Association of Arab Universities
Journal of Engineering Sciences
مجلة اتحاد الجامعات العربية للدراسات والبحوث الهندسية

# Review on Conjugate Heat Transfer in Enclosures

*Asmaa Ali Hussein* [1]

[1] *Middle Technical University, Institute of Technology-Baghdad, Baghdad, Iraq*

**Corresponding author: Asmaa Ali Hussein and email* asmaa 31930@ yahoo.com

Published online: 31 March 2025

**Abstract—** Conjugate convection (fluid) and conduction (solids) heat transfer in enclosures has received broad interest because of its wide importance in many mechanical applications, such as melting and solidification in thermal storage system, the fusion reactors, heat protection of thermal transport systems, solar collectors, the geothermal energy extractions, etc. Other situations including the conjugate heat transfer are heat sinks. The conduction heat transfer is observed in the heat sink while the natural convection is presented in the fluid medium. The subject of conjugate convection and conduction heat transfer in enclosures were studied by many authors. This paper presents a literature review of this problem for various geometrical enclosures, heat transfer modes, working fluids, enhancement techniques of heat transfer, and thermal boundary conditions. Very important conclusions were submitted in these literatures. Some of these conclusions are general for all literatures which addressed this topic. Generally, it was concluded that the streamlines, isotherms and heat transfer rate depended on both the thermal conductivity of the conductive wall, the thermal conductivity of fluid, and the thickness of the conjugate wall. For enclosure contain fixed or rotation inner cylinder, improvement of heat transfer coefficient is greatly affected by radius ratio between enclosure and cylinder, position of cylinder, and the rotational value and direction.

**Keywords—** Conjugate, Natural convection and conduction, Heat Transfer, enclosure.

## 1. Introduction

Conjugated heat transfer and thermally driven flow in differentially heated cavities and enclosures have received important attention by the authors in the last two decades, due to its wide applications in the industry. Theoretical and experimental investigations on conjugate conduction-convection heat transfer in different geometries of enclosures have been conducted by many authors. Many parameters such as Rayleigh number, finite thickness of conductive wall, magnetic field, porous media, position of heat source, system size, using of fins, adding nanoparticles to the base fluid, and thermal conductivity ratio were studied.

**[11]** Studied conjugate heat transfer throughout a rectangular enclosure filled with water. The enclosure was divided by two different horizontal conductive fins to enhance heat transfer. It was observed that the effectiveness of using fins depended on different parameters such as the radius ratio of enclosure and the number of fins.

**[1]** Studied the influence of MHD on conjugate convection and conduction heat transfer in a shallow rectangular cavity. Two cases were studied: enclosure with rigid boundaries and an enclosure with a top wall. It was concluded that at high Hartmann numbers, the hydrodynamic boundary layer in the core is constant in the out region of the two Hartmann layers.

**[5]** Investigated this problem in enclosures contained a chimney with openings. The chimney consisted of a vertical solid insulated and uniformly heated walls. The horizontal boundaries were adiabatic. The application of this problem was considered in buildings (see Fig.1). It was obtained that the heat flow rate and the volume flow rate depend on Rayleigh number, the opening dimensions, and the thermal conductivity of the wall.

**[37]** examined the fluid field and thermal patterns resulted from the conjugate conduction-convection heat transfer in square cavities encircled with centered solid wall (see Fig. 2). It was noticed that average Nusselt number for both cavities depended on of the aspect ratio and the thermal conductivity.

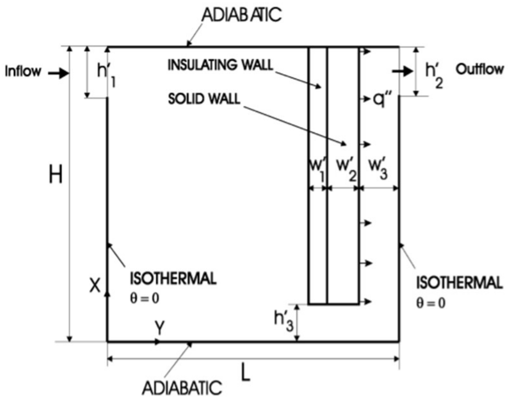


**Figure 1**: Physical domain of Bilgen and Yamane work [5].

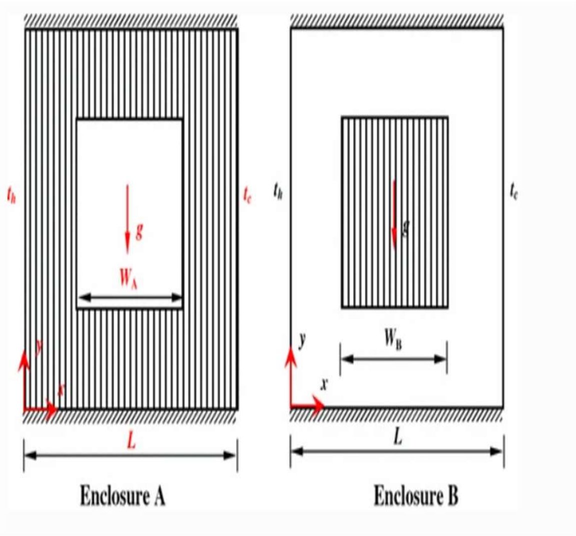


**Figure 2:** Physical domain of Zhao et al. work [37].

[38] Studied this phenomenon in a vertical cavity with cyclic temperature at the vertical wall. The cavity has a hot body located concentrically. It was concluded that increasing the body size and thermal conductivity ratio caused a decrease in the resonant frequency.

[35] Studied this problem in a triangular enclosure saturated with a porous medium. The conduction heat transfer was across the bottom wall while the vertical wall and inclined wall were insulated and isothermal cooled; respectively. It was concluded that the streamlines, isotherms and heat transfer rate depended on both the thermal conductivity wall-fluid ratio, and the thickness of the bottom wall.

[17] Used a rectangular cavity with existing the mass transfer within enclosure under local heat and contaminant sources to study the effects of Grashof number, Buoyancy ratio and solute concentration on stream function, vorticity, and isotherms.

[28] Studied this problem inside a cavity having a partition at the middle to investigate the influences of Ra, thermal conductivity ratio and partition thickness on the characteristics of flow and thermal patterns. It is noticed that the intensity of streamlines increases with increase in Rayleigh number or thermal conductivity ratio. The increase of thermal conductivity ratio gives lower temperature distribution along the partition. The conjugate convection- conduction heat transfer across a hot bottom cylindrical cavity is important problem in chemical and nuclear industries

[2] Studied the influences of materials thermal conductivity of the disc and inner cylinder (conduction), and geometrical shape of outer cylinder on the annular cavity with centrifuge machines. The aim of this problem is to obtain more uniform distribution of temperature in the cavity. This was achieved by utilizing inner cylinder made of aluminum metal with a constant temperature for the bottom disc equals to 433K.

[34] Studied three-dimensional conjugate natural convection in a cubic cavity. The enclosure had one hot sidewall with time-periodic pulsating temperature, isothermal opposing sidewall, and adiabatic parallel horizontal walls. It was shown that the flow field which change with time periodically and the performance of conjugate conduction-convection heat transfer of the cavity were strongly affected by the thermophysical properties of thickening walls.

[12] Studied conjugate conduction-convection in a square cavity having a concentric polygon object with different types and thermal conductivities. It is concluded that the heat transfer rate across the enclosure remains stable by varying the polygon types and the number of polygon sides. It was only depended on the inner body location, inclination angle, and rotation angle with various angular speed.

**[9]** Used two partial enclosures, connected by refrigerator/heater to investigate the effects of Rayleigh numbers, conductive walls to fluid thermal conductivity ratio, aspect ratio, and refrigeration coefficient on the isothermals and streamlines. It was concluded that the characteristics of thermal patterns and fluid field were unaffected by aspect ratio, while the convection increases with increase in aspect ratio.

[6] Studied this phenomena in a square enclosure with isothermal partially hot left wall and cold vertical wall, and insulated horizontal walls, as shown in Fig. 3. It was concluded that for a given thickness of vertical hot wall, the heat transfer process enhances as Rayleigh number is increased and as the thickness of the bounded wall decreases.

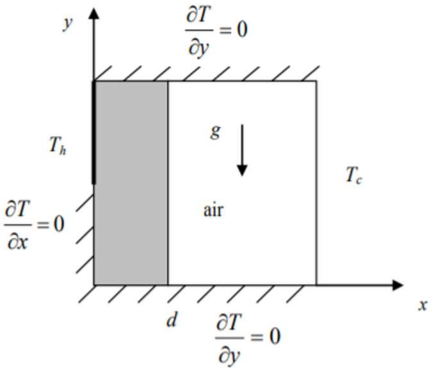


**Figure 3:** Physical domain of Belazizia et al. work [6].

**[10]** Used water as a working fluid to study the heat transfer process by natural convection within rectangular cavity. The heating source was a computer device CPU located on a vertical plane wall of cavity, while a heat sink was mounted on the other vertical plane wall of the cavity, see Fig. 4. The turbulent air flow was driven by using an exhaust fan inside the computer compartment. It was observed that the chip temperature declined with increase in the size of the enclosure. The temperature was decreased by 38% when the cavity was filled with water.

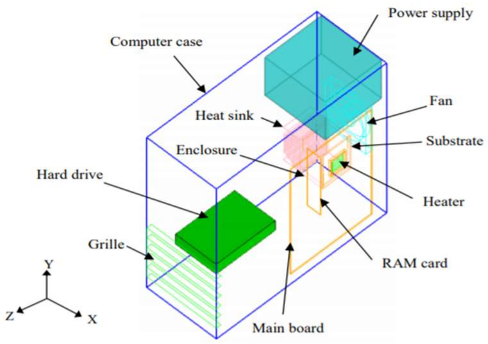


**Figure 4:** Physical domain of Gdhaidh et al. work [10].

**[13]** Submitted another study of conjugate natural convection inside a square cavity having thicken walls, as shown in Fig. 5. It was observed that the fluid field and the thermal distribution were affected by the conduction heat transfer in the bottom wall and the thermal-conductivity ratio. The average Nusselt number is increased as the natural convection effects increase and the conduction heat transfer through the thickening wall, and it is decreased as the wall thickness increases.

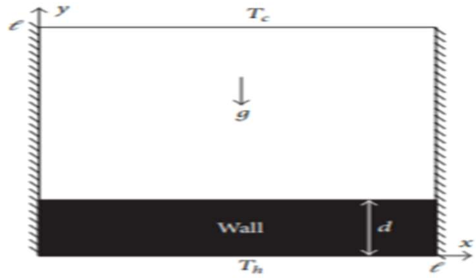


**Figure 5:** Physical domain of Habibis and Ishak work [13].

**[18]** Studied this problem in a cavity having rectangular geometry with a local heat source which was represented by a gas infrared radiator over the inner surfaces of enclosures. It was concluded that the radiation heat flow rate was affected the intensity of heat transfer.

**[3]** Studied the effects of both the thermal conductivity in a vertical wall and MHD on the natural; convection in a square enclosurecavity subjected to horizontal temperature gradient and filled with liquid gallium. It was observed without magnetic field that natural convection increases with increase in both Rayleigh number and conductivity ratio. For low conducting wall, the most average heat transfer rate was by conduction and it was relatively constant with small values if compared with high wall thermal conductivity. While, in the presence of a magnetic field the average Nusselt number is decreased with increase in Hartmann number (Ha) at a certain value of Rayleigh number.

**[14]** Used the lattice Boltzmann method (LBM) to investigate conjugate heating process in a heterogeneous medium having a microstructure with random behavior inside porous enclosure. It was concluded that the results proved the accuracy of the mathematical model in simulated complex both fluid and thermal dynamics in complex geometrical shapes.

**[31]** Analyzed conjugate conduction-natural convection heat transfer in an inclined square cavity containing a porous medium and adjacent to having conductive walls with finite thickness. One of the inclined walls of the cavity is hot, and the other inclined sidewall is cooled at constant temperature. On the other hand, the horizontal parallel walls are insulated. It was concluded that the local Nusselt number of fluid phase is increased as the thermal conductivity ratio increases and it is decreased along the heat source with increase in the thermal conductivity ratio. Moreover, the average heat transfer coefficients for both the solid wall and fluid are affected by the angle of inclination.

**[32]** analyzed this phenomenon in a rotating cavity, its walls have a finite thickness, as shown in Fig. 6. The results show that stability of the convective flow field and heat transfer oscillation were affected by reducing the thermal conductivity ratios or/and rotational speeds. The average heat transfer process is increased with increase in the conductivity ratio and it is decreased with increasing the wall thickness for a certain rotation speed.

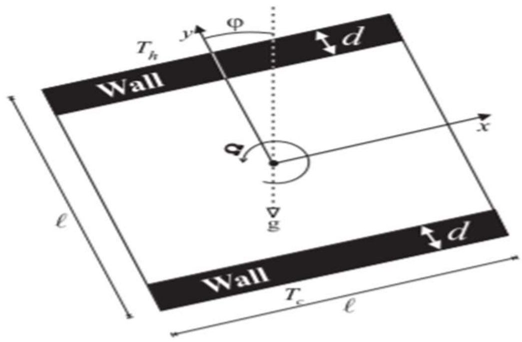


**Figure 6:** Physical domain of Saleh and Hashim work [32].

**[33]** studied the turbulent conjugate conduction-natural convection in a square cavity with conductive right vertical and top walls. The distribution of local heat flux and the local heat transfer coefficient along the vertical wall was analyzed.

**[39]** Investigated the influences of Rayleigh number (Ra), system size, ratio of thermal conductivity, number of blocks, and heat flux profile, on the inverse solutions of conjugate conduction- convection phenomena inside enclosure with different heat fluxes. The results show that these solutions submitted with simulated thermal measurements produced persuaded results for the functions of unbeknown heat fluxs. These results are significant to design the electronic cooling.

**[20]** Studied this problem to find the best location of the radiation heat source that produces minimum entropy generation in an enclosure filled with air (see Fig. 7). The internal surfaces of cavity were gray, opaque and diffuse. The effects of natural convection and radiation on the entropy generated inside enclosure and the best location of the heat source were discussed.

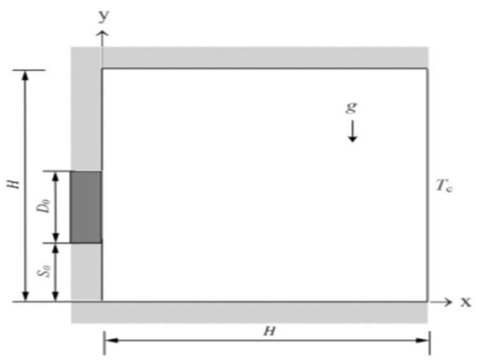


**Figure 7:** Physical domain of Mohammad Amin and Ali Safavinejad work [20].

**[7]** Studied the effects of heat transfer by radiation on the conjugate conduction-convection between fluid and solid media inside two geometries: two infinite parallel plates and square enclosure. It was concluded that the system thermodynamics strongly affected by the surface radiative heat transfer. As a result, the fluid–solid interface temperature will increase (see Fig.8).

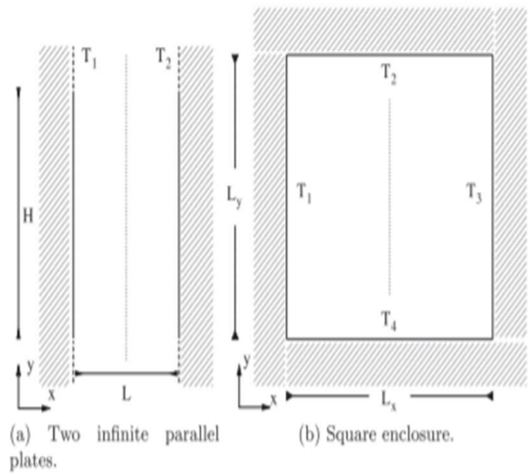


**Figure 8:** Physical domain of Carlo Cintolesi et al. work [7].

**[21]** Studied the influences of the wall and partition thicknesses of two square enclosures; respectively, on the streamlines and thermal field as shown in Fig.9. The results show that modifying the wall thickness relative to the thermal conductivity ratio produced the maximum heat transfer rate. The heat transfer rate of the cavity increased under the same conditions.

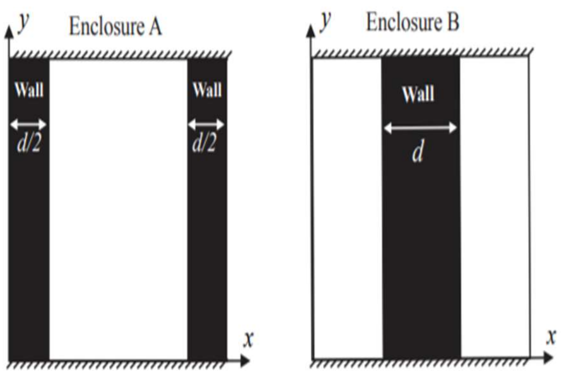


**Figure 9:** Physical domain of Marhama Jelita et al. work [21].

**[16]** Investigated this problem in a porous enclosure saturated with a fluid and having two partitions with the same thickness. The results show that, using a solid partition inside the cavity decreases the Nusselt number. Moreover, the heat transfer rate is proportional to the ratio of thermal conductivity for solid wall to porous region.

[40] Studied the influence of MHD on conjugate heat transfer in a rectangular enclosure. The cavity was filled with copper water nanofluid. The enclosure had

uniformly heated conducting vertical wall as shown in Fig.10. It was shown that average Nusselt number increases as the solid volume fraction increases. Moreover, the Nusselt number increases with increase in natural convection effects and decrease in Hartmann number.

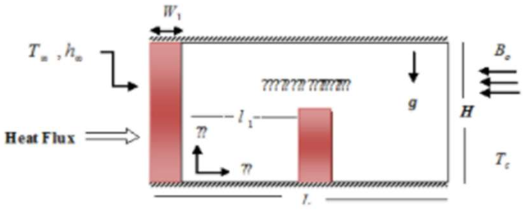


**Figure 10**: Physical domain of Zahan et al. work [40].

**[22]** Studied the conjugate heat transfer of polyurethane nonadecane particles (phase change material) suspended in a water inside square cavity. Two different layers fill the system: porous and clear layers. The heat transfers from the conductive hot wall to cold wall through the porous layer. It was concluded that the average Nusselt number enhances as Stefan number decreases and nanoparticles volume fraction increases.

**[36]** Investigated the influence of the solar radiation on the conduction-convection heat transfer characteristics through the cabin seat fabric. The decreasing of conjugate conduction-convection and radiation heat transfer produced decrease in emissivity and the energy absorbed. This produced an enhancement of the cabin thermal environment.

**[8]** Studied the influences of radiation on the interaction thermal conductivity between the solid wall and the fluid in a cavity. Three cases were considered, radiation-conduction heat transfer, conjugate conduction-forced convection-radiation heat transfer, and conjugated conduction-natural convection-radiation heat transfer. The results show that, the system thermodynamics was strongly affected by the surface radiative heat transfer. This produced an important increasing for the interface temperature between the fluid and solid.

**[30]** Studied numerically the effect of aspect ratio of partitions on conjugate heat transfer of water-($Al_2O_3$) nanofluid in a cavity with two vertical conductive partitions. It was concluded that, the average Nusselt number increases with decrease in the height and thickness ratio .

**[15]** Studied this problem in a cavity saturated with fluid and porous medium, see Fig. 11. The enclosure had two isothermal vertical walls, insulated horizontal upper wall, and horizontal partially heated lower wall. The effect of Darcy number, Rayleigh number, heat source length to the bottom wall ratio, the amount of thickening wall thickness and its height, and inclination angle on the thermal patterns and fluid field were discussed. The results show that the average Nusselt number was unaffected by inclination angle.

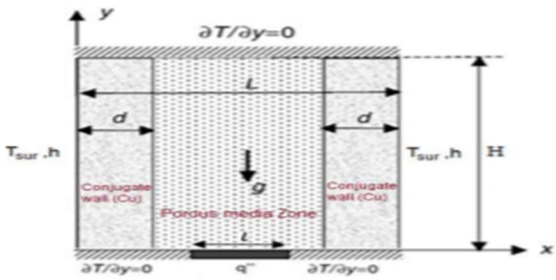


**Figure 11:** Physical domain of Hassan et al. work [15].

**[23], 2021** studied numerically this problem in a cavity with a thicken partition having different thermal conductivities. It was found that the effect of the partition thickness on heat transfer is significant mainly when the partition-fluid thermal conductivity ratio is small.

**[24], 2022** investigated conduction- combined convection generation in a square cavity. With internal heat. The moving air was driven by a moving the cold upper wall of enclosure and rotating the inner cylinder which located at the center of enclosure. The bottom wall of enclosure was kept at a constant hot temperature. It was concluded that the solid cylinder's rotational speed and its direction have unaffected greatly the thermal performance of system.

**[4], 2023** investigated numerically improvement the conjugate heat transfer in a cavity containing $H_2O$-nano-encapsulated PCM . The enclosure contained a hot cylinder located centrally inside enclosure. The aims of this work were studying the influences of the cylinder radius, cylinder's location, the rotation speed, the Rayleigh number, the thermal conductivity ratio, and the NEPCMs concentration on the heat transfer process. It was concluded that improvement of heat transfer coefficient is greatly affected by the rotational direction.

**[25], 2023** submitted a numerical study of the effect of entropy generation on the conjugate heat transfer in a cavity saturated with a $H_2O$-NEPCM suspension flanked by thermally conductive solid blocks along the bottom and top walls. The results show that the Nusselt number and generation of entropy increases with increase in increased thermal conductivity ratio and NEPCM concentration.

**[26], 2023** studied the unsteady conjugate heat transfer in a hexagonal cavity. The cavity has a multi-blade flow modulator rotated adiabatically to generate the forced convection. The natural convection was resulted from the bottom heated wall. The results show that a modulator produces best serves with low values of Ra and high values of Reynolds numbers.

**[19], 2024** examined the influences of wall conduction on conjugate conduction-convection (CNC) in a horizontal annular enclosures. It was remarked that when the solid wall is quantified, the overall heat transfer will be reduced inside the cavities. Correlations were deduced to obtain the overall heat transfer inside both enclosures.

**[27], 2024** used metallic phase change materials in thermal energy storage systems used in the technology of mobile applications. The numerical model analyzed the transient conjugate heat transfer. While, the experimental work was used to validate the numerical simulation results. The discharge time and total heat flow show good agreement with the experimental data, indicating the model's successful validation.

**[29], 2024** studied the conjugate heat transfer (CHT) to understand the combined effects of CHT, mixed convection, magnetic fields, and viscous dissipation on flow and thermal field, and local skin friction over a vertical plate. A new correlation for local skin friction and heat transfer parameters were deduced.

## 2. Conclusions

1. The streamlines, isotherms and heat transfer rate depended on both the thermal conductivity of the conductive wall and fluid, and the thickness of the conjugate wall.
2. Decreasing Stefan number and increasing nanoparticles volume fraction produced higher heat transfer rate inside enclosure filled with phase change material and nanoparticles.
3. Stability of the convective flow field was affected by reducing the conductivity ratio in addition to reducing the rotational speed for the rotating enclosure.
4. The chip temperature declined with increase in the size of the enclosure.
5. In the presence of MHD, the average Nusselt number decreases as Hartmann number is increased at a certain value of Rayleigh number.
6. The heat transfer rate is increased as Rayleigh number and thermal conductivity ratio increase, and it is decreased with increasing the wall thickness.
7. With the presence the perioding time, the performance of flow field and conjugate conduction-convection inside the cavity were strongly affected by the thermo-physical properties of conjugated wall and its thickness.
8. The characteristics of thermal patterns and fluid field were unaffected by aspect ratio, while the convection increases with increase in aspect ratio.
9. For low conducting wall, the most average heat transfer rate was by conduction and it was nearly constant with lower values if compared with large conducting walls.
10. For enclosure contain fixed or rotation inner cylinder, improvement of heat transfer coefficient is greatly affected by radius ratio between enclosure and cylinder, position of cylinder, and the rotational value and direction.

## References

[1] Alchaar S., P. Vasseur, E. Bilgen. Aug 1995. Natural Convection Heat Transfer in a Rectangular Enclosure with a Transverse Magnetic Field. *J. Heat Transfer*., 117(3): 668-673 (6 pages). https://doi.org/10.1115/1.2822628.

[2] Asif Hussain Malik; M. S. I. Alvi; Shahab Khushnood; F. M. Mahfouz; M. K. K. Ghauri; Ajmal Shah. Numerical study of conjugate heat transfer within a bottom heated cylindrical enclosure, Proceedings of 2012 9th International Bhurban Conference on Applied Sciences & Technology (IBCAST), IEEE.

[3] Abdennacer Belazizia, Said Abboudi and Smail Benissaad. (2015). Conjugate natural convection in a square enclosure under horizontal magnetic field effect. Mechanics & Industry,Volume 16, No 4, 409.

[4] Abeer Alhashash, Habibis Saleh. August 2023. Enhancement of conjugate heat transfer in an enclosure by utilizing water and nano encapsulated phase change materials with active cylinder, Journal of Energy Storage, Volume 66, 30, 107422, https://doi.org/10.1016/j.est.2023.107422

[5] Bilgen E., T. Yamane. (2004) .Conjugate heat transfer in enclosures with openings for ventilation, *Heat and Mass Transfer* volume 40, pages401–411. DOI: 10.1007/s00231-003-0418-z .

[6] Belaziza A., S. Abboudi, S. Benissaad. 2013. Numerical study of conjugate natural convection in a square enclosure with top active vertical wall, 21ème Congrès Français de Mécanique Bordeaux, 26 au 30 août.

[7] Carlo Cintolesi, Håkan Nilsson, Andrea Petronio, Vincenzo Armenio. (2017). Numerical simulation of conjugate heat transfer and surface radiative heat transfer using the P1 thermal radiation model: Parametric study in benchmark cases. / International Journal of Heat and Mass Transfer 107 956–971.

[8] Carlo Cintolesi, Hakan Nilsson, Andrea Petronio, Vincenzo Armenio. 2020. Numerical simulation of conjugate heat transfer and surface radiative heat transfer using the P1 thermal radiation model: parametric study in benchmark cases. International Journal of Heat and Mass Transfer.

[9] Di Liu, Fu Yun Zhao. December 2013.Conjugate Heat Transfer in Two Partial Enclosures Connected by Refrigerator/Heater. Advanced Materials Research (Volumes 860-863), pp. 1451-1457, DOI: https://doi.org/10.4028/www.scientific.net/AMR.860-863.1451

[10] Gdhaidh F A. , K Hussain and H S Qi. (2014). Numerical Study of Conjugate Natural Convection Heat Transfer Using One Phase Liquid Cooling, IOP Conf. Series: Materials Science and Engineering 65 012012. doi:10.1088/1757-899X/65/1/012012.

[11] Ho C J. , J.Y.Chang. June 1993.Conjugate natural-convection- conduction heat transfer in enclosures divided by horizontal fins, International Journal of Heat and Fluid Flow, Volume 14, Issue 2, Pages 177-184.

[12] Habibis Saleh and Ishak Hashim. 2013. Conjugate Heat Transfer in an Enclosure Containing a Polygon Object, World Academy of Science, Engineering and Technology, International Journal of Mathematical and Computational Sciences, Vol:7, No:2, 241-244.

[13] Habibis Saleh and Ishak Hashim. 2014. Conjugate Heat Transfer in Rayleigh-Bénard Convection in a Square Enclosure, Hindawi Publishing Corporation. Scientific World Journal, Volume, Article ID 786102, 8 pages http://dx.doi.org/10.1155/2014/786102.

[14] Hamid Karani and Christian Huber. Lattice Boltzmann formulation for conjugate heat transfer in heterogeneous media. Phys. Rev. E 91, 023304 – Published 5 February 2015.

[15] Hassan H. Hatem, Luma F. Ali. January 2021. CONJUGATE NATURAL CONVECTION IN A POROUS ENCLOSURE SANDWICHED BY FINITE WALLS AND SUBJECTED TO CONVECTION COOLING CONDITION, Journal of Engineering and Sustainable Development, Vol. 25, No. 01.

[16] Jayesh Subhash Chordiya, Ram Vinoy Sharma. Conjugate natural convection in a fluid-saturated porous enclosure with two solid vertical partitions, HEAT TRANSFER, First published: 02 August 2018. https://doi.org/10.1002/htj.21364.

[17] Kuznetsov GV. , M.A.Sheremet. January 2009 .Conjugate heat transfer in an enclosure under the condition of internal mass transfer and in the presence of the local heat source. International Journal of Heat and Mass Transfer. Volume 52, Issues 1–2, 15, Pages 1-8.

[18] Kuznetsov G V. , T. A. Nagornova, A. Ni. 2015 .Computational modeling of conjugate heat transfer in a closed rectangular domain under the conditions of radiant heat supply to the horizontal and vertical surfaces of enclosure structures. Journal of Engineering Physics and Thermophysics, vol. 88, Issue 1, pp. 168-177.

[19] Kuldeep Tolia, Sai Ravi Gupta Polasanapalli, and Kameswararao Anupindi. Off-lattice Boltzmann simulation of conjugate heat transfer for natural convection in two-dimensional cavities. Physical Review E 109, 015101, Vol. 109, Issue 1, January 2024.

[20] Mohammad Amin Dashti, Ali Safavinejad. Optimal design with EGM approach in conjugate natural convection with surface radiation in a two-dimensional enclosure, arXiv:1711.09263 [physics.flu-dyn], Physics > Fluid Dynamics, 25 Nov 2017.

[21] Marhama Jelita, Sutoyo & Habibs Saleh. 2018. CONJUGATE HEAT TRANSFER ANALYSIS IN TWO SQUARE ENCLOSURES WITH BOUNDED AND PARTITIONED CONDUCTIVE WALL, Journal of Quality Measurement and Analysis JQMA 14(1), 91-99.

[22] Mehryan S. A. M. , Muneer Ismael, Mohammad Ghalambaz. Local thermal nonequilibrium conjugate natural convection of nano-encapsulated phase change particles in a partially porous enclosure, Mathematical Methods in the applied sciences, special Issue, 18 March 2020. https://doi.org/10.1002/mma.6338.

[23] Mehdi Khatamifar, Wenxian Lin, Liqiang Dong. June 2021.Transient conjugate natural convection heat transfer in a differentially-heated square cavity with a partition of finite thickness and thermal conductivity. Case Studies in Thermal Engineering, Volume 25 , 100952, https://doi.org/10.1016/j.csite.2021.100952

[24] Md. Jisan Mahmud, Md. Rakib Hossain, Sumon Saha. December 2022 .Conjugate mixed convection heat transfer with internal heat generation in a lid-driven enclosure with spinning solid cylinder, , Heliyon, November

29, Volume 8, Issue 12, e11974 , DOI: https://doi.org/10.1016/j.heliyon.2022.e11974

[25] Mehdi Ghalambaz, Masoud Mozaffari, Shima Yazdani3, Mohammad Abbaszadeh4, Mikhail Sheremet, Mohammad Ghalambaz. 2023. Conjugate entropy generation and heat transfer of a dilute suspension of nano-encapsulated phase change material in a partially heated wall cavity, Reports in Mechanical Engineering, Vol.4, No.1, pp. 175-192, DOI: https://doi.org/10.31181/rme040115092023g.

[26] Maruf Md. Ikram, Goutam Saha, Suvash C. Saha. January 2023.Unsteady conjugate heat transfer characteristics in hexagonal cavity equipped with a multi-blade dynamic modulator, International Journal of Heat and Mass Transfer, Volume 200 , 123527, https://doi.org/10.1016/j.ijheatmasstransfer.2022.123527

[27] Nees F., and Y S Pai. Conjugate heat transfer analysis of the transient thermal discharge of a metallic latent heat storage system. Journal of Physics: Conference Series 2766 (2024) 012212. https://doi.org/10.1088/1742-6596/2766/1/012212.

[28] Pensiri Sompong, Supot Witayangkurn. (2012).Visualization of Conjugate Natural Convection in a Square Enclosure Divided by Conducting Partition, Current applied science and Technology, Vol. 12 No. 2.

[29] [29] Pınar YAĞLICA 1, a, Özdeş ÇERMİK. The Impact of Conjugate Heat Transfer in Flow Over a Vertical Plate and Application of Artificial Neural Network. Ç.Ü. Müh. Fak. Dergisi, 39(4), Aralık 2024.

[30] Rasul Mohebbi, Hassan lakzayi, Hamed Rasam, “Numerical simulation of conjugate heat transfer in a square cavity consisting the conducting partitions by utilizing lattice Boltzmann method”, Physica A: Statistical Mechanics and its Applications, Volume 546, 15 May 2020.

[31] Sameh Elsayed Ahmed, Ahmed Kadhim Hussein, M. M. Abd El-Aziz, Sivanandam Sivasankaran. 2016 .Conjugate natural convection in an inclined porous enclosure with finite wall thickness and partially heated from its left side wall. Heat Transfer Research, Vol. 47, Issue 4, pages 383-402. DOI: 10.1615/HeatTransRes.2016007964.

[32] Saleh H., and I. Hashim. 2016. Conjugate Natural Convection Heat Transfer in a Rotating Enclosure, Journal of Applied Fluid Mechanics, Vol. 9, No. 2, pp. 945-955.

[33] Sachin, Tom,. (2016). Numerical Study of Turbulent Natural Convection in an Enclosure with Conjugate Heat Transfer, Thesis (MTech).

[34] Wei Zhang, Zhu Huang, Chuhua Zhang, Guang Xi. 2012 .Numerical Study on Conjugate Conduction–Convection in a Cubic Enclosure Submitted to Time-Periodic Sidewall Temperature. ASME International, Journal of Heat Transfer, No. 2. https://doi.org/10.1115/1.4007738.

[35] Yasin Varol, Hakan F. Oztop, Ioan Pop. Conjugate heat transfer in porous triangular enclosures with thick bottom wall. International Journal of Numerical Methods for Heat & Fluid Flow, ISSN: 0961-5539, Volume 19 Issue 5, 12 June 2009, pp. 650-664. https://doi.org/10.1108/09615530910963571.

[36] Yijie Zhang and Juhong Jia. Numerical Simulation of Solar Radiation and Conjugate Heat Transfer through Cabin Seat Textile, Autex Research Journal, 29 Sep. 2020.

[37] Zhao Fu-Yun, Di Liu & Guang-Fa Tang. (2007) .Conjugate heat transfer in square enclosures. *Heat and Mass Transfer* **volume 43**, Article number: 907.

[38] Zhao Fu-Yun., Guang-Fa Tang &Di Liu. 2007. Conjugate Heat Transfer in an Enclosure with a Centered Conducting Body Imposed Sinusoidal Temperature Profiles on One Side**.** Numerical Heat Transfer, Part A: Applications, An International Journal of Computation and Methodology, Volume 53, Issue 2, Pages 204-223.

[39] Zhang, DD, Zhang, JH, Liu, D Zhao, FY Wang, HQ Li, XH. 2016 .Inverse conjugate heat conduction and natural convection inside an enclosure with multiple unknown wall heating fluxes, International journal of heat and mass transfer, v. 96, p. 312-329.

[40] Zahan Ishrat, Nasrin R, Alim MA. MHD Effect on conjugate Heat Transfer in a nanofluid filled rectangular enclosure, International Journal of Petrochemical Science & Engineering, Volume 3 Issue 3, June 29, 2018.

# مراجعة حول انتقال الحرارة المترافق في العبوات

***أسماء علي حسين***[1]

[1] *معهدالتكنلوجيا ،بغداد ،العراق ،asmaa31930@yahoo.com*

* *الباحث الممثل: أسماء علي حسين asmaa31930@yahoo.com*

نشر في: 31 اذار 2025

**الخلاصة** – لقد حظي نقل الحرارة بالحمل المترافق (السوائل) والتوصيل (المواد الصلبة) في العبوات باهتمام واسع بسبب أهميته الواسعة في العديد من التطبيقات الميكانيكية، مثل الذوبان والتصلب في نظام التخزين الحراري، ومفاعلات الاندماج، والحماية الحرارية لأنظمة النقل الحراري، والطاقة الشمسية. المجمعات، واستخراج الطاقة الحرارية الأرضية، وما إلى ذلك. الحالات الأخرى بما في ذلك نقل الحرارة المترافق هي المشتتات الحرارية. يتم ملاحظة انتقال الحرارة بالتوصيل في المشتت الحراري بينما يتم عرض الحمل الحراري الطبيعي في الوسط السائل. تمت دراسة موضوع الحمل الحراري المترافق وانتقال الحرارة بالتوصيل في العبوات من قبل العديد من المؤلفين. تقدم هذه الورقة مراجعة الأدبيات لهذه المشكلة لمختلف العبوات الهندسية، وأنماط نقل الحرارة، والسوائل العاملة، وتقنيات تعزيز نقل الحرارة، وظروف الحدود الحرارية. تم تقديم استنتاجات مهمة جدًا في هذه الأدبيات. بعض هذه الاستنتاجات عامة بالنسبة لجميع الأدبيات التي تناولت هذا الموضوع. وبشكل عام، تم التوصل إلى أن الانسيابية والأيسوثرمات ومعدل انتقال الحرارة تعتمد على كل من التوصيل الحراري للجدار الموصل، والتوصيل الحراري للمائع، وسمك الجدار المرافق. بالنسبة للعلبة التي تحتوي على أسطوانة داخلية ثابتة أو دوارة، فإن تحسين معامل نقل الحرارة يتأثر بشكل كبير بنسبة نصف القطر بين العلبة والأسطوانة، وموضع الأسطوانة، وقيمة واتجاه الدوران.

**الكلمات الرئيسية** – المترافق، الحمل والتوصيل الطبيعي، انتقال الحرارة، التضمين.