International Journal of Engineering & Technology, 7 (4) (2018) 4892-4898

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.26764
Research paper

Natural convection heat transfer inside enclosure with various geometries and enhancement methods a review

Akeel Abdullah Mohammed [1] *, Ahmed Fakhrey Khudheyer [1]

[1] Al-Nahrain University, College of Engineering, Mechanical Engineering Department
**Corresponding author E-mail:*

Abstract

Natural convection heat transfer from a hot surface to its surrounding enclosure is used in several technological applications especially in microelectronic systems, solar concentrators; thermal storage plants, pressurized water reactors and gas insulated electrical transmission systems. The function of the outer surface of the enclosure is to reduce the heat transfer from the inner hot surface or to protect the inner body in harsh outdoor environment. There are so many researches are conducting on the above same topic in different aspects by changing the position and geometry of the heated surface and the enclosure. In addition to changing the thermal boundary conditions, using of porous media, magnetic field and nano fluid to enhance heat transfer process. In this paper, a review on the influence of a wide range of parameters on the heat transfer process has been investigated.

Keywords: *Natural Convection; Heat Transfer; Enclosure; Various Geometries; Enhancement.*

1. Introduction

Natural convection heat transfer in enclosures has been the subject of numerous investigations in recent years. There is a growing demand for a better understanding of this phenomenon in areas like nuclear design, electronic packaging, passive cooling space heating, and geophysical systems.In general, enhancement techniques can be divided into two groups: a) Passive techniques which require special surface geometries, thermal packaging, or fluid additives; and b) Active techniques which require external forces, such as electrical and magnetic fields and vibration. The study of effect of magnetic field, nanofluid, vibration, porous media, geometry and other parameters has attracted attentions of engineers and sciences due to its wide industrial applications, such as metal casting, crystal growth, and liquid metal cooling blankets for fusion reactors, etc.

The purpose of this paper is to review some aspects of computational studies of the flow initiated by natural convection, including some interesting and, perhaps, unexpected phenomena exhibited by such flows.

2. Literature review

2.1. Circular enclosure

Esam (2008), [1] studied the effect of Rayleigh number, oscillating eccentricity, and transversely oscillating frequency of the inner cylinder on the flow structure and heat transfer in a horizontal annulus enclosure. He proved that the oscillating inner cylinder highly enhances the average Nusselt number at the inner cylinder and it together with oscillating eccentricity have a negative effect on the Nusselt number at the outer cylinder.

Xu Xu et al. (2009), [2] used four different Rayleigh numbers and four different radius ratios, and four different inclination angles for the inner triangular cylinder to study the laminar natural convection heat transfer in a horizontal annulus between a heated triangular cylinder and its circular cylindrical enclosure. They concluded that at constant radius ratio, the inclination angles of the inner triangular cylinder have negligible effects on the average Nusselt number.

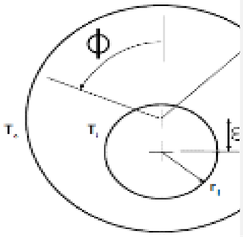
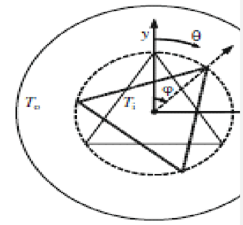
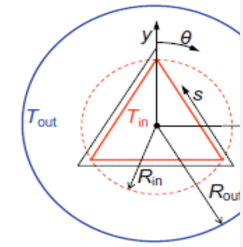
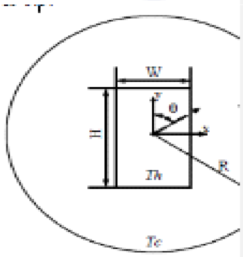
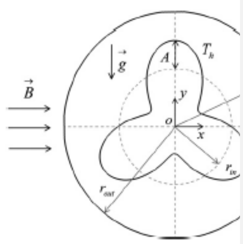
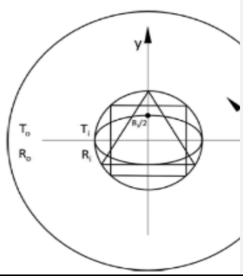
Zi-Tao et al. (2010), [3] studied Prandtl number dependence of laminar natural convection heat transfer from a horizontal coaxial triangular cylinder to its concentric cylindrical enclosure. They found that the fluid flow and heat transfer characteristics for a low Prandtl number (Pr = 0.03) are unique and they are independent of Prandtl number when Pr0.7.

Han Wang et al. (2011), [4] studied the laminar natural convection arising from horizontal rectangle cylinder to its concentric cylindrical enclosure with a wide ranges of Rayliegh number and aspect ratio. They found that the vortexes occurring on the top of the rectangle cylinder have considerable effects on the average Nusselt numbers, when the aspect ratio exceeds to 1.2.

Sheikholeslami et al. [5], (2012) used Cu–water nanofluid in a cold outer circular enclosure containing a constant temperature hot inner sinusoidal circular cylinder in the presence of horizontal magnetic field. They concluded that in the absence of magnetic field, enhancement ratio decreases with increasing of Rayleigh number while an opposite behavior was observed in the presence of magnetic field. Also they found that the heat transfer process is an increasing function of Rayleigh numbers and nanoparticle volume fraction.

Xing et al. [6], (2015) studied the effect of different shapes (circular, elliptical, square, and triangular cylinder) inside cylindrical enclosure with or without surface radiation at relatively higher Rayleigh numbers 105. It was observed that the surface radiation and presence of corners and larger top space enhances the heat transfer rate. As the reference temperature increases, surface radiation plays a more prominent role in the overall heat transfer performance. Table 1 shows a summary of the available studies about natural convection heat transfer concerning with circular enclosure and different shapes of inner hot cylinder.

Table 1: Summary of Researches Concerning with Circular Enclosure and Different Shapes of Inner Cylinder

S I n o	Research-ers	Geometry	Buoyan-cy strength	Limitations
1	Esam M. Alawadhi [1]		$10^4 \leq Ra \leq 10^5$ Pr=0.71	Study the effect of oscillating of inner cylinder
2	Xu Xu et al. [2]		$10^3 \leq Ra \leq 10^6$ Pr=0.71	Using wide ranges of radius rati-os, and inclination angles for the inner triangular cylinder
3	Zi-Tao et al [3]		$10^3 \leq Ra \leq 10^6$ $10^{-2} < Pr < 10^3$	Using wide range of Prandtl number
4	Han Wang et al. [5]		$10^3 \leq Ra \leq 10^6$ Pr=0.71	Using rec-tangular cylinder inside circu-lar enclosure
5	Sheikhole-slami et al. [5]		$10^3 \leq Ra \leq 10^5$ Cu-water nano fluid.	• Using of inner sinusoidal circular cylinder. • Study of magnetic field effect
6	Xing et al. [6]		$10^3 \leq Ra \leq 10^5$	Using of different shapes of inner cylin-der with or without surface radiation

2.2. Traingular enclosure

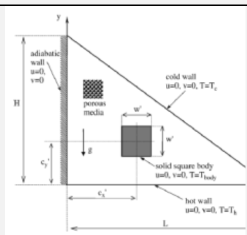
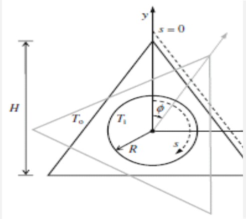
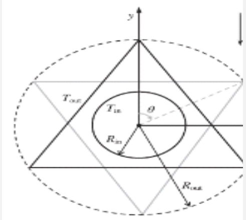
Yasin et al. (2007), [7] studied the steady-state buoyancy induced convection in a right-triangular enclosure with a solid square body located far from the origin with the distance of 0.3 in both direc-tions. Four different temperature boundary conditions were ap-plied for the body as heated, cooled, neutral and adiabatic at dif-ferent Rayleigh numbers. They concluded that fluid flow and heat transfer strongly depend on thermal boundary conditions of the body.

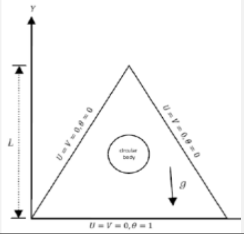
Xu et al. (2010), [8] studied the steady-state laminar natural con-vective heat transfer around a horizontal cylinder to its concentric triangular enclosure. The enclosure was filled with air and both the inner and outer cylinders were maintained at uniform tempera-tures. They concluded that at constant aspect ratio, both the incli-nation angle and cross-section geometry have insignificant effects on the heat transfer rates though the flow patterns.

Zi-Tao et al. (2011), [9] studied the unsteady natural convection heat transfer in a horizontal heated inner circular cylinder enclosed by a coaxial triangular enclosure for a wide range of Grashof numbers, aspect ratios, and inclination angles of the triangular cylinder. The results showed that different phases are identified during the course of flow development through the evolutions of the average Nusselt number over the inner circular wall.

Raju et al. (2015), [10] studied the natural convection inside a triangular enclosure filled with a fluid saturated porous medium with an insulated circular body in presence of heat generation. The bottom wall of the triangular cylinder was heated at a constant temperature while the left and right inclined wall of the cavity was maintained at cold temperature. They concluded that the heat gen-eration effect is negligible for large size of circular body. Also, the average Nusselt number significantly worse with increasing both heat generation and size of the circle. Table 2 shows a summary of the available studies about natural convection heat transfer con-cerning with triangular enclosure and different shapes of hot sources.

Table 2: Summary of Researches Concerning with Triangular Enclosure and Different Shapes of Inner Cylinder

S I n o	Re-search-ers	Geometry	Buoyan-cy strength	Originality
1	Yasin et al. [7]		$10^3 \leq Ra \leq 10^6$ Pr=0.71 (air)	Porous enclo-sure with inner square body
2	Xu et al. [8]		$10^3 \leq Ra \leq 10^7$ Pr=0.71 (air)	High ranges of Rayleigh num-ber and incli-nation angle of triangular enclosure.
3	Zi-Tao et al. (2011), [9]		$10^5 \leq Gr \leq 10^7$ Pr=0.71 (air)	• Un-steady natural convection • High values of Grashof num-ber

4	Raju et al. (2015), [10]		Ra=10^5 Pr=0.71	Triangular porous enclosure in presence of heat generation

2.2. Square enclosure with different sources of hot surfaces

Ding et al. (2006), [11] studied the effect of geometric parameters, such as eccentricities and angular positions, on the mean and local heat transfer rates in a horizontal eccentric annulus between a square outer cylinder and a heated circular inner cylinder. It was shown the local MQ-DQ method can accurately simulate the natural-convection problem at large Rayleigh number (106).

Ahmed et al. (2006), [12] studied the effect of a single and multiple partitions on natural convection phenomena in an inclined square cavity, differentially heated. The partitions are attached to the cold wall of the cavity. The investigation is performed for various inclination angles and gap widths W. The results showed that at lower Ra (Ra 105), the average hot wall Nusselt number is higher in inclined cavities than in vertical ones; while at larger Ra (Ra = 106), the opposite occurs. Also, the heat transfer process decreases when the number of partitions attached to the cold wall of the enclosure increases.

Abdullatif and Ali (2007), [13] focused on conjugate natural convection heat transfer in a square enclosure which has three thick cooled walls and one thin heated vertical wall of arbitrary thermal conductivities with a heated inclined thin fin of three arbitrary length attached to its middle. It was found that the thin fin inclination angle and length, and solid-to-fluid thermal conductivity ratio have significant effects on overall heat transfer coefficient of heated surfaces of the enclosure/fin system.

Elif (2009), [14] used water-based nanofluids in an inclined square enclosure with uniformly heated left vertical side and cooled right side, and the other sides were kept adiabatic. The inclination angles varied from 0o to 90o, solid volume fractions ranging from 0% to 20%, constant heat flux heaters of lengths 0.25, 0.50 and 1.0. The ratio of the nanolayer thickness to the original particle radius is kept at a constant value of 0.1. The heat source is placed at the center of the left wall. Five types of nanoparticles are taken into consideration: Cu, Ag, CuO, Al2O3, and TiO2. The results show that the average heat transfer rate increases as particle volume fraction and Rayleigh number increase and it starts to decrease for a smaller inclination angle as heater length increases.

Yasin et al. (2009), [15] studied the phenomena of natural convection heat transfer in an inclined square enclosure heated via corner heater with various lengths in x and y directions. One wall of the enclosure was isothermal but its temperature was colder than that of heaters while the other walls were adiabatic. The inclination angle was (0o270o). It was observed that the inclination angle and length of the corner heater have significant effects on average heat transfer rates. Also, the effect of Prandtl number on mean Nusselt number is more significant for Pr < 1.

Ahmed and Salam (2010), [16] used water to study the laminar natural convection in a two-dimensional inclined square enclosure with isothermal hot temperature left side wall and isothermal cold temperature opposite side wall. The other top and bottom walls were considered thermally insulated. The inclination angles ranging from 00 to 300 and Pr=6. They concluded that, the thermal boundary layers increases as the internal heat source increases. While the hydrodynamic boundary layer at the hot and cold side walls decreases with increasing of the inclination angle.

They [17] submitted another study of two dimensional steady natural convection for a uniform heat source applied on the inner circular cylinder inside square air (Pr=0.7) filled enclosure in which all boundaries were assumed to be isothermal. It was found that there is no much influence on the flow field at small Rayleigh number while at high Rayleigh numbers have significant effect on the flow pattern. Also, the total average Nusselt number behaves nonlinearly as a function of locations.

Revnic et al. (2011), [18] studied the effects of an inclined magnetic field and heat generation on unsteady natural convection within a horizontal square enclosure filled with a fluid-saturated porous medium. The top and bottom walls of the enclosure are adiabatic whereas the vertical walls are kept at constant but different temperatures. The result showed that the diffusive heat transfer become prominent even though the Rayleigh number increases as Hartmann number increases.

Hojat and Seyed (2012), [19] made a comparison of natural convection around a hot circular cylinder with a hot square cylinder inside a cooled square enclosure. The location of the inner cylinder is vertically changed along the center-line of the square enclosure. The results show that at the same Rayleigh number, the rate of heat transfer from the enclosure which the circular cylinder is located inside is better than square cylinder.

Roslan et al. (2014), [20] analyzed the conjugate natural convection heat transfer in a differentially heated square enclosure containing a conductive polygon object with heated left wall, cooled right wall, and adiabatic horizontal walls. The study covered wide ranges of the polygon type and size, thermal conductivity, and Rayleigh number. They concluded that the heat transfer rate increases with the increase of the size of the solid polygon, until it reaches its maximum critical value after which the heat transfer will decrease.

Balamurugan and Krishnakanth (2015), [21] used square and triangle bar of hot sources inside square enclosure with cold vertical walls and insulated horizontal walls by using air as a medium. Different aspect ratio of sources of both square and triangle bar was used. They concluded that the higher heat transfer rate in square source than triangle source varying enclosures and different aspect ratio.

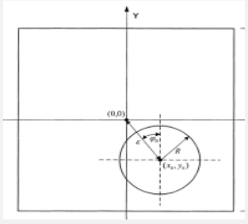
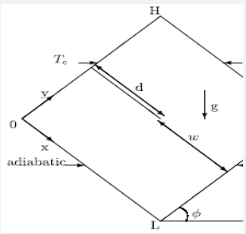
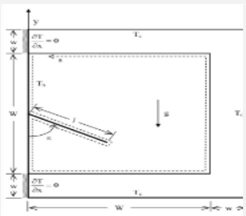
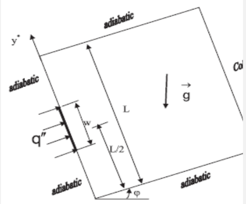
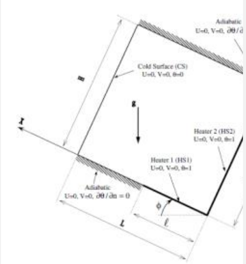
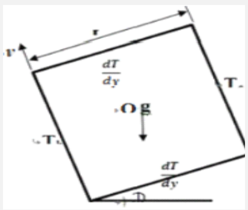
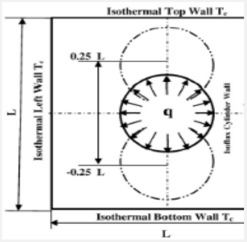
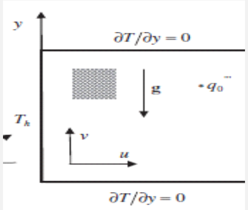
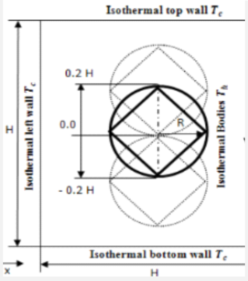
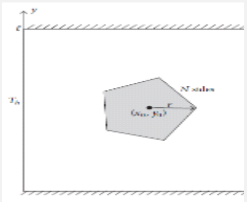
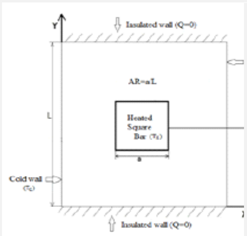
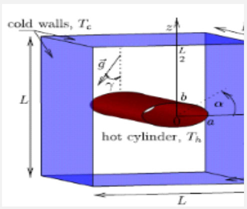
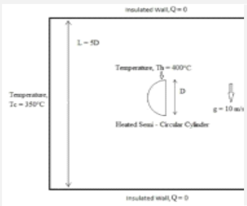
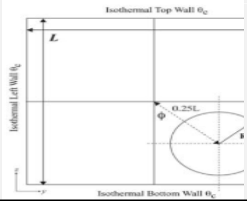
Ravnik and Škerget (2015), [22] used Al2O3, Cu and TiO2 nanofluid , as well as pure water and air for validation purposes as a medium to study the natural convection in an inclined cooled cubic enclosure with a heated circular and an ellipsoidal cylinder. Steady laminar regime is considered with Rayleigh number values up to a million. The results show conduction dominated flow in the regime gives highest heat transfer enhancement, where the enhanced thermal properties of nanofluids play a significant role. When convection is the dominant heat transfer mechanism, the using nanofluids yields a smaller increase in heat transfer efficiency.

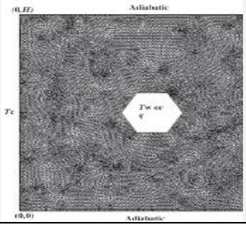
Sharma and Kumar (2017), [23] analyzed of heat transfer and air flow due to natural convection around heated semi-circular cylinder placed at various incidences inside a square cavity. The top and bottom wall of square cavity is adiabatic, while left and right wall of the square cavity have constant wall temperature and the flow geometry is assigned with higher temperature then the walls with no heat generation. It was found that surface heat transfer coefficient increases, for all incidences, for 104 Rayleigh number.

Yen et al. (2017), [24] used the thermal lattice Boltzmann scheme for simulating the steady and unsteady natural convection in cubical enclosure with different inner cylinder positions at Rayleigh numbers of 104- 106 and a Prandtl number of 0.7. The location of the inner cylinder is changed vertically along the centerline of the enclosure. The effects of the boundary wall on heat transfer and fluid flow in the enclosure depend on both the position of the cylinder and the Rayleigh number.

Krunal and Manikandan (2017), [25] studied laminar natural convection characteristics in a square enclosure with heated hexagonal block for non-Newtonian power law fluids. The thermal boundary conditions of hexagonal block are constant wall temperature (CWT) or uniform heat flux (UHF). The results show that Nusselt number varies linearly with Grashof and Prandtl numbers; while convection heat transfer decreases for power law index value. Higher heat transfer rate can be achieved by using uniform heat flux condition. Table 3 shows a summary of the available studies about natural convection heat transfer concerning with square enclosure and different shapes of hot sources.

Table 3: Summary of Researches Concerning with Square Enclosure and Different Shapes of Hot Sources

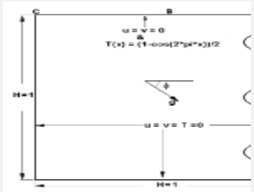
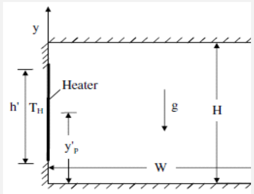
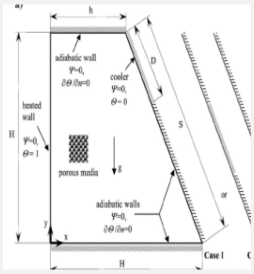
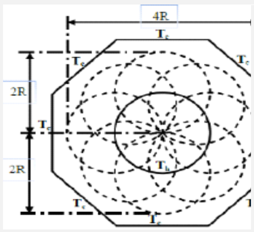
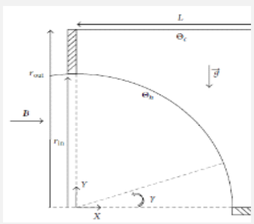
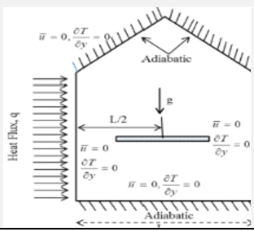
Sl no	Researchers	Geometry	Buoyancy strength	Limitations
1	Ding et al. (2006), [11]		$10^4 \le Ra \le 10^7$ Pr=0.71 (air)	Using of local multi-quadrics-based differential quadrature (MQ-DQ) method to solve this problem.
2	Ahmed et al. (2006), [12]		$10^3 \le Ra \le 10^6$ Pr=0.71 (air)	Using of numerical coupling between the lattice Boltzmann equation and finite-difference to solve this problem.
3	Abdullatif and Ali (2007), [13]		Ra=10^4-10^5 Pr=0.707	Conjugate heat transfer with heated inclined fin
4	Elif (2009), [14]		$10^4 \le Ra \le 10^6$ water-based nanofluids	Five types of nanoparticles were used: Cu, Ag, CuO, Al_2O_3, and TiO_2
5	Yasin et al. (2009), [15]		10^3Ra10^6 0.07Pr70	• Wide range of heater lengths in both directions. • Wide ranges of Pr, Ra, and inclination angle
6	Ahmed and Salam (2010), [16]		external Ra= 10^3 & 10^6 internal Ra 10^5Ra10^8 Pr=6 (water)	Using high ranges of Rayleigh number
7	Salam and Ahmed (2010), [17]		$10^3 \le Ra \le 10^6$ Pr=0.71 (air)	The location of the inner cylinder was changed vertically along the centerline of the enclosure from upward to downward.
8	Revnic et al. (2011), [18]		Ra=10^3 &10^5 Ha=1 & 1000 fluid-saturated porous medium	• Using of magnetic field and heat generation • unsteady natural convection
9	Hojat and Seyed (2012), [19]		Ra=10^3–10^5 Pr=0.707 (air)	Taking of two shapes of inner cylinder at different locations
10	Roslan et al. (2014), [20]		$10^3 \le Ra \le 10^6$ Pr=0.71 (air)	• Study of conjugate natural convection heat transfer • Taking of new geometry of inner cylinder
11	Balamurugan and Krishnakanth (2015), [21]		Q=24.65-60.95W Air	Using of square and triangle cylinder with different aspect ratios
12	Ravnik and Škerget (2015), [22]		10^3Ra10^6 Nano fluid Water Air	• Using Al_2O_3, Cu and TiO_2 nanofluid • 2D &3D • Elliptic and circular inner cylinder
13	Sharma and Kumar (2017), [23]		Ra=10^4 Pr=0.7 (air)	Using of semi - circular cylinder placed at various incidences
14	Yen et al. (2017), [24]		$10^4 \le Ra \le 10^6$ Pr=0.7 (air)	Eccentric cube annulus with inner circular cylinder at different vertical locations

15	Krunal and Manikandan (2017), [25]		10^3Gr10^6, 1Pr100, power law index (0.5n1.5).	Using of non-Newtonian fluid

2.3. Arbitrary enclosure with various geometries of inner surface

Amaresh and Manab (2005), [26] studied the laminar natural convection in an inclined complicated cavity with three cold flat wall and one wavy wall having a sinusoidal temperature profile. The geometrical configurations considered were namely, two and three undulations. The results obtained show that with increase in amplitude, the average heat transfer rate on the wavy wall is appreciably high at low Rayleigh number. Increasing the number of undulations beyond two is not beneficial.
Hakan and Eiyad (2008), [27] investigated natural convection heat transfer in a partially heated rectangular enclosure using nanofluids with different volume fraction. The flush mounted heater was located to the left vertical wall with finite different lengths. The temperature of the right vertical wall was lower than that of heater while other walls were insulated. They concluded that the mean Nusselt number increases with the volume fraction of nanoparticles for the whole range of Rayleigh number. Heat transfer rates also increases with increasing of height of heater. It was found that the heater location affects the flow and temperature fields when using nanofluids.
Yasin et al. (2009), [28] studied the natural convection phenomena in right-angle porous trapezoidal enclosure partially cooled from inclined wall filled with a fluid-saturated porous medium. The left vertical wall of the cavity is heated; while the inclined wall is partially cooled; and the remaining walls are insulated (adiabatic). Numerical results indicated that there exist significant changes in the flow and temperature fields as compared with those of a differentially heated square porous cavity.
Salam and Ahmed (2013), [29] analyzed heat transfer around a hot solid circular cylinder embedded inside an octagonal enclosure at various orientation locations. A circular hot solid cylinder was placed at the center of the enclosure while all the eight walls of the enclosure was kept at a cold isothermal temperature. The cylinder moves by an equal amount (R/2 and R) in
the horizontal, vertical and diagonal directions. The results showed that the cylinder location has a significant effect on the flow and thermal fields in the octagonal enclosure.
Shekholeslami et al. (2013), [30] studied the effect of magnetic field on natural convection in a curved-shape enclosure. The numerical investigations are performed for various values of Hartmann number and Rayleigh number. The results show the significant effects of Hartmann number on the fluid flow and temperature distribution inside the enclosure. Also, it was found that the Nusselt number decreases Hartmann number increases.
Ahmed et al. (2015), [31] examined the natural convection in a triangular top wall enclosure with strip. Natural convection inside a two-dimensional rectangular cavity with a triangular roof having an adiabatic solid strip inserted at a middle of the cavity. Both of the triangular roof and the bottom wall are adiabatic while the vertical left side wall has constant temperature. The right side wall is differentially heated by supplying a constant heat flux. It was found that the solid adiabatic strip inside the cavity has a significant effect on the flow and thermal performance. Table 4 shows a summary of the available studies about natural convection heat transfer concerning with arbitrary enclosure and different shapes of hot sources.

Table 4: Summary of Researches Concerning with Arbitrary Enclosure and Different Shapes of Hot Sources

SI no	Researchers	Geometry	Buoyancy strength	Limitations
1	Amaresh and Manab (2005), [26]		$10^3 \leq Ra \leq 10^6$ Pr=0.7 (air)	Using complicated cavity and sinusoidal temperature profile
2	Hakan and Eiyad (2008), [27]		10^3Ra5$10^5$ nanofluid (00.2)	Using different types of nanoparticles with different thermal boundary conditions
3	Yasin et al. (2009), [28]		$100 \leq Ra \leq 1000$	Three different cases were considered: the cooler wall was located adjacent to the top wall, in the middle inclined wall, and finally adjacent to the bottom wall.
4	Salam and Ahmed (2013), [29]		$10^3 \leq Ra \leq 10^7$ Pr=0.707 (air)	Using new geometry of annulus
5	Shekholeslami et al. (2013), [30]		$10^3 \leq Ra \leq 10^5$ Pr=0.025 Ha=0, 10, 100	Study magnetic field effect on natural convection in a curved-shape enclosure for liquid metal
6	Ahmed et al. (2015), [31]		$10^3 \leq Ra \leq 10^6$ Pr=0.7 (air)	Using new geometry with different thermal boundary conditions.

3. Conclusions

The present paper has been presented the available theoretical literatures concerning with the steady and unsteady, two and three dimensional natural convection, combined natural convection and radiation, and conjugate heat transfer inside circular, triangular, square, and other shapes of enclosure with different shapes of hot sources and boundary conditions. As can be shown above, many factors play significant rule in the heat transfer process such as shape of enclosure, hot source, type of fluid, buoyancy strength, angle of inclination of enclosure or inner hot surface, presence of porous media, presence of magnetic field, etc.

References

[1] Esam M. Alawadhi, "Natural convection flow in a horizontal annulus with an oscillating inner cylinder using Lagrangian–Eulerian kinematics", Computers & Fluids 37 (2008) 1253–1261. https://doi.org/10.1016/j.compfluid.2007.10.011.

[2] Xu Xu, Gonggang Sun, Zitao Yu , Yacai Hub, Liwu Fan , Kefa Cen " Numerical investigation of laminar natural convective heat transfer from a horizontal triangular cylinder to its concentric cylindrical enclosure", International Journal of Heat and Mass Transfer 52 (2009) 3176–3186. https://doi.org/10.1016/j.ijheatmasstransfer.2009.01.026.

[3] Zi-Tao Yu, Li-Wu Fan, Ya-Cai Hua, Ke-Fa Cen, "Prandtl number dependence of laminar natural convection heat transfer in a horizontal cylindrical enclosure with an inner coaxial triangular cylinder", International Journal of Heat and Mass Transfer 53 (2010) 1333–1340. https://doi.org/10.1016/j.ijheatmasstransfer.2009.12.027.

[4] Han Wang, Chuang Sun, Xin-Lin Xia, He-ping Tan, "Numerical investigation of laminar natural convection in a circular enclosure with a rectangle cylinder" Authorized licensed use limited to IEEE Xplore. Downloaded on August 13, 2011 at 13:42:16 UTC from IEEE Xplore. Restrictions apply.

[5] M. Sheikholeslami, M. Gorji-Bandpy, D.D. Ganji, Soheil Soleimani, S.M. Seyyedi, "Natural convection of nanofluids in an enclosure between a circular and a sinusoidal cylinder in the presence of magnetic field", International Communications in Heat and Mass Transfer 39 (2012) 1435–1443. https://doi.org/10.1016/j.icheatmasstransfer.2012.07.026.

[6] Xing Yuan, Fatemeh Tavakkoli, and Kambiz Vafai, "Analysis of natural convection in horizontal concentric annuli of variable inner shape", Numerical Heat Transfer, Part A, 68: (2015) 1155–1174. https://doi.org/10.1080/10407782.2015.1032016.

[7] Yasin Varol, Hakan F. Oztop, Tuncay Yilmaz, "Two-dimensional natural convection in a porous triangular enclosure with a square body", International Communications in Heat and Mass Transfer 34 (2007) 238–247. https://doi.org/10.1016/j.icheatmasstransfer.2006.10.001.

[8] Xu Xu , Zitao Yu b, Yacai Hub, Liwu Fan, Kefa Cen, "A numerical study of laminar natural convective heat transfer around a horizontal cylinder inside a concentric air-filled triangular enclosure", International Journal of Heat and Mass Transfer 53 (2010) 345–355. https://doi.org/10.1016/j.ijheatmasstransfer.2009.09.023.

[9] Zi-Tao Yu, Xu Xub, Ya-Cai Hua, Li-Wu Fan, Ke-Fa Cen," Unsteady natural convection heat transfer from a heated horizontal circular cylinder to its air-filled coaxial triangular enclosure",

[10] International Journal of Heat and Mass Transfer 54 (2011) 1563–1571. https://doi.org/10.1016/j.ijheatmasstransfer.2010.11.032.

[11] Raju Chowdhury, Md. Abdul Hakim Khan, Md. Noor A-Alam Siddiki," Natural convection in porous triangular enclosure with a circular obstacle in presence of heat generation", American Journal of Applied Mathematics 2015; 3(2): 51-58. https://doi.org/10.11648/j.ajam.20150302.14.

[12] H. Ding, C. Shu, K. S. Yeo, and Z. L. Lu, "Simulation of natural convection in eccentric annuli between a square outer cylinder and circular inner cylinder using local MQ-DQ method", Numerical Heat Transfer, Part A, 47: 291–313, 2005. https://doi.org/10.1080/10407780590889545.

[13] Ahmed Mezrhab , Mohammed Jami , Cherifa Abid , M'hamed Bouzidi , Pierre Lallemand, "Lattice-Boltzmann modelling of natural convection in an inclined square enclosure with partitions attached to its cold wall", International Journal of Heat and Fluid Flow 27 (2006) 456–465. https://doi.org/10.1016/j.ijheatfluidflow.2005.11.002.

[14] Abdullatif Ben-Nakhi, Ali J. Chamkha, "Conjugate natural convection in a square enclosure with inclined thin fin of arbitrary length", International Journal of Thermal Sciences 46 (2007) 467–478. https://doi.org/10.1016/j.ijthermalsci.2006.07.008.

[15] Elif Buyuk Ogut, "Natural convection of water-based nanofluids in an inclined enclosure with a heat source", International Journal of Thermal Sciences 48 (2009) 2063–2073. https://doi.org/10.1016/j.ijthermalsci.2009.03.014.

[16] Yasin Varol, Hakan F. Oztop, Ahmet Koca, Filiz Ozgen, "Natural convection and fluid flow in inclined enclosure with a corner heater", Applied Thermal Engineering 29 (2009) 340–350. https://doi.org/10.1016/j.applthermaleng.2008.02.033.

[17] Ahmed Kadhim Hussein and Salam Hadi Hussain, "Numerical Analysis of Steady Natural Convection of Water in Inclined Square Enclosure with Internal Heat Generation", International Conference on Mechanical and Electrical Technology (ICMET 2010), IEEE, pp. 502-508.

[18] Salam Hadi Hussain, Ahmed Kadhim Hussein, "Numerical investigation of natural convection phenomena in a uniformly heated circular cylinder immersed in square enclosure filled with air at different vertical locations", International Communications in Heat and Mass Transfer 37 (2010) 1115–1126. https://doi.org/10.1016/j.icheatmasstransfer.2010.05.016.

[19] Revnic C., Grosan T., Pop I., D.B. Ingham, "Magnetic field effect on the unsteady free convection flow in a square cavity filled with a porous medium with a constant heat generation", International Journal of Heat and Mass Transfer 54 (2011) 1734–1742. https://doi.org/10.1016/j.ijheatmasstransfer.2011.01.020.

[20] Hojat Khozeymehnezhad, Seyed Ali Mirbozorgi, "Comparison of Natural Convection around a Circular Cylinder with a Square Cylinder inside a Square Enclosure", Journal of Mechanical Engineering and Automation 2012, 2(6): 176-183. https://doi.org/10.5923/j.jmea.20120206.08.

[21] Roslan R., Saleh H., and Hashim I., "Natural Convection in a Differentially Heated Square Enclosure with a Solid Polygon", Hindawi Publishing Corporation,The Scientific World Journal, Volume 2014, Article ID 617492, 11 pages, http://dx.doi.org/10.1155/2014/617492.

[22] Balamurugan S and Krishnakanth K, "Numerical Study of Convective Heat Transfer for Different Shapes of Hot Sources inside an Enclosure", Research and Reviews: Journal of Engineering and Technology RRJET, Volume 4, Issue 3, July-September 2015, pp. 18-34.

[23] J. Ravnik, L. Škerget, "A numerical study of nanofluid natural convection in a cubic enclosure with a circular and an ellipsoidal cylinder", International Journal of Heat and Mass Transfer 89 (2015) 596–605. https://doi.org/10.1016/j.ijheatmasstransfer.2015.05.089.

[24] Ankit Sharma, Saurabh Kumar, "Analysis of heat transfer and flow due to natural convection around heated semi-circular cylinder placed at incidences inside a square cavity", International Journal of Advance Research in Science and Engineering, Vol. 6, Issue No. 2, September 2017, ICITTESE-17, pp. 330-337.

[25] Yen Ting Ho, Tsung Hsien Yu, Kuang C. Lin, "Laminar natural convection over a heated cylinder in a cubic – a Lattice Boltzmann study", Proceedings of IASTEM International Conference, Chengdu, China, 17th-18th June 2017, pp.4-8.

[26] Krunal M. Gangawane, B.Manikandan, "Laminar natural convection characteristics in an enclosure with heated hexagonal block for non-Newtonian power law fluids", Chinese Journal of Chemical Engineering 25 (2017) 555–571. https://doi.org/10.1016/j.cjche.2016.08.028.

[27] Amaresh Dalal, Manab Kumar Das, "Laminar natural convection in an inclined complicated cavity with spatially variable wall temperature", International Journal of Heat and Mass Transfer 48 (2005) 3833–3854. https://doi.org/10.1016/j.ijheatmasstransfer.2004.07.051.

[28] Hakan F. Oztop, Eiyad Abu-Nada, "Numerical study of natural convection in partially heated rectangular enclosures filled with nanofluids", International Journal of Heat and Fluid Flow 29 (2008) 1326–1336. https://doi.org/10.1016/j.ijheatfluidflow.2008.04.009.

[29] Yasin Varol, Hakan F. Oztop, Ioan Pop, "Natural convection in right-angle porous trapezoidal enclosure partially cooled from inclined wall", International Communications in Heat and Mass Transfer 36 (2009) 6–15. https://doi.org/10.1016/j.icheatmasstransfer.2008.09.010.

[30] Salam Hadi Hussain and Ahmed Kadhim Hussein, “Natural Convection Analysis around a Hot Solid Circular Cylinder Embedded inside an Octagonal Enclosure at Various Orientation Locations”, World Academy of Science, Engineering and Technology 78 2013, pp.1238-1243.
[31] Shekholeslami M., Hashim I., Soheil Soleimani, “Numerical Investigation of the Effect of Magnetic Field on Natural Convection in a Curved-Shape Enclosure”, Mathematical Problems in Engineering, Volume 2013, Article ID 831725, pp. 1-10.
[32] Ahmed Kadhim Hussein, Sachindra Kumar Rout, “Natural convection in a triangular top wall enclosure with a solid strip”, Journal of Engineering Science and Technology, Vol. 10, No.10 (2015) 1326 – 1341.