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Review Study of Non-Forced Convection Heat Transfer Inside Enclosures with Different Enhancement Techniques and Configurations

Sarmad A. Ali [1]*

[1] *Department of Automobile Engineering, College of Engineering-Al Musayab, University of Babylon, Province of Babylon, 51001, IRAQ*

*Corresponding Author: sarmad.ahmed96@uobabylon.edu.iq
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Abstract

Many industrial engineering applications, such as thermal storage plants, solar energy, cooling in reactors, microelectronic electrical systems, and gas-insulated electrical systems, use natural convection heat transfer represented by the principle of heat transfer from the heating source to the cold ambient or cold cavity wall. The function of the outer surface of the cavity is to protect the body inside the cavity in the harsh external environment by also reducing the heat transfer process from the hot inner surface. On this topic, many researchers conducted their previous studies and literary investigations using various methods to enhance heat transfer by natural convection, such as mixing nanomaterials with water or inserting porous materials into various configurations to increase the coefficient of thermal conductivity of the main working fluid. Other methods have been applied, for example, vibration, Rayleigh numbers, boundary conditions, magnetic field, or changing the geometry of the cavity composition. The current research work aims to review the previous literature that has studied heat transfer by natural convection inside cavities of various configurations, including square, non-square, triangle, and rectangle, in addition to addressing ways to enhance heat transfer, the most important nanofluid and porous medium.

1. Introduction

In recent years, many researchers have focused on studying heat transfer by natural convection within cavities due to its many important industrial engineering applications, including space heating, passive cooling, electronic device packaging, nuclear design, and geophysical systems. Generally, heat transfer enhancement methods are divided into two main categories: passive methods require thermal packaging, special surface engineering, or the addition of certain liquid materials, while active methods require external forces such as magnetic and electric fields, as well as vibrations. Many parameters have attracted the attention of engineers and scientists because of their importance in engineering and industrial applications, including nanofluids, porous materials, vibration, as well as the magnetic field. As for the applications, they are crystal growth, metal casting, liquid metal cooling blankets for nuclear reactors, etc. The current research paper is concerned with reviewing previous studies and literature, the most numerical studies using one of the simulation tools, for example (Ansys Fluent or COMSOL Multiphysics), which dealt with the study of heat transfer by natural convection of various cavity configurations and ways to improve heat transfer such as nanofluids, heat sources, porous materials, fins, and others.

2. Literature Survey

2.1 Enclosure with Straight or Inclined Rectangular Configuration

Souad Morsli et al. [1] a numerical investigation was presented using a commercial fluid program (Fluent 6.3.26) by applying the turbulence model (k-ε) to study convection heat transfer inside a two-dimensional rectangular cavity with a corrugated hot wall by changing the aspect ratio for different ranges of Rayleigh numbers (10^5-10^8) where constant temperatures, flow function and total entropy generation were plotted by changing the aspect ratio. The study discovered that by increasing the aspect ratio of the cavity, the total entropy generation increases. Lyes Khezzar et al. [2] numerically studied the heat transfer by natural convection inside a rectangular two-dimensional cavity tilted at an angle (0°-180°) heated by the bottom wall, cooled by the top, and insulated from the sides. The effect of angle change on flow patterns, temperature distribution, and heat transfer rate at different ranges of Rayleigh numbers (10^4-10^6) was investigated. The results showed that the number of Nusselt is affected by a change in the angle of inclination, as it gradually decreases with an increase in the amount of angle.

M. Saleem et al. [3] numerically check the heat transfer by natural convection of a rectangular cavity heated at the bottom and cooled by the other sides of a micropolar liquid with a stable and transient flow. At different ranges of Rayleigh numbers, the effect and flow pattern on the heat transfer rate, skin friction factor, cavity length, and vortices were studied. The governing equations of the transient flow were solved numerically using two methods (Alternate Direct Implicit ADI and Successive Over Relaxation SOR). The results were obtained by changing the Rayleigh numbers, showing that the Eddy cells are affected by the length of the cavity. Under the same physical conditions and in comparison, with the Newtonian fluid, from the hot surface, the heat transfer rate of the micropolar fluid is lower.

Hua-Shu Dou et al. [4] the problem of heat transfer instability in natural convection through an inclined rectangular cavity was numerically analyzed using the energy gradient method. A good correlation was found with the maximum value of the heat energy gradient function at the location where the working fluid flow instability occurs. The influence of cavity length, inclination angle, and flow time on the instability was also discussed. It was also observed that with increasing plate length, the instability initially decreases on the upper wall of the cavity, with the instability locations gradually moving to the right side.

Hamza Sayyou et al. [5] analyzed and studied numerically, using the finite volume method, the heat transfer and free convective flow inside an inserted rectangular cavity with a porous mass and filled with nanofluid as a means of enhancing heat transfer. The conditional boundary layer on the cavity is exposed by exposing the side walls to a constant thermal overflow, and the upper and lower walls are thermally insulated. Several important parameters were studied numerically, including the types of porous medium, Rayleigh numbers, aspect ratio, volume fractions of the nanomaterial, as well as the porosity of the porous material. The numerical results indicated that the number of Nusselt increases gradually by increasing the variable aspect ratio (0.1-0.7), nanomaterial, and porous medium also significantly contributed to enhanced heat transfer. Moreover, correlations have been derived between the average number of Nusselt and the influential parameters.

Mounir Bouabid et al. [6] Numerically achieved normal convective heat transfer inside an air-filled rectangular cavity with an angle isolated from the upper and lower walls, heated by the left and cooled by the right. The governing equations of laminar flow involving the equation of continuity, momentum, and thermal energy were solved using the finite element volume control method. She studied three effects of dimensionless parameters, including Rayleigh numbers, aspect ratio, and angle of inclination. The obtained findings demonstrate that, for lower thermal Grashof number values, entropy generation tends towards asymptotic values, whereas, for larger thermal Grashof number values, it exhibits oscillatory behavior.

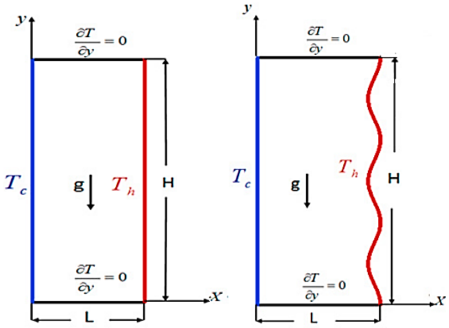
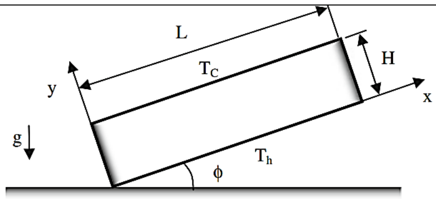
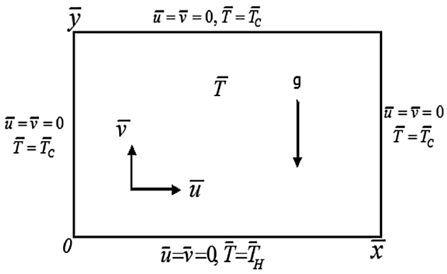
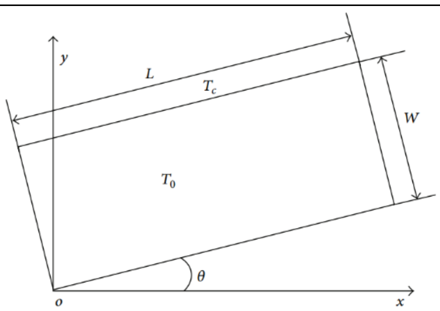
Hamza Sayyou et al. [7] numerically reviewed the study of convective heat transfer by natural convection in a rectangular porous cavity filled with nanofluid to optimize the heat transfer process. Vertical walls have a thermal gradient where the left wall is heated and the right is cooled, while the other two horizontal walls are thermally insulated. The parameters that were focused on for this study are the aspect ratio, the volume fractions of the nanomaterial, and the Rayleigh numbers. The most striking result obtained heat transfer increases and improved by increasing the volumetric fractions of the nanomaterial.

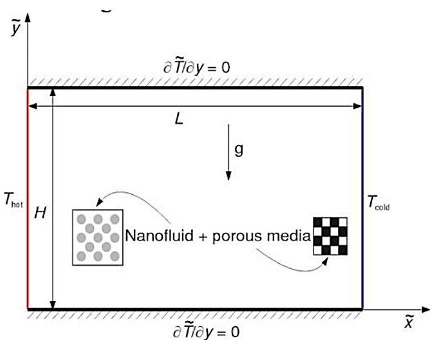
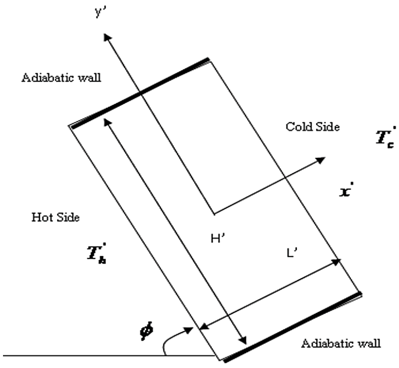
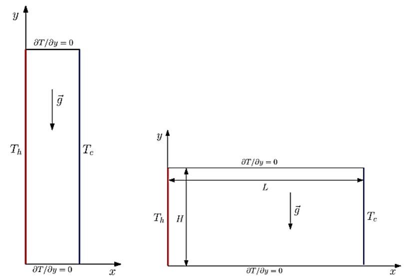
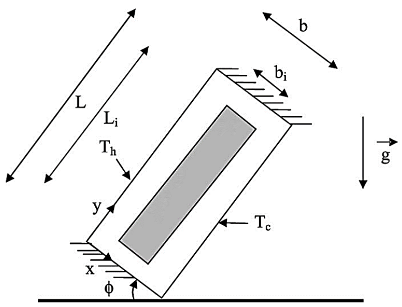
H. Bouali et al. [8] presented a numerical paper to study the effect of changing the angle of inclination and surface radiation on the flow structure and heat transfer by natural convection inside a rectangular cavity with insulated walls from the top and bottom, heated left and cooled right with a solid body inside. The finite volume method was used to solve the governing differential equations. The results found that the total heat transfer decreases by increasing the angle of inclination of the cavity increases.

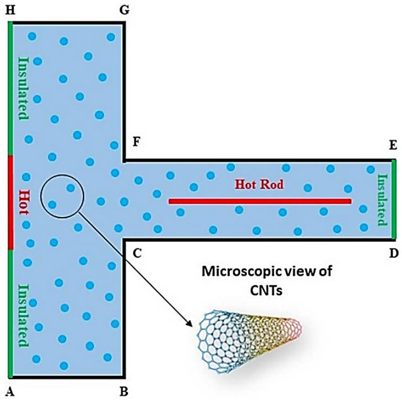
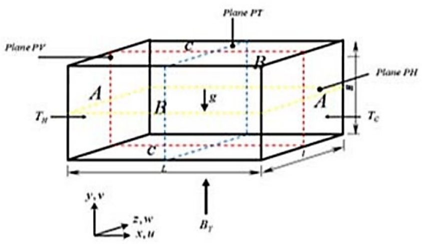
M. Hamid et al. [9] numerically investigated the increase of heat transfer of carbon nanotubes and hydromagnetic flux by natural convection of a partially heated rectangular cavity in the form of a fin. To provide heat transfer and create internal resistance, A Rod was inserted inside the cavity. For three different temperatures, including constant, hot, and cold, the horizontal right side of the cavity is tested, while the rod is tested for hot cases only. Flow lines and Equalities of temperature, velocity, and pressure are discussed and graphed.

K. N. Mohamed et al. [10] conducted a numerical study of the effect of the magnetic field of a rectangular three-dimensional cavity with a fixed aspect ratio at (4) for a heat flow similar to the cavity used in the artificial growth of single crystals from melting. In comparison with the experimental and data results, the results of this study were validated. The relationship between the flow generated by Mercury's buoyancy and the electrical conductivity of the wall and the vertical direction of the magnetic field was also investigated numerically.

Table 1 *Summary of articles involving heat transfer of circular cavities inside which cylinders of various configurations are inserted*

No.	Author Name	Configuration of Geometry	The strength of buoyancy	Condition
1	Souad Morsli et al. [1]		$10^5 \leq Ra \leq 10^8$	All of the other walls are thermally insulated, but the left wall is exposed to a cold temperature, while the right wall is exposed to a hot temperature in two different configurations: the first is straight, and the second is corrugated.
2	Lyes Khezzar et al. [2]		$10^4 \leq Ra \leq 10^6$ $0° \leq Ø \leq 180°$	The right and left walls are thermally insulated, the top is exposed to a cold temperature, the bottom to a hot one, and the cavity is inclined at an angle.
3	M. Saleem et al. [3]		$2x10^3 \leq Ra \leq 2 x10^5$	The lower wall is thermally heated, and the rest of the walls are exposed to a cold temperature.
4	Hua-Shu Dou et al. [4]		≤Ra≤	The upper wall is exposed to a cold temperature, the remaining three walls are thermally insulated, and the fluid is at a temperature higher than cold inside the inclined rectangular cavity.

No.	Author Name	Configuration of Geometry	The strength of buoyancy	Condition
5	Hamza Sayyou et al. [5]		0.1≤AR≤0.7 (Cu+Water +PM)	The left wall is heated, the right wall is cooled, and the upper and lower walls are thermally insulated with the inclusion of a block of porous material and a nanofluid inside the cavity to enhance heat transfer.
6	Mounir Bouabid et al. [6]		10^3≤Ra≤10^5 0≤Ø≤180	The left wall is heated, the right wall is cooled, and the upper and lower walls are thermally insulated for a rectangular cavity inclined at different angles.
7	Hamza Sayyou et al. [7]		0.5≤AR≤2 (Water + Cu or Al2O3)	The upper and bottom walls are thermally insulated, while the left and right walls are heated and cooled, respectively.
8	H. Bouali et al. [8]		$1.25x10^4$≤Ra ≤$7.5x10^4$ -60≤Ø≤60	The upper wall of the cavity is heated, the lower wall is cooled, and the other walls are completely thermally insulated with variable angle inclinations.

No.	Author Name	Configuration of Geometry	The strength of buoyancy	Condition
9	M. Hamid et al. [9]		$10^3 \le Ra \le 10^6$	A rectangular cavity is exposed to optimization and partial thermal insulation on the left side, and on the right, a fin with thermal insulation is installed at the tip with a thermally heated rod inserted inside.
10	K. N. Mohamed et al. [10]		$10^3 \le Ra \le 10^7$	The left wall is heated, the right is cooled, the bottom is exposed to a magnetic field, and the other is thermally insulated in a three-dimensional rectangular cavity.

2.2 Enclosure with Triangular Configuration

Roshani H et al. [11] numerically achieved the effect of inserting obstacles of various configurations, including a rhombus, a square, and an inverted triangle inside a two-dimensional cavity with a triangular cross-section, to study the thermophysical properties of the nanofluid structure and heat transfer by natural convection of the cavity. All the governing differential equations of the flow are solved numerically using the finite volume method. Boundary conditions were applied in two different ways to the lower wall of the cavity, the first shed uniform temperature and the second non-uniform (sine function). Several parameters have been studied for their influence on Rayleigh and Prandtl numbers, including controlling the distribution of temperature, pressure, and velocity. The results showed the formation of vortices inside the cavity, which caused an increase in the velocity of the fluid due to the presence of the listed obstacle effect.

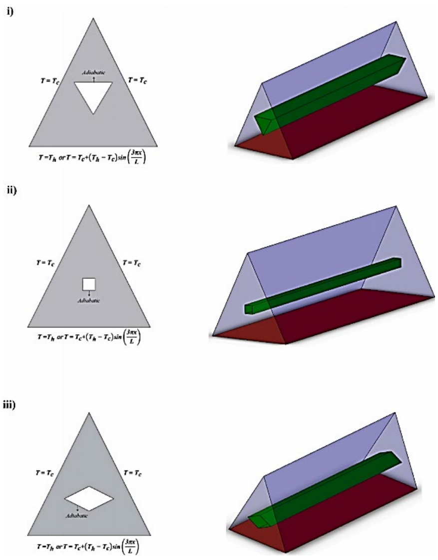
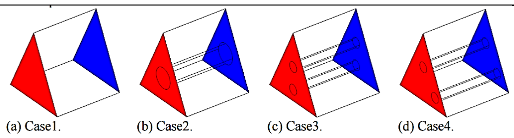
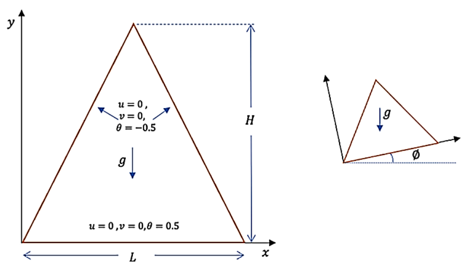
Zainab Kareem Ghoben et al. [12] presented a numerical study to improve the heat transfer by natural convection of a three-dimensional cavity with a triangular cross-section by differentially heating the walls of the left and right walls exposed to a cold temperature. A rod with a circular cross section was inserted along the triangular cavity. Nanofluid operates mainly with different volume fractions and with unstable laminar flow at Rayleigh number ranges (10^3-10^6). The results indicated enhanced heat transfer gave the maximum value at high volume fractions of the nanomaterial and also increased with increasing Rayleigh numbers.

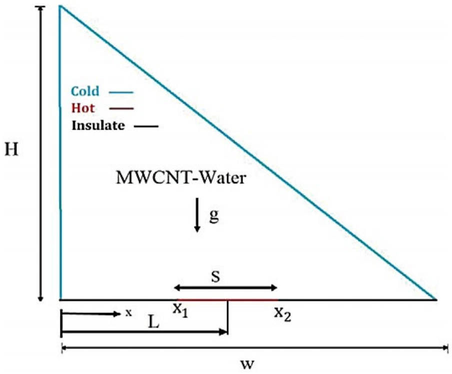
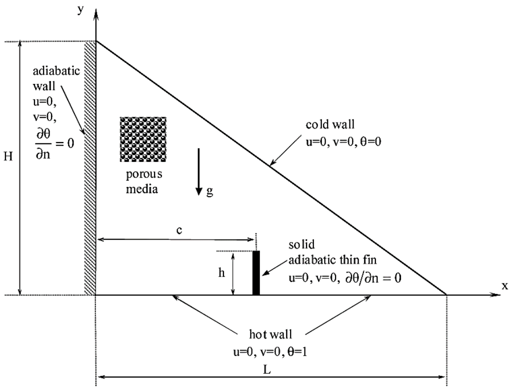
M. S. Aghighi et al. [13] numerically studied the effect of several important parameters, including the aspect ratio, the angle of inclination, and Rayleigh numbers for a two-dimensional cavity with an air-filled triangular cross-section. The equations are solved numerically using the finite volume method of a commercial numerical fluid program involving continuity, momentum, and energy. The results showed a temperature gradient due to the walls exposed to heating and cooling, and two models affected the heat transfer process. Moreover, by changing the height of the cavity, the behavior of viscous fluid flow and heat transfer significantly changes.

Sayyed Aboozar Fanaee et al. [14] presented a numerical paper using the Boltzmann lattice method to study heat transfer by natural convection in a triangular cavity filled with nanomaterial (MWCNT) and partially heated below by a solar heater with a role of irregular distribution while the other sides are cooled, as a result of the density difference and for the coupling of hydrodynamic and thermodynamic fields the Boussinesq approximation is used. The heating energy is compensated by an absorber directly exposed to sunlight. The influence of a set of parameters on heat transfer, including Rayleigh numbers, the location of the heating source, and the volume fractions of the nanomaterial, was studied numerically. The most prominent result predicted by all Rayleigh numbers can be observed in the increase of Nusselt numbers.

Yasin Varol et al. [15] presented an impressive numerical study aimed at enhancing the heat transfer by natural convection through the inclusion of a porous medium block at the top and a thin variable-height fin at the bottom. The boundary conditions were applied by insulating the horizontal left wall, heating the bottom, and cooling the inclined wall. Using the finite difference method, the equations governing the fluid flow are solved and written according to the Darcy model. The parameters studied numerically include Rayleigh numbers (10^2-10^3), fin height (0.1-0.4), location of fin (0.2-0.6), and aspect ratio (0.25-1).

Table 2 *Summary of articles involving heat transfer of triangular cavities inside which cylinders of various configurations are inserted*

No.	Author Name	Configuration of Geometry	The strength of buoyancy	Condition
1	Roshani H et al. [11]		$10^3 \leq Ra \leq 10^5$	A triangular cavity is heated at the bottom, exposed to cooling from the rest of the sides, and inserted inside a cylinder of various configurations.
2	Zainab Kareem Ghoben et al. [12]		$10^3 \leq Ra \leq 10^5$ (Al2O3 +Water)	A three-dimensional cavity in four different cases with the inclusion of a cylinder and a nanofluid inside is exposed to heating from the left and cooling from the right, while the rest of the walls are completely isolated.
3	M. S. Aghighi et al. [13]		$10^4 \leq Ra \leq 10^6$ $0 \leq Ø \leq 90$ $0.5 \leq AR \leq 2.5$	The triangular cavity is heated below, exposed to cooling from the rest of the sides, and tilted at different angles.

No.	Author Name	Configuration of Geometry	The strength of buoyancy	Condition
4	Sayyed Aboozar Fanaee et al. [14]		$10^3 \leq Ra \leq 10^5$ (MWCNT+Water)	A heated and partially insulated triangular cavity at the bottom, exposed to cooling from the rest of the sides, and a nanofluid runway as a technology to enhance heat transfer.
5	Yasin Varol et al. [15]		$100 \leq Ra \leq 1000$ $0.25 \leq AR \leq 1$	The right wall is exposed to a cold temperature, and the bottom to a hot temperature, and thermal insulation is exposed on the left wall with the inclusion of a block of porous material at the top and a fin in the middle of the cavity as techniques to enhance heat transfer.

2.3 Enclosure with Square Configuration

M. November and M. W. Nansteel [16] presented a numerical analysis and investigation using the technique of finite differences in solving the governing equations of the flow of water filled inside a square cavity exposed to heating at the bottom and a cold temperature on the left vertical wall, and the rest with complete insulation.
K. B. Sahu and Ravi Kumar Singh [17] studied the effect of changing the aspect ratio of a cylinder with a triangular configuration inserted into a two-dimensional square cavity. The boundary conditions were applied by heating the cylinder walls to a higher temperature than the vertical walls of the square cavity while insulating the horizontal walls of the cavity. The mathematical model is solved numerically using a package for a numerical fluid program based on the Computational Fluid Dynamics technique. The Rayleigh numbers range within (10^4-10^6) and the aspect ratio within (0.2-0.5). The isotherm and stream function contours are used to display the results.
Sarmad A. Ali and Ali Baqer Hussein [18] use a numerical simulation tool based on the finite difference method to solve the equations governing the flow pattern of continuity, momentum and thermal energy for numerical investigation of convective heat transfer inside a two-dimensional closed square cavity exposed to partial optimization by changing the positions of the left wavy wall and the right wall exposed to cold temperature and the rest with complete thermal insulation. Several parameters have been studied numerically to show their effect when changing Rayleigh numbers, including Nusselt numbers, temperature distribution, velocity, and pressure. The simulation was done using the (COMSOL Multiphysics) program.

Tahar Tayebi and Ali J. Chamkha [19] presented a numerical study with the technique of finite volumes to optimize the heat transfer by free convection and the flow of a hybrid nanofluid (Al_2O_3+Cu) stabilized inside a two-dimensional square cavity. A wavy circular cylinder is inserted inside the cavity under the influence of a magnetic field. The effect of several parameters has been studied, including the ratio of the volume fractions of the nanomaterial, Rayleigh numbers, Hartmann numbers, and the ratio of liquids to solid conductivity. According to the results of numerical control inside the system in the patterns of heat flow and heat transfer rate are affected by the result of the corrugated conductive cylinder.

Sameh E. Ahmed et al. [20] subjected a laminar non-coercive magnetohydrodynamic convection in a square container filled with a porous material to a two-dimensional numerical analysis utilizing the finite difference technique in order to investigate the impacts of radiation and viscosity dissipation. The container was heated from the left vertical sidewall and chilled from the opposite right vertical sidewall in order to apply the boundary conditions. The container's upper and bottom walls are regarded as thermal insulation. A homogeneous magnetic field with varying direction angles (0°, 30°,45°,60° and 90°) is applied to the flow within the square container. Numerous ranges of Rayleigh number, viscosity dissipation coefficient, magnetic field direction angles, Hartmann number, and radiation coefficient are used in numerical computations. The results of the numerical study showed that with the increase in radiation, the local and medium Nusselt numbers increase at the hot and cold walls. On the other hand, the Nusselt numbers improve at cold walls and decrease at Hot Walls, influenced by viscous dissipation.

Jong Yun Oh et al. [21] numerically studied the square cavity subjected to lateral heating, lateral cooling, and thermal insulation from above and below with the inclusion of a solid object as a heat source inside the cavity. The single-phase fluid flow is laminar and stable at the ranges of the Rayleigh numbers (1000-10000) and the temperature difference ratio (0-50) while the Prandtl numbers and the conductivity ratio are constant at (0.71 and 1), respectively. The dimensionless equations governing the flow are solved numerically using the finite volume difference approach.

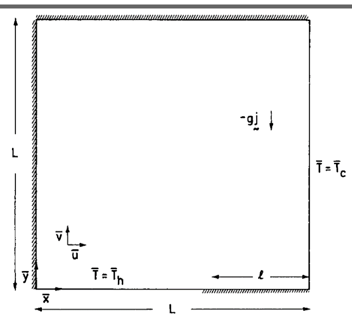
Doaa Kamal and Raed G. Saihood [22] numerically examined the heat transfer and the air flow as a working fluid inside a square cavity open on the left side and exposed to a constant, uniform thermal overflow for a range of (1500-6000 W/m^2). All the governing equations are solved by the finite element difference approach described in (COMSOL Multiphysics). Using the distribution of flow lines and temperatures of the fluid, the transfer of heat and momentum was studied. A method was used to enhance heat transfer by natural convection in which the porous material filled the cavity to increase the thermophysical properties of the fluid. The results showed that by changing the extent of thermal flooding, the Reynolds numbers increase with increasing Darcy numbers.

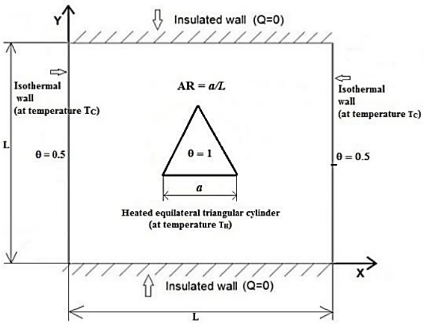
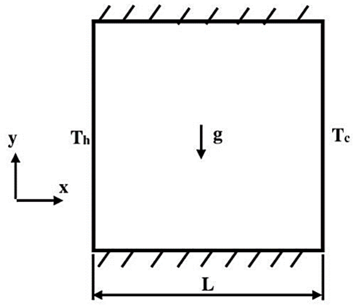
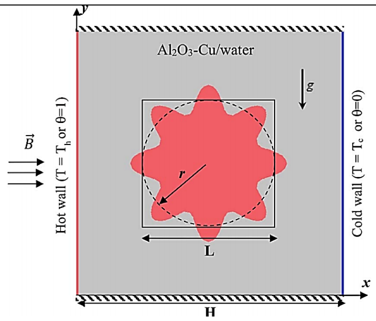
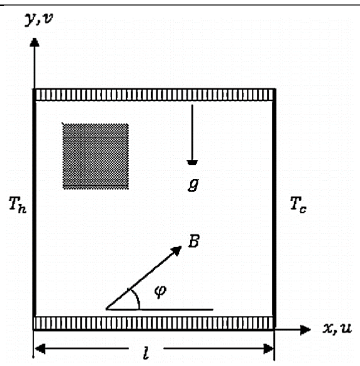
Ahmed Mezrhab et al. [23] touched upon the transfer of heat by the natural convection of the air flow inside a square cavity inclined at a variable angle, differentially heated at the bottom, and insulated from the sides. The cavity was exposed to a cold temperature above, with the inclusion of a single and multiple barriers on the wall to create swirls. The working ranges of the Rayleigh numbers were at (10^3-10^6), and the Prandtl numbers at (0.71). The solution to this issue involves numerical linkage between the lattice Boltzmann equation and the temperature finite-difference.

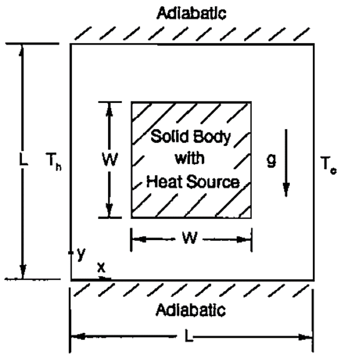
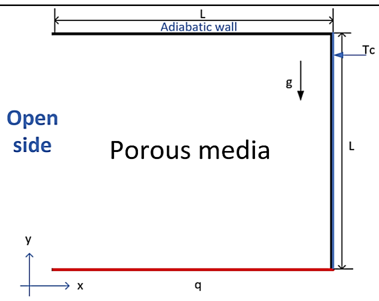
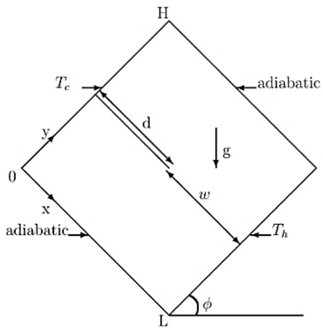
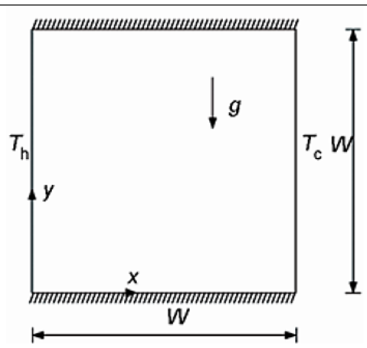
Massimo Corcione et al. [24] presented a numerical study based on the algorithm method (SIMPLE-C) for a computer code of commercial numerical fluid code. The nanomaterial was added with a single-phase working fluid inside the heated square cavity on the left side, and the system of equations governing the flow was solved numerically. Based on a set of data and using two experimental equations, the thermophysical properties of the nanofluid are calculated as thermal conductivity and dynamic viscosity.

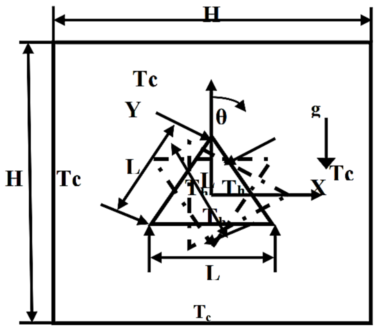
Ali Hamza Altaee et al. [25] prepare a numerical study using computational fluid dynamics technology with the help of a program (Ansys Fluent) for heat transfer by free convection and the flow of filled air into the vacuum of a square cavity in which a cylinder with an equilateral triangle configuration rotating at variable angles is inserted (0°-105°) at different Rayleigh numbers. The heat transfer rate is represented by the Nusselt number, while the temperature and properties of the fluid are represented by the contour temperature lines and the flow function. The results were shown at the Rayleigh number (10^6), and the steering angle at (30 degrees) showed the maximum value of the Nusselt number.

Table 3 *Summary of articles involving heat transfer of square cavities inside which cylinders of various configurations are inserted*

No.	Author Name	Configuration of Geometry	The strength of buoyancy	Condition
1	M. November and M. W. Nansteel [16]		$0 \le Ra \le 10^6$ (Water)	The left and top wall is thermally insulated, the right wall is exposed to a cold temperature, and the bottom wall is exposed to a hot temperature.

No.	Author Name	Configuration of Geometry	The strength of buoyancy	Condition
2	K. B. Sahu and Ravi Kumar Singh [17]		$10^4 \leq Ra \leq 10^6$ (Air)	The upper and lower walls of the cavity are thermally insulated, the left and right walls are exposed to a cold temperature, and the hot temperature is highlighted on the walls of the triangular cylinder inserted inside the cavity.
3	Sarmad A. Ali and Ali Baqer Hussein [18]		$1.3x10^5 \leq Ra \leq 4.55x10^5$ (Air)	The upper and lower walls of the cavity are insulated, and the hot temperature is projected around the left wall while the cold is projected on the right.
4	Tahar Tayebi and Ali J. Chamkha [19]		$10^3 \leq Ra \leq 10^6$ (Al2O3+Cuo with Water)	The right and left walls are exposed to cold and hot temperatures, respectively, while the thermal insulation is exposed to the upper and lower walls with the inclusion of a circular corrugated cylinder in the middle of the square cavity.
5	Sameh E. Ahmed et al. [20]		≤Ra≤	Thermal insulation of the upper and lower cavity walls with a hot temperature for the left wall and a cold temperature for the right wall, with the placement of a block for the porous medium in the upper left point of the cavity

No.	Author Name	Configuration of Geometry	The strength of buoyancy	Condition
6	Jong Yun Oh et al. [21]		$10^3 \le Ra \le 10^5$ Pr= 0.71 (Air)	Heating the lift wall of the cavity and cooling the right wall with thermal insulation of the upper and lower walls, and inserting a solid body at the middle of the cavity
7	Doaa Kamal and Raed G. Saihood [22]		$4.025\times10^{-10} \le Da \le 4.025\times10^{-6}$ 1500≤q''≤600 (Air)	The lower wall is thermally heated with various heat fluxes, the right wall is exposed to a cold temperature, and the thermal insulation is at the upper wall; the left is completely open.
8	Ahmed Mezrhab et al. [23]		$10^3 \le Ra \le 10^6$ Pr=0.71	Cold temperature the upper wall is exposed to an inclined cavity at an angle, the lower wall is exposed to a hot temperature, and the rest of the walls are thermally insulated.
9	Massimo Corcione et al. [24]		$10^3 \le Ra \le 10^7$ 293K≤Tc≤313K 298K≤Th≤343K (Al_2O_3+Water)	Thermal insulation of the upper and lower walls of the square cavity, with the exposure of the left and right walls to a hot and cold temperature, respectively.

No.	Author Name	Configuration of Geometry	The strength of buoyancy	Condition
10	Ali Hamza Altaee et al. [25]		$10^4 \le Ra \le 10^6$ Pr=0.71 (Air)	Expose a cold temperature to all the walls of the square cavity with the inclusion of a cylinder with a temperature-heated triangular configuration.

2.4 Enclosure with Non-Square Configuration

M. E. Newell and F. W. Schmidt [26] used a numerical technique to study laminar airflow inside a horizontal two-dimensional rectangular cavity. All the time-dependent flow-governing differential equations have been numerically solved. The effect of changing the aspect ratio (1-20) and Grashof numbers (4000-140000) was also studied numerically.

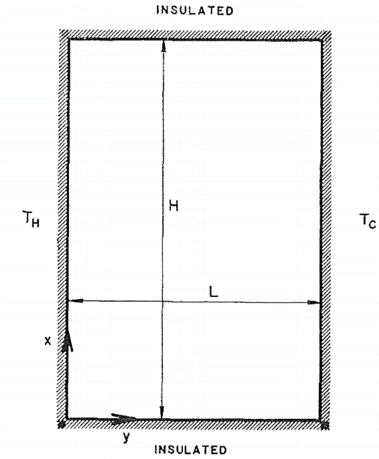
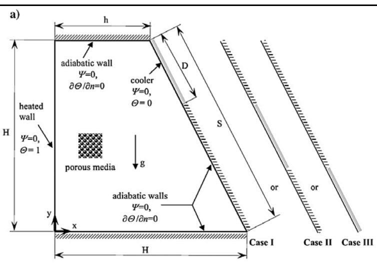
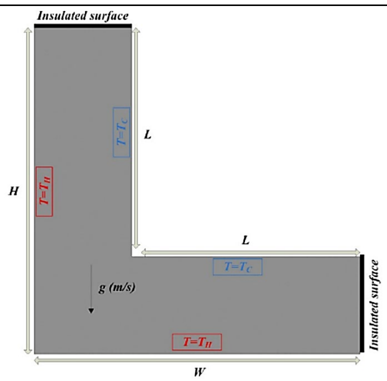
Yasin Varol et al. [27] A numerical investigation of heat transfer by natural convection was carried out in a trapezoidal cavity filled with a saturated porous medium. As boundary conditions of the matter, the vertical left wall is heated and the inclined wall is cooled, while the remaining walls are constant temperature. The Cold Wall is taken into account in three different cases, the first near the upper wall, the second near the inclined wall, and the third near the lower wall. Fluid flow and heat transfer inside the cavity are studied within the range of Rayleigh numbers (100-1000) and aspect ratios (0.25-0.75). According to numerical studies, the flow and temperature fields differ significantly from those of a square porous cavity that is differentially heated. The position of minimal heat transmission across the cavity is predicted by these results, which is particularly relevant for building thermal insulation and other technological applications.

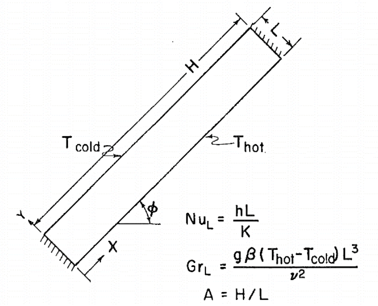
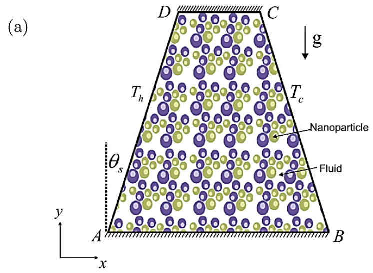
Bader Alshuraiaan [28] is treated numerically using a simulation tool based on the method of finite element differences of heat transfer and the structure of fluid flow inside a cavity in the form of (L). Several visualization approaches were used to display the investigation's findings. The flow and temperature distribution inside the L-shaped cavity will be shown visually using a variety of techniques, including streamlines, temperature contours, and heat transfer enhancement. The numerical results indicated that the Nusselt numbers are affected by the Rayleigh numbers and the elasticity of the wall, where compared to the rigid wall, the flexible wall has a higher average Nusselt number.

K. R. Randall et al. [29] Experimentally studied the heat transfer by natural convection of a rectangular plate inclined at an angle using the interferometry method. Several parameters have been studied experimentally, including the Grashof numbers (4000-310000), the angle of inclination (45-90 degrees), and the aspect ratio (9-36) to demonstrate their effect on the average and the rate of Nusselt numbers. The results proved that the rate of heat transfer is affected by the change of angular ranges and aspect ratio.

H. Saleh et al. [30] A numerically investigated study in enhancing heat transfer using various nanofluids (Cu+Water and Al_2O_3 +Water) in a trapezoidal container for various relevant parameters. All transport equations are modeled by the eddy current formula and solved numerically by the finite difference approach. Oblique sloping borders are treated by adopting zigzag lines resembling stairs. Among the most important parameters studied numerically are the Grashof numbers, the angle of inclination of the wall, and the volume fractions of nanomaterials on the flow patterns and temperatures of the nanofluid. The results found that heat transfer improves when using the highest percentage of volumetric fractions in the nanomaterial. Also, relationships were derived between the angle of inclination and the heat transfer rate represented by the average Nusselt numbers.

Table 4 *Summary of articles involving heat transfer of non-square cavities inside which cylinders of various configurations are inserted*

No.	Author Name	Configuration of Geometry	The strength of buoyancy	Condition
1	M. E. Newell and F. W. Schmidt [26]		$4x10^3 \leq Gr \leq 1.4x10^4$	Expose a hot temperature to the left wall, cool to the right wall, and the rest of the walls are insulated.
2	Yasin Varol et al. [27]		$100 \leq Ra \leq 1000$ $0.25 \leq AR \leq 0.75$	The left wall is exposed to a hot temperature, and the right wall is exposed to a partial cold temperature; the remaining walls to the trapezoidal cavity.
3	Bader Alshuraiaan [28]		$10^3 \leq Ra \leq 10^6$	The left and bottom wall is exposed to a hot temperature, while the upper and right walls are thermally insulated, and the rest of the walls are exposed to a cold temperature.

No.	Author Name	Configuration of Geometry	The strength of buoyancy	Condition
4	K. R. Randall et al. [29]		$4x10^3 \le Gr \le 3.1x10^5$ $45 \le Ø \le 90$	A flat plate tilted at an angle where the left wall is exposed to a hot temperature, the right wall is exposed to a cold temperature, and the rest is thermally insulated.
5	H. Saleh et al. [30]		$10^3 \le Gr \le 10^5$ (Cu+Water) (Al2O3+Water)	The trapezoidal cavity is filled with different nanomaterials with water and thermally insulated at the top and bottom, with the left is exposed to a hot temperature while the right wall is exposed to a cold temperature.

3. Methods of Heat Transfer Enhanced

Improving heat transfer by natural convection is one of the critical topics in thermal and energy engineering because the enhancement of thermal systems can be achieved without external energy. The more common ones are the use of fins to enhance the heat transfer area, the alteration of the shape or location of the voids to accelerate the fluid movement, and the introduction of nanofluid, which has better thermal characteristics the conventional fluids, as shown in Table (5). A powerful way to improve the natural convection processes and heat spreading in the analyzed volume is also the modification of the engineering features of the systems, such as placing the internal barriers or the inclusion of objects of different shapes [31-33].

Table 5 *Methods for improving heat transfer by natural convection*

No.	The method used	Mechanism	Influence on heat transfer
1	The use of nanofluids	Raising the thermal conductivity of the fluid	A noticeable increase in the heat transfer coefficient
2	Improve the shape of the cavity or container	Geometry adjustment (such as Fins, cylinders, corners)	Promote fluid circulation and improve normal load
3	Adding internal or external fins	Increased surface area exposed to heat exchange	Improved heat transfer and increased efficiency
4	The use of magnetic or electric fields	Stimulation of fluid motion in conductive or magnetic fluids	Improve the natural convective flow of fluid
5	Temperature control on the walls	Generate a large thermal difference to stimulate pregnancy	Increasing the thermal gradient and, consequently, the load
6	Use of Phase Change Materials (PCM)	Absorption/release of heat during thawing/freezing	Improved thermal system performance and heat stability
7	Integration of multiple heat sources	Balanced or directed heat distribution as needed	Improve the efficiency of natural pregnancy
8	Thoughtful ventilation or vents	Enhance the natural air flow inside the system	Increased cooling and improved heat transfer
9	The use of corrugations or surface roughness	Generating a disturbance in the fluid flow and stimulating thermal mixing	Improve normal pregnancy by promoting ataxia
10	Reducing the viscosity of the fluid or modifying its physical properties	Facilitate fluid movement within the system	Promote normal load and reduce motor resistance

4. Conclusions

The current research work includes a review of the literature and previous studies on heat transfer by natural convection inside cavities of various configurations and with a stable and unstable two-and three-dimensional flow, also by applying boundary conditions and different heat sources. Parameters that have an important influence on the mechanism of heat transfer are noted, including Rayleigh numbers, type of fluid, optimization methods used, angle of inclination, and others. The main conclusions of the current study can be listed as follows:

- By increasing the Rayleigh numbers (or Prandtl and Grashof numbers), the rate of heat transfer by free convection improves.
- By increasing the internal heat source, the thermal boundary layer of the cavity walls increases, both hot and cold.
- In the field of thermal distribution and fluid flow, there is a noticeable effect of the solid strip inside the cavities.
- By increasing the volume fractions of various nanomaterials, the natural convective heat transfer rate gradually increases.
- The rate of heat transfer is affected by changing the angle of inclination of the cavity or the inserted heat source.
- The field of fluid flow and heat transfer is affected by the corrugated cavity walls as well as the unevenly inserted heat source.
- With the increase in the Rayleigh and Darcy numbers, an increase in flow lines and Nusselt numbers was observed.
- The movement of liquids and the rate of rotation increase, where at low Rayleigh numbers the movement of liquids is almost uniform and prominent at the walls, and vice versa, at high Rayleigh numbers the movement of liquids stagnates in the core area.
- As the cylinder volume increases, the rotation rate decreases for the small cavity, while the rotation rate increases with the volume of the inserted cylinder for the large cavity.
- The addition of hybrid nanofluids enhances the natural convective heat transfer even more compared to the use of nanomaterials with the basic working fluid.

- High efficiency nanofluids provide but require greater investment and precise processing.
- Porous media are less expensive and easier to apply, but may not achieve the same levels of thermal efficiency, making them a good choice for low- or medium-load industrial applications.

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Conflict of Interest

With regard to the process of publishing the current article, the researcher acknowledges no conflict of interest.

Author Contribution

The author confirms that Sarmad A. Ali makes the sole contribution to the paper

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