=500 G.



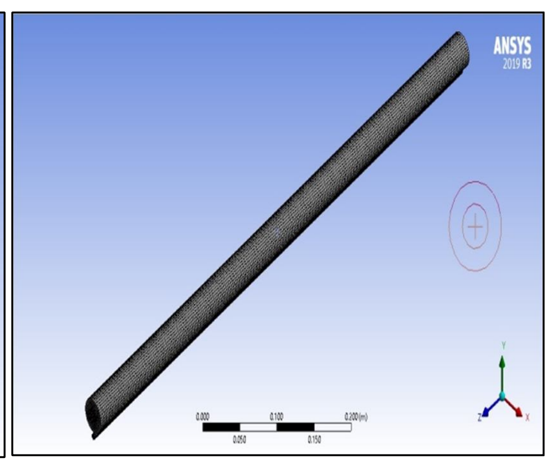


Figure 1 : Smooth Plain Tube with Copper Conductor alongside pipe   Figure2: Meshing of Ferro fluid Domain and Conductor Using ICEM CFD

The hot ferrofluid is flowing through the pipe at temperature of 340 K to 343 K and the free stream air temperature is 298 K. General Governing Equations with coupled magnetic field related Maxwell equation is solved using Fluent MHD module. This emphasizes the change in flow pattern with disruption of flow and flow reversal in order to increase the heat transfer rate.

Fig. 3 And Fig 4Showsvelocity streamlines for fluid flowing through plain tube. From this, we can observe that, velocity is considerably higher in the inner portion of tube. While velocity is considerably very lower in outer region of tube. It indicates heat transfer rate is slower from inner region of tube to outer region of tube.

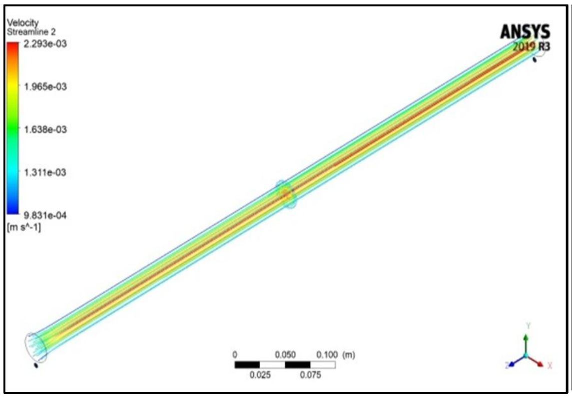


Figure 3 : Velocity streamline plot in plain tube without Magnetic Field

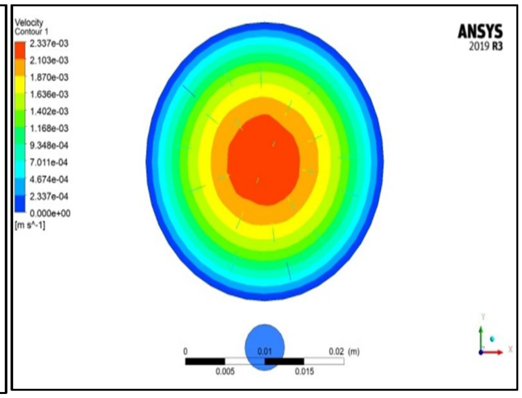


Figure 4: Velocity contour plot in plain tube without Magnetic Field

Fig. 3 shows velocity streamline plot for hot working fluid flowing through inner plain pipe,without application of magnetic field for Re= 250 to Re= 800. In this case the change in temperature of ferrofluid is due to heat transfer from outer periphery of tube.

As shown in Fig. 5, flow reversal occurs in the fluid flow when magnetic field is applied Thisoccurs at very low Reynolds number.The heat transfer augmentation increases with the application of constant magnetic field without any pumping power.

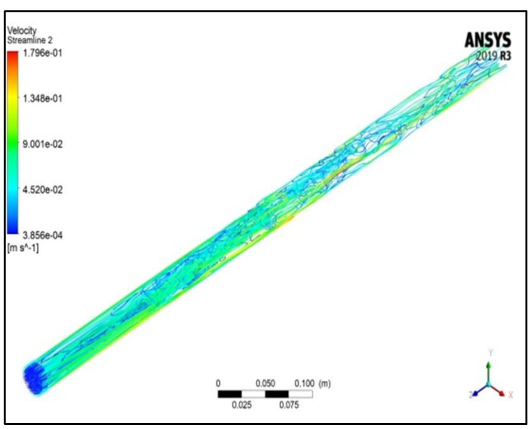


Figure5: Velocity contour plot in plain tube with application of B=500G Magnetic Field

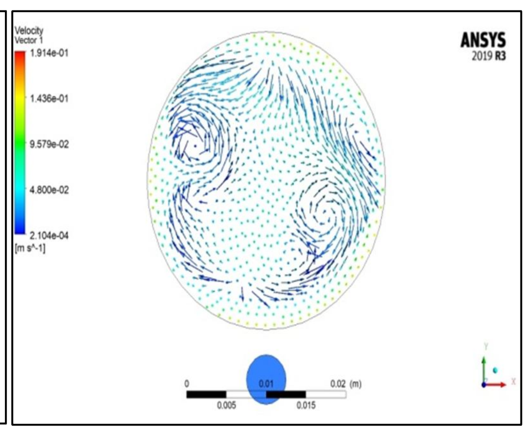


Figure 6: Velocity Vector in plain tube with application of B=500G Magnetic Field

Fig. 6 indicates the flow recirculation under constant magnetic field application.It indicates significant improvement in heat transfer rate due to disruption of thermal boundary layer and increased flow mixing seems to be a possible reason for heat transfer enhancement by application of constant magnetic field.Constant heat transfer rate is observed from pipe.

Fig. 7 and Fig. 8 represents velocity contour plat and temperature contour plot for ferrofluid flowing through plain tube under the application of constant magnetic field of B = 500G. From diagram it can be observed that significant flow mixing and temperature difference is obtained which leads to enhanced heat transfer rate.

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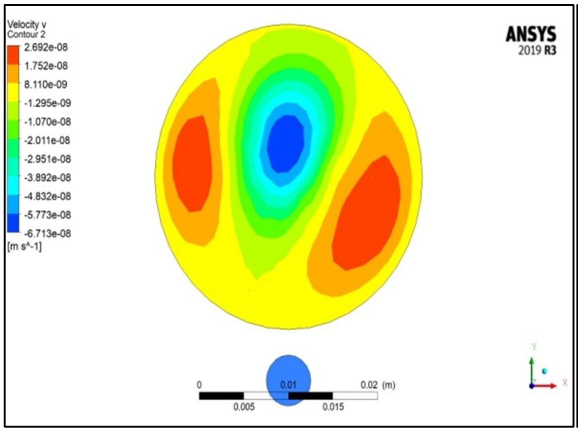


Figure7: Velocity Contour in plain tube with application of B=500G Magnetic Field

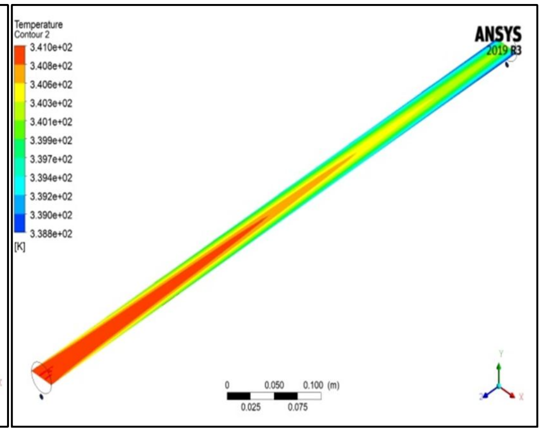


Figure 8: Temperature contour plot in plain tube with application of B=500G Magnetic Field

III. CONCLUSION

A. Ferrofluid responds to externally applied magnetic field. It becomes magnetic in the presence of externally applied magnetic field.

B. Under the application of constant magnetic field heat transfer rate increases as it leads to disruption of the thermal boundary layer and velocity boundary layers

C. The heat transfer rate increases with addition of ferrous particles in the base fluid.

D. Heat transfer rate also increases due to flow reversal.

E. Flow reversal introduces secondary flow in the outer region of the fluid flow which increases the heat transfer rate at the outer periphery of the fluid domain.

F. Under constant magnetic field application, flow recirculation occurs.It indicates significant improvement in heat transfer rate due to disruption of thermal boundary layer and increased flow mixing.

REFERENCES

[1] Ashouri, M.,Ebrahimi, B., Shafii, M. B., Saidi,M. H., Saidi, M. S.,2010. Correlation for Nusselt number in pure magnetic convection ferrofluid flow in a square cavity by a numerical investigation.Journal of Magnetism and Magnetic Material 322, 3607-3613.

[2] Aursand, E.,Gjennestad, M. A.,Lervag, K. Y., Lund, H., 2016. Potential of enhancing a natural convection loop with a thermomagnetically pumped ferrofluid. Journal of Magnetism and Magnetic Materials 417, 148-159.

[3] Bozhko, A. A.& Putin, G. F., 2004. Magnetic action on convection and heat transfer in ferrofluid. Indian Journal of Engineering & Materials Sciences 11, 309-314.

[4] Chaudhary, V., 2012.Self pumping magnetic cooling, Journal of Physics D: Applied Physics 50, 03LT03.

[5] Gavili, A.,Zabihi, F.,Dallali, T.,Isfahani, Sabbaghzadeh, J., 2012.The thermal conductivity of water base ferrofluids under magnetic field. Experimental Thermal and Fluid Science 41, 94-98.

[6] Ghasemian, M.,Ashrafi, Z. N.,Goharkhah, M.,Ashjaee, M., 2015. Heat transfer characteristics of Fe_3O_4 ferrofluid flowing in a mini channel under constant and alternating magnetic fields. Journal of Magnetism and Magnetic Materials 381, 158–167.

[7] Goharkhah, M., Ashjaee, M.,2014. Effect of an alternating nonuniform magnetic field on ferrofluid flow and heat transfer in a channel. Journal of Magnetism and Magnetic Materials 362, 80–89.

[8] Goharkhah, M.,Ashjaee, M., 2015. Convective heat transfer characteristics of magnetite nanofluid under the influence of constant and alternating magnetic field. Powder Technology 274, 258–267.

[9] Jafari, A.,Tynja, T.,Mousavi, S. M.,Sarkomaa, P., 2008.Simulation of heat transfer in ferrofluid using computational fluid dynamics technique. International Journal of Heat and Fluid Flow 29, 1197–1202.

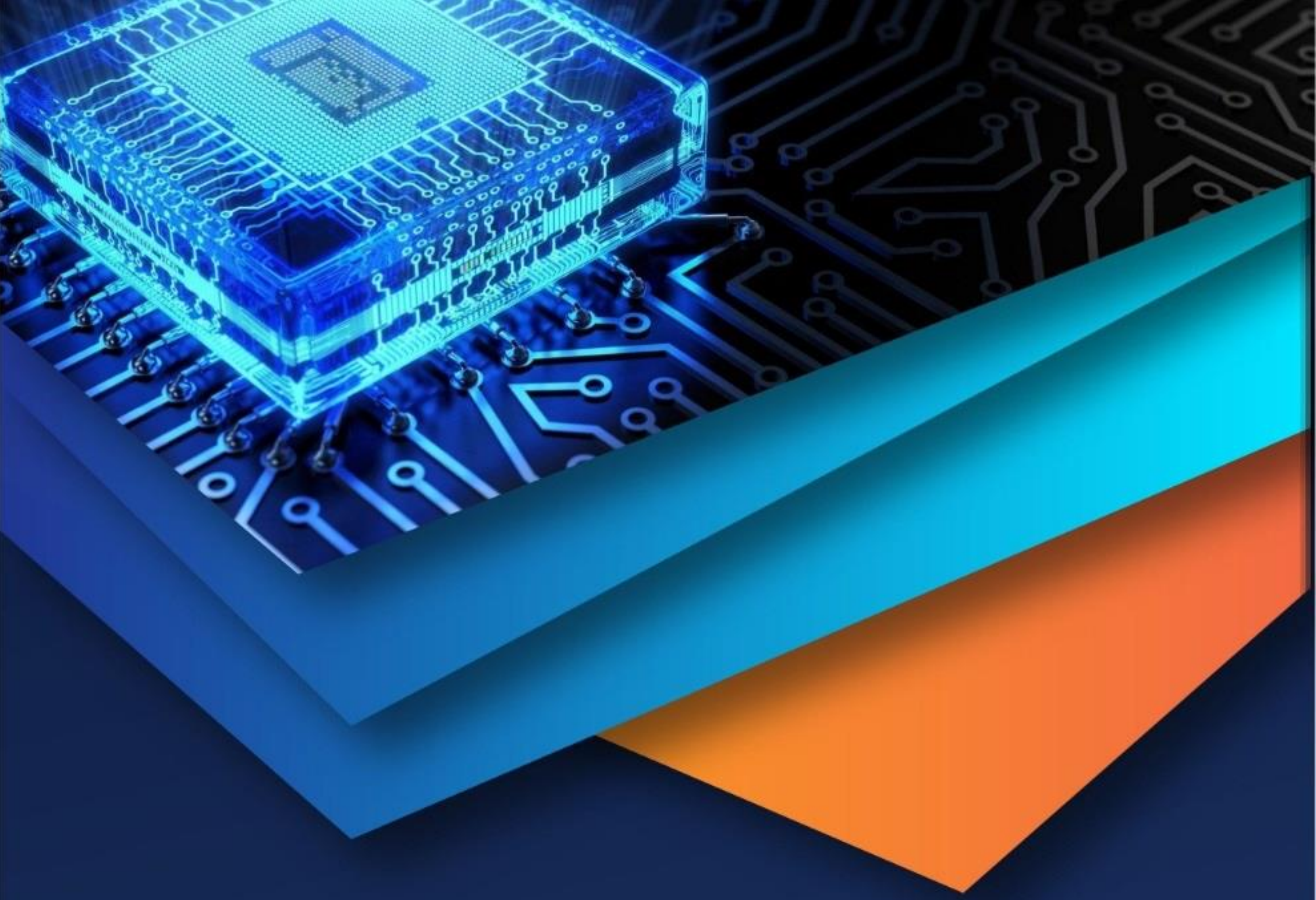
[10] Krichler, M.,Odenbach, S., 2013.Thermal conductivity measurements on ferrofluids with special reference to measuring arrangement. Journal of Magnetism and Magnetic Materials 326, 85-90.

[11] Lajvardi, M.,Moghimi-Rad, J.,Hadi, I., Gavili, A.,Isfahani, T. D.,Zabihi, F.,Sabbaghzadeh, J., 2010. Experimental investigation for enhanced ferrofluid heat transfer under magnetic field effect.Journal of Magnetism and Magnetic Materials 322, 3508-3513.

[12] Mehrali, M.,Sadeghinezhad, E.,Akhiani, A. R., Latibari, S. T., Talebian, S.,Dolatshahi-Pirouz, A., Mehrali, M., 2016. An ecofriendly graphene-based nanofluid for heat transfer applications. Journal of Cleaner Production 137, 555-566.

[13] Mohammadi, M., Mohammadi, M.,Shafii, M. B.,2012.Experimental Investigation of a Pulsating Heat Pipe Using Ferrofluid (Magnetic Nanofluid). Journal of Heat transfer 134, 1-3.

[14] Mohammad Goharkhah, Mehdi Ashjaee, Mahmoud Shahabadi, Experimental investigation on convective heat transfer and hydrodynamic characteristics of magnetite nanofluid under the influence of an alternating magnetic field, International Journal of Thermal Sciences, 99 (2016) 113-124
[15] Mojumder ,S., Khan, Md. R.,Saha, S., Hasan, M. N.,Saha, S. C.,2016. Magnetic field effect on natural convection and entropy generation in a half-moon shaped cavity with semi-circular bottom heater having different ferrofluid inside. Journal of Magnetism and Magnetic Materials 407, 412–424.
[16] Qiang Li, Xuan, L.,2009. Experimental investigation on heat transfer characteristics of magnetic fluid flow around a fine wire under the influence of an external magnetic field. Experimental Thermal and Fluid Science 33, 591–596.
[17] Selimefendigil, F.,Oztop, H. F., Al-Salem, K.,2014.Natural convection of ferrofluids in partially heated square enclosures. Journal of Magnetism and Magnetic Materials 372, 122-133.
[18] Sheikholeslami, M., Ganji, D. D., 2016.Ferrofluid convective heat transfer under the influence of external magnetic source. Alexandria Engineering Journal, 313-324.
[19] Sundar, L.S., Singh, M. K., Sousa, A. C. M., 2013. Investigation of thermal conductivity and viscosity of Fe_3O_4 nanofluid for heat transfer applications. International Communications in Heat and Mass Transfer 44, 7-14.



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