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Characteristics and Numerical Investigations on Natural Convection in Triangular Porous media: A Review

Prerna Rai[1] , Dr. R. V. Sharma[2] , Dr. Shalendra Kumar[3]

[1]Research Scholar , NIT Jamshedpur 2018RSME016@nitjsr.ac.in

[2]Professor, NIT Jamshedpur rvsharma.me@nitjsr.ac.in

[3]Professor, NIT Jamshedpur shalkumar.me@nitjsr.ac.in

Abstract

A descriptive study about the numerical investigation of natural convection in an area of triangular porous is discussed on multiple natural processes of heat transfer as well as heat exchange in the particular place of the triangle. Focus on the particular experiment as well as a scientific function between nature and engineering applications, its multiple cells which are formed from the system of air raising an area of water as well as land, various issues of this kind of experiment, process function about natural convection, what are the importance of forced convection in the platform of natural convection in triangular porous are described in this analysis paper. Also, this paper focuses on elaborating on triangle geometry, various models like the Darcy model, Darcy Brinkman, various boundary values of porous media, and also about multiple obstacle factors. The study of numerical investigations identifies importance, strategies, examples, process factors, and also mathematical calculations along with equation models of natural convection.

Keywords: Numeric investigation, Natural convection, Triangular porous media, Cu water, Scientific engineering application, Obstacle

Introduction

Analysis of natural convection into the area of the right-angled triangle provides a better solution as well as a proper experiment where cold water density is nearly around 3.98 c. At this particular density (maximum) the results are conforming well as per expectation. The initial research on porous media concentrated on ideal fluid and Newtonian fluid with certain assumptions which was difficult to validate through experimental results; later investigations with nanofluid , water and cu water were introduced. Natural convection in triangular porous is performing in the area of especially the bottom and vertical wall which based on multiple mathematical formulas, calculations, variations and also depend on some models like Darcy model Darcy Brinkmann Model or other these all are functioning well in the particular segment as well as in a platform of the ratio of height and also the different base of the enclosure. To observe all these phenomena, the effect of numerical investigation, its density, and its impact associating the way of proper analysis on the area of numerical investigation.

The area of aim and objective mentions the process of numerical investigation function, the effect of this experiment in the area of triangular media, mathematical formulas, variations, outcomes of the experiment, and results. The literature review area focuses on some particular sections of triangle geometry, various models of experimental work, various value functions, barriers, and difficulties. The result and discussion part identify the section of mathematical analysis, review, information as well as numerical application and result. The part of the recommendation and future scope elaborate on multiple segments which are needed to improve or enhance experimental work, finding solutions of various models, triangular enclosures, and conduction of heat transfer systems. In this analytical paper based on the area of natural convection in triangular porous media is elaborate by the method of measuring several temperatures and the result is also discussed on similar ways of methodology.

Aim and objective

The particular study of numerical investigation in the segment of natural convection is focused on some particular prudential area to understand properly the experimental function of the numerical convection process. The objectives of this analysis study are mentioned below (Oztop et al. 2008).

- About the process of numerical investigation for the area of natural convection program
- Process of heat transfer in the function of numerical experiment with the triangular surface.
- About the system of density, the percentage maximize in triangular enclosure (Abuhegazy et al. 2020).
- Different functions as well as multiple variations of natural convection process in the area of experiment.
- Multiple parameters and sectional division about the experiment as well as the function of the numerical investigation process system.
- System of energy distribution to enhance the program of investigation functions in the area of numerical convection (Zaang et al. 2020).
- Priority of natural convection process research, to enhance the program of numerical investigation.
- Various figures of porous medium and configuration systems elaborate on the model of natural convection.
- Multiple conditions or situations of transferring heat, setting the parameter of experiment and analysis of the perfect condition of thermal performance.

Literature review

Triangle geometry in the area of natural convection system

In the area of natural convection, this process considers a minimum of three types of convection, natural convection, forced convection & mixed convection to perform in a particular section of numerical investigation. In the experimental process of heat transfer convection and variations are like convection of air forced, convection of liquids forced and the type of boiling water convection along with this process all types of convection are considering different amounts of heat to transfer into the experimental system in the area of natural convection (Varol et al. 2006).

Various geometric figures are working in the particular section of natural convection system as like to protruding isothermal heater, triangular for natural convection process, a program of centered conducting enclosures (varol Y 2011), for natural convection square cavity responsibility, triangular function to perform for MHD natural convection process of experiment, heat transfer process into the area of the triangular and rectangular figure, a system of heat transfer and flow system in the area of natural convection (Alam et al. 2021). For all these processes and programmers multiple functions of triangular angle and model such as right angle, triangle, and acute angle geometry are mostly responsible.

Natural convection is an experimental process of understanding which is considered with various numerical investigations, formulas, problems, and solutions, modeling, ford ratio function, and elaborate result. In the function or experiment of nature investigation, numerical modeling is associated with multiple triangular angles or enclosures. To progress the system of numerical investigation as well as modeling the function of experiment fluent software application as well as modeling of the numerical solution is a very important aspect to an understanding about parameters of the experimental function. In the area of heat transfer modeling systems various figures, mathematical calculations, and variations are applicable to function well in experimental processes (Akinsete et al. 1982).

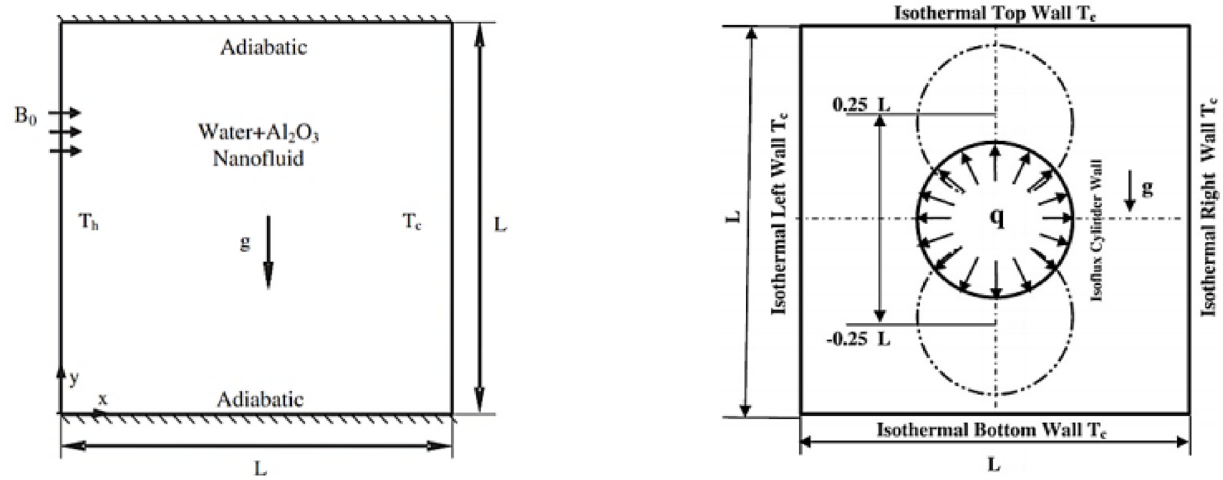


Figure 1: Physical model of coordinate system.

(Source: Yadav et al. 2021)

The figure number 1 is elaborate process of physical model of coordination system through simple shape of schematic diagram in area of enclosure. This model is presented also the area of inner body of schematic diagram within enclosure shape and mathematical model.

About model function in the area of numerical investigation and nature convection process

The process of model function is a very important aspect of experimental work as well as the function of numerical investigation. Model function or classification of modeling in the area of nature convection process is elaborate various experimental functions like heat transfer process, heat increase and decrease, porosity, fluid density and viscosity, movement of multiple molecules within the portion of the fluid element which is associated or based on the form of gas and liquids. Modeling function or classification system is very important to meet with the segment of bulk movement system into the area of fluid processing function another side, the process of convection modeling is a way of experiment program that making a support system as well as a transferring function of heat transfer between two segments of the like object and the other hand it's connecting to fluids to mix both of elements to enhance motion program of the component of the fluid (Basak et al. 2007).

Darcy equations for steady state natural convection

Continuity equation: $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0,$

Momentum equation : $\frac{\partial u}{\partial y} - \frac{\partial v}{\partial x} = \frac{2gK\gamma(T - T_m)}{\nu}\frac{\partial T}{\partial x}$

Energy equation: $u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha_m\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right)$

here boussinesq's approximation is considered for density variation

Darcy Brinkman Forchheimer equation for steady state natural convection

Momentum equation X direction:

$$\frac{\rho_0}{\epsilon^2}\left(u_D\frac{\partial u_D}{\partial x} + v_D\frac{\partial u_D}{\partial y}\right) = -\frac{\partial p}{\partial x} - \frac{\mu_f}{K}u_D + \frac{\mu_f}{\epsilon}\left(\frac{\partial^2 u_D}{\partial x^2} + \frac{\partial^2 u_D}{\partial y^2}\right) - \frac{1.75\,\rho_0}{\sqrt{150K}\,\epsilon^3}u_D\sqrt{(u_D^2 + v_D^2)}$$

Momentum equation Y direction:

$$\frac{\rho_0}{\epsilon^2}\left(u_D\frac{\partial u_D}{\partial x} + v_D\frac{\partial u_D}{\partial y}\right) = -\frac{\partial p}{\partial x} - \frac{\mu_f}{K}v_D + \frac{\mu_f}{\epsilon}\left(\frac{\partial^2 u_D}{\partial x^2} + \frac{\partial^2 u_D}{\partial y^2}\right) - \frac{1.75\,\rho_0}{\sqrt{150K}\,\epsilon^3}v_D\sqrt{(u_D^2 + v_D^2)} + \rho_0 g(T - T_0)$$

The Darcy model is an important approach of solving the problem in the system or function in the experimental platform of equations as well as the process of nature confectioning performance. The particular model Darcy is mostly used as an approach function in the program of convecting equations, this particular model is built by the system of a particular equation of Darcy into the area of the mass conservation program of the equation. This modeling is considering multiple positive functions of experimentation in the system of natural convectional performance. Mostly Darcy models are used in this system of convection only because of their distribution, good function, and fast solution capability and also for their energetic fluid flow system in experimental programmers.

On another side, the model of Darcy's large use also supports the flow system of water especially aquifers (Liu et al. 2021). This model supports the process of groundwater flowing equation systems under any experiment that is considering the process of natural convection program and creating a basic bonding as well as a scientific relationship between water and flow of equation program which associates with a large segment of hydrology. The process or system of Darcy approach also follows the area of gas flows, water flows, oil flows and other various liquid flows.

Darcy Brinkman's modeling process in the area of nature convection modeling as well as the system of Brinkman equation is a process to use in the area of microscopic performance of experimental programmers. In the area of nature conditioning systems sometimes the model process of Brinkman is used to support to elaborate or represent the palace of various channels fluid-filled. This model also provides suggestions of equations and proper results of that particular function. Various laws, formulas, functions, and variations of the calculator in the particular platform of numerical investigation program is supports an experimental network system with various aspects as such flow of water, the flow of heat transfer system, the system of modeling function, the process of energy distribution, calculation, heat increase and decrease program, analysis of confectioning response, classifying the function of fluid flow channels, developing process of experiment and also the most important part of nature convectional process in the area of triangular porous media is present and classifying the function of the frictional heating process (Varol et al. 2011).

Darcy equations for transient convection

Momentum equations in Darcy Law: X direction: $\frac{\square u}{\partial t} + \frac{\mu u}{k} = -\frac{\partial p}{\partial x}$

Y direction: $\frac{\partial v}{\partial t} + \frac{\mu v}{k} = -\frac{\partial p}{\partial x} - \rho g$ where k is the permeability of porous media

Energy equation $(\rho C_p)_p \frac{\partial T}{\partial t} + (\rho C_p)_f \left[u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right] = k_p \left[\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right]$

Boussinesq's approximation $(\rho = \rho_i[l - \square(\square - \square\square)]$

Darcy Lapwood Brinkmann equations for transient convection

Momentum equation

X direction: $\rho_o\left(\frac{1}{\epsilon}\frac{\partial u}{\partial t} + \frac{1}{\epsilon^2}u\frac{\partial u}{\partial x} + \frac{1}{\epsilon^2}v\frac{\partial u}{\partial y}\right) + \frac{\mu}{k}u + \frac{\partial p}{\partial x} - \mu_{eff}\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) = 0$

Y Direction: $\rho_o\left(\frac{1}{\epsilon}\frac{\partial v}{\partial t} + \frac{1}{\epsilon^2}u\frac{\partial v}{\partial x} + \frac{1}{\epsilon^2}v\frac{\partial v}{\partial y}\right) + \frac{\mu}{k}v + \frac{\partial p}{\partial y} - \mu_{eff}\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) = -\rho g$

Energy equation: $\sigma\frac{\partial T}{\partial t} - \alpha\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = 0$

Buoyancy relation: $\rho = \rho_c(1 - \beta(T - T_c))$ subscript c refers to cold fluid

σ = ratio of heat capacity = $(\rho c)_s / (\rho c)_f$

α= effective thermal diffusivity = $k/\rho c$

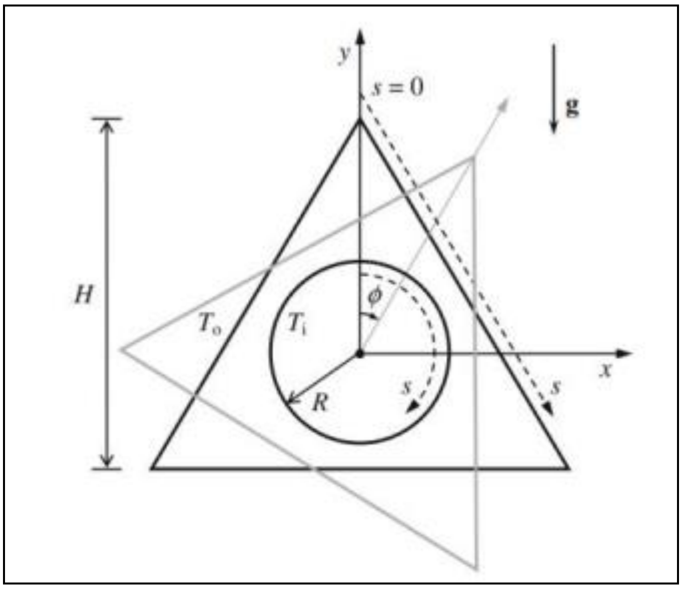


Figure 2: Model function in the area of numerical investigation and nature convection process.

(Source: Pordajani et al. 2022)

The above Figure 2 is a proper explanation of triangular inner body in the particular area of schematic diagram. The process of inner cylinder is elaborating the natural result of breaking system. The particular process is also maintained influence of various systematic equation of mass.

Table 1: summery of natural convection process

(Source: Prordajani et al. 2019)

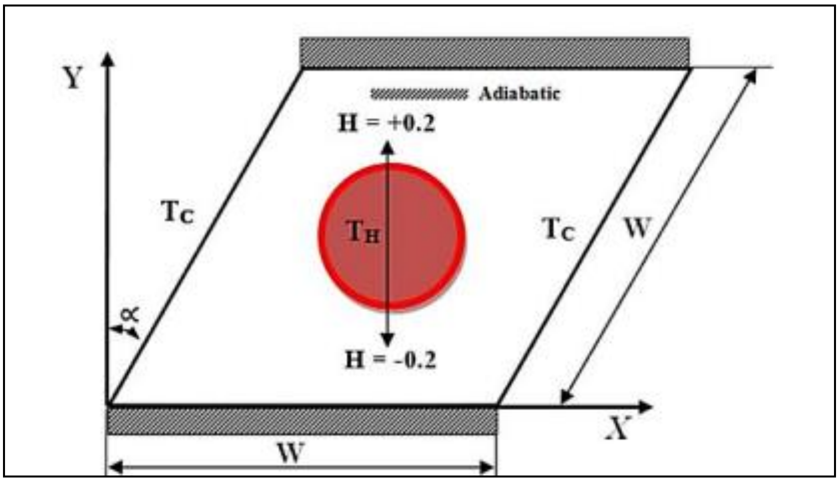
Objective	Enclosure shape	Software/ model used	Conclusions	Special findings
Laminar free convection, effect of Ra, aspect ratio and inclination angle	Cylinder inside triangular enclosure	CVM	At constant aspect ratio, the inclination angle and Ra effect significantly on Nusselt number.	Correlation of Nusselt number as a function of Ra for each value of aspect ratio
Effect of Prandtl number	Cylinder inside coaxial triangular	FVM	Inclination angle had a strong impact on Nu	Unique effect of low Prandtl number Nu while when Pr≥0.7 it does not affect Nu
Mixed convection, MHD, nanofluid, entropy	Rotating insulated cylinder inside triangular enclosure	FEM	Increasing nanofluid concentrations and rotating lead to an increasing in total entropy and Nusselt number	Hartmann number increasing leads to a reduction in both the entropy and Nusselt number
Unsteady natural convection	Cylinder inside coaxial triangular	ANSYS Fluent	Correlations of Nusselt number had been developed.	Nusselt number history had been presented
Mixed convection, nanofluid	Cylinder inside coaxial triangular	ANSYS Fluent	Increasing Ra and nanofluid volume fraction improve the Nu	Rotational velocity effect significantly on Nu

The above table is maintained various shape of enclosure including model of software like the area of FVM, FEM and other. These manners also elaborate area of result findings and the perfect area of conclusion. Results are elaborate various phase of conduction.

Condition of boundary in the platform of nature convection process

In the particular research area of numerical investigation as well as in the segment of convection process, condition of boundary is very important to highlight experiment in the secretion of research methods, the process of developing an experiment, functioning equation or variations, explicit result from the process and also provide solutions. The boundary condition process is an analytical understanding system in the area of research methods. In the area of natural convection process or function condition of boundary is very essential performance to enhance as well as progress the system of experiment. The particular boundary system in the particular function of the conventional process system of boundary condition is classified into various processes that all are considered the function of the natural boundary process (Pordajani et al. 2022). In the system of numerical investigation into the process of nature, multiple types of boundary systems function like the system of Dirichlet, Neumann process, mixed boundary function, Robin boundary function, and another positive boundary condition is the Cauchy function of the boundary.

Conditions of boundary processes are used in the section of nature convections system function used for multiple reasons such as this process identifying or detecting various problems in the dynamic process of experiment, defining various functions of fluid, classifying numerical processes or functions to decide the process function of the natural convections system (Ahmed et al. 2013).



Model 2:Schematic diagram of inner body in area of parallelogram enclosure

(Source: Tang et al. 2021)

Methodology

The methodology that is used in this study is the best method to analysis the characteristics and numerical investigations on natural convection in triangular porous media. The study of nature convectional process in the area of numerical investigation is very potential to understand the function of the experiment, the system of the heat transfer process, the function of heat increase and decrease function, a system of modeling in the platform of nature conventional system, fluid flow process as like water flow, oil flow process and another process of any liquid flow function.

Numerical analysis of porous media problems has primarily been dealt through successive accelerated replacement (SAR) method wherein primary aim is to guess the profile of each variable that satisfies boundary conditions. In this scheme ω is acceleration factor which varies from 0 to 2. $\omega < 1$ is called under-relaxation whereas $\omega > 1$ is called over-relaxation. A proper experimental process of a natural conventional system is following multiple processes or systems to reach the area of the natural convection process system heat transferring module in the particular point of water fluid as like any character of volume. To continue and progress the function of natural convections, the experimental chain follows various supporting tools as well as various models of the method as described below (Tang et al. 2021).

Measuring variations of temperature is a process or tool to understand as well as research on the particular area of natural convection experimental process. This way of experimental tool focuses on the segment of plot variation program in the platform of the natural convection process system. On the other hand, this tool also supports the temperature rate of experimental work in the area of numerical investigation within a fixed conditional boundary of thermal performance that supports the program of the experiment. On the other hand, the system or tool of measuring variations of temperature rate is considering the boundary layer in an area of multiple location segments for the particle experiment of nature convectional process (Trivani et al. 2016).

Result and discussion

Multiple valuations between two segments with porous media and without nanofluids

In the area of natural convectional experimental work, the component of nanofluid is a major thing or aspect to continue experimental work. Nano fluid is a very useful as well as an energetic coordinator that creates a positive bond and a potential experimental application in the way of heat transfer or heat transferring system. The nanofluid element is a strong phenomenon that leads the process of the experimental system of numerical investigation. This valuation of porous media and without media is engaging in various aspects like controlling the system of the heat transfer process, the function of heat increase and decrease chain, fluid flow function, the function of energy cooling, management of thermal performance system in the area of experiment, exchanging volume of many experimental aspects in experiment function (Muhammad et al. 2019). The process of multiple variations is considering various important functions to grow the process of experiment, classified about variation, elaborate about various uses in areas of experimental work especially in the lab, elaborate about heat transfer system, managing process of fluid, energy, cells and other elements of experiments (Zhu et al. 2021).

In the area of the natural process of convection, nanofluids are effects heavily on the system of the investigation process in the area of the triangular surface. These effects are modeled for growth thermal performance, heat transfer function, radiation variation of the experiment, and others. The flow of nanofluid is impacted positively to modify the process of heat transfer, thermal no equilibrium, proper modeling, way of fluid flow control and also manage in the particular platform of nature conventional experimental function (Ahmad et al. 2013). Process of nanofluid or the system of nanofluid function in the area of numerical investigation in a particular section of triangular surface is playing a lead role to continue the process with various dynamic volume, completing with various fictional aspects, controlling water flow process, control to water fluid and the operating system of the heat transfer process from the area heat increase to the segment of heat decrease function. For water preparation in the process of experiment, the nanofluid function is an important part to prepare that area of water for the process, setting the diameter of the experiment, fluctuating the nanofluids within many nanoparticles, transferring heat as per experiment demand, making great and positive connectivity between the section of fluid and water, focusing into the area to use solid for process convectional experiment, analysis about thermal performance, differentiate among geometrics channels, focus into enhancing the power of experiment in the fixed area of numerical investigation program, control the particular flow process, reviewing the system of experimental function and various other function to control and also process successfully the chain of natural convection experimental system in the part of numerical investigation within the area of the triangular surface (Cheng et al. 2018).

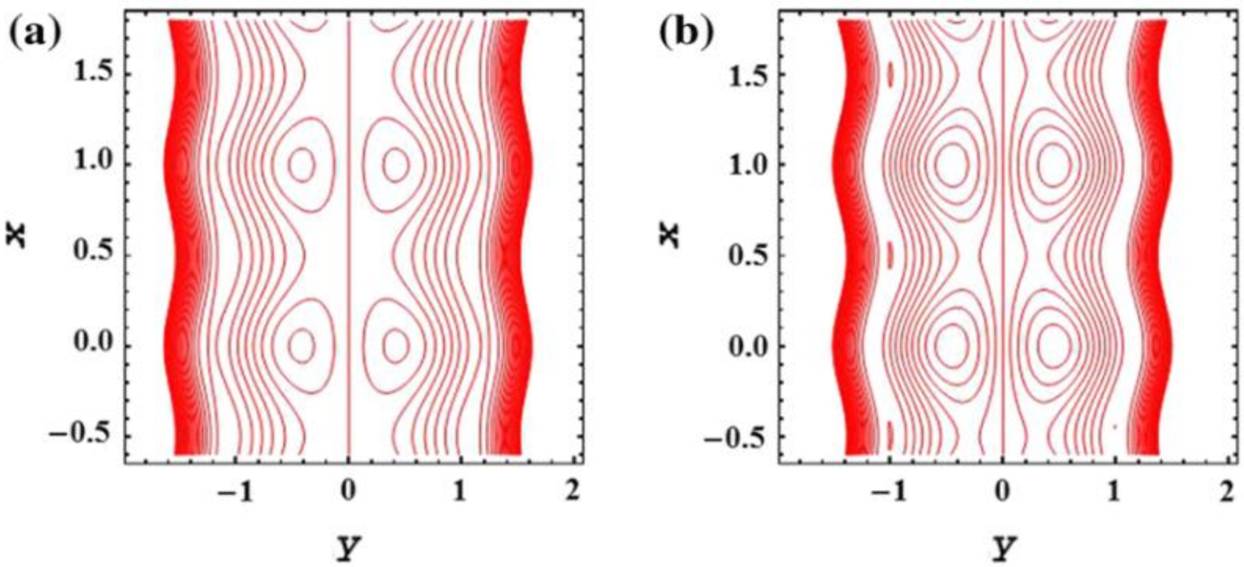


Figure 3: multiple valuations between two segments with porous media and without nanofluids

(Source: Abuhegazy et al. 2020)

The function of triangular porous media with conducting and no conducting obstacle

It is clear from the streamline and isotherm contours for various values of the heat generation parameter Q at Da 14 103, Ra 14 105, f 14 0:05, D 14 5, B 14 0:5, and F 14 p 6. The fluid motion is accelerated by an increase in Q, and the maximum temperature is also increased. A higher heat generation parameter results in a higher heat acquisition for the nanofluid, which improves the flow of natural convection. It has been found that both the local and average Nusselt numbers drop as the heat source length rises. This is explained by the fact that as B rises, the total heat input rises as well, increasing the heat source temperature and lowering the average and local Nusselt number in the process. When the heat generation rises, the same result is seen. The inverse relationship between the Nusselt number and the temperature of the heat source is what causes this behavior. However, an increase in the volume fraction of nanoparticles leads to a definite improvement in the average Nusselt number. This is because an increase in the volume percentage of nanoparticles causes the nanofluid's thermal conductivity to rise (Alam et al. 2021). It has been noted that raising the Darcy number results in a noticeable increase in Numbing actuality, an increase in Da indicates that the porous medium is becoming more permeable, which lowers the flow resistance, lowers the heat source temperature, and raises the average Nusselt number. The local Nusselt number likewise rises with an increase in D. A decrease in heat source temperature results from the heat sources moving to the top left and bottom right corners as D increases.

The smoothes out and isotherms for Cu water nanofluid for various upsides of the triangle tendency point F at Da ¼ 103, 4 ¼ 0.05, Ra ¼ 105, Q ¼ 1, B ¼ 0.5, D ¼ 0.5. It is seen that, for all upsides of F, the liquid stream is addressed by one clockwise roundabout cell inside the triangle while the isotherms are disseminated inside the entire triangle. For the non-slanted nook, F¼0, the stream involves the entire triangle aside from little regions close to the sides of the triangle. Expanding F to 30, a more vulnerable convective stream is gotten contrasted with F¼0. Likewise, the smoothes out are compacted from the top corner and stretched out towards the base right corner. At F¼120, the smooth movement gathers in the base portion of the triangle. At F¼240, the liquid stream diminishes contrasted, and at F¼120 and the smoothes out stretch towards the top corner. Stream is acquired contrasted and F¼240 and the smooth movement is concentrated close to the base intensity source. The justification behind this large number of ways of behaving is because of the lightness force that changes with the variety of the tendency point F.

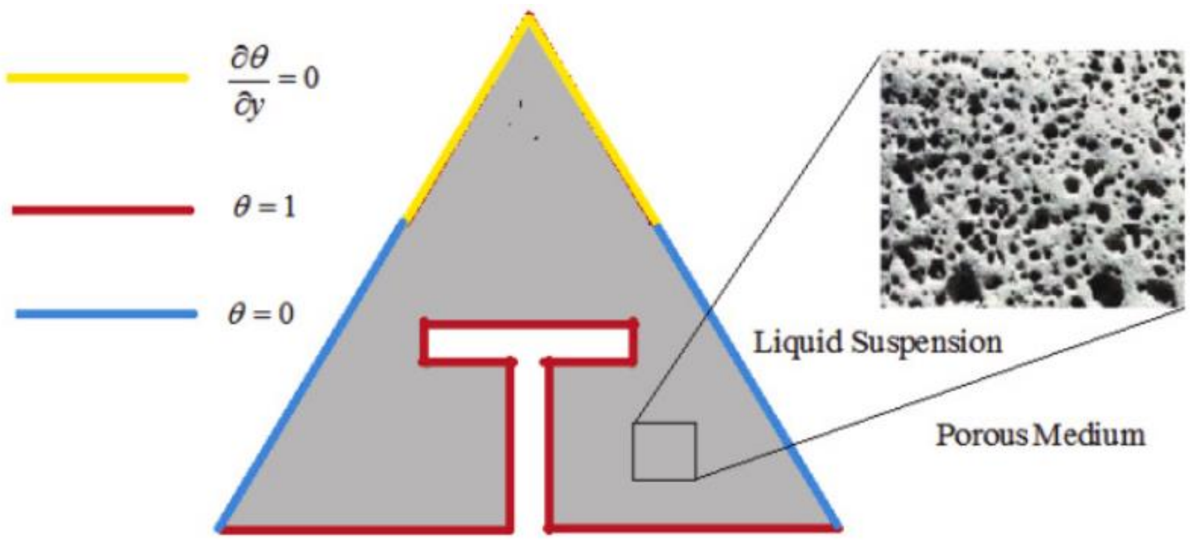


Figure 4: Function of triangular porous media with conducting and no conducting obstacle

(Source: Zhang et al. 2022)

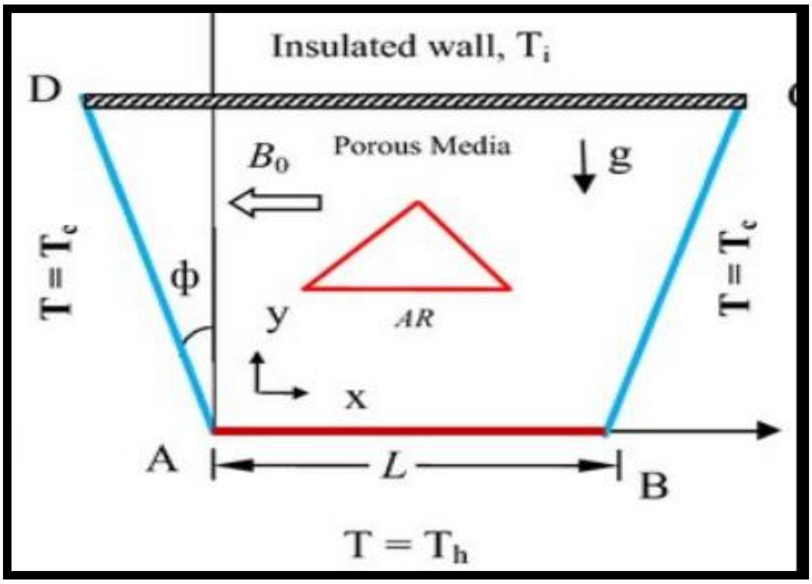


Figure 5: Function of triangular porous media with conducting and no conducting obstacle

(Source: Li et al. 2021)

Conclusion

The experimental process of nature convocational process and the function of numerical investigation is elaborate about the various experimental program of application, area of software to enhance modeling system, focus on multiple mathematical aspects of numerical investigation in the area of the triangular surface of application and also the classification or function of heat transferring process in area to control heat for nature conventional process. All aspect of the experimental process of numerical investigation also identifies about the area of improvement to progress area of thermal performance as well as experimental work in the lab.

Recommendation

Application of the model as well as the function of triangular porous media with the major aspects of conducting focus into various recommendations.

- Focus on the area of fluid flow segment with unsteady flow.
- Look into the section on the heat transfer process.
- Implementation of various modeling systems to enhance experimental programmers.

Reference

Oztop HF, Varol Y, Pop I. Effects of wall conduction on natural convection in a porous triangular enclosure. Acta mechanica. 2008 Oct;200(3):155-65.

Varol Y, Oztop HF, Varol A. Free convection in porous media filled right-angle triangular enclosures. International Communications in Heat and Mass Transfer. 2006 Dec 1;33(10):1190

Akinsete VA, Coleman TA. Heat transfer by steady laminar free convection in triangular enclosures. International Journal of Heat and Mass Transfer. 1982 Jul 1;25(7):991-8.

Basak T, Roy S, Thirumalesha C. Finite element analysis of natural convection in a triangular enclosure: effects of various thermal boundary conditions. Chemical Engineering Science. 2007 May 1;62(9):2623-40.

Varol Y, Oztop HF, Pop I. Numerical analysis of natural convection in an inclined trapezoidal enclosure filled with a porous medium. International Journal of Thermal Sciences. 2008 Oct 1;47(10):1316-31.

Varol Y. Natural convection in porous triangular enclosure with a centered conducting body. International Communications in Heat and Mass Transfer. 2011 Mar 1;38(3):368-76.

Mushatet KS. Natural convection heat transfer inside a porous triangular enclosure with baffles. Global J. Res. Eng.. 2010;10(1):63-75.

Anandalakshmi R, Kaluri RS, Basak T. Heatline based thermal management for natural convection within right-angled porous triangular enclosures with various thermal conditions of walls. Energy. 2011 Aug 1;36(8):4879-96

Basak T, Roy S, Ramakrishna D, Pandey BD. Analysis of heat recovery and heat transfer within entrapped porous triangular cavities via heatline approach. International journal of heat and mass transfer. 2010 Sep 1;53(19-20):3655-69.

Muhammad RU. Analysis of Heat Transfer in a Triangular Enclosure Filled with a Porous Medium Saturated with Magnetized Nanofluid Charged by an Exothermic Chemical Reaction. Mathematical Problems in Engineering. 2019 Dec 6;2019.

Triveni MK, Panua R. Numerical simulation of natural convection in a triangular enclosure with caterpillar (C)-curve shape hot wall. International Journal of Heat and Mass Transfer. 2016 May 1;96:535-47.

Ahmed SE, Rashad AM, Reddy Gorla RS. Natural convection in triangular enclosures filled with nanofluid saturated porous media. Journal of thermophysics and heat transfer. 2013 Oct;27(4):700-6.

Chowdhury R, Khan MA, Siddiki MA. Natural convection in porous triangular enclosure with a circular obstacle in presence of heat generation. American Journal of Applied Mathematics. 2015 Mar 21;3(2):51-8.

Abuhegazy, M., Talaat, K., Anderoglu, O. and Poroseva, S.V., 2020. Numerical investigation of aerosol transport in a classroom with relevance to COVID-19. *Physics of Fluids*, *32*(10), p.103311.

Zhang, H. and Liu, Q., 2020. Numerical investigation on the performance of moisture separator: Experimental validation, applications, and new findings. *Annals of Nuclear Energy*, *142*, p.107362.

Li, T., Dai, Z., Yu, M., and Zhang, W., 2021. Numerical investigation on the aerodynamic resistances of double-unit trains with different gap lengths. *Engineering Applications of Computational Fluid Mechanics*, *15*(1), pp.549-560.

Alam, Z., Sun, L., Zhang, C., Su, Z. and Samali, B., 2021. Experimental and numerical investigation of the complex behavior of the localized seismic response in a multi-story plan-asymmetric structure. *Structure and infrastructure engineering*, *17*(1), pp.86-102.

Yadav, A.S., Shrivastava, V., Chouksey, V.K., Sharma, A., Sharma, S.K., and Dwivedi, M.K., 2021. Enhanced solar thermal air heater: A numerical investigation. *Materials Today: Proceedings*, *47*, pp.2777-2783.

Liu, C., Wang, F., He, L., Deng, X., Liu, J. and Wu, Y., 2021. Experimental and numerical investigation on dynamic responses of the umbrella membrane structure excited by heavy rainfall. *Journal of Vibration and Control*, *27*(5-6), pp.675-684.

Pordanjani, A.H. and Aghakhani, S., 2022. Numerical investigation of natural convection and irreversibilities between two inclined concentric cylinders in presence of uniform magnetic field and radiation. *Heat Transfer Engineering*, *43*(11), pp.937-957.

Tang, C., Tan, J.L. and Wong, C.H., 2018. A numerical investigation on the physical mechanisms of single track defects in selective laser melting. *International Journal of Heat and Mass Transfer*, *126*, pp.957-968.

Zhu, C., He, M.C., Jiang, B., Qin, X.Z., Yin, Q., and Zhou, Y., 2021. Numerical investigation on the fatigue failure characteristics of water-bearing sandstone under cyclic loading. *Journal of Mountain Science*, *18*(12), pp.3348-3365.

Cheng, Y., Yang, B., Lin, Z., Yang, J. and Du, Z., 2018. Cooling load calculation methods in spaces with stratified air: A brief review and numerical investigation. *Energy and Buildings*, *165*, pp.47-55.