Review On Enhancement Of Natural Convection Heat Transfer Inside Enclosure

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ABSTRACT: Heat transfer by natural convection from a hot source to its cold surrounding or then to cold enclosure were used in wide engineering applications such as solar energy, thermal storage plants, cooling of reactors, microelectronic systems, and gas insulated electrical transmission systems. The aim of existing of the enclosure is to reduce the heat transfer from the inner hot wall or to protect the inner body in harsh outdoor environment. Many authors carried out studies about this topic and used different methods to enhance the heat transfer such as using of nanofluids or porous media to increase the thermal conductivity of the base fluid. Other methods included applying the vibration and magnetic field on the system, or by changing the geometry of the enclosure, Rayleigh number, thermal boundary conditions, etc. The present paper includes a review on the natural convection heat transfer enhancement techniques inside enclosure with different geometries.

KEYWORDS: Natural convection, heat transfer, cavity, porous media, enclosure

INTRODUCTION

Heat transfer process by natural convection in cavities has been received widespread attention by researchers in the last two decades because of its importance in the engineering and industrial applications. The applications include cooling of nuclear reactor, electronic devices, solar collectors, passive cooling space heating, and geophysical systems [1].

Generally, heat transfer enhancement techniques can be divided into two types; passive and active techniques. The first one requires special surface geometries such as corrugated surface, thermal packaging such as heat generation, or fluid additives such as nanofluids and porous medium. The second technique requires external means, such as magnetic fields and vibration. Many authors tried to enhance the natural convection heat transfer by using different parameters such as geometry, inclination angle, Rayleigh number, shape and position of heat source [1-17]. The enhancement techniques by increasing the thermal conductivity of the base fluid is achieved by adding nanofluids and porous media [18-34]. The study of magnetic field and vibration effects on the heat transfer and fluid field has significant attentions of engineers and sciences [35-40], because of its wide industrial applications, such as metal casting and liquid metal cooling for fusion reactor, etc. Hussein et al. [41] Studied the enclosure heat transfer characteristics numerically using a rectangular model enclosure. Meanwhile Alguboori et al. [42] studied the elliptic enclosure with circular heat source. Both free and forced convection in enclosure was studied as well [43, 44]. Enclosure fitted with porous medium was studied to show the effect of porosity on the heat transfer characteristics of enclosure [45, 46].
The present paper comprises a literature review for heat transfer enhancement techniques by using different geometries and thermal boundary conditions. It has given important conclusions resulted from these studies.

HEAT TRANSFER ENHANCEMENT USING DIFFERENT SHAPES AND POSITIONS OF HEAT SOURCE

Ding et al. (2006), [1] studied the influences of eccentricities and angular positions on the heat transfer process in an eccentric square enclosure with a hot circular inner cylinder. It was concluded that the natural-convection heat transfer enhances at large Rayleigh number ($10^6$). Ahmed et al. (2006), [2] used a hot single and multiple partitions attached to the cold wall of inclined square cavity. It is noticed that for low, the average heat transfer rates are better in inclined cavities than in vertical ones; and the opposite is obtained for high Rayleigh number ($Ra = 10^6$). Abdullatif and Ali (2007), [3] studied the effect of wall thickness on heat transfer in a square cavity containing three thick cold walls and one thin hot wall. The heat source was an inclined thin fin with three arbitrary lengths attached to the middle point of vertical wall. The results show that the inclination angle and length of fin affect greatly the heat transfer rates inside the enclosure. Xu Xu et al. (2009), [4] investigated the influences of Rayleigh number, radius ratio, and inclination angle of the inner hot triangular cylinder on natural convection heat transfer inside a horizontal circular enclosure. The results show that there is no effect for inclination angle of inner cylinder on the heat transfer rate at constant radius ratio. Yasin et al. (2009), [5] examined the influence of inclination angle, corner heater lengths, and Prandtl number on the natural convection heat transfer in an inclined square enclosure. They concluded that these parameters have important effects on average Nusselt numbers. Moreover, for low Prandtl number Pr < 1, the variations of mean Nusselt number is more pronounced. Zi-Tao et al. (2010), [6] examined the influence of Prandtl number on natural convection heat transfer in a circular enclosure containing concentrically a coaxial triangular cylinder. It is observed that the flow pattern and thermal field change only for a low Prandtl number (Pr = 0.03). Xu et al. (2010), [7] investigated the influence of inclination angle of cold triangular enclosure filled with air and having a horizontal hot cylinder on the heat transfer rate. The results show that at constant aspect ratio, there are no effects for the inclination angle and cross-section geometry on the thermal field the flow patterns. Han Wang et al. (2011), [8] studied the effect of aspect ratio on natural convection generated from a rectangle cylinder to its concentric circular enclosure. It is noticed that the vortex generates on the upper region of the rectangle cylinder and it has a significant effect on the heat transfer rates for the aspect ratio equals to 1.2. Zi-Tao et al. (2011), [9] studied the effect of Grashof number, aspect ratio, and inclination angle of the hot triangular inner cylinder on natural convection arising from it towards a triangular enclosure. It is concluded that various phases are specified throughout the flow development. Hojat and Seyed (2012), [10] took two shapes of inner hot cylinder at different locations inside a cold square enclosure. They concluded that for the same Rayleigh number and aspect ratio, the hot circular cylinder gives higher heat transfer rates than square hot cylinder. Roslan et al. (2014), [11] investigated the conjugate natural convection resulted from left heated wall of square enclosure containing a conductive polygon object. The results show that the average Nusselt number increases with increase in size of the solid polygon until reaches to maximum value after which Nusselt number decreases. Xing et al. (2015), [12] used different shapes of inner cylinder inside circular enclosure with or without surface radiation. It was concluded that the heat transfer process surface enhances with increase in the radiation and, presence of corners and larger top space. Ahmed et al. (2015), [13] investigated the heat transfer by natural convection in a rectangular cavity with a triangular roof. They concluded that there is a significant effect of solid strip located inside the cavity on the flow field and thermal patterns. Balamurugan and Krishnakanth (2015), [14] compared between the square and triangle hot bars inside square enclosure filled with air. It is observed that the heat transfer rate in the square bar is higher than that in the triangle bar at the same Rayleigh number and aspect ratio. Sharma and Kumar (2017), [15] used semi-circular cylinder as a hot source placed inside a square cavity. It is observed that the heat transfer rate enhances, for all incidences, for Rayleigh number $Ra \geq 10^4$. Yen et al. (2017), [16] concluded that the inner cylinder position inside cubical enclosure has significant effect on the natural convection heat transfer at $Ra=10^4-10^6$ and Pr$=0.7$. Krunal and Manikandan (2017), [17] studied the natural convection arising from hot hexagonal block inside a square enclosure filled with non-Newtonian fluid. It is concluded that the heat transfer rate increases with increase in Grashof and Prandtl numbers; while natural convection decreases for power law index value. Table 1 shows a summary of the above literatures.

**Table 1.** Heat transfer enhancement using different shapes and positions of heat source.
<table>
<thead>
<tr>
<th>SI no</th>
<th>Researchers</th>
<th>Geometry</th>
<th>Buoyancy strength</th>
<th>Originality</th>
</tr>
</thead>
</table>
| 1     | Ding et al. (2006), [1] | ![Geometry Image] | $10^4 \leq \text{Ra} \leq 10^7$  
$\Pr = 0.71$ (air) | Using of local multiquadrics-based differential quadrature (MQ-DQ) method to solve this problem. |
| 2     | Ahmed et al. (2006), [2] | ![Geometry Image] | $10^3 \leq \text{Ra} \leq 10^6$  
$\Pr = 0.71$ (air) | Using of numerical coupling between the lattice Boltzmann equation and finite-difference to solve this problem. |
| 3     | Abdullatif and Ali (2007), [3] | ![Geometry Image] | $\text{Ra} = 10^4 \cdot 10^5$  
$\Pr = 0.707$ | Conjugate heat transfer with heated inclined fin |
| 4     | Xu Xu et al. (2009), [4] | ![Geometry Image] | $10^3 \leq \text{Ra} \leq 10^6$  
$\Pr = 0.71$ | Using wide ranges of radius ratios, and inclination angles for the inner triangular cylinder |
| 5     | Yasin et al. (2009), [5] | ![Geometry Image] | $10^3 \leq \text{Ra} \leq 10^6$  
$0.07 \leq \Pr \leq 70$ | Wide range of heater lengths in both directions.  
Wide ranges of $\Pr$, $\text{Ra}$, and inclination angle |
| 6     | Zi-Tao et al. (2010), [6] | ![Geometry Image] | $10^3 \leq \text{Ra} \leq 10^6$  
$10^{-2} \leq \Pr < 10^3$ | Using wide range of Prandtl number |
| 7     | Xu et al. (2010), [7] | ![Geometry Image] | $10^3 \leq \text{Ra} \leq 10^7$  
$\Pr = 0.71$ (air) | High ranges of Rayleigh number and inclination angle of triangular enclosure. |
| 8     | Han Wang et al. (2011), [8] | ![Geometry Image] | $10^3 \leq \text{Ra} \leq 10^6$  
$\Pr = 0.71$ | Using rectangular cylinder inside circular enclosure |
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<table>
<thead>
<tr>
<th>No.</th>
<th>Author(s)</th>
<th>Reference</th>
<th>Conditions</th>
<th>Observations</th>
</tr>
</thead>
</table>
| 9   | Zi-Tao et al. (2011), [9]        | ![Image](image1) | \(10^5 \leq Gr \leq 10^7\)  
\(Pr=0.71\) (air) | Unsteady natural convection. 
High values of Grashof number. |
| 10  | Hojat and Seyed (2012), [10]     | ![Image](image2) | \(Ra=10^4 - 10^5\)  
\(Pr=0.707\) (air) | Taking of two shapes of inner cylinder at different locations |
| 11  | Roslan et al. (2014), [11]       | ![Image](image3) | \(10^5 \leq Ra \leq 10^6\)  
\(Pr=0.71\) (air) | • Study of conjugate natural convection heat transfer 
Taking of new geometry of inner cylinder |
| 12  | Xing et al. (2015), [12]         | ![Image](image4) | \(10^4 \leq Ra \leq 10^5\) | Using of different shapes of inner cylinder with or without surface radiation |
| 13  | Ahmed et al. (2015), [13]        | ![Image](image5) | \(10^5 \leq Ra \leq 10^6\)  
\(Pr=0.7\) (air) | Using new geometry with different thermal boundary conditions. |
| 14  | Balamurugan and Krishnakanth (2015), [14] | ![Image](image6) | \(Q=24.7-61\) W  
\(Pr=0.7\) (air) | Using of square and triangle cylinder with different aspect ratios |
| 15  | Sharma and Kumar (2017), [15]    | ![Image](image7) | \(Ra=10^4\)  
\(Pr=0.7\) (air) | Using of semi-circular cylinder placed at various incidences |
| 16  | Yen et al. (2017), [16]          | ![Image](image8) | \(10^4 \leq Ra \leq 10^6\)  
\(Pr=0.7\) (air) | Eccentric cube annulus with inner circular cylinder at different vertical locations |
| 17  | Krunal and Manikandan (2017), [17] | ![Image](image9) | \(10^4 \leq Gr \leq 10^6\), 
\(1 \leq Pr \leq 100\), power law index 
\(0.5 \leq n \leq 1.5\). | Using of non-Newtonian fluid |
HEAT TRANSFER ENHANCEMENT USING NANOFLUIDS AND POROUS MEDIA

Yasin et al. (2007), [18] investigated the natural convection heat transfer in a right-triangular cavity containing a hot square body. The results show that the heat transfer characteristics depend strongly on thermal boundary conditions of the body. Hakan and Eiyad (2008), [19] enhanced the natural convection heat transfer arising from the finite lengths of vertical wall of rectangular enclosure using nanofluids. They concluded that the heat transfer rates increase with increase in heater height. Elif (2009), [20] used Cu, Ag, CuO, Al$_2$O$_3$, and TiO$_2$ nanoparticles to increase the thermal conductivity of water in an inclined square enclosure with heat source located at the center of the left wall. It was concluded that the average Nusselt number increases with increase in particle volume fraction and Rayleigh number and it decreases with decrease in inclination angle and increase in heater length. Yasin et al. (2009), [21] concluded that there are significant changes in the behavior of fluid field and thermal patterns inside right-angle porous trapezoidal enclosure containing a fluid-saturated porous medium. Bouchoucha and Bessaïh (2015), [22] concluded that the using of Cu-H$_2$O nanofluid increases the performance of heat transfer higher than Ag, Al$_2$O$_3$ and TiO$_2$-water nanofluids in square cavity with hot and cold vertical walls; respectively. Moreover, the heat transfer rate increases as the length of the heat source decreases. The free convection in a triangular cavity containing an insulated circular body and filled with a saturated porous media in presence of heat generation was studied by Raju et al. (2015), [23]. It is noticed that the heat transfer rate increases with increase in both heat generation and circular body size. Balla and Naikoti (2015), [24] studied the natural convection heat transfer in a square cavity filled with Cu, TiO$_2$ and Al$_2$O$_3$ nano-fluid-saturated porous medium in the presence of thermal radiation. It is noticed that the strength of the streamlines increases as the radiation parameter $R_A$ increases. The heat transfer rate increases as the radiation parameter $R_A$ and Rayleigh number $Ra$ increase, while it decreases with the increase in nanoparticle volume fraction $\phi$. Ravnik and Škerget (2015), [25] studied the natural convection heat transfer in an inclined cooled cubic enclosure with a hot circular and an ellipsoidal cylinder. They added Al$_2$O$_3$, Cu and TiO$_2$ nanoparticles to pure water and air for comparison between two fluids. The results show that the using of nanofluids gives a smaller increase in heat transfer efficiency when the convection is the dominant factor in the heat transfer process. Ghalambaz et al. (2016), [26] studied the effects of the viscous dissipation and radiation on the free convection in a square cavity filled with porous media saturated with a nanofluid. It is concluded that the heat transfer rate at hot wall increases with decrease in Eckert number. Rasul et al. (2017), [27] found the maximum heat transfer rate in a C-shaped cavity saturated by a nanofluid at $Ra = 10^3$ is obtained when the heat source is located at the top horizontal cavity. While at $Ra = 10^6$, the heat transfer rate increases when the heat source is located at the vertical cavity. Rado and Habibis (2017), [28] studied the natural convection in an inclined square porous cavity filled with H$_2$O-Ag nanoliquid. The heat transfer enhancement increases linearly with increase in the Ag concentration depending on increase in the orientation angles. Alsabery (2017), [29] analyzed natural convection of a H$_2$O-Ag, Cu, Al$_2$O$_3$, TiO$_2$ nanofluid in an inclined enclosure containing a porous layer and a nanofluid layer with sinusoidal temperature distribution imposed on the two vertical walls. It is concluded that the heat transfer mechanism is markedly affected by the porous layer increment. Mehryan et al. (2018), [30] used local thermal non-equilibrium model to investigate the conjugate free convection heat transfer of micropolar nanofluid in a porous cavity. The results show that the power of micro-rotations increases with increase in the Darcy– Rayleigh numbers and vortex-viscosity parameter. Zehba (2019), [31] studied the natural convection of dusty hybrid nanofluids in a rectangular enclosure having two inclined hot fins with different lengths. It obvious that the increasing of the mixture densities ratio and dusty parameter decreases the heat transfer rate. Jasem (2019), [32] studied non-equilibrium conjugate free convection in the layer of porous media closed by two vertical thick walls. It is concluded that the heat transfer rate of the fluid phase increases slightly with increase in the porous-fluid interface convection parameter (H). Abeer (2020), [33] found that the heat transfer rate in the corrugated hot cylinder enclosed by square enclosure is slightly better than that in the smooth cylinder under the same conditions, but generally, the heat transfer rate is decreased by using the corrugated surface. Heat transfer enhancement increases up to 10% as the nanoparticle volume fraction increases. Akeel et al. (2020), [34] investigated the effect of porous media thermal conductivity on the flow field and thermal characteristics in a square cavity filled with air mixed by saturated porous medium. The natural convection arising from a hot inner circular cylinder located at the center of cavity. The results show that increasing the thermal conductivity of fluid at the expense of thermal conductivity of porous material leads to strong convection currents on the upper region of enclosure, while the conduction heat transfer is the
dominated at the other regions of enclosure. Table 2 shows the summary of literatures deal with Heat transfer enhancement using nanofluids and porous media.

**Table 2. Heat transfer enhancement using nanofluids and porous media.**

<table>
<thead>
<tr>
<th>SI no</th>
<th>Researchers</th>
<th>Geometry</th>
<th>Buoyancy strength</th>
<th>Originality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yasin et al. 2007, [18]</td>
<td>10^6 ≤ Ra ≤ 10^6&lt;br&gt;Pr=0.71 (air)</td>
<td>Porous enclosure with inner square body</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Hakan and Eiyad (2008), [19]</td>
<td>10^3 ≤ Ra ≤ 5 × 10^5&lt;br&gt;Nanofluid volume fraction (0 ≤ φ ≤ 0.2)</td>
<td>Using different types of nanoparticles with different thermal boundary conditions</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Elif (2009), [20]</td>
<td>10^3 ≤ Ra ≤ 10^6&lt;br&gt;(0 ≤ φ ≤ 0.2)&lt;br&gt;inclusion angles varied from 0° to 90°,</td>
<td>Using different nanoparticles were used: H_2O-Cu, CuO, Ag, TiO_2 and Al_2O_3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Yasin et al. (2009), [21]</td>
<td>100 ≤ Ra ≤ 1000</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Bouchoucha and Bessaïh (2015), [22]</td>
<td>(10^3 ≤ Ra ≤ 10^6),&lt;br&gt;(0 ≤ φ ≤ 0.10),&lt;br&gt;dimensionless heat source lengths =0.5- 1.</td>
<td>Using different types of nanoparticles (Cu, Al_2O_3 and TiO_2),</td>
<td></td>
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<td>6</td>
<td>Raju et al. (2015), [23]</td>
<td>Ra=10^5&lt;br&gt;Pr=0.71</td>
<td>Triangular porous enclosure in presence of heat generation</td>
<td></td>
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<tr>
<td>7</td>
<td>Balla and Naikoti (2015), [24]</td>
<td>Ra=50,200,800, thermal radiation parameter (Rd=0, 0.5, 1)&lt;br&gt;φ=0.02, 0.2, 0.6</td>
<td>Using Cu, TiO_3 and Al_2O_3 nanofluid-saturated porous medium</td>
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<td>Notes</td>
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<tr>
<td>8</td>
<td>Ravnik and Škerget (2015), [25]</td>
<td>$10^5 \leq Ra \leq 10^6$&lt;br&gt;Nano fluid&lt;br&gt;Water&lt;br&gt;Air</td>
<td>• Using Al$_2$O$_3$, Cu and TiO$_2$ nanofluid&lt;br&gt;• 2D &amp; 3D&lt;br&gt;Elliptic and circular inner cylinder</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Ghalambaz et al. (2016), [26]</td>
<td>Ra = 100, Ec = 0.001,&lt;br&gt;$\varepsilon = 0.7$, $N_R = 1/4$, $N_b = 10^{-6}$, $N_i = 10^{-6}$, $Le = 1000$ and $N_r = 20$</td>
<td>Viscous dissipation and radiation effects</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Rasul et al. (2017), [27]</td>
<td>Ra = $10^3$-$10^6$ and $\varphi = 0 - 0.05$</td>
<td>using a C-shaped cavity with heat source.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Rado and Habibis (2017), [28]</td>
<td>Ra = 500 and $\varphi = 0 - 0.05$</td>
<td>Square Inclined Porous Enclosure Filled with an Ag Nanoliquids</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Alsabery et al. (2017), [29]</td>
<td>H$_2$O-Ag, Cu, Al$_2$O$_3$, TiO$<em>2$ nanofluid, $Ra</em>{bf} = 10^5$, $Da = 10^{-4}$ and $\varepsilon = 1$, $\varphi = 0$ &amp; $0.1$</td>
<td>natural convection of a nanofluid in a square enclosure containing a porous layer and a nanofluid layer with sinusoidal temperature distribution</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Mehryan et al. (2018), [30]</td>
<td>Da = 10, Ra = 1000, porosity $\varepsilon = 0.1 - 0.9$, interface parameter $H = 1 - 1000$, $K_t = 0.1 - 10$, $\varphi = 0 - 0.08$, $R_{k} = 0.1 - 10$ (thermal conductivity ratio).</td>
<td>Conjugate natural convection within a porous square enclosure occupied with micropolar nanofluid</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Zehba (2019), [31]</td>
<td>Fin inclination angle $\gamma$ ($0^\circ - 180^\circ$), fins lengths $L_1 = L_2$ ($0.1 - 0.9$), $\varphi = 0.01 - 0.04$, mixture densities ratio $D_z$ ($1 - 1000$) and dusty parameter $\alpha_s$ ($0.001 - 0.01$). $Ra = 10^5$</td>
<td>Using hybrid nanofluids in an enclosure including two oriented heated fins at different lengths and inclination angles</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Jasem (2019), [32]</td>
<td>$10^5 \leq Ra \leq 10^6$, $10^5 \leq Da \leq 10^{-3}$</td>
<td>The local thermal nonequilibrium approach is employed for modelling the porous layer.</td>
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</tbody>
</table>
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The amplitude, \(0 \leq A \leq 0.3\), number of undulations \(3 \leq N \leq 6\), the radius, \(Ra= 10^7\).

Using wavey heat source inside square enclosure.

Pr=0.71 and Da=0.01, \(Gr=5 \times 10^6, 10^7, 5 \times 10^7\) porosity \((\varepsilon=1.0)\), thermal conductivity ratios \((k_r)\) are \(0.1, 0.5, 1.0, 2.5, 5, 7.5, \) and 10.

Effect of thermal conductivity of porous media on thermo-fluid fields

HEAT TRANSFER ENHANCEMENT USING VIBRATION AND MAGNETIC FIELD

Esam (2008), [35] investigated the influences of transversely oscillating frequency for the inner cylinder enclosed by annulus enclosure on the flow field and thermal behavior. It is concluded that the oscillating frequency of inner cylinder greatly enhances the average heat transfer rate at the inner cylinder. Revnic et al. (2011), [36] studied the influences of magnetic field and heat generation on the natural convection in a square cavity filled with a fluid-saturated porous medium. It is noticed that the heat transfer diffusion becomes notable even though the Rayleigh number increases with increase in Hartmann number. Sheikholeslami et al. (2012), [37] used three enhancement techniques of natural convection in a cold circular enclosure containing hot sinusoidal cylinder; which are using of Cu–water nanofluid, horizontal magnetic field, and corrugated inner cylinder. It is observed that in the presence of magnetic field, enhancement ratio increases with increase in Rayleigh number while an opposite behavior was observed in the absence of magnetic field. Sheikholeslami et al. (2013), [38] concluded that Hartmann number has a significant effect on the fluid field and thermal patterns in a curved-shape cavity. Moreover, the heat transfer rates decrease as Hartmann number increases. Ishra et al. (2018), [39] concluded that the heat transfer process in a rectangular enclosure containing Cu-H2O nanofluid increases with increase in Rayleigh number and decrease in Hartmann number. Moreover, the increasing of solid volume fraction leads to enhancing the heat transfer rate. Iman and Razieh (2020), [40] proved that the magnetic field orientation has a significant effect on natural convection of water–nanofluids in a square porous enclosure. Additionally, the increasing of magnetic field strength reduces the heat transfer rate and this effect vanishes with increase in the magnetic field inclination angle. Table 3 shows the literatures deal with heat transfer enhancement using vibration and magnetic field.

Table 3. Heat transfer enhancement using vibration and magnetic field.

| SI
| Researchers         | Geometry | Buoyancy strength | Originality                        |
|-------|---------------------|----------|-------------------|------------------------------------|
| 1     | Esam M. Alawadhi (2008), [35] |          | \(10^4 \leq Ra \leq 10^5\)  
Pr=0.71 | Study the effect of oscillating of inner cylinder |
| 2     | Revnic et al. (2011), [36] |          | Ra=10^3 & 10^5  
Ha=1 & 1000 fluid-saturated porous medium | • Using of magnetic field and heat generation  
• unsteady natural convection |
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<table>
<thead>
<tr>
<th></th>
<th>Authors</th>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
</table>
| 3 | Shekholeslami et al. (2013), [37] | $10^3 \leq \text{Ra} \leq 10^5$  
Pr=0.025  
Ha=0, 10, 100 | Study magnetic field effect on natural convection in a curved-shape enclosure for liquid metal |
| 4 | Sheikhholeslami et al. 2012, [38] | $10^3 \leq \text{Ra} \leq 10^5$  
Cu-water nano fluid. | - Using of inner sinusoidal circular cylinder.  
- Study of magnetic field effect |
| 5 | Ishra et al. (2018), [39] | $\text{Ra} = 10^3 - 10^7$,  
with $\phi = 0 - 0.05$,  
Pr=6.2,  
Ha= 0 to 60 | (MHD) conjugate natural convection flow in a rectangular enclosure filled with copper water nanofluid. |
| 6 | Iman and Razieh (2020), [40] | $H_a = 1, \gamma = 0 - \frac{\pi}{2}$,  
and $\phi = 4\%$,  
Ra=10,100,1000. | using magnetic field with nanofluid in a porous cavity. |

CONCLUSIONS

The present paper presents the available literatures related to study the steady and unsteady, two- and three-dimensional natural convection heat transfer, or combined natural convection-radiation, or conjugate heat transfer inside different geometries of cavities with different shapes of hot sources and boundary conditions. It is noticed that, different parameters play important rule in the heat transfer mechanism. The most important conclusions can be noticed from the above literatures are:

1. The natural-convection heat transfer enhances with increase in Grashof and Prandtl numbers (or Rayleigh number).
2. The thermal boundary layer at the hot and cold side walls increases with increase in the internal heat source.
3. There is a significant effect for the solid strip in the cavity on the fluid flow field and thermal distribution.
4. The average heat transfer rate increases with increase in particle volume fraction of nanofluid.
5. The inclination angle of enclosure or heat source has a significant effect on the heat transfer rate.
6. The geometry of the corrugated enclosure or heat source has a significant effect on the flow field and thermal pattern.
7. The streamlines and Nusselt numbers increase with increase in the Rayleigh and Darcy numbers (using of porous medium).
8. The heat transfer rate of the fluid phase increases slightly with increase in the porous-fluid interface parameter.
9. The magnetic field orientation has a significant effect on natural convection.
10. The oscillating frequency of inner cylinder greatly enhances the average heat transfer rate.

REFERENCES


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