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Review on Heat Transfer Process Inside Open and Closed Porous Cavity

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ABSTRACT

Many researchers used different methods in their investigations to enhance the heat transfer coefficient, one of these methods is using porous medium. Heat transfer process inside closed and open cavities filled with a fluid-saturated porous media has a considerable importance in different engineering applications, such as compact heat exchangers, nuclear reactors and solar collectors. So, the present paper comprises a review on natural, forced, and combined convection heat transfer inside a porous cavity with and without driven lid. Most of the researchers on this specific subject studied the effect of many parameters on the heat transfer and fluid field inside a porous cavity, like the angle of inclination, the presence of vibration, magnetic fields, and heat generation. They used different thermal and hydrodynamic boundary conditions, different geometries of cavity, and different saturated-fluids. Results manifested that the fluid and thermal characteristics enhance greatly as porosity increases at a high value of Darcy number. Also, vibrational effects are a dominant factor in the heat transfer process only at high Darcy and Reynolds numbers.
Keywords: Heat Convective, Natural, Lid-Driven, Porous Medium, Enclosure.

مقالة تخص عملية انتقال الحرارة داخل الفوهات المسامية المغلقة و المفتوحة

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الخلاصة

أستخدم العديد من الباحثين طرق مختلفة في تحرياتهم لتحسين معامل أنتقال الحرارة. واحدة من تلك الطرق هي أستخدام الوسط المسامي. أن عملية أنتقال الحرارة داخل الفوهات المغلقة و المفتوحة المملوؤة بمائع مشبع بوسط مسامي لها أهمية معتبرة في عديد من التطبيقات الهندسية، مثل المبادلات الحرارية, المفاعلات النووية, و المجمعات الشمسية. لذلك, العمل الحالي يعرض مقالة تخص عملية أنتقال الحرارة بالحمل الحر, القسري, و المختلط داخل فوهة مسامية بوجود و بعدم وود الغطاء المتحرك. أغلب

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الباحثين درسوا في هذا الموضوع تأثير متغيرات عديدة على عملية أنتقال الحرارة و مجال المائع داخل فوهة مسامية, مثل زاوية الميل, وجود الأهتزاز, الحيز المغناطيسي, و توليد الحرارة. لقد أستخدموا شروط حدية حرارية و هيدروديناميكية مختلفة, أشكال هندسية مختلفة للفوهات, و موائع مشبعة مختلفة. بينت النتائج أن الخصائص الحرارية و المائع تتحسن بشكل كبير بزيادة المسامية عند القيم العالية لرقم دارسي. كذلك, تأثيرات الأهتزاز هي عامل مسيطر بعملية أنتقال الحرارة فقط عند القيم العالية لرقم دارسي و رقم رينولدز.

الكلمات الرئيسية: الحرارة بالحمل, طبيعي, غطاء متحرك, وسط مسامي, حيز مغلق.

1. INTRODUCTION

Convective heat transfer is influenced by two modes of energy transfer between a solid wall and the adjacent fluid. The first mode is called natural convection in which the fluid motion is caused by buoyancy forces due to the density differences resulted from the variation of temperature in the fluid. The second mode of fluid motion is known as forced convection which is caused by forcing fluid over the wall surface by using external means, such as fan, compressor, or internal means within the system itself, like rotating cylinder and driven lid. In most practical applications, both modes are presented, this is known as mixed convection. Heat transfer enhancement leads to energy saving by reducing the time of operating as well as reducing the cost of constructing by decreasing the size of equipment. There are several methods to increase the heat transfer performance. One of these efficient methods is increasing the thermal conductivity of the working fluid by using nanofluids and porous media. Porous medium is formed by many closely packed particles containing pores (voids) filled with fluids **(Kaviany, 1992)**, see **Fig.1**. It is characterized by its porosity. The porosity of a medium represents the fraction of the actual total volume of the porous media filled the void space **(Nield and Bejan, 1992)**. Other important properties of the porous medium (e.g. permeability, electrical conductivity, tensile strength, etc.) can be derived from the respective properties of its basic elements (packed particles and fluid) and the porosity media in addition to pores structure.

The use of porous media in the convective heat transfer applications has received a considerable attention in the last two decades from many researchers because of its importance in many uses of industry **(Kakac, et al., 1991)**, such as heat transfer through an insulator filled with air and heat transfer from pipes buried in a bed of small stones saturated with ground water **(Oosthuizen and Naylor, 1999)**. Other practical applications under different heat transfer processes include crude oil production, building insulation, grain storage, geothermal systems, storage of the nuclear waste material, ground water pollution, and solar collectors.

Heat transfer characteristics in a lid-driven cavity have been an important attention due to its many applications in engineering and science. Applications include cooling of electronic devices, oil extraction, compact heat exchanger devices, etc. Lid-driven cavities filled with a saturated porous medium have a great importance in engineering applications, such as solar power collectors, heat exchangers, packed-bed catalytic reactors, nuclear industrial systems and so on **(Nield and Bejan, 1999)** and **(Vafai, 1984).**

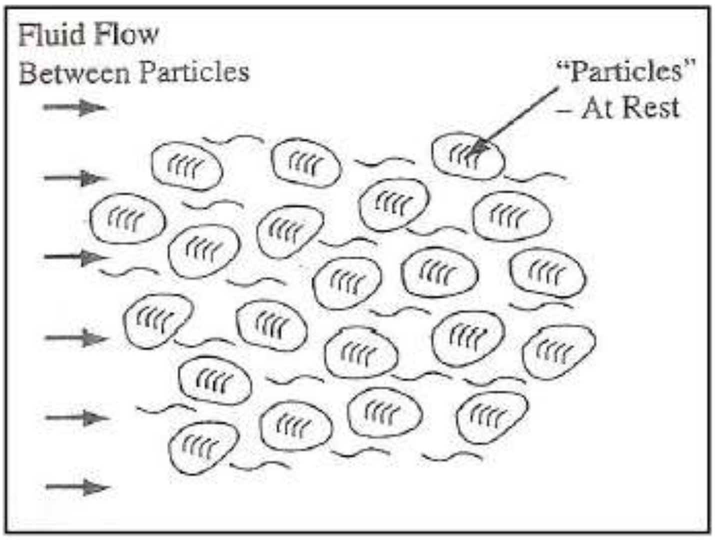


Figure 1. Fluid flow behaviour through a porous medium **(Oosthuizen and Naylor, 1999)**.

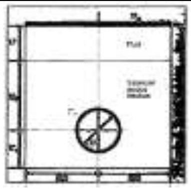
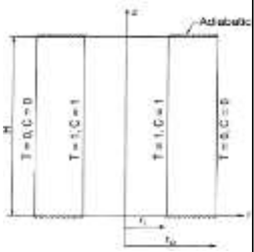
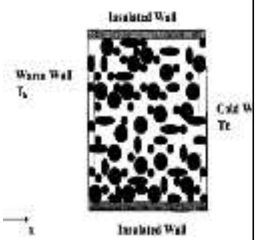
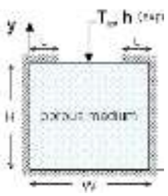
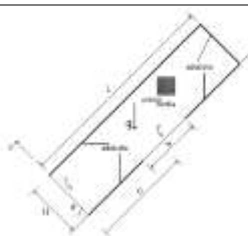
2. LETERATURES DEAL WITH NATURAL CONVECTION

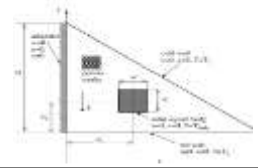
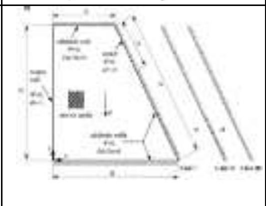
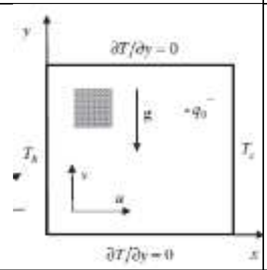
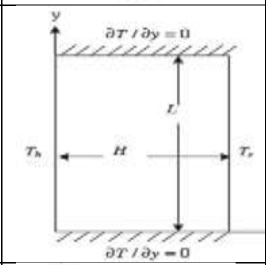
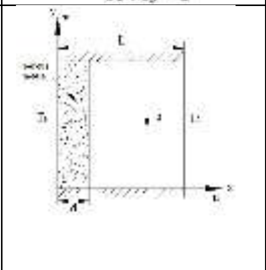
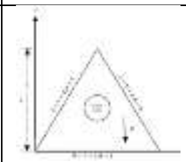
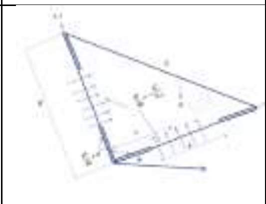
Free convection flow and heat transfer in porous media inside enclosure have been receiving a considerable attention in the literature. Based on these studies, various correlations have been reported for the average Nusselt number for triangular, square, rectangular and tall cavities.

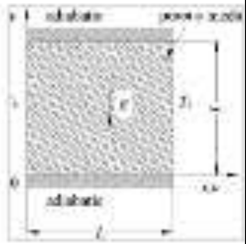
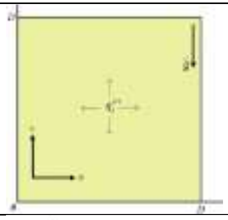
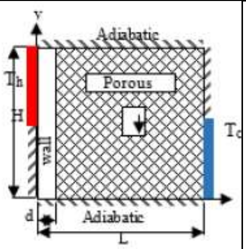
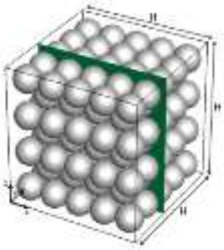
(Oosthuizen and Naylor, 1996) studied the laminar natural convection from a cylinder placed inside a porous square enclosure saturated with a fluid. It was found that there is a dimensionless fluid layer thickness that gives a minimum mean Nusselt number for a given situation because of no motion in the fluid layer leading to a decrease in the mean heat transfer rate. (**Nithiarasu, et. al., 1997)** used both Darcy and non-Darcy flow regimes to study the double-diffusive natural convection in an axisymmetric saturated porous cavity. It was concluded that the predicted heat transfer rate is lower for the generalized model if compared with the existing non-Darcy model, because the generalized model includes inertial, viscous and non-linear drag forces. (**Getachew, et. al., 1998)** studied the double-diffusive free convection inside a rectangular porous cavity saturated by a non-Newtonian fluid with a constant vertical walls temperature and concentration. Results for flow field, temperature and concentration distributions, and the heat and mass transfer rates agree with those obtained by discrete numerical experiments. (**Watit and Phadungsak, 2006)** investigated the transient natural convection heat transfer through a fluid-saturated porous medium in a square cavity with insulated vertical and bottom walls and heated top wall. It was found that the flow pattern has a local effect on the heat convection rate. **(Hakan, 2007)** proved that the inclination angle of a partially cooled rectangular porous enclosure with one hot wall as well as aspect ratio is the dominant factor on the fluid field and heat transfer behavior. The heat transfer process enhances as aspect ratio decreases. **(Yasin, et. al., 2007)**used four different temperatures as boundary conditions for the square body to obtain its effect on heat transfer and fluid flow inside right-triangular porous enclosure. It was observed that the body thermal boundary condition plays a significant role in the heat transfer process and the behavior of fluid flow. **(Yasin,**

et. al., 2009) utilized three different positions for the cooler part of partially cooled inclined wall of trapezoidal enclosure contains a fluid-saturated porous medium. It was inferred that the Nusselt number and flow strength are strongly depending on the location of the cooler. (**Revnic, et. al., 2011)** studied the combined effects of magnetic field and heat generation on the transient heat transfer by convection inside a square cavity filled with a fluid-saturated porous medium. The horizontal walls of the enclosure are adiabatic, whereas the vertical walls are isothermal. The result depicted that as Hartmann number increases, the diffusive heat transfer becomes prominent even though the Rayleigh number increases. (**Prakash and Satyamurty, 2011)** concluded that the use of Brinkman extended non-Darcy model to describe the flow and temperature fields in a rectangular porous enclosure causes reducing the velocity and temperature gradients near the walls because of no-slip velocity boundary condition. Also, it was found that the average Nusselt number increases as permeability ratio increases (**Shou-Guang, et. al., 2014),** revealed that the effect of free convection and the porosity on the heat transfer process inside square cavity partially filled with porous media becomes siginifcant at high values of Rayleigh number and Darcy number. (**Raju, et. al., 2015)** inferred that the characteristics of streamlines and isotherms due to free convection in a triangular cavity filled with a fluid saturated porous medium strongly depend on the position of the circular body inside the cavity. The average heat transfer data is significantly worse with increasing both heat generation and size of the circle. (**Mansour and Sameh, 2015)** debated the free convective heat transfer in a triangular enclosure with different angles of inclination containing Cu-water saturated porous medium and subjecting to heat generation. It was concluded that increasing the value of nanoparticle volume fraction significantly enhances the average Nusselt number. **(Chen, et. al, 2016)** simulated the free convective in a square porous enclosure using the local thermal equilibrium model and the local thermal non-equilibrium model. It was shown that both models give an excellent agreement. (**Saravanan and Brin, 2018)** examined the natural convective flow inside closed square cavity filled with a porous medium at nonequilibrium thermal condition between the fluid and solid phases. It was inferred that the maximum overall heat transfer occurs at the isothermal hot vertical walls of the cavity. **(Ammar, et. al, 2018)** studied the affectivity of aspect ratio in a conjugate porous cavity with partially heated vertical wall, cooled vertical right wall, and insulated horizontal walls. It was concluded that decreasing the wall thickness and aspect ratio leads to improve the rates of heat transfer. **(Iman, et. al, 2019)** examined experimentally the natural convection inside enclosure with a heated bottom and cooled top walls, filled with large solid spheres. The higher heat transfer rates resulted from the higher Rayleigh number values depend on the packing size and thermal conductivity of the used spheres. **Table 1** represents a summary of researches concerning with natural convection inside porous cavity.

Table 1. Summary of researches concerning with natural convection inside porous cavity.

Reference	Geometry	Parameters Ranges'	Novelty	Results and Conclusion
(Oosthuizen and Naylor, 1996)		$10^4 \leq Ra \leq 10^5$, $Pr = 0.7$ $2 \times 10^{-2} \leq Da \leq 2 \times 10^{-4}$	Hot cylinder placed on the lower part of porous square cavity	There is a dimensionless fluid layer thickness that gives a minimum mean Nusselt number for a given situation.
(Nithiarasu, et al. 1997)		$10^4 \leq Ra \leq 10^9$, $0.5 \leq AR \leq 5$, $\varphi = 0.8$ $10^{-2} \leq Da \leq 10^{-6}$ $Le = 1$	Study two cases: Darcy and non-Darcy flow fields in an axisymmetric cavity	The heat transfer process and flow characteristics in non-Darcy regime depend strongly on the separate parameter Darcy number.
(Getachew et al., 1998)		50≤Ra≤500, 0≤R≤20, 0.1≤Le≤ 500, 0. 5 ≤n≤1.6, R:buoyancy ratio Le: Lewis number N: flow index	Rectangular porous enclosure contains non-Newtonian fluid with impermeable walls	Four heat transfer regimes may arise in the system:1) pure conduction, 2) tall layers, 3) high *Ra* convection, and 4) shallow layers.
(Watit and Phadungsak , 2006)		*The Darcy number* $= 5x10^4$, $Pr = 1.0$, $h = 60 \frac{W}{m^2K}$, *and porosity* $= 0.8$	Unsteady natural convection heat transfer through a fluid-saturated porous medium inside square cavity with partial heating or cooling	The heat transfer coefficient, Rayleigh number and Darcy number considerably influenced the characteristics of flow and heat transfer mechanisms.
(Hakan, 2007)		$10 \leq Ra \leq 1000$; *center of location* (0.1≤c≤0.9), *inclination angle* (0 ◦ ≤ θ ≤90 ◦)	Free convection in partially cooled and porous rectangular enclosures with different inclination angles.	Inclination angle causes the multicellular flow, especially for a square enclosure. Aspect ratio affects the heat transfer and fluid flow.

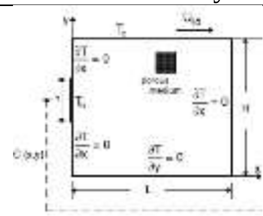
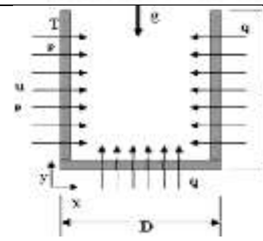
(Yasin et al., 2007)		$Ra = 100, 500, 1000$ $Pr = 0.71$	Four different boundary conditions were subjected to the inner square body.	Fluid and thermal characteristics depend on thermal conditions of the body.
(Yasin, et. al., 2009)		$100 \leq Ra \leq 1000$; $aspect\ ratio\ AR = 0.25, 0.50\ and\ 0.75$	Porous trapezoidal cavity partially cooled from an inclined surface at different three positions	Nusselt number and flow strength are strongly depending on the location of the cooler.
(Revnic, et al., 2011)		$Ra = 10, 10^2, 10^3, 10^4$ $Ha = 1\ \&\ 100$, $Angle\ of\ inclination = 0$, $\pi/6$, $\pi/4$ and $\pi/2$.	Using combined effects of magnetic fields and heat generation on unsteady natural convective inside a square cavity.	As Ha increases, the diffusive heat transfer becomes prominent even though the Rayleigh number increases.
(Prakash and Satyamurty, 2011)		$10^2 \leq Ra \leq 10^3$, $0.5 \leq AR \leq 5$, Permeability=0.5-5, *thermal conductivity ratio= 0.5 -5* and $0 \leq Da \leq 0.1$	The study involves the simultaneous effect of the hydrodynamic and thermal anisotropy.	The change in average heat transfer coefficients depends on the Darcy and non-Darcy flow.
(Shou-Guang, et al., 2014)		$10^3 \leq Ra \leq 10^6$; $10^{-2} \leq Da \leq 10^{-6}$ ($0 \leq porosity \leq 1$), $Pr = 1$	Simulated by lattice Boltzmann method (LBM). The porous medium is at one side of enclosure only.	The fluid and thermal characteristics enhance greatly as porosity increases at a high value of Darcy number.
(Raju, et al., 2015)		Pr=0.71, Ra=10^5 $Da = 0.4$	Circular body enclosed by a triangular cylinder containing a fluid saturated porous medium with a heat generation	Increasing both heat generation and size of the circle leads to decrease the average Nusselt.
(Mansour and Sameh, 2015)		$10^3 \leq Ra \leq 10^6$; $10^{-3} \leq Da \leq 10^{-6}$ ($0. \leq \varphi \leq 0.9$), $source\ length$ ($0.2 \leq \theta \leq 0.8$)	The presence of the angle of enclosure inclination, nanofluid porous medium, and heat generation	Increasing of the heat generation parameter leads to a decrease in the heat transfer rates.

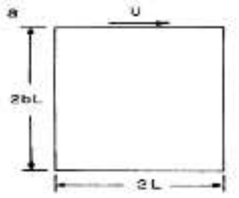
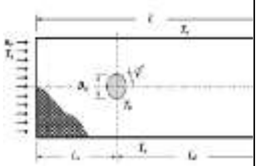
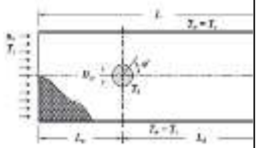
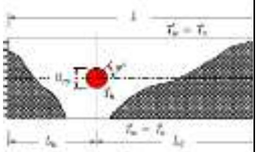
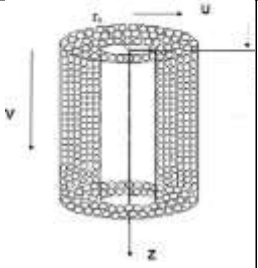
(Yuan-Yuan Chen, et al., 2016)		$10^4 \leq Ra \leq 10^6$; $10^{-3} \leq Da \leq 10^{-6}$ (0.≤ φ ≤0.9),	Using of spectral collocation method (SCM) and two models: the local thermal equilibrium and non-equilibrium models.	The results were compared with these of the exact solutions and gave a high accuracy.
(Saravanan and Brin, 2018)		Ra=10^7–10^{11} Da=10^{-6}–10^{-10}	Applying the non-equilibrium thermal conditions on convection inside a porous enclosure	Bifurcation of the existing cellular pattern when the system moves towards thermal equilibrium.
(Ammar, et al., 2018)		$10 \leq Ra \leq 10^3$, $0.02 \leq D \leq 0.5$ $0.1 \leq Kr \leq 10$ $0.5 \leq A \leq 10$ A=aspect ratio	Partially insulated vertical surfaces in addition to the top and bottom surfaces.	The Bottom-Top arrangement (the lower part of left wall is heated and the upper part of right wall is cooled) gives higher heat transfer rate than that of Top-Bottom.
(Iman, et al. 2019)		Ra = (10^7- 10^9) $z/H = 0.37, 0.63, and\ 0.90$ $x/H = 0.3, 0.5, and\ 0.7$	They used different sizes and thermal conductivities of sphere with a high range of Ra (10^7-10^9).	At high Ra, the convective contribution of the total heat transfer for all sphere conductivities, sizes, and packing types is similar to the case of pure Rayleigh-Bénard convection.

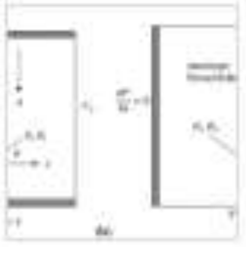
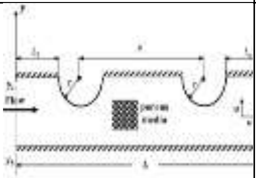
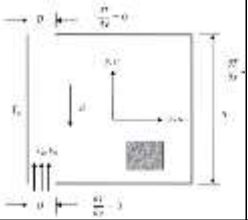
3. LETERATURE DEAL WITH FORCED AND MIXED CONVECTION

(Hakan, 2006) studied the combined heat convective in a porous lid-driven cavity with a top wall moving at constant velocity from left to right. It was demonstrated that the maximum rate of heat transfer occurs when the isothermal heating condition lies in the left vertical wall. **(Chaves, et al. 2008)** investigated the combined convection heat transfer in a semi porous open cavity. It was found that the maximum temperature takes place at the heated bottom wall for high values of Reynolds and Grashoff numbers. **(Wang, 2009)** found that the affectivity and the recirculating eddies decrease with the presence of porous medium, especially for deep cavities inside lid-driven rectangular cavity filled with a porous Darcy–Brinkman medium. **(Stephen and Kambiz, 2010)** focused on the buoyancy induced flow and vertical vibration on the left wall of an open-ended cavity filled with a porous medium. It was found that the higher values of Darcy and Reynolds numbers give vigorous vibrational effects, whereas the vigorous buoyancy influences occur at lower Darcy number and higher modified Rayleigh numbers. (**Mohd Irwan, et al., 2010)** found that the porosity of media affects the velocity of boundary layer and the strength of vortex through porous media inside lid-driven square cavity. **(Gazy, et al., 2012)** studied the effects of solid boundaries, inertia forces, and thermal dispersion on the transient forced convection from a non-equilibrium heated cylinder embedded in a packed bed of spherical particles. It was elucidated that the porous particles prevents the appearance of wakes behind the cylinder and improves significantly the process of heat transfer. **(Gazy, et al., 2012)** compared in another study between the two-phase energy model (local thermal non-equilibrium between the solid medium and the fluid) and the local thermal equilibrium model to study the influence of the particle diameter of a packed bed of spherical particles on the forced convection about an embedded circular cylinder. It was concluded that using the porous media with large particles around the heated cylinder improves considerably the average Nusselt number and decreases significantly the increasing of the unfavorable pressure drop in the bed if small particles are used. **(Gazy and Mark, 2013)** found that using porous media enhances the heat transfer rate from the cylinder placed in either an empty or a porous medium filled channel much higher than that promoted by using non-zero mean sinusoidal varying the pulsating forced convective flow, particularly at higher Reynolds number. (**Manal and Salman, 2014)** investigated the forced convection heat transfer by clean or dusty air in a two-dimensional annulus enclosure filled with porous media (glass beads) between two vertical concentric cylinders with a uniformly heated inner cylinder and a cooled outer cylinder. The results evinced that the clean air flow decreases the wall temperature as Reynolds number increases, while the reverse behavior takes place for the dusty air flow. **(Abdelraheem and Sameh, 2014)** used a non-Darcy model to study the heat transfer by natural and mixed convection in a saturated cavity. It was concluded the heat transfer rate and the flow regime are affected by porosity, permeability ratio, Darcy number, and the angle of inclination. **(Mouwaffaq and Amir, 2015)** proved that the rate of heat transfer increases as the distance between semicircular sections increases and the separation is prevented by porous media**. (Luma, 2015)** showed that the heat transfer process enhances with increase of aspect ratio and Re and decrease of porosity ratio. **Table 2**. Represents a summary of researches concerning with forced and mixed convection inside porous cavity.

Table 2. Summary of researches concerning with forced and mixed convection inside porous cavity.

Reference	Studied Geometry	Parameters Ranges'	Novelty	Conclusion
(Hakan, 2006)		$Pr = 0.71.$ $Ri = 0.1, 1 \& 10$	Mixed heat convection in a porous lid-driven cavity	The best heat transfer occurs when the left vertical wall is subjected to constant heat rate.
(Chaves et al., 2008)		Re=1,10, 100, 1000 Gr=0, 100,000	One vertical wall only of uniformly heated open cavity is a porous wall with normal fluid flows.	At constant values of Reynolds and Grashof numbers, the minimum heat transfer rate occurs at the bottom wall.

(Wang, 2009)		Permeability=10^{-3}, 2, and 10 $Ri = 0.1, 1$ & 10	Lid-driven rectangular cavity contains a saturated porous Darcy–Brinkman medium.	Decreasing the strength and the recirculating eddies with presence of porous media.
(Stephen and Kambiz, 2010)	-	$0.1 \leq Ri \leq 10$; $0.1 \leq f \leq 0.4$ $10 \leq Re \leq 400$; $10^{-2} \leq Da \leq 10^{-4}$	Mixed convection under the effect of vibration induced in an open-ended cavity	Vibrational effects are a dominant factor in the heat transfer process only at high Darcy and Reynolds numbers
(Mohd Irwan, et al., 2010)	-	$10 \leq Re \leq 400$; $10^{-2} \leq Da \leq 10^{-4}$ $porosity = 1$), $Pr = 1$	Combined formulation of Brinkman-Forcheimer equation and lattice Boltzmann solution	The lattice Boltzmann model is an effective method to predict the flow fields in a lid-driven porous square cavity.
(Gazy, et al., 2012)		$Re_D = 1 - 250$ $\frac{k_s}{k_f} = 0.01\&1000$ $Biot\ number$ $Bi = 0.01\&100$	Unsteady forced convective from a non-equilibrium heated cylinder enclosed by porous media	The porous material with the high values of thermal conductivity ratio improves the heat transfer rate.
(Gazy, et al., 2012)		$D_{cy}/d_p = 10\text{–}100$, $Re_D = 1 - 250$ $\frac{k_s}{k_f} = 0.01\&1000$	The effect of porous media particle size on the heat transfer under the local thermal non-equilibrium condition	The porous materials enhance the overall heat transfer with increasing the pressure drop.
(Gazy and Mark, 2013)	 (b) Porous channel	$Re_D = 1 - 250$ $\frac{k_s}{k_f} = 0.1, 1, 10, 100$ $0.2 \leq A \leq 1.8$ A=amplitude	It is an extension line of [30] but with adding the case of flow without porous media.	Porous-medium filled open cavity gives a highly stable flows and prevents forming wakes behind and in front of the cylinder.
(Manal and Salman, 2014)		$input\ power = 6.3, 4.884, 4.04\ and\ 3.26\ W$, $Re = 300, 700, 1000, 1500, and\ 2000$ $dust\ ratio\ N = 2, 4, 6\ and\ 8$	Forced convection heat transfer by clean or dusty air in an open ended annulus containing a porous media.	For dusty air flow, the wall temperature increases with Reynolds number and vice versa for clean air.

(Abdelraheem and Sameh, 2014)		Da=10^{-4}- 10^{-2}, $porosity = 0.4 - 0.9$, $permeability\ ratio$ 0.1– 10, $inclination\ angle =$ 0–90°	Using numerical methods to investigate the transient free and combined convection in non-Darcy porous cavities.	Darcy number and permeability ratio significantly affect the heat transfer characteristics.
(Mouwaffaq and Amir, 2015)		$Re = 50, 100, 150,$ and 200 $radius\ ratio = 0.25, 0.5, 0.75$	Using new geometry of cross section of channel	The rate of heat transfer enhances as the distance between semicircular sections increases. The separation is prevented by porous media
(Luma, 2015)		$Aspect\ ratio = 0.1 - 0.6,$ $porosity = 0.91 - 0.97, Re = 1 - 20,$ Gr=$10^4 - 3 \times 10^6$	Using of metal foam	The heat transfer enhances with increase aspect ratio and Re and decrease of porosity ratio.

4. CONCLUSIONS

Increasing of heat transfer coefficient is an important factor in the industrial and engineering applications to save energy and reduce the constructing and operation costs. There are several methods to increase this coefficient. One of these efficient methods is using porous-fluid media as working fluid to increase the fluid thermal conductivity. Most of the researchers carried out as theoretical investigations in this field because of spending much money and time in the experimental work. So, the present paper has introduced the available theoretical literature concerning with the steady and unsteady, two- and three- dimensional free, forced and combined convection heat transfer inside different geometries of cavity and different hydrodynamic and thermal boundary conditions. As can be shown above, many factors play a significant role in the heat transfer process, such as the shape of cavity, the type of porous-fluid media, the angle of inclination, vibration, magnetic field, heat generation, etc. The most important conclusions have been given in **Table 1 & 2**. Finally, as can be revealed from **Tables 1 & 2.**, there are no researches dealing with the natural convection heat transfer for compound nanofluids inside porous spherical enclosure or porous corrugated annulus. Also, the periodic heat flux boundary condition can be applied to all cases studied in the above literature. So, my suggestion to researchers is studying these cases.

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