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A Theoretical Study of Natural Convection Heat Transfer in A Partially Opened Square Cavity with an Internal Heat Source

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Abstract

Engineering and industrial applications are constantly on the lookout for new methods to dissipate heat from heated surfaces. It is critical in the construction of solar arrays, the cooling of electronic components and electrical transformers, and the thermal exchange process between hot and liquid surfaces. Theoretical analysis of convective heat transmission in a square cavity with internal heat sources is presented in this article. Engineers are especially interested in this subject because it calls for the development of heat exchangers and systems for naturally convective cooling or heating of objects. Free or natural convection occurs when buoyant forces caused by density changes, which are caused by temperature changes in a fluid, create fluid flow motions. (involving currents and paths). Many engineering systems, such as open cavity solar heat receivers, flat panel solar collectors with stacks of vertical strips, electronic cooling devices, buildings, and so on, have partly open cavities. Natural convection that occurs in a closed cavity is used in many fields, including thermal power, petrochemical, aerospace, and construction. Many studies have been conducted in order to better comprehend this occurrence. Furthermore, previous study has revealed that many powerful secondary cycles form in fluids with small rays but not in fluids with higher rays. In order to complete this comprehensive research, orifice temperatures and horizontal air velocities were examined.

Keywords: Heat Transfer, Natural Convection, Square Cavity, Finite Element Method, Internal Heat Source.

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1. Introduction

Many studies on the topic of cavities have recently been conducted. Natural convection in open cavities and slots is used in a wide range of technical applications, such as solar thermal receivers, heat transfer convection from extended surfaces, and insulated ribbon solar collectors. Many electrical devices have side-slit cavities and an internal heat source because the slots allow for improved internal component cooling. This case's investigation is also pertinent to a variety of other applications, such as nuclear reactor design and operation, grain storage, solar collectors, energy storage systems, and indoor environment design and building (Supraja & Raju, 2021).

Several studies assessing the behavior of fluids within cavities have been documented in the literature, and we discuss a few of them below. The distinction between a vertical and a horizontal case is that a vertical case produces a horizontal case (Mezrhab, 2006). In those studies, the authors evaluated the effect of a thermal gradient (Kaluri, 2009), partial opening, and elimination of the thermal properties of the cavity (Mezrhab, 2006).

Kaluri et al. (2009), they considered three distinct cases in their numerical study on heat distribution and thermal mixing during static natural laminar heat flow within a liquid-saturated porous square cavity: a uniformly heated bottom wall, separate heat sources on the walls, and a uniformly heated left and bottom wall. Deng and Chang (2008) numerically investigate stratified and constant two-dimensional natural convection in an air-filled rectangle with thermally insulated horizontal

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walls and sinusoidal temperature distributions that varied both spatially and in terms of amplitude and phase.

Michalek (2005) measured the water movement inside a cubic chamber with isothermal vertical walls and adiabatic horizontal walls for Ra values greater than 109. During the transition from constant to non-constant flow, the critical Rayleigh number was less than the theoretical value (Michalek, 2005).

Bilgen and Oztop performed a numerical study of natural convective heat transmission in a two-dimensional inclined, partly open cavity. A parametric study by the same authors showed that, for Ra values between 103 and 106, the Nusselt number was at its highest for angles of 30-60 for low values of Ra, and angles of 60-90 for high Ra values (Bilgen & Oztop, 2005). Kuznik et al. used the Lattice-Boltzmann method with an irregular grid to simulate natural convection in a square cavity. (Kuznik, 2007). As a consequence, this paper investigates natural convection in a partially open square cavity with an internal heat source.

2. Heat transfer in partially open cavities

2.1 Natural convection

Convection is the transfer of heat from one place to another. (also known as convective heat transmission). Despite being frequently cited as a distinct method of heat transfer, convection heat transfer includes the processes of co-conduction (heat diffusion) and delay. (heat transfer by bulk fluid flow). Convection is the most common way of heat transmission in liquids and gases (Supraja & Raju, 2021).

Convective heat transfer happens when an object is immersed in a fluid that is either hotter or colder than the object. (Kaluri, 2009). Heat will flow between the fluid and the body as a consequence of the temperature difference, causing a change in the density of the fluid near the surface. (Grosan & Ingham, 2009).

Convectional heat transfer, which mainly mimics heat transfer via mass transfer, is the movement of heat from one location to another via the flow of fluids. Fluid flow improves heat transfer in many physical situations, such as between a solid surface and a fluid. Convection is the most common form of heat transmission in liquids and gases (Taylor, 2012). Despite being discussed as a third form of heat transfer, convection is commonly used to refer to the combined impact of heat conduction within the fluid (diffusion) and heat transfer by the flow paths of the fluid's flow. The term transport is used to characterize the process of translational movement through fluid currents, but net transport is more commonly used to describe the transfer of mass only in fluids, such as gravel movement in a river. In the context of heat transfer in fluids, convection is known to be the sum of heat transfer by transfer plus diffusion or conduction, where transfer in a fluid is always joined by thermal diffusion (also known as thermal conduction) (Engel, 2003).

Heat is transmitted through convection along with the movement of the fluid's constituent parts when a stream of fluid (liquid or gas) flows. Outside forces may affect fluid flow, or in some cases (in gravitational

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fields), buoyant pressures caused by the fluid's thermal energy expanding (as in smoke plumes) may also affect flow, which has an effect on the fluid's own thermal energy transmission. The final process is known as "natural convection" Conduction (diffusion) is used to move heat in all convective processes. Another form of convection is forced convection. A pump, fan, or other mechanical device is used in this case to force the fluid to move (Lienhard, 2019).

When buoyant forces caused by density changes caused by fluid temperature changes initiate fluid flow motions, this is referred to as free or natural convection. (paths and currents) (Faghri, 2010). External media, such as fans, stirrers, and pumps, generate paths and currents in the fluid, resulting in an intentionally caused load current (Supraja & Raju, 2021).

Convection can be "forced" by moving a stream with forces other than buoyant forces. (for example, a water pump in a car engine). Thermal expansion of a substance can also cause convection. When a fluid is heated, natural buoyant forces—also known as "natural convection"—may be entirely accountable for the fluid's movement. When different densities of fluids are influenced by gravity, an increase in temperature causes a drop in density, which leads to fluid movement due to stresses and forces (or any force g). When water is heated on a burner, hot water rises from the bottom of the pan, replacing the cooler liquid that lowers. At the end of heating, mixing, and conduction caused by natural convection, the result is a nearly homogeneous density and consistent temperature. Natural convection does not occur in the absence of gravity (or any other circumstance that results in any kind of acceleration force), force; only forced convection patterns can exist in such circumstances (Deng & Chang, 2008).

Convectional heat transfer is a heat transfer mechanism that happens as a result of fluid mass movement. (observed movement). Heat is being investigated as it is transmitted (carried) and diffused. (distributed). Heat transfer by conduction is the transfer of energy via molecular motions through a solid or fluid, whereas heat transfer by radiation is the transfer of energy via electromagnetic waves (Lienhard, 2019). Convective heat transmission occurs as a result of the movement of a fluid, which can be a gas or a liquid. The masses of the warmer portions increase while the masses of the cooler parts decrease as the density of the liquid decreases with increasing temperature. Heat is transferred from one side to the other as a consequence of the mass movement of fluids. Convection is distinguished from conduction and radiation by the fact that there is always a net movement of masses in convection. Radiation, on the other hand, does not need a physical medium to propagate, and conduction transport is created by successive collisions between atoms and molecules, with no total movement of matter (Çengel, 2003).

Convection transfers heat in natural fluid flows such as winds, ocean currents, and motions within the Earth's mantle. The load is also used in home engineering, industrial operations, the cooling of machinery, and so on. The use of a heat sink, often in conjunction with the use of a fan, can increase the rate of convective heat transfer. A traditional CPU, for example, has a dedicated fan to keep the temperature within acceptable limits while operating (Taylor, 2012).

Convective heat transfer involves only one mechanism. In addition to the transfer of energy caused by molecular motion, energy is transferred by mass, or the macroscopic motion of a fluid. (diffusion). This motion is related to the fact that many molecules are moving collectively or in groups at any given moment. When there is a temperature gradient, this movement helps with heat transfer. Because the aggregated molecules retain their random motion, total heat transfer is caused by the superposition of energy transfer by random motion of the molecules and overall motion of the fluid. This accumulated transport is commonly referred to as convection, while transport induced by the movement of bulk fluids is referred to as advection (Hinojosa, 2012).

Convection currents involve the simultaneous transfer of heat and mass in fluids (liquids and gases); a well-known example of convection currents occurs when water is heated in a container over a bummer the cooler, denser molecules fall to the bottom of the container, where they will be subsequently heated, whilst warmer ones rise the process continues in this way until all of the water is heated. Natural convective heat transfer is a type of convection that occurs due to the buoyant force of fluids as a result of temperature and density differences without the intervention of external forces (Massinissa, 2017).

Natural or unrestricted convection happens when fluids move due to buoyant forces caused by changes in density induced by changes in the thermal temperature of the fluid. When a liquid comes into contact with a hot surface, its molecules split and disperse, resulting in a less dense liquid. Because there is no internal heat source, the warmer fluid shifts, while the cooler fluid becomes denser and sinks. As a consequence, heat moves from the hotter to the cooler part of the fluid. The circulation of water in a vessel heated from below and the upward flow of air produced by a fire or a hot object are both examples, and both take place without human involvement. Hot gases, for example, rise to the top of the atmosphere due to density differences and are replaced by cold gases as hot air moves from a hot to a frigid climate (Hinojosa, 2012).

Natural convection is a very important topic "because of its occurrence applications in various areas of nature. A although there is no forced velocity to generate this type of convection, natural convection currents are generated within fluids that urge them to flow as a result of the effects of the buoyancy force or so-called power of flotation." Natural load plays an important role in the design or performance of many devices that include multiple methods of heat transfer through which the rates of heat transfer or operating cost are affected, as seen in many devices that include multiple methods of heat transfer through which the rates of heat transfer or operating cost are affected, which is much favored over forced load. In addition, natural convection can happen in partially open square cavities, and the treatment of heat transfer and fluid flow within such cavities, that have internal heat sources has been studied both practically and theoretically. As a result, heat transfer by natural convection will be investigated in this article in a partially open square cavity with an internal heat source (Ibrahim, 2011).

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Many engineering and industrial applications are designed to disperse heat from heated surfaces. They are used to cool electronic components and electrical transformers, as well as to produce solar complexes and to improve the thermal exchange process between hot and liquid surfaces. A wide variety of electronic components are cooled by using air as heat carrier, and natural convection to remove heat that is produced internally. Heat transmission by natural convection occurs in many areas, as evidenced by numerous studies (Ibrahim, 2011).

Natural convection is produced by the buoyant force caused by the density difference between the fluid and the heated surface caused by the temperature difference between the fluid and the surface. Numerous experimental studies of heat transfer by natural convection from surfaces with horizontal and vertical surfaces [7, inclined, 6] have all been used to analyze stratigraphic flow along surfaces in the horizontal, inclined, and vertical cases [Phase 2, 3, Analytical]. Some experimental investigations on heat transmission by natural convection from heated surfaces in the shape of rings revealed a mathematical relationship between the averages of multiples and the averages of multiples. (rings). NU = C (RA): n is one of the best formulas for heat transfer in free natural systems of different shapes and rallies. None of these studies looked at the effect of cavity rate on heat transmission on square-shaped surfaces, which are more frequently found in electronic devices (Supraja & Raju, 2021).

2.2 Partially open cavities

Open cavity solar thermal receivers, flat-panel solar collectors with vertical strip rows, electrical chips, space heating, and other applications use partially open cavities. As a result, experts in cavity heating have become interested in studying fluid flow and heat transfer in these circumstances. Numerous studies have been conducted in the literature on natural convection in rectangular and square cavities that are open to heat flow and temperature. Costa (2002) investigated natural convection in rectangular differentially heated containers with diffused vertical sides. The suggested method's efficacy was assessed by comparing the results to those of a complete 2D numerical simulation of the conjugate heat transfer problem that happens in an entire enclosure with diffuse walls (Doğan, 2009).

Aydin et al. (1999) investigated natural convection in rectangular receptacles heated on one side and cooled from above using numerical analysis. They investigated the steady natural convection of air in a two-dimensional container using a vortex-functional stream model. Salat et al., (2004) studied natural turbulent convection by conducting experiments and numerical modeling adiabatic conditions, as well as measuring temperature on horizontal walls in a large air-filled cavity. Di Piazza and Ciofalo (2000) performed separate studies in which they numerically simulated the free heat flow in two dimensions for a thin cavity with AR = 4 and a low Prandtl number (0.0321).

Arcidiacono et al., (2001) examined a square cavity with adiabatic upper and lower walls and isothermal side walls. Chang and Tsay (2001) looked at normal convection in a container with a hot backward step. The impacts of Rayleigh number, Prandtl number, and shell geometry on flow

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structure and heat transmission properties have been thoroughly investigated.

The freezing of an n-paraffin solution in a rectangular container with a vertical sidewall and other isothermal sides was investigated empirically by Leong and Tan (2001). The impact of aspect ratio on the natural convection of a fluid inside a rectangular cavity with partially thermally active sides was studied by Nithyadevi et al., (2007). The active area of the left lateral wall was warmer than the active region of the right lateral wall. Thermal insulation was found in the top and bottom parts of the cavity, as well as the inactive regions of the side walls.

Poujol (2000) did additional experimental and numerical research on transient natural convection in a square cavity heated by time-dependent convection over one vertical wall and cooled by keeping the opposite wall temperature constant. Başak et al. (2006) studied the effect of thermal boundary conditions on spontaneous convective flows inside a square cavity. They looked at normal, static laminar heat flow in a square cavity with a heated lower wall that could be heated evenly or unevenly and an adiabatic upper wall that maintained the cold vertical wall at a constant temperature. The numerical method used in this research was applied to a wide range of parameters for the continuous and discontinuous Dirichlet boundary conditions. (Rayleigh Ra number, 103 Ra105; Prandtl Pr number, 0.7 Pr10). Mr. Elsayed and Chakroun (1999) examined how orifice geometry affects heat transmission in partially open and oblique cavities. They conducted experiments to determine how the geometry of the orifice impacted heat transmission between the cavity and the surrounding air. They played around with different geometric arrangements, aperture ratios, and tilt angles.

Polat and Bilgen (2002) investigated natural laminar convection in shallow and open inclined cavities numerically for Rayleigh numbers ranging from 103 to 107 and cavity aspect ratios varying from 1 to 0.125. Bilgen and Oztop (2005) investigated the heat transfer induced by natural convection in partly open inclined square cavities using numerical analysis. They used natural laminar convection to study steady-state thermal transfer in a partially open, two-dimensional cavity. Kasayapanand (2007) studied the effect of an electric field on natural convection in partially open square cavities using a computational fluid dynamics method (Doğan, 2009).

2.3 Heat transfer in open cavities

Many thermal engineering applications, such as electronic equipment cooling and solar condenser receiver development, are inextricably connected to heat transfer in open cavities. The solar concentrator in a parabolic dish solar thermal system that uses a Stirling heat engine contains a tracking system to maintain its optical axis pointed straight toward the sun. The receiver (open bore), which is situated at the capacitor's focal point and is used for tracking, can work at various angles of inclination. The circulation changes the heat loss in the open chamber, as well as the heat field and air movement structure. Improved thermal design and thermal performance of the solar thermal system will result from a greater understanding of how heat is transferred from the receiver (Hinojosa, 2012).

There are numerous numerical studies in the literature that explain heat transmission in open cavities. Some studies on natural convection heat transfer have considered the impacts of the Rayleigh number, aspect ratio, and cavity inclination angle on flow patterns, temperature ranges, and heat transfer behavior within the open cavity (Polat & Belgen, 2002; Bilgen & Oztop, 2005).

Other authors have focused on the analysis of flow instability (Hinojosa et al., 2005), and the definition of approximate orifice-plane boundary conditions (Khanafer & Vafai, 2000, Khanafer & Vafai , 2002), mixed convection (Khanfer et al., 2002), the presence of conjugated heat transfer (Polat & Bilgen, 2003; Koca, 2008), three-dimensional flow systems (Hinojosa et al., 2006; Hinojosa and Cervantes , 2010) and combined natural convection and radiative heat transfer in the cavity (Singh & Venkateshan, 2004; Hinojosa et al. 2005; Nouaneguea et al., 2008).

Bilgen and Oztop (2005) investigated inclined and partly open square cavities with adiabatic and partially open walls numerically. Numerous investigations on convective heat transmission in partially open cavities have been conducted. In this parametric study, Rayleigh numbers 103 to 106, dimensionless aperture sizes 0.25 to 0.75, aperture positions of high, medium, and low, and aperture inclinations ranging from 0° (facing up) to 120° (facing 30° down) were used as factors. The Rayleigh number, aperture size, and overall aperture location were found to be increasing functions of the Nusselt number. Koca (2008) studied natural convection and conduction in a partially open square cavity containing a vertical heat source. At the top of the bore, there were three distinct positions and several various sizes of holes. The heat source was situated at the cavity's bottom. The Rayleigh number, among other governing variables, was studied, and it was discovered that the ventilation position has a significant effect on heat transfer.

The cavities studied by Bilgen and Oztop (2005) are smaller in size than those typically used as receptors in Stirling dish thermal devices. Furthermore, the angles of inclination considered did not account for the thermal receiver's full rotation during operation (Hinojosa, 2012).

The second and most important step is to solve the governing equations so that the various parameters of interest in the porous medium can be forecasted. The finite differences method, finite volume method, and finite element method are the most frequently used numerical techniques for solving these problems. The selection of these numerical methods is important because it is influenced by a number of factors, one of which is field geometry. Other factors to consider include the ease with which these PDEs (Partial Differential Equation) can be reduced, the time required for calculation, and the adaptability of computer of writing computer code to solve these equations. In this study, the finite element method (FEM) was mainly used (Supraja & Raju, 2021).

The finite element technique is a well-known scientific approach. This technique was created to investigate mechanical stresses in complicated

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airframe structures, and Zienkiewicz and Cheung promoted it by employing continuum mechanics. Since then, the finite element technique has been used to solve numerous problems in a variety of engineering fields. A notable advantage of the finite element method's outstanding feature is its ease of generalization to a broad range of engineering problems involving various materials. The finite element method (FEM) has the notable advantage of being able to be applied to a wide range of geometric shapes with irregular boundaries, which is difficult to achieve with other contemporary methods (Supraja & Raju, 2021).

3. Numerical modeling of convective heat transfer

Because of the numerous engineering applications, numerical modeling of convective heat transfer has lately received a lot of attention. In contrast to experimental analysis, numerical analysis provides a more direct method of increasing/decreasing heat transfer in order to improve the performance or structure of a thermal device. Natural convection in enclosures has been studied experimentally and numerically due to the widespread interest in its many engineering applications, including building insulation, solar energy harvesting, cooling of heat-generating components in the electrical and nuclear industries, and flows in rooms caused by thermal energy sources (Mariani, 2007). Corcione's (2003) and Ben-Nakhi and Chamkha's (2006) work, as well as numerical analyses for natural convection heat transmission and flux in closed packages without a local heat source, have all been published.

Natural convection has been researched by other writers. Studies on natural convection in partly open packages that are only caused by external heating have been done by Chan and Tien, 1985; Polat & Belgen, 2002; Bilgen & Oztop, 2005; and Lauriat and Desrayaud, 2006. Despite the fact that these issues are frequently significant and their study is required to comprehend the functioning of complex natural convective flow and heat transfer, only a small number of simultaneous results of natural convection from external heating in partially open enclosures and internal local heat sources have been reported.

In a roundabout manner, Xia and Zhou (1992) studied a square, partially open container with an internal heat source, which is linked to the current study. Only three R ratios were moved by these writers, and they did so on the left vertical wall or lower wall. They discovered that the hole enabled heat to enter the cavity and flow. The location of the heat source, the outer and inner Rayleigh numbers, and the size of the opening all have an effect on the flow and heat transfer in this situation. Reinehr et al., (2002) studied natural convection using an internal heat source whose location only changes on the lower wall and an aspect ratio of H/W = 2. No heat transfer results were recorded in this study, and only a few Rae and R ratios were examined (Mariani, 2007).

4. Natural convection heat transfers in partially open square cavities

Many engineering systems, such as open-cavity solar thermal receivers, flat-panel solar collectors with vertical strip stacks, electronic cooling

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systems, structures, and so on, have partially open cavities. The majority of these studies, with the exception of a few Rayleigh experiments, used fully open horizontal cavities with all three isothermal walls or the wall facing the isothermal opening with two other isothermals. Because completely open cavities are a subset of the more general case examined in this research, we provide a brief overview of them here. Several writers conducted experiments on open cavities (Kaluri, 2009).

The first two sections had a horizontal bore that was completely exposed. The last three openings were both full and partial. In the center of a square bore was a dimensionless aperture with a size of 0.5. They investigated flow characteristics and found the local Nusselt number at various scales, spanning Rayleigh numbers from 107 to 1011 in laminar and turbulent systems, using laser Doppler velocity and flow visualization methods. (Bilgen & Oztop, 2005).

Chakroun et al., (1997) used aperture sizes varying from 0.25 to 1 to investigate fully and partially open oblique cavities. The aperture was located in the middle. Grashof's number had a fixed value of 5.5 * 108. They then used the same experimental apparatus to examine the effect of size in an inclined square cavity with an isothermally heated wall and the same Grashof number. Others theoretically investigated heat transmission via naturally occurring stratified convection in fully open cavities. (Elsayed & Chakroun, 1999).

Le Quere et al. studied thermally driven natural stratified convection in vessels with three isothermal sides, one of which was opposite the hatch. It was somewhere between 104 and 107 Grashof.

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Pinot looked at related problem using the flow function, which is part of the vortex formula. His Grashof range was 103 to 105. Chan and Ten numerically investigated a fully open square cavity with two horizontally connected thermocouples and a heated vertical side facing the hole. An extended field was used to make the calculation in these trials. Despite the challenges posed by unknown boundary conditions at the opening level, the other studies mentioned above were carried out using a computational field limited to the cavity (Bilgen & Oztop, 2005).

In an extended arithmetic area, Chan and Ten performed a numerical analysis of shallow fully open cavities as well as a comparison with square cavities. They found that an open square cavity with two adjacent horizontal sides and an isothermal vertical side facing the hole can achieve satisfactory heat transfer results, especially for high Rayleigh numbers.

Similarly, Muhammad used a constrained arithmetic field to investigate fully inclined open square cavities. In contrast to Chan and Ten, the slopes for both velocity components were zero at the start. The flow was found to be unstable at large Rayleigh numbers and small tilt angles, and heat transfer was found to be insensitive to tilt angle.

At constant temperature and pressure, Polat and Bilgen (2002) examined shallow, numerically inclined, fully open cavities with a hole in contact with a tank. Two adjacent walls were insulated, and the hole was heated using a steady heat flow. The only arithmetic region was the cavity.

Miyamoto et al. numerically investigated a square cavity that had three isothermal walls, and was partially and completely open. The dimensionless measurement for a partially open bore was 0.5, and it was located in the center. The Rayleigh number varied from 0.7 to 7 * 105 for straight bores and from 7 * 103 to 7 * 104 for inclined bores. They used a broad range of arithmetic. A review of the literature shows that in experimental studies with partially open cavities, the Rayleigh number either remained constant or was exceptionally high. The three sides of the same numerical analysis were heated (Miyamoto, 1989). Following the applications found in thermal systems, the wall opposite the opening is isothermal and in touch with the air of the open case. Insulation is installed on the final sides. Natural convection dissipates heat from the heated wall through the opening, enabling room-temperature air to flow through it (Bilgen & Oztop, 2005).

Natural convection in a closed cavity is used in many fields, including thermal power, petrochemicals, aerospace, and construction. Many studies have been performed in order to better understand this phenomenon. Natural stratified convection in a rectangular and square cavity was computed by De Vahl Davies (Massinissa, 2017).

Bejan and Georgiadis (1992) conducted extensive research on the sensitivity of fluid properties, particularly the effect of the Prandtl number on normal pressure. Yoo (1999) investigated the transfer of free convective flux in a horizontal ring with a wide gap. They find that the Prandtl number depends on the bifurcation points. Poujol, Rojas, and Ramos (2000) investigated spontaneous convection for a Prandtl spike in a square cavity. Natural convection is known to be affected by the set of boundary conditions applied to the walls, as well as the cavity's position in relation to the center of gravity (Cianfrini et al., 2005; Huelez, & Rechtman 2013).

Because of the buoyancy forces inherent in temperature gradients, which tend to increase heat transfer, normal convection becomes more common as the temperature gradient increases. (Mahmoudi, 2011). Al- Sadaoui et al. (2015) conducted numerical research on natural convection in square cavities with a thin plate exposed to high temperature inside the enclosure. They investigated how the plate impacted flow and heat transmission. The plate's geometry and location have the greatest influence on heat transmission. As the Rayleigh number increases, heat transmission becomes more visible.

Natural stratified convection was investigated by Aminossadati et al. (2014) in a thin-finned square cavity with a uniform magnetic field. At higher Rayleigh numbers, the magnetic field has an impact on the temperature, rate of heat transfer, and flux fields of the cavity.

Oztop et al. (2011) investigated the fluid flow and heat transmission caused by buoyant forces in a tube inserted into a square cavity filled with fluid. The results show that changes in Rayleigh number influence the flow field and heat transfer, and that this is dependent on where the tube is inserted.

Regarding the numerical studies that support the experimental studies, the heat transfer by natural convection and thermal radiation on a cubic-type solar receiver, studied by Montiel et al. (2015), demonstrates that using a model with variable thermophysical properties over the Boussinesq approximation improves the comparison of experimental and theoretical results. Nardini and Paroncini, (2012) examine the impact of various heat source sizes and locations on convective heat transfer. For Rayleigh numbers between 104 and 105, there is a high degree of agreement between empirical and numerical evidence.

As Rayleigh numbers increase, convective heat evolution accelerates, and the magnitude and location of heat sources affect the velocity range. Algebraic geometry is another field of study. In a numerical analysis of natural convection in an inclined triangle cavity under various thermal boundary conditions, Al-Mahmoudi et al. (2013) found that the angle of inclination has a significant effect on heat transmission. Koca et al. (2007) investigated natural convection in triangle bundles numerically. The flow field and temperature were affected by changes in the Rayleigh (2012) number, Prandtl number, heater position, length, and temperature. For the cylindrical bore, Chandra and Chhabra investigated natural convection heat transmission from a heated horizontal semicircular cylinder. They developed predictive relationships to calculate the value of the Nusselt number based on Prandtl and Grashof numbers in a novel application.

Pesso and Piva (2009) examined a cavity heated through its side walls numerically and theoretically at low Prandtl numbers with large density variations. Heat transfer becomes worse as the Prandtl number increases, especially for very large Rayleigh numbers, according to the research.

Hinojosa and Cervantes-de Gortari (2010) provided a numerical study of natural convection in an isothermal open cavity in three dimensions. Each of these pieces depicts a distinct physical phenomenon associated with natural convection in cavities (Massinissa, 2017).

The Rayleigh numbers discovered by the authors for the transition region between 103 and 109 are in excellent agreement with those reported in the literature. Using the same approach, Mezrhab et al., (2006) investigated the effect of the cavity's slope and the presence of an internal spacer. Rayleigh numbers between 6103 and 2104 showed the greatest decrease in heat transfer.

Some investigations combine the impacts of radiation and natural convection in cavities that are heated differentially (Bahlaoui, 2007). When there is an internal heat source in the cavity, the interior flow properties change significantly. Natural convection in cavities with an inner heat source or internal barriers is investigated by Kuznetsov et al. (2006). The cavity frequently functions as a partial opening, allowing mass movement and, as a result, cooling. Mariani and Silva investigated the thermal behavior and fluid dynamics of air in partly open 2D containers using a numerical analysis based on two sides of the radius, H/W = 1 and 2 (Mariani & Silva, 2007). The container had a small heat source on the lower or left side and an opening on the right wall, and could be used in three ways. Ra was the subject of numerical calculations between 103 and 106, and it was discovered that variations in this parameter significantly affect the average local Nusselt numbers (Nu) for the containers (Supraja & Raju, 2021).

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Mariani and Coelho conducted a second study to examine static heat transfer and flow phenomena in enclosures with three aspect ratios (H/W = 1, 2, and 4) and a heat source positioned on the bottom wall in three distinct modes. (Mariani, 2007). Kandaswamy et al. investigated the impact of heat source location and size in a similar study. This research focused on Grashof codes 103 through 105 (Kandaswamy, 2007).

In light of this, this research looks at natural convection in a partially open square cavity with three distinct openings in the right wall, H/4, H/2, and 3H/4, where H is the cavity's height. The cavity had an internal heat conduction source and was exposed to temperature differences between the left and right vertical sides. The impact of an internal heat source at R = 400, 1000, and 2000 intensities on the thermodynamics, fluid dynamics, and mass flow rate of the air inside the cavity was investigated.

The nonlinear coupled partial differential equations of the flow field and temperature were transformed using the finite element technique into a matrix form of equations that could be solved iteratively with the aid of computer code. The precursor to the finite element method, the Galerkin Finite Element method, divides the material sphere into smaller pieces by using three overlapping trigonometric elements.

Numerical results are presented in terms of current functions, isotherms, temperature profiles, and Nusselt numbers. This study looks at natural convection in a partially open square cavity with openings on the right side that are H/4, H/2, and 3H/4 in size, where H is the cavity's height. The cavity was subjected to temperature differences between the left and right vertical sides and had an internal heat conduction source. Investigations were carried out to determine how an internal heat source with R = 400, 1000, and 2000 impacted the thermodynamics, fluid dynamics, and mass flow rate of the cavity's air (Supraja & Raju, 2021).

5. Conclusion

Thermal power, petrochemical, aerospace, and construction are just a few of the many sectors that use natural convection that happens in a closed cavity. Many studies have been conducted to better understand this occurrence. Previous research results have explained a variety of physical phenomena observed during natural convection in cavities. When different densities of fluids are influenced by gravity, an increase in temperature causes a drop in density, causing fluids to move as a result of stresses and forces.

This research looked at the rheology and isometrics of a square cavity that was partially open and contained a heat source. Previous study discovered that the presence of a heat source, the size of the opening, and the temperature difference between the vertical walls all have a significant influence on the fluid's thermodynamics and fluid dynamics. Large secondary cycles occur inside the cavity when the flow is mainly controlled by the heat source, and the isotherms behave similarly (high R and low Rae values). As a result, the local Nusselt number numbers rise. (in modulus). When convection is controlled by the temperature difference between the walls, the volume of the secondary circulation is negligible in comparison to the primary circulation and consists primarily of horizontal isotherms (low values of R and high values of Rae). Except for the smaller size H/4, the contribution of convection to the local Nusselt number increases in the lower region near the hot wall and in the upper region near the cold wall as the air temperature rises in the higher region of the cavity near the hot wall for larger Rayleigh numbers and R values. Lower local Nusselt numbers appear only if the R values are lower as a result of the simultaneous drop in air temperature in the lower region to the right of the cavity near the cold wall.

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