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Numerical Investigation in Augmentation of Heat Transfer in a Rectangular Duct Using Al_2O_3 and CuO Nanofluids

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***Abstract* - A numerical investigation was conducted to predict the greater thermal enhancement in the rectangular duct using different nanofluids - Aluminum oxide ($Al_2\ O_3$) and Copper oxide (CuO) are employed in the investigation and magnitude are compared with base fluid to ascertain the augmentation of thermal efficiency. Ansys-Fluent 13 used for simulation to identify the augmentation of heat transfer among fluids. A simulation conducted in Laminar flow with Reynolds number (Re) ranges from 20 to 40 at constant heat flux 2000 W/m^2. The research reported the contour of temperature distribution, pressure variation, and magnitude velocity, Result reveals that copper oxide nanofluids have produced significant thermal performances than other nanofluid particles.**

Keywords: **Al_2O_3nanofluids, CuOnanofluids, rectangular duct, Heat Transfer**

I. INTRODUCTION

Recent trends, implementing nanofluids in the combination of material or water mostly used in industrial applications are increasing gradually and producing promising convective heat transfer in many applications *eg* – nonrenewable energy, *etc*. Earlier stage, thermal augmentation was attained by blending nanomaterials (*not in fine power)*with base fluids and shows significant performance. Many researchers [1–4] proved that implementing nanofluids like water, ethyl glycol and others produced remarkable results. Later sizes of the nanomaterial like Al_2O_3, CuO, and MWCNTs are decreased in 10^{-9} to make solvent easily in any fluids that can utilize in application like heat transfer, thermal storage, *etc* detailed reports are presented by researches in numerical and experiment methods [5–13]. In traditional methods using nanomaterial their Thermo physical properties vary depending on the temperature used in various applications and the duration needed for the process is a long time and worked with a lesser limit. Overcome these issues by researchers conducted an experimental and numerical investigation to extend the duration of convective heat transfer. Sharafeldin *et al* [14]. Conducted an experimental investigation using CeO_2 with water-based nanofluidsin a solar collector. The result reveals a 10.74% thermal efficiency enhanced in the solar collector. Allouhi *et al* [15]. Investigated the parabolic collector at medium and high-temperature uses by Al_2O_3 and copper oxide nanofluids. The comparative results reveal that 9.05% enhancement attained copper oxide and 5% attained in Al_2O_3 nanofluid. Pordanjani *et al* [16]. conducted a review innanofluids application in thermal devices with nanofluids stability mechanisms and the effect of efficiency in the heat exchanger. Shahsavar *et al* [17]. reported the performances of hybrid nanofluids containing carbon nanoparticles along with magnetic nanoparticles ina double-pipe counter flow heat exchanger. The author reveals that overall thermal enhancement of nanofluids greater than base fluids Cuce *et al* [18]. reviews researches focused on nanofluids applications in solar energy. Singh *et al* [19]. reviewed the nanofluids application in solar thermal systems and detailed analysis of thermo-physical properties for nanofluids are reported.

From detailed literature, the stage of development of nanofluids and their properties utilization is presented by the various researchers in past decades and proved that implementing nanofluids in heat exchange application shows significant improvement. Even though it identified that comparing different nanofluids with varying volume fraction in heat exchange application and their performances are minimum in the count. This paper aims to report a numerical investigation in the rectangular duct as a solar collector using two different nanofluids and compared the result with base fluid to ascertain the thermal enhancement in this investigation.

A. Numerical approach

1.Rectangular duct –Geometry

The total length of the duct is 250mm, width has 30 mm height. A schematic diagram of the rectangular duct is shown in fig .1. As per ASHRAE recommendation, the dimension of the duct was engaged. 2 D simulation analysis was done by using ANSYS 14 Fluent software. The velocity of fluids varies from Reynolds number ranges from 20 to 40 which entered in inlet region and passed out through outlet region at atmospheric condition. The upper wall of the duct is assumed as constant heat flex at 2000W/m^2 and other regions are assumed as no-slip, adiabatic condition.

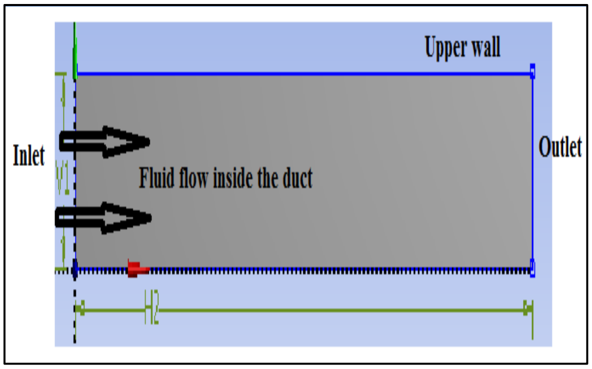

Fig. 1 Schematic diagram of a rectangular duct

2. Grid independent study

In the numerical investigation, distributing the size of the test section into the small region is imperative to predict the accuracy of heat transfer. Different meshing sizes are shown in fig.2. Identifying element size in simulation investigation inveterate by grid-independent test. In a rectangular duct with base fluid, four different sizes are used to confirm the element size and it is confirmed by temperature distribution results. Detailed values are shown in table [1]. From the analysis, the element size 30,832was taken for further investigation.

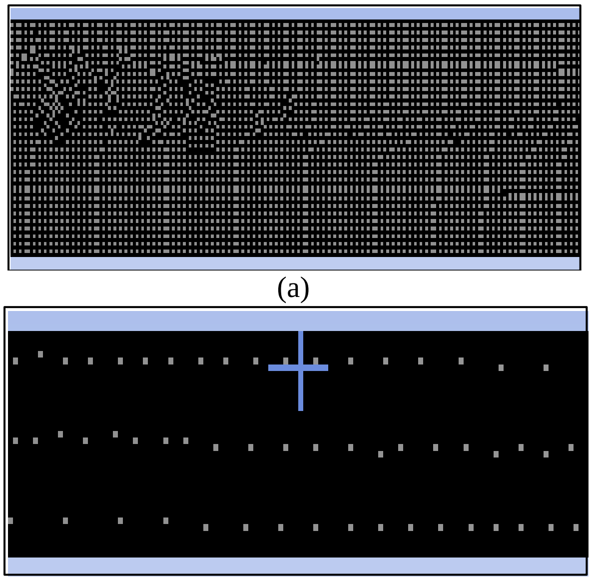
(a)

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Fig.2 Grid independent study of rectangular duct - a) normal meshing b) fine meshing

TABLE I GRID-INDEPENDENT TEST

Sl. No.	Element size /(mm)	Cell in number	Temperature (K)
1	0.08	18,957	296.5
2	0.07	21,451	297.9
3	0.06	27,658	299.7
4	0.05	30,832	300.2

3. Solution

Boundary conditions and simulation models are employed in this solution part. Initially, meshing size convergent and boundary naming regions are identified and values for base fluids are initialized in this pre-solution. Laminar – Viscous flow, assumed in the inlet region at a velocity of fluids varied from Reynolds number ranges from 20 to 40. Outlet fixed as atmospheric pressure condition. The upper wall is assumed as 2000W/m^2 Heat flex and the remaining region is adiabatic condition. Depend upon fluid volume fraction and thermo physical condition of nanofluids the temperature varies and applied at the thermal conversion part in the upper wall. In the post - solution operation the SIMPLE -pressure discretized methods opted for investigation. In monitoring, residual selected at 10^{-6} to predict the values are very accurate. Later, initialization is done with the selected condition and calculated the setup in the given conditions.

II. RESULT AND DISCUSSION

A. Contour Plot of Velocity Distribution

In the numerical investigation, the fluid flow inside the rectangular duct is varied on Reynolds number ranges from 20 to 40. Maximum temperature convection is possible by increasing Reynolds number ranges. To identify the higher thermal variation in base fluids with engaged nanofluids the velocity distribution diagram can be evidence to trace the local heat transfer in the duct. Detailed velocity circulation inside the rectangular duct as shown in fig .3.1 to 3.3 [a - c]. It shows that maximum velocity has yield minimum heat transfer than lower Reynolds number in all fluids. Among them, copper oxide has significant thermal performances in all ranges Reynolds number than other fluids.

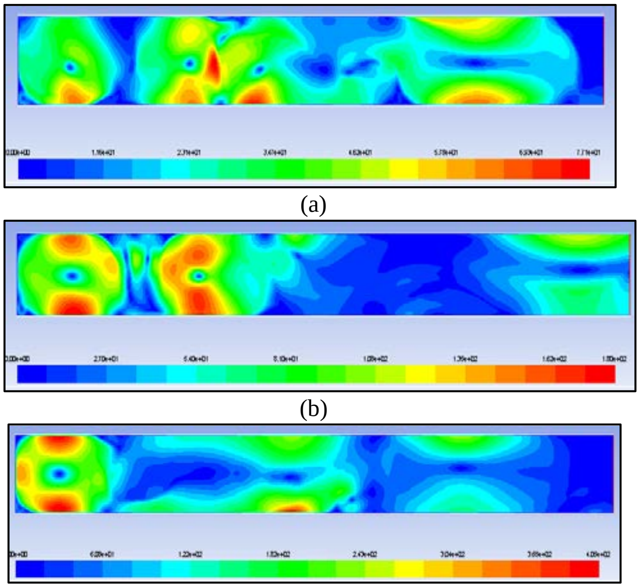
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Fig.3.1 Velocity distribution of base fluids with different Reynolds number, a)Re 20 b) Re 30 c)Re 40

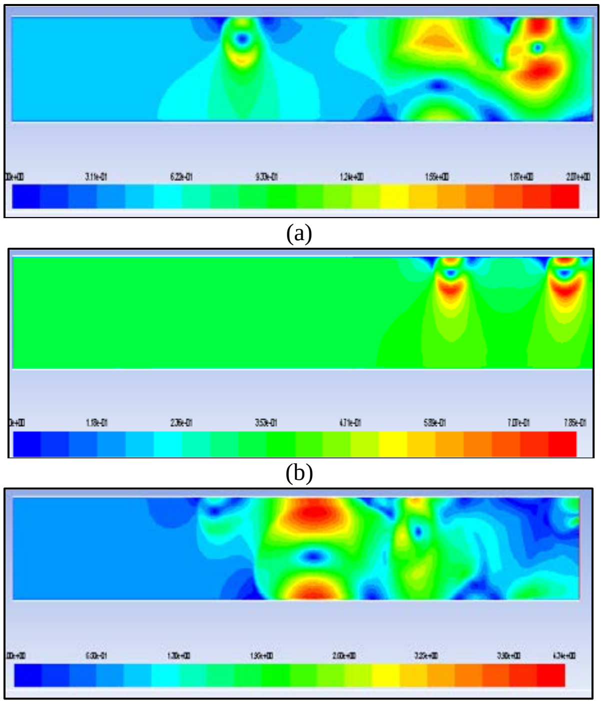

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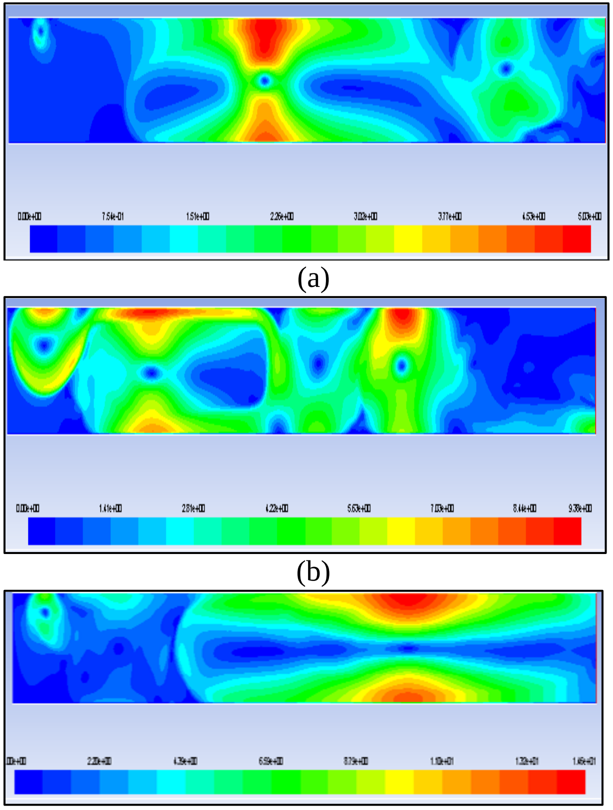
Fig.3.2 Velocity distribution of nano-fluid CuOwith different Reynolds number. a) Re 20 b) Re 30 c)Re 40



(a)

(b)

(c)

Fig.3.3 Velocity distribution of nano-fluid Al_2O_3 with different Reynolds number, a) Re 20 b) Re 30 c)Re 40

B. Contour Plot of Pressure Distribution

It's also imperative in a fluent simulation that maximum friction factor can measure by pressure distribution contour diagram as shown in fig. 4.1 to 4.3 [a-c].It was observed that based fluids have a wide range of friction accorded closer to the wall surface than flow direction in all Reynolds numbers. In performances of nanofluids, the condition shows lesser pressure drop occurred in wall surface, causes to discharge maximum heat energy in the minimum velocity of fluid flow inside the duct. The outcome of this has not desired a higher pumping power for fluid flow inside the duct. The Al_2 O_3 contour illustrates that pressure distribution occurred maximum is closer to the inner region and flow after middle portion as smooth distribution causes minimum heat losses than other fluids and it has formed significant performances in a range of Reynolds number.

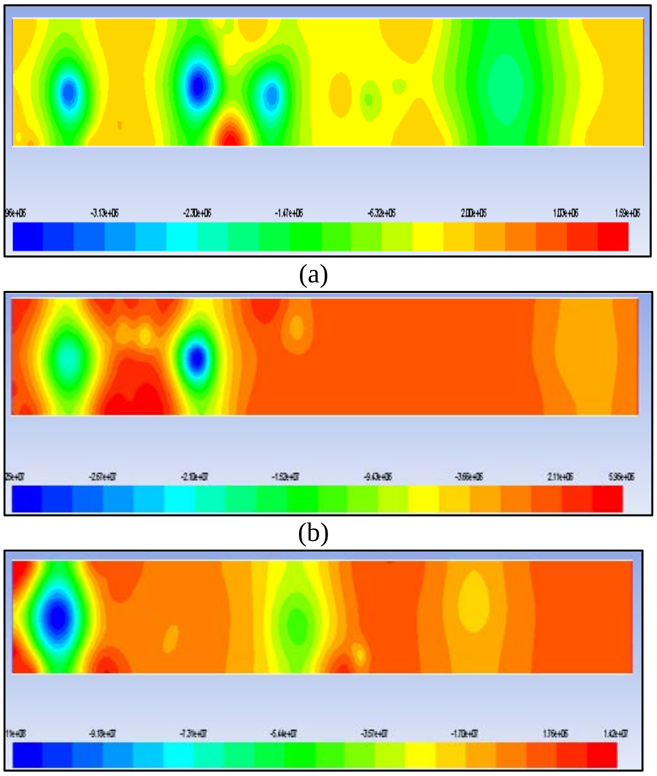


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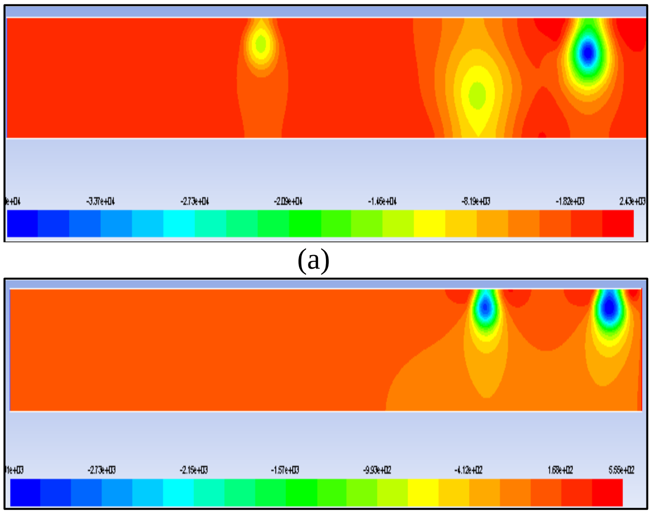
Fig.4.1 Pressure distribution of base fluids with different Reynolds number. a) Re 20 b) Re 30 c)Re 40



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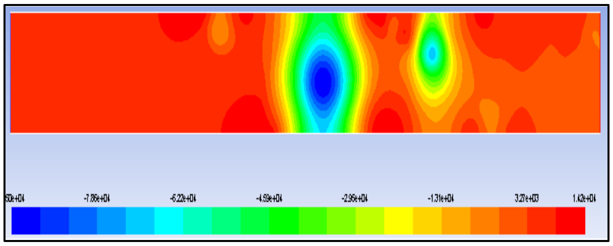
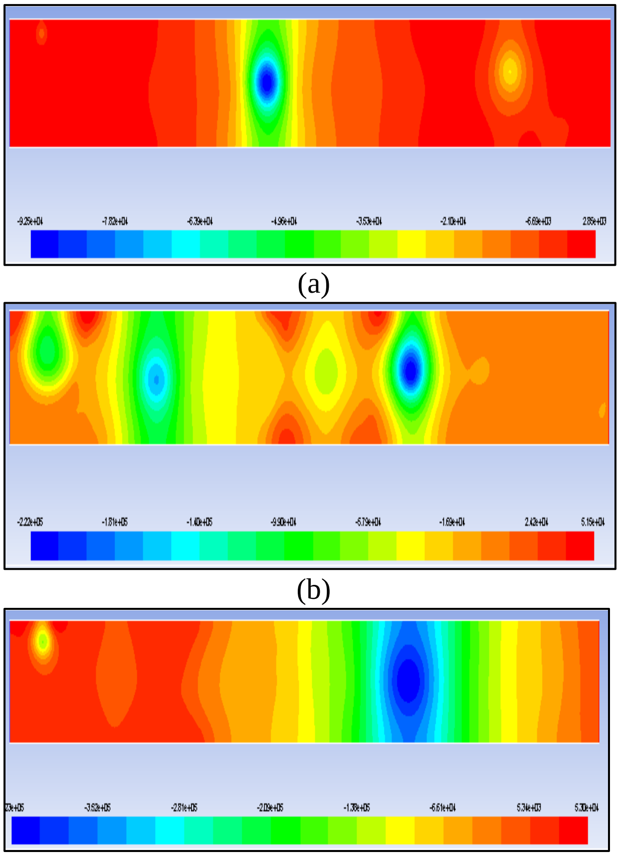


(c)

Fig.4.2 Pressure distribution of nano-fluid CuOwith different Reynolds number. a) Re 20 b) Re 30 c)Re 40

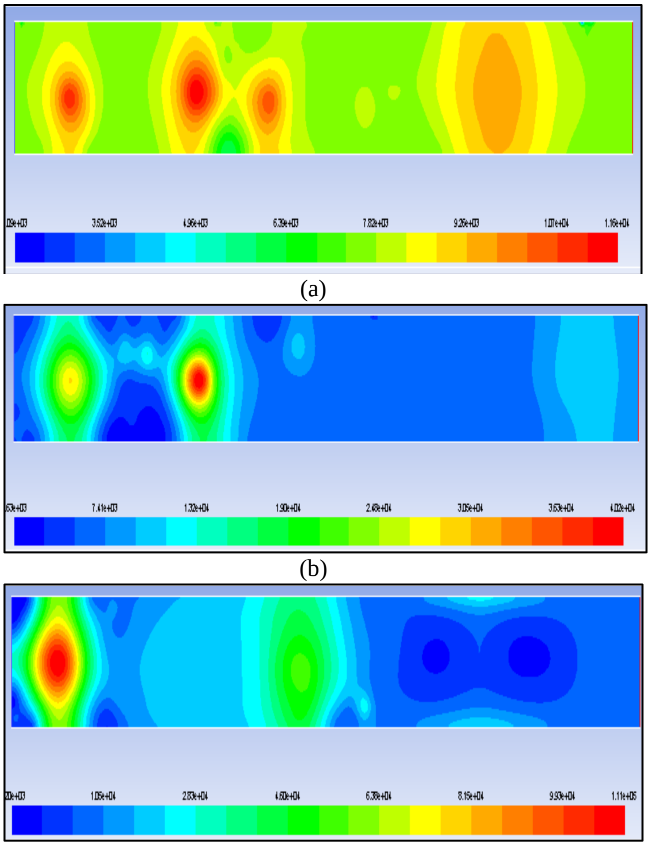


(c)

Fig.4.3 Pressure distribution of nano-fluid $Al_2\ O_3$ with different Reynolds number. a) Re 20 b) Re 30 c)Re 40

C. Contour Plot of Temperature Distribution (Internal Energy)

The prominent portion of this investigation is the heat distribution ratio among nanofluids compared with base fluids. The comprehensive temperature distribution is shown in fig 5.1 to 5.3 [a-c]. The simulation result reveals that copper oxide has shown significant performances than others owing to it has maximum thermal conductivity has to produce a higher heat distribution ratio, it can be observed in 5.2 [a-c] that the center portion of duct and lower wall surface region has distributing maximum heat energy than other fluids in all ranges of Reynolds number and produced better thermal efficiency than others.



(c)

Fig.5.1 Temperature distribution of base fluids with different Reynolds number. a) Re 20 b) Re 30 c) Re 40

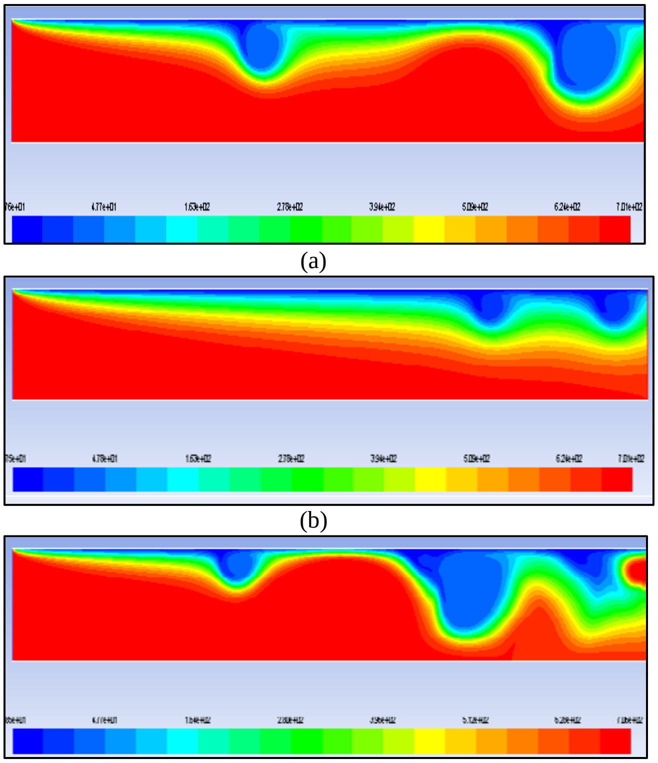


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Fig.5.2 Temperature distribution of nano-fluid CuOwith different Re No. a) Re 20 b) Re 30 c)Re 40

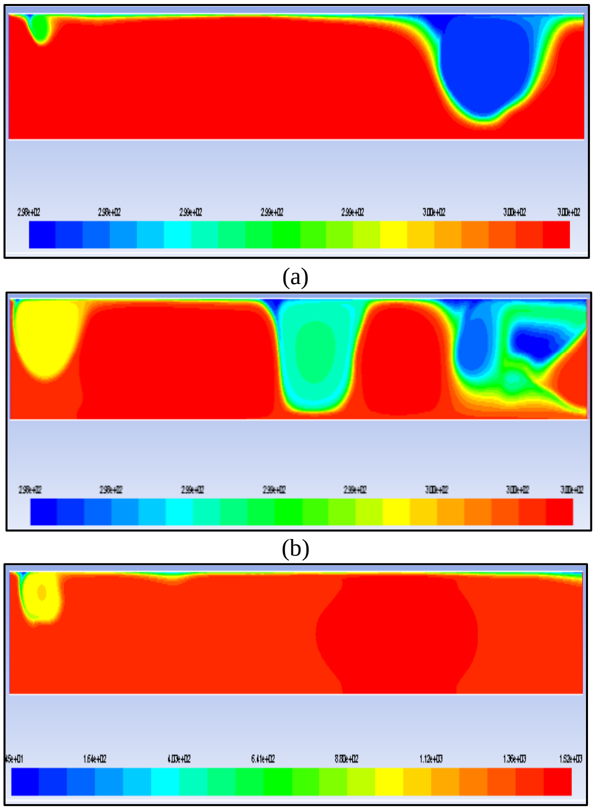
(a)

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Fig.5.3 Temperature distribution of nano-fluid Al_2 O_3 with different Re No. a) Re 20 b) Re 30 c)Re 40

In fig. 6 illustrate the persistent distribution of temperature in the duct and heat transfer is measured values are recorded in all direction. It is clear evidence to present the gradual increase of transfer heat takes place inside to outlet direction. It also, understands that implementing nanofluids in heat transfer application steady increment will occur.

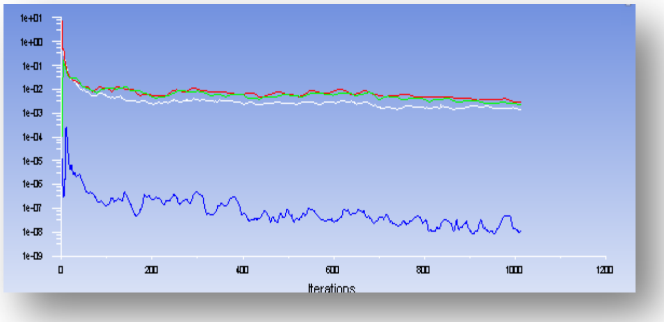

Fig .6 Energy and x,y z velocity values

III. CONCLUSION

The simulation analysis was carried out to investigate the performances of nanofluids in convective heat transfer. It has produced significant thermal performance than base fluids and simulation analysis is evaluated to confirm the heat transfer performances by varying Reynolds number. From the investigation, copper oxide has produced maximum temperature distribution than other fluids, so it is recommended to implement or blend with base fluids or further investigation with different nanofluids with varying volume fractions for the application of heat transfer.

REFERENCES

[1] SUS Choi , ZG Zhang , W. Yu , FE Lockwood and EA Grulke. “Anomalous thermal conductivity enhancement in nanotube suspensions,” *ApplPhysLett* , Vol.79, No14,pp 2252-4. 2001.

[2] W. Duangthongsuk and S. Wongwises. “Measurement of temperature-dependent thermal conductivity and viscosity of TiO2-water nanofluids,” *ExpTherm Fluid Sci*,Vol.33 No.4, pp706–14. 2009.

[3] C.K. Leong, and DDL. Chung. “Carbon black dispersions as thermal pastes that surpass solder in providing high thermal contact conductance,” *Carbon*, Vol.41, No.13, pp.2459–69. 2003.

[4] J.F. Feldhoff ,K.Schmitz, M. Eck. L. Schnatbaum-Laumann, D. Laing, F. Ortiz-Vives and J. Schulte-Fischedick. “Comparative system analysis of direct steam generation and synthetic oil parabolic trough power plants with integrated thermal storage,” *Sol Energy*, Vol.86, No.1, pp.520–30. 2012

[5] C.A.Nieto de Castro, M.J.V. Lourenco, A.P.C. Ribeiro, E. Langa, S.I.C.Vieira and P.Goodrich, et al. “Thermal properties of ionic liquids and ionanofluids of imidazolium and pyrrolidinium liquids,” *J Chem Eng Data*, Vol.55,pp.653–61. 2010.

[6] B. Wang, X.Wang, W.Lou and J. Hao. “Ionic liquid-based stable nanofluids containing gold nanoparticles,” *J Colloid Interface Sci*, Vol..362, pp.5–14. 2011.

[7] B. Wang, X. Wang, W. Lou and J. Hao. “Rheological and tribological properties of ionic liquid-based nanofluids containing functionalized multi-walled carbon nanotubes,” *J PhysChem C*;2010, Vol..114,pp.8749–54. 2010

[8] C.S. Jwo, H. Change, T.P. Teng, M.J. Kao, and Y.T. Guo, “A study on the effects of temperature and volume fraction on thermal conductivity of copper oxide nanofluid. 25650 North Lewis Way, Stevenson Ranch, CA 9138-1439, United States: American Scientific Publishers; 2007. pp. 2161 -2166. 2007.

[9] L.J. Cheng ,L.J. Guo, “ Ionic current rectification, breakdown, and switching in heterogeneous oxide nanofluidic devices,” ACS Nano;2009,Vol..3, pp.575–84. 2009

[10] C.Y. Lin , J.C. Wang ,T.C. Chen , “Analysis of suspension and heat transfer characteristics of Al2O3 nanofluids prepared through ultrasonic vibration,” *Appl Energy*; Vol..88, pp.4527–33. 2011.

[11] T. Yousefi , F. Veysi , E. Shojaeizadeh and S. Zinadini. “An experimental investigation on the effect of Al2O3-H2O nanofluid on the efficiency of flat-plate solar collectors,” *Renewable Energy* Vol..39, pp.293–8. 2012.

[12] H. Chang, M.J. Kao, Y.C. Chang and D.Y. Huang, “A new approach of synthesis of Al2O3 nanofluid. In: 3rd Workshop on metastable and nanostructured materials, NANOMAT 2006, June 5, 2006 - June 8, 2006. Rio de Janeiro, Brazil: Trans Tech Publications Ltd; 2008. pp.155-161.2006.

[13] J. Liu , F. Wang, L. Zhang, X. Fang and Z.Zhang. “Thermodynamic properties and thermal stability of ionic liquid-based nanofluids containing Graphene as advanced heat transfer fluids for medium-to-high-temperature applications,” *Elsevier - Renewable Energy*; Vol. 63(2014), pp.519–23. 2014.

[14] M.A. Sharafeldin , “Grof G. Experimental investigation of flat plate solar collector using CeO2-water nanofluid. Energy Conv Manage-Elsevier Vol.155, pp. 32–41. https://doi.org/10.1016/j.enconman.2017.10.070. 2018.

[15] A. Allouhi , M.B.Amine ,R. Saidur ,T. Kousksou and A.Jamil , “ Energy and exergy analyses of a parabolic trough collector operated with nanofluids for medium and high temperature applications,” *Energy Conv Manage-Elsevier* , Vol.155,pp.201–17. 2018. https://doi.org/10.1016/j.enconman.2017.10.059.

[16] A. HajatzadehPordanjani , S. Aghakhani , M. Afrand , B. Mahmoudi , O.Mahian and S.Wongwises , “An updated review on application of nanofluids in heat exchangers for saving energy,” *Energy Convers Manage* 2019;198:111886. https://doi.org/10.1016/j.enconman.2019.111886.

[17] Shahsavar, Z.Rahimi and M.Bahiraei. "Optimization of irreversibility and thermal characteristics of a mini heat exchanger operated with a new hybrid nanofluid containing carbon nanotubes decorated with magnetic nanoparticles," *Energy Conv Manage-Elsevier*;Vol.150,pp. 37–47. 2017.https://doi.org/10.1016/j.enconman.2017.08.007.

[18] E. Cuce , P.M.Cuce ,T. Guclu and A.B. Besir, "On the use of nanofluids in solar energy applications," *J ThermSci*;Vol.29,No.3,pp.513–34. 2020.

[19] A.H. Elsheikh , S.W. Sharshir,M.E. Mostafa,F.A. Essa and M.K Ahmed Ali , "Applications of nanofluids in solar energy: A review of recent advances," *Renew Sustain Energy Rev*,Vol.82,pp.3483–502. 2018.