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THERMAL PERFORMANCES OF HYBRID NANO FLUID IN A RECTANGULAR DUCT

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Abstract

The present work aims to augment the thermal performance of rectangular duct by implementing square rib in test section and consuming hybrid-nanofluids such as Al_2O_3 -CuO as a working fluid. The investigation outcome is compared with base fluid (water) to ascertain the enhancement of heat transfer rate. A parameter consider for the research is average Nusselt number, friction factor and velocity of fluid assumed in the range of Reynolds number 5000 – 15000. The RNG-turbulent model was selected for the investigation to validate the convective heat transfer achieved closer to the top wall. The characteristic of heat transfer and pressure drop of fluid flow inside the rectangular duct are identified by contour results of turbulent kinematic energy and intensity, static pressure, velocity. The result reveals that 14% of advancement of Nusselt number were recorded in hybrid nanofluid than base fluid with a nominal friction factor.

Keywords:

Rectangular duct;
Al_2o_3- CuO;
Nusselt number;
Friction factor.

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1. Introduction

In recent decades many researchers looking advancement in consuming nano fluids in various industrial and commercial applications to enhance thermal performances in both heating and cooling usage. Some authors reveal implementing rough surface in a duct with nanofluid as a working fluid has produced promising enhancement in heat transfer rate. A nano fluid with different base fluids such as ethylene glycol, oils and water are preferred in experimental

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investigation [1 -3]. It observed that significant temperature difference recorded by varying volume fraction, size of a nanomaterials, blending more base fluids. Li et al [4] conducted investigation using Cu nanofluid with water for better heat transfer rate. It reveals that more pumping power required to operate nanofluids as a working medium. Zeinali et al [5] investigated using CuO with water and Al2 O3 with water in annual tube in the velocity of laminar regime. Author reveals that increasing nano particle in fluid has achieved higher thermal performances than base fluid. Yue et al [6] use Al2O3 nanofluid and compare with water in different volume fraction 0.01 to 0.04. the investigation focused to increase thermal performances and assessed by Nusselt number and pumping power. The result reveals that increasing size of nano particles in fluids decrease Nusselt number and friction factor. And also report increasing Reynolds number the Nusselt number also increase. Abdollahi et al [7] use different nanofluids such as SiO_2, Al_2O_3, Zn O and Cu O are compared with water as a base fluid by varying volume fraction 0.01 to 0.02. the diameter of nano particles presents in the fluids measured in the rage of 30,40,60 nm. The research report revels increasing volume fraction of nano particles in working fluids the advancement of Nusselt number recorded with nominal pressure drop. And reveals higher thermal performances achieved in Al_2O_3. Sakanoca et a; [8] implemented same nanofluids for their research with various volume fraction 0.01,0.02,0.03 and 0.04. The report reveals wavy effect noticed in wall surface of the channel causes greater heat transfer rate than base fluid. Nebbati et al [9] compared Al_2O_3 with base fluid to demonstrate nanofluids achieved higher thermal performance than base fluid. Diameter of nanoparticles as 38 nm with various volume fraction 0.00 to 0.04. The research reveal increase Nusselt number observed in top wall of the channel and decrease in bottom wall and also further identified a slight stress noticed to the mower side of wall region. Rimbault et al [10] consumed CuOnanofluid with base fluid of water in volume fraction of 0.0024 to 0.045. the author reveals that low volume fraction enhances heat transfer in 0.24% and 1.03% in higher volume fraction. It further noticed a higher pumping power required to operate in greater volume fraction. Kuppusamy et al [11] conducted investigation in Al_2O_3, Cu O, Si O_2, Zn O nano fluids are compared with base fluid water with volume fraction of 0.01 to 0.04 with nano particles diameter size in the ranges of 25 to 80 nm, Authors pragmatic increase Reynolds number and identified greater vortex generator closed to groove area to causes higher heat transfer rate than base fluid.

From a detailed literature survey, we observed implementing nanofluids in heat exchanger application casus significant thermal improvement in all nano fluids in higher volume fraction. Among them Al_2O_3 with base fluid water combination conducted by many researchers to prove higher heat transfer rate achieved in their research work. However, minimum research work conducted in hybrid nano fluid and among them implementing rough surface investigation work are minimum.

The main objective of the paper is enhanced thermal performances in rectangular duct by implementing square rib mounted in test section and working fluid selected as higher thermal conductivity of Al_2O_3 blended with Cu O. the significant outcomes are compared with average Nusselt number and compared with base fluid to ascertain the augmentation of heat transfer attained in proposed nanofluids.

2.Computational procedure

2.1 Modelling

A 2 D rectangular duct of height 100 mm and length 3000 mm assumed for the investigation and schematic diagram as shown in fig 1. A square shape of rib mounted in test section ranges between 1200 mm to 2400 mm from the inlet at pitch distance P = 15 mm. A working fluid enter in left side of rectangular duct at a velocity of Reynolds number 5000 to 15000 and heated fluid exit at right side of the duct. Top surface of a duct assumed as heated wall where constant heat flux 1000 W/m^2 applied to heat working fluid.

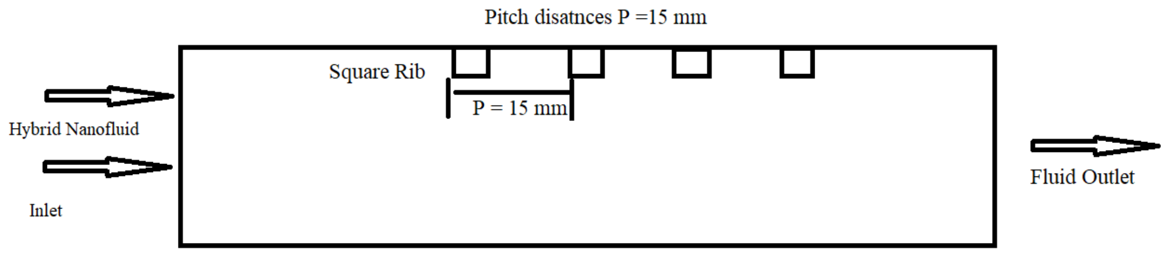
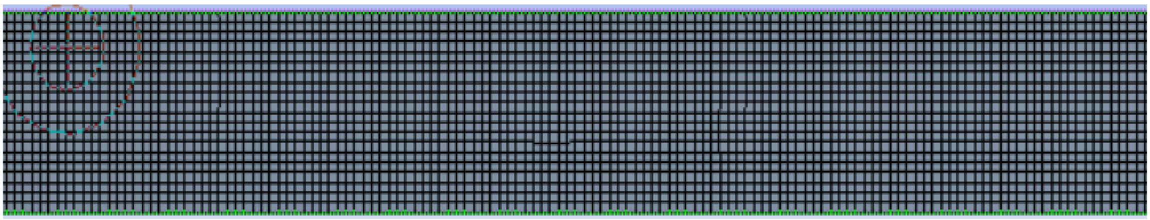


Fig 1. Schematic diagram of rectangular duct with square rib.

2.2 Meshing

A grid independent study conducted to defend the selected element cell is validated for the present investigation. An element size meshed in the range of 1 mm to 0.5 mm and average Nusselt number predicted from the range of 64.7 to 78.5. It was observed that in the element size 27,743 has attained maximum Nusselt number and further it recorded least differences. $\pm$ 5% in further reduction of element cell size. Detailed meshing rectangular duct as shown in fig 2. A boundary condition clearly mentioned that left side of rectangular duct has inlet velocity and right size as exit. The top wall assumed as constant heat flux and bottom condition considered as adiabatic condition.

a) 

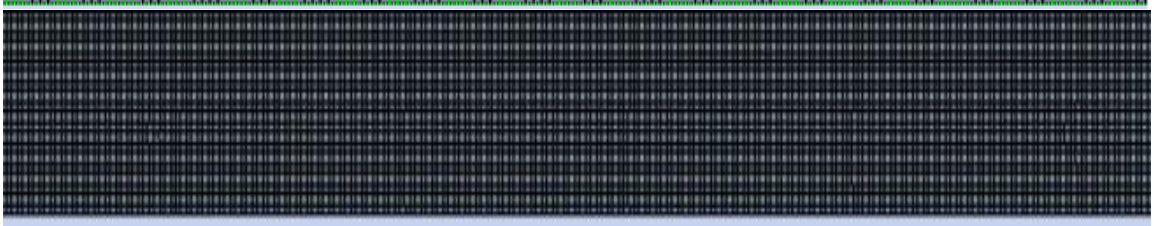
b) 

Fig. 2. Various Meshing size of rectangular duct

2.3 Solution

In preprocessing process, selection of energy equation, turbulent models are assumed in steady state condition. Based on review, RNG-Turbulent models are selected for the investigation for precises prediction. In material selection, a thermo-physical property of hybrid nanofluids values are used for the simulation with nomination of turbulent intensity lesser than 5%. And inlet velocity of working fluids assumed in the range of Reynolds number 5000 to 15000. A SIMPLE pressure -velocity equation opted with second order literation process. Further, calculation values are assumed and started the literation to finalize the average Nusselt number and friction factor of proposed geometry. Detailed achievement and predicted values are discussed in result part

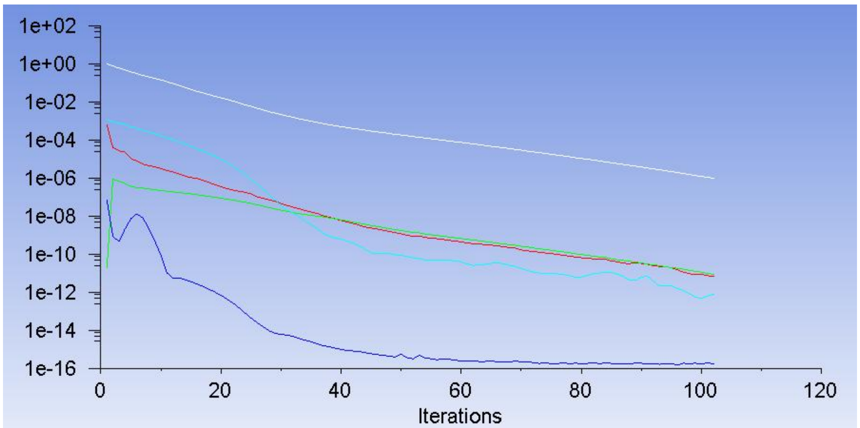


Fig.3. Residual result and Iteration

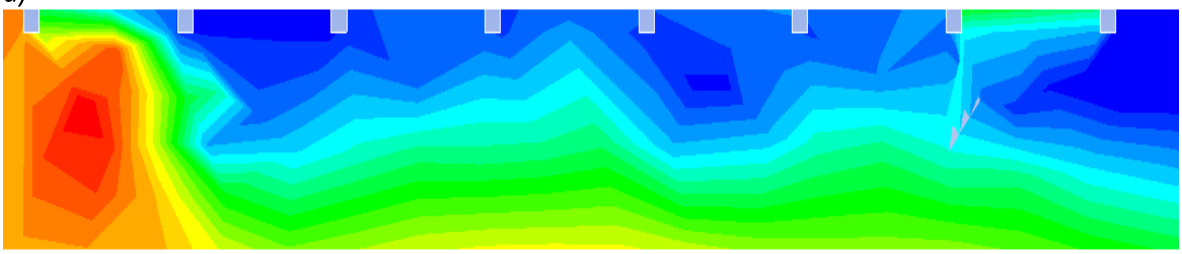
3 Result and discussion

A characterization of heat flow and pressure drop in rectangular duct by using rough surface with hybrid nano fluids are presented elaborately. A Reynolds number ranged from 5000to 15000 are taken and significant results are discussed.

3.1 Characterization of average Nusselt number:

In simulation analysis of rectangular duct with square rib in test section of thermal performance are analyze by varying Reynolds number and compared the performances of hybrid nanofluids with base fluids – water. Detailed heat flow characterization is illustrating in turbulent dissipation in fig. 4 [a & b]. It expresses that rough surface inside a rectangular duct has creates vortex in stream line in fluid flow direction causes turbulences. The size of recirculation influences augment convective heat transfer rate based on varying Reynolds number. Fig 3.a demonstrate size of reattachment has increase owing to diameter of nanoparticles presented in the 0.2 volume fraction of nanofluids in higher Reynolds number 15000. It reveals maximum enhancement of heat transfer occurred than base fluid. And also, in fig. 4.b it simple illustrates the vortex generation and size of turbulence in boundary condition reports normal structure deformation and it record lesser thermal performance than proposed hybrid nanofluids owing to its thermo physical properties in all condition of Reynolds number.

a)



b)

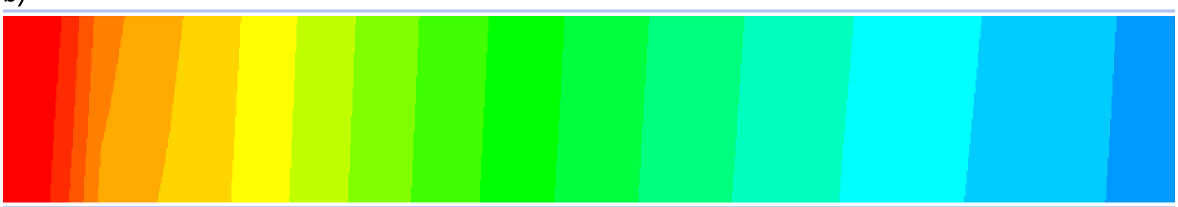


Fig.4. a & b Turbulent kinematic energy of Hybrid nanofluids and Base fluids water

Besides, a clear flow behavior can also trace in turbulent intensity as shown in fig 5. it illustrates that stronger vortex generates in closed region of wall surface where near to the square ribs and increasing Reynolds number the size of vortex increases Moreover, a size of vortex greater in first pair of ribs and it gradually decreasing in fluid flow direction on further pair of ribs in top wall of the rectangular duct. However, similar traces are recorded in base fluids, but minimum differences in flow character, illustrates the thermo-physical property of fluids yields maximum heat transfer rate than water.

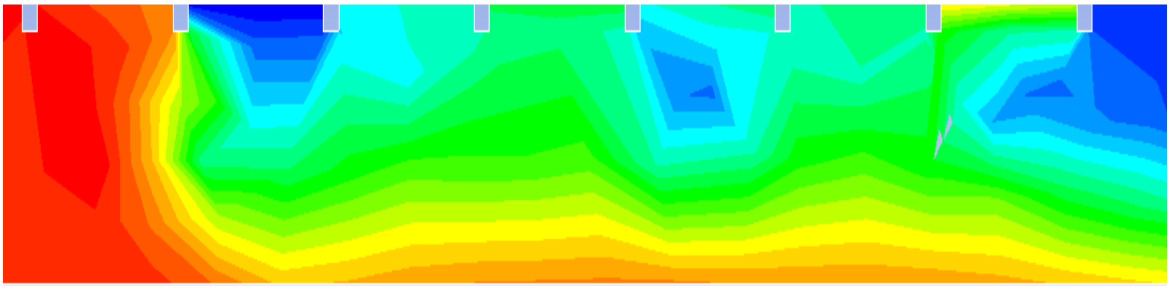
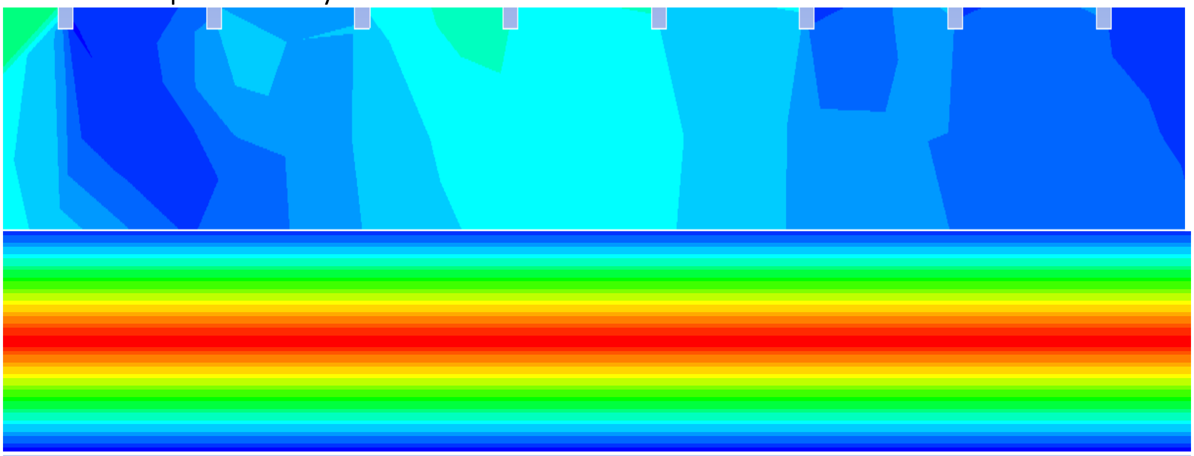


Fig 5. Turbulent Intensity of Hybrid nanofluids

3.2 Characterization of friction factor:

In numerical investigation, it is important to assess the pressure drop occurred by implementing rough surface inside a duct in the range of various Reynolds number. Generally, in forced convection and nanofluids working medium its required higher pumping power to increase the convective heat transfer. In fig 6. illustrates the characterization of friction factor decreases with increasing Reynolds number. Moreover, a nominal pressure drops differences occurred in base fluids were compared with hybrid nanofluid.

a)



b)

Fig 6. Static pressure and velocity ofHybrid nanofluids and Base fluids water

4 Conclusion

In numerical study, the augmentation of thermal performance in rectangular duct are analyzed by using hybrid nanofluid -Al_2O_3 blended with Cu O. besides, rough surface in the test section plays a addition thermal performances than base fluids. Significant result of research work is presented below

a. Hybrid nanofluids Al_2O_3 with CuO as a working fluid in rectangular duct yields higher average Nusselt number than base fluids.

b. It observed a square shape of rib in test section generated stronger vortex in fluids flow direction cause higher heat transfer rate than smooth surface.

c. Enhancement of heat transfer was noticed clearly in contour results of turbulent dissipation and turbulent intensity

d. In static pressure contour a nominal pressure drop recorded in both fluids and recorded a higher pumping power required in higher volume fraction in nanofluids.

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