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Research Paper

Numerical Investigation of Heat and Fluid Flow in a Ventilated Cavity with Nanofluids using two-phase mixture model

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***ABSTRACT**:-* In this study the mixed convection (laminar) air chamber in the presence of internal barriers in the biphasic (mixed) is examined. Adiabatic chamber walls and the inlet fluid temperature is assumed transferring heat in nanofluidics, single-phase and two-phase method can be used to switch the current study, the Euler- Euler method - biphasic (mixed) to check the nanofluids used. Internal spring has a constant heat flux and the fin is mounted on springs. In this study, using a finite volume method is used. Impact Grashof number, nanoparticle volume fraction, Reynolds number and position of the source has been studied and the results are line graphs of flow, temperature and Nusselt number are presented. In this study, water-alumina nanofluid nanoparticles with a diameter of 33 nm and a temperature of 300 K were used as the working fluid. Range used for integer between 10^3 and 10^5 Grashof, nanoparticle volume fraction between 0 to 0.05 and the Reynolds number is between 100 and 500. The results showed that increasing the volume fraction of nanoparticles increases the Nusselt but Grashof increase or decrease depending on the Reynolds and Nusselt flow is going to increase. Right position of springs on both the Reynolds number is high right corner.

Keywords:- Nanofluids, ventilated cavity, mixed convection, two-phase mixture model.

I. INTRODUCTION

In recent years, due to the need to improve the heat transfer of nanofluid in the field of nano-fluids were common inside the enclosure and effects on the rate of heat transfer nanofluids volume percentages changes in flowline andtemperature is an important parameter studied. Nanofluid is a suspension of nanoparticles of metallic or non-metallic 100-10 nm in size in a conventional coolant such as water, ethylene glycol or oil. One of the first numerical studies by Khanafer et al [1] took place. Their results show that in a certain Grashf heat transfer rate with increasing volume fraction of nanoparticles increases. Huang et al [2] studied the heat transfer in a rectangular enclosure filled with nanofluids numerically evaluated. They use different models to evaluate the thermal conductivity and viscosity of nanofluids used. Putra et al [3] in an experimental study of heat transfer in a vertical cylinder heated from below was provided by the natural movement that arose. They use water-alumina nanofluid concentration of 1 and 4 per cent ratio to examine different perspectives. They range in all different volume ratios of nanoparticles reduced Rayleigh number and thermal conductivity, respectively. In a numerical study, Hu et al [4], dynamic viscosity and thermal conductivity of nanofluids on heat transfer in a square enclosure were investigated. The results of this study indicate that it is a Rayleigh with the increase in the rate of flow of nanofluids buoyancy force is reduced. King and colleagues [5] examined the combined motion of freely nanofluids thermal springs with thick walls; a bottom horizontal wall is installed successfully. They reported improved heat transfer due to the different Grashof. Conservation equations are solved using finite volume and viscosity and conductivity of nanofluids, respectively Brinkman models [6] and Patel [7] is applied. Richardson and Nusselt number increases the heat transfer was observed to improve the air temperature near the heat source is reduced. Increase concentration has followed by similar results.

Abunda and Oztap [8] study the effect of the angle on the heat transfer rate in a cavity containing nano-fluid numerically studied and showed that the effect of nanoparticle concentration on Nusselt number at low values of the volume fraction of the volume fraction is much higher values. Aminossadati Ghasemi [9] and Mahmood et al [10] to simulate natural convection in two-dimensional bins provided. They all increase and improve the natural convection caused by the use of nanofluids were reported. They estimate the nano-fluid viscosity Brinkman model [6] was used. Alizadeh et al [11] to study the flow and heat transfer of nanofluids in the conditioning chamber where an internal body temperature has been investigated numerically doing. The

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results of this study raise a predictable effect on the Nusselt, Reynolds and Grashof no amount of increased fluid on the thermal springs or reduced Nusselt heat source in the chamber is dependent on the position.

In this study examines the displacement of the mixture (laminar) for water-alumina nanofluid in a square enclosure with ventilation with heat source using a two-phase model is discussed. In particular, in a recent issue of the effects of changing parameters on the flow field and the heat transfer to the work often costly and difficult experimentally, therefore, an alternative method for the numerical simulation of such problems is presented. Continue the work done in [11] and two-phase analysis has not been performed in the same geometry and here the two-phase model to explore the issue described above.

II. PHYSICAL MODELING AND PROBLEM FORMULATION

Desired geometry is shown in Figure (1), have the length of C and thickness of C 0.1. Chamber walls and adiabatic vertical wall height H and horizontal holes L is considered. Internal source of heat flux is constant. The size of the inlet and outlet of the chamber to 0.1 the height of the cavity is assumed. Thermo physical properties of water at a temperature of 300 K and aluminum oxide in the temperature of the reference presented in Table 1.

Mixed model assumes that the phases do not influence each other and each phase has its own velocity field. But instead of solving the transport equations separately for each of the phases, the equations of continuity, momentum and energy for mixed with a volume fraction equation is used.

Figure 1 Geometry of the problem studied

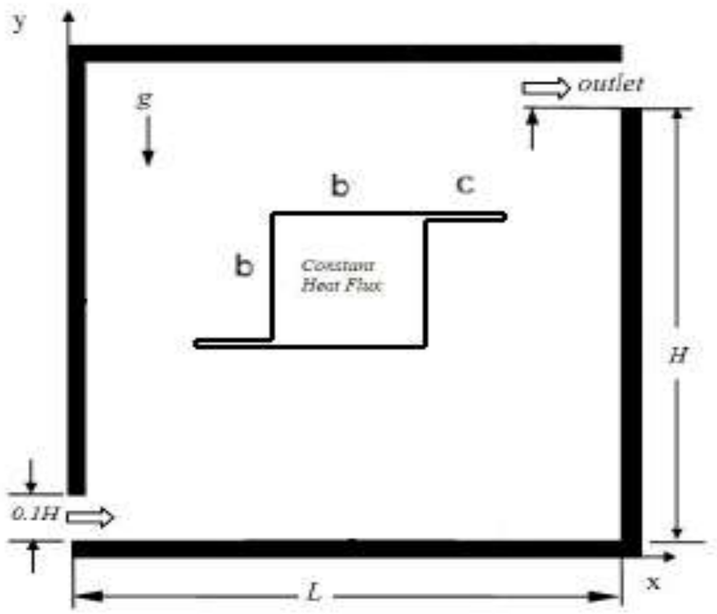

Table 1 thermo-physical properties [11]

Alumina	Water	Thermo-physical properties
765	4179	*Cp*(J/Kg.K)
397	1.997	*ρ*(Kg/m3)
40	0.613	*k*(W/m.K)
0.85	21	$\beta \times 10^5$ (1/K)

Properties used in the equations of fluid properties (initial phase) establish fashion (secondary phase) forming a suspension. Therefore, these equations can be written as follows. Mixture continuity equation is:

(1) $$\frac{\partial(\rho_m)}{\partial t} + \nabla.(\rho_m V_m) = 0$$

Where Vm, the density average velocity vector and ρm is mixed mass.

(2) $$V_m = \frac{\phi \rho_p V_p + (1-\phi)\rho_f V_f}{\rho_m}$$

(3) $$\rho_m = \phi \rho_p + (1-\phi)\rho_f$$

Momentum equation for the mixture of individual momentum equations for all phases is obtained and can be expressed as follows: Mix Momentum equation for all phases of a single momentum equation is obtained and can be expressed as follows:

(4) $$\frac{\partial(\rho_m V_m)}{\partial t} + \nabla.(\rho_m V_m V_m) = -\nabla P + \nabla.[\mu_m(\nabla V_m + \nabla V_m^T)] + \rho_m \vec{g} + \vec{F} + \nabla.\left(\sum_{K=1}^{n} \phi_k \rho_k V_{dr,k} V_{dr,k}\right)$$

Where n is the number of phases, F the force and volume of the mixture is mμ.

In equation (4), Vdr, k i is the rate of drift for phase k is defined as follows:

(5) $$V_{dr,k} = V_{pq} - V_m$$

As the relative speed difference between the speeds of the secondary phase (p) the initial phase velocity (q) is known:

(6) $$V_{pq} = V_p - V_q$$

The relationship between driving speed and relative speed is as follows:

(7) $$V_{dr,k} = V_{pq} - \sum_{k=1}^{n} \frac{\phi_k \rho_k}{\rho_m} V_{qk}$$

In [12] proposed the following equation for the relative velocity:

(8) $$V_{pq} = \frac{\rho_p d_p^2}{18\mu_q f_{drag}} \frac{(\rho_p - \rho_m)}{\rho_p} \vec{a}$$

In this equation pd is second phase particle diameter p and a secondary phase particles are accelerated. Drag the fdrag, the relationship between the chiller and Namn [13] provided:

(9) $$f_{drag} = \begin{cases} 1 + 0.15Re^{0.687}\, Re \le 1000 \\ 0.0183ReRe > 1000 \end{cases}$$

The acceleration "a" is as follows:

(10) $$\vec{a} = \vec{g} - (V_m.\nabla)V_m - \frac{\partial V_m}{\partial t}$$

Energy equation for the mixing of suspensions is as follows:

(11) $$\frac{\partial}{\partial t}\left(\sum_{k=1}^{n} \phi_k \rho_k E_k\right) + \nabla.\sum_{k=1}^{n}\left(\phi_k \vec{V}_k(\rho_k E_k + P)\right) = \nabla.\left(k_{eff} \nabla T\right) + S_E$$

In equation (11) KE for a compressible phase is:

(12) $$E_k = h_k - \frac{P}{\rho_k} + \frac{V_k^2}{2}$$

For an incompressible phase is $E_k = H_k$.

To calculate the effective thermal conductivity of the Patel [7] is used:

(13) $$\frac{Keff}{Kf} = 1 + \frac{KpAp}{KfAf} + CkpPe\,\frac{Ap}{Kf\ \ Af}$$

(14) $$\frac{Ap}{Af} = \frac{df\,\emptyset}{dp\ \ (1-\emptyset)},\quad pe = \frac{updp}{\alpha f} u_p = \frac{2\,TKB}{\pi\mu\, f\, d_P{}^2}$$

pd solid particle diameter equal to 33 nm have been considered in the present study and df represents the molecular diameter of the base fluid. Up of the velocity of particles in Brownian motion, and kB is the Boltzmann constant. C is an empirical coefficient depending on the diameter of the nanoparticles is considered to be 0.13500. To calculate the effective viscosity of the model - corsion [14] is used:

(15) $$\frac{\mu_{ffe}}{\mu_f} = \frac{1}{1-34.87(d_p/deq)^{-0.3}\phi^{1.03}}$$

The local Nusselt a vertical wall is defined as follows:

(16) $$Nu_s(Y) = -\frac{1}{\theta s(X)}\frac{\partial\theta s}{\partial X}$$

To obtain the overall Nusselt we have:

(17) $$Nu_m = \frac{\int Nus(Y)dY}{\int dY}$$

To have an effective thermal expansion coefficient [1]:

$$= \left(\frac{1}{1+\frac{\emptyset\rho_P}{(1-\emptyset)\rho_f}} + \frac{p\beta}{1+\frac{(1-\emptyset)\ f\beta f\rho}{\emptyset\rho_P}}\right)\beta f$$

III. NUMERICAL METHODS AND VALIDATION OF RESULTS

In the present study, calculations were performed by using the computer code. Equations of energy, continuity and momentum with the boundary conditions, the finite volume method with grid system were replaced by numerically solved. Computer program solves simultaneous equations based on the algorithm of Semple's

dismissal. For the discretization of the equations of momentum and energy of Power Law and the volume fraction equation QUICK method is used. The convergence criterion in this study is limited to less than 10^{-6}. In this study, body walls with adiabatic output ports, internal spring has a constant heat flux and inlet fluid temperature is assumed. For optimal Web search results and ensuring the independence of the network size, the average Nusselt changes in thermal springs in Gr=10^5, Re=100 for water nanofluids of alumina and per cent by volume concentration 0.05 is investigated. According to Table 2, by comparing its results are independent of the network is the best option to solve the shortest time and at the same time calculate the density of 83 × 80 was detected. In Figure 2 the velocity profiles for different networking is presented.

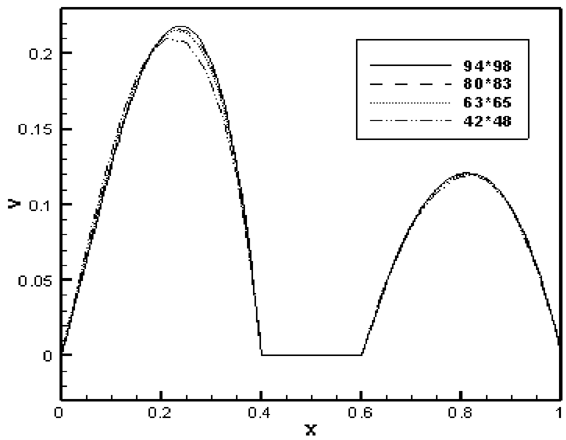

Figure 2 shows the distribution of horizontal velocity at intermediate compartments for different lattice

Table 2 independent evaluation of network

uN_m	Number of points
19.35565	**48×42**
18.96556	**65×63**
18.85556	**83×80**
18.85115	**98×94**

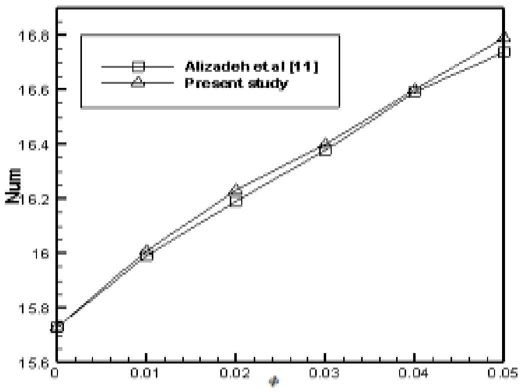

Figure 3 compares the average Nusselt number of the existing code with the results of Ref. [11]

Ra=10^6	**Ra=10^5**	**Ra=10^4**	**Ra=10^3**	
9.088	4.604	2.248	1.118	present work
8.799	4.519	2.243	1.118	Davis [15]

Table 3 compares the average Nusselt existing code with the results of Ref. [15]

In order to validate and investigate the authenticity and accuracy of the computer code used in the modeling, numerical tests on a simple square chamber with the left wall of the hot and cold wall horizontal walls insulated in accordance with the authority [15]. To ensure numerical method proposed in this study, using a different simulation results by Alizadeh et al [11] has been done, has been validated. The average Nusselt numbers obtained from the two problems above are presented in Table 3 and Figure 3. And as we have seen in both cases there is good agreement between our results and the results of the authorities.

IV. REVIEW THE RESULTS

Figure 4 shows the flow lines in Reynolds 500 and 100. As can be seen from the flow lines in Reynolds 100 general shape of the lines are the same in pure water and nanofluids but Reynolds 100 vortices generated in pure water nanofluids was somewhat smaller. For nanofluids flow tends to creep movement and better penetrate deep into the chamber and prevents the formation of large vortices. Flow lines in the thermal springs of pure water in the upper part of it away, but it closes off the nanofluids. Given the general shape of the contours of the flow lines in Reynolds 500, Reynolds 100 has changed. The flow lines in this case are very similar to the lines of air inside the chamber is empty. Regarding the fin thermal springs on either side of the vortex is created in the upper and lower springs.

Figure 5 isotherms at Reynolds 100 and 500 and Grashof show 10^5. According to the figures depicted, showing the improvement in heat transfer chamber temperature of these lines is the use of nanofluids. Reynolds 100 some of theisotherms in the thermal springs bypassed been drawn to the outlet. eynolds 500 completely changed the shape of the lines so that the distribution of isotherms in a circle around hot springs accordingly.

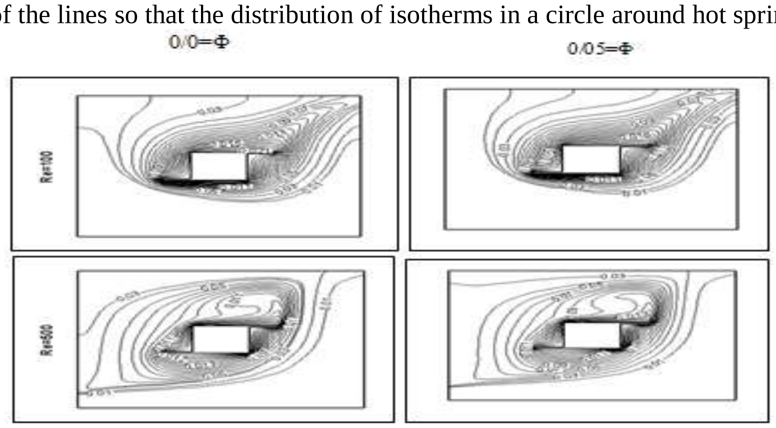

Figure 4 compares the flow line between a pure fluid and nanofluid at different Reynolds numbers

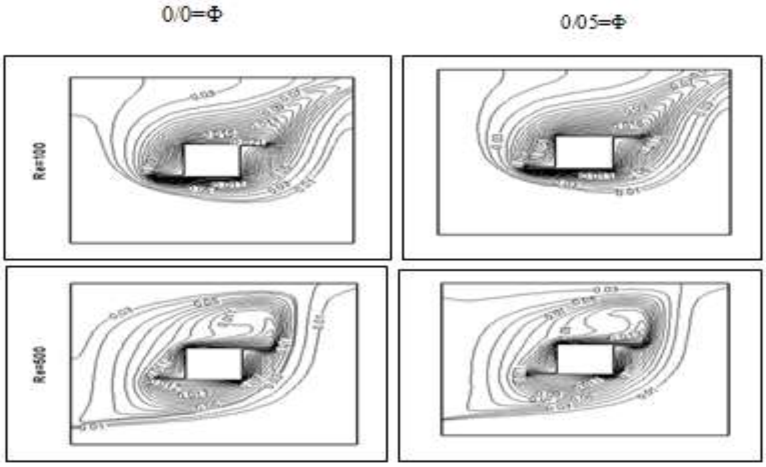

Figure 5 compares the isotherms of the pure fluid and nanofluid at different Reynolds numbers

Figures 6 and 7, shows the variation of average Nusselt in Reynolds 100 and 500. According to the figures, the average Nusselt trend for increasing concentration can be seen. In Reynolds 100 increase Grashof causes increases at Nusselt but at Reynolds 500 by increasing Grashof Nusselt been reduced. Here you can participate in improving the heat transfer fin pointed. For example, in the case of, Reynolds 100 and Grashof 10^5 for Nusselt pure water the average in case without fins is equal to 15.75 and in the case of Finn equal to 18 is 12.5% increase in Nusselt are visible.

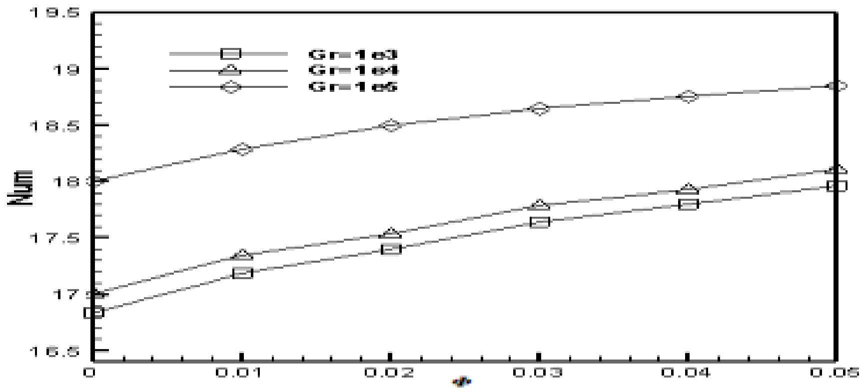

Figure 6 shows changes in the average Nusselt springs in Reynolds 100

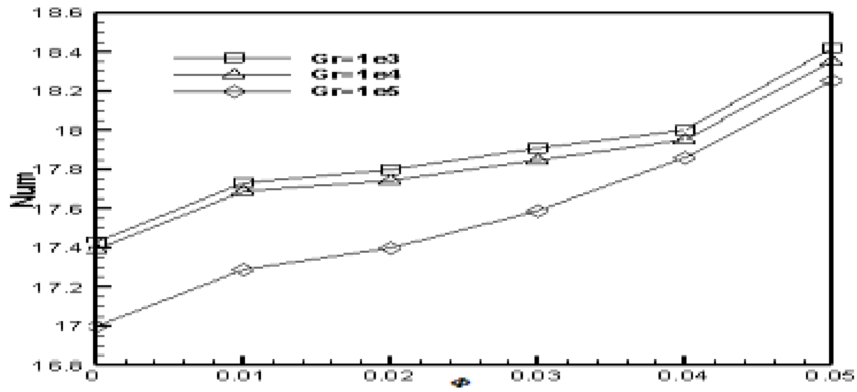

Figure 7 shows changes in the average Nusselt springs in Reynolds 500

4.1 Evaluation of different situations Springs

The purpose of this review is to select the optimum location of springs. Evaluation criteria for the selection are the maximum temperature of the chamber so that the lowest number is the position in which the maximum temperature is right for the position.

Figure 8 shows contours of constant temperature and net fluid and nanofluids in thermal springs Reynolds 100 and Grashof 10^5 positions for four the position of thermal spring.

According to 8- a fountain located in the flow path, which improves heat transfer and reduce the operating temperature of the chamber. According to the flow lines, in this case the vortex is created in the left compartment. Due to the shape of the isotherms it surrounding the lines the fountain.

Figure 8- b Due to the bulk of the flow lines near the fountain crossed and crossed from the left and slightly below the vortices is formed. Unlike the previous lines around the fountain does not surrounding temperature due to the location of the fountain.

Figure 8- c fluid into a chamber at the bottom and left of the fountain facing as a result of fluid passed source. Due to the shape of the isotherms, the lines drawn through the chamber outlet and considering the fountain at the bottom left of the fountain is located in the direction of flow is cooler.

Figure 9 isothermal fluid flow lines and pure nanofluids in Reynolds 500 and Grashof 10^5 for four the position of thermal spring is shown.

9- a position with respect to the Reynolds number vortices are formed within the chamber due to engulfed the whole body during the spring and surrounding temperature lines surrounding the object.

9 -b in the majority of the flow from the lower body crossing vortex is created around. Unlike Reynolds 100 around object is surrounded.

9 -c position given that the object is in the path of the main entrance to the lower left of the object passes and isotherms around object is surrounded and the outlet chamber is drawn.

9- d The bulk of the current position of around the object crossed lines is surrounded and continue to output.

In Table 4, the maximum temperature of the chamber in positions presented herein is based on sources identified the proper position. According to a statement by the position of top right corner of the net fluid when a maximum temperature is equal to 0.03686 and in the case of nano-fluid is reduced to 0.02354. Position b, chamber temperature maximum amount of pure fluid at 0.83701 is a different position than the maximum value of the temperature.

In Table 5, the same as before to determine the optimum location is at 500 Reynolds. Here are the best positions in the top right corner of the net fluid maximum temperature is equal to 0.01129 and in the case of nanofluids is 0.00627. B position of the chamber temperature is the highest value. According to the figures presented in the upper left corner of b, or in other words, less contact with the springs that flow is a major factor in both the inappropriateness of the situation is Reynolds.

The following figures relate to the situations listed above.

Table 4 compares the data on the maximum temperature of the chamber in Reynolds 100

θmax **Ø= 0.0**	θmax **Ø= 0.05**	**Position of Springs**
0.03686	0.02354	**a**
0.83701	0.83641	**b**
0.34384	0.28946	**c**
0.68259	0.66956	**d**

Table 5 compares the data on the maximum temperature of the chamber in Reynolds 500

θmax **Ø= 0.0**	θmax **Ø= 0.05**	**Position of Springs**
0.01129	0.00627	**a**
0.63318	0.56464	**b**
0.02305	0.01932	**c**
0.14353	0.12417	**d**

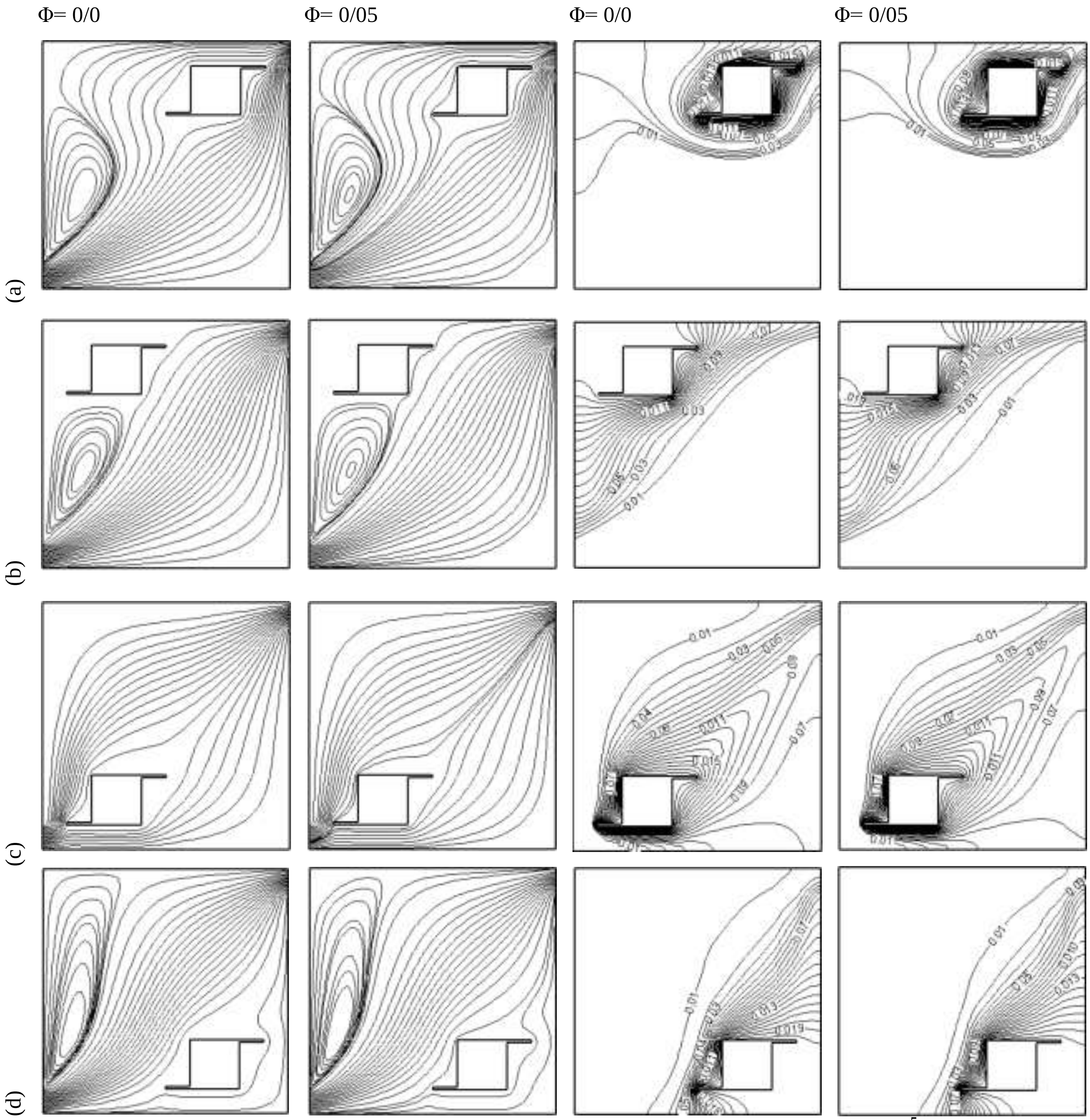

Figure 8 compares the isotherms of the pure fluid and nanofluid with Reynolds 100 and 10^5 for various occasions Grashof thermal springs

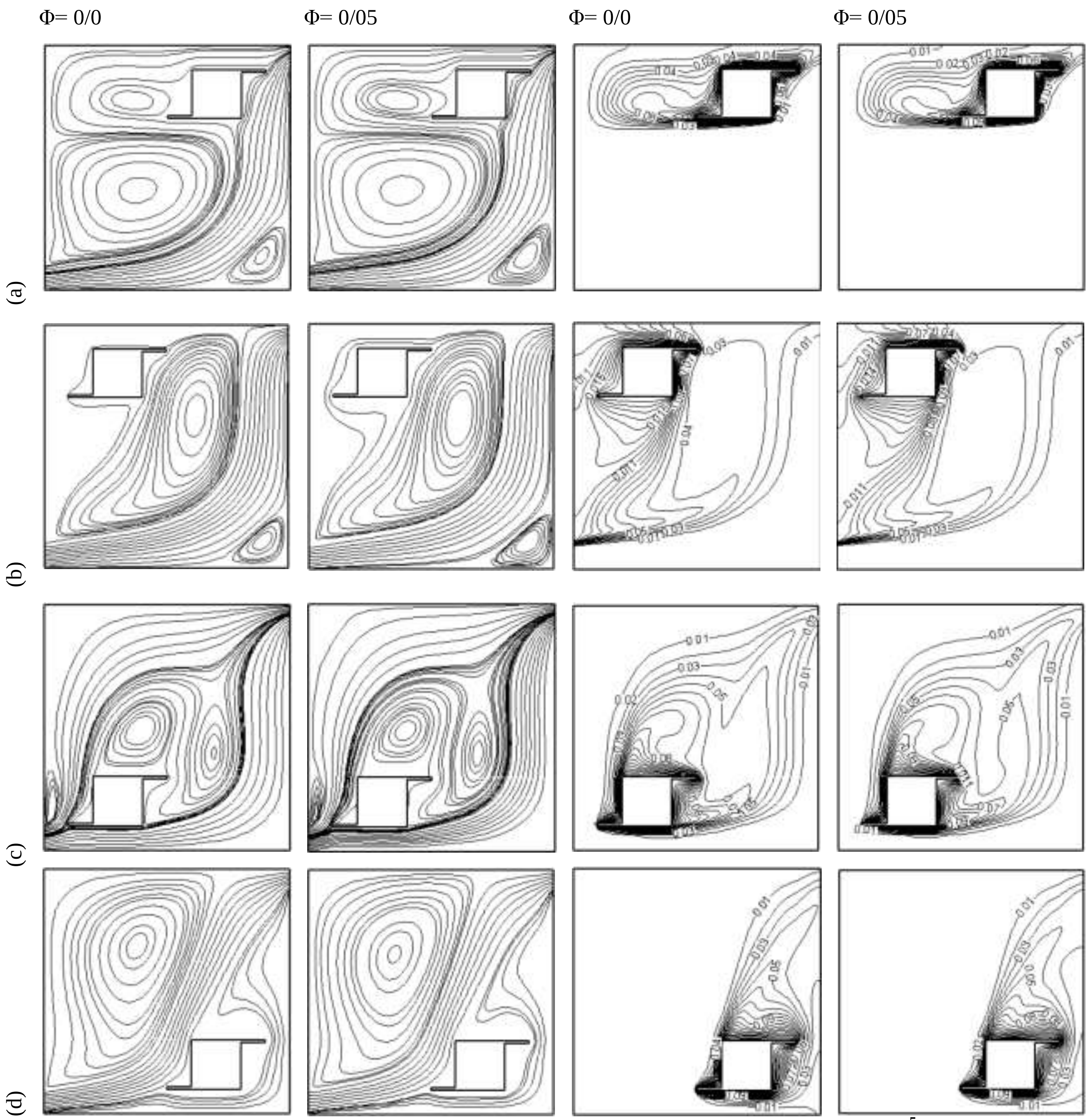

Figure 9 compares the isotherms of the pure fluid and nanofluid with Reynolds 500 and 10^5 for various occasions Grashof thermal springs

V. CONCLUSIONS

In this study the mixed convection in the air in the chamber with the inner barrier in the two-phase mixture, was investigated. For the case that the body was placed in the center hole, it's the average Nusselt, Reynolds, Grash of and different volume percentages were examined. Reynolds and Grashof is a good opportunity to analyze specific studies has been done. As the results of this research are as follows:

Increasing concentration of nanoparticles increases the average Nusselt and this demonstrates the improved heat transfer due to the use of nanofluids in comparison to pure water. Increase Grashof in low Reynolds increased the average Nusselt and improves the heat transfer but at high Reynolds increase Grashof increase natural motion that the increase in container handling mixed weakening and it reduces the amount of thermal springs. Accordingly, for the increase Grashof in high Reynolds average Nusselt is reduced. Finn because of the increased heat transfer area will be responsible for the improvement in heat transfer. Here, considering the average Nusselt fountain in the center of the cavity, with the addition of fins on both sides of the stream, it improves heat transfer relative to the case without fins. As was mentioned above, the position where the maximum temperature is the lowest number is appropriate. According to sources the best position to evaluate the various positions in both the top-right corner is 100 and 500 Reynolds. The maximum temperature in the chamber is the lowest number.

List of Symbols

A area (m^2)
a acceleration (m/s^2)
b length of the spring (m)
C length of the fin (m)
C_p specific heat (J/k$g.k$)
d diameter (m)
fdrag drag coefficient
Gr number Grashof
g acceleration due to gravity (m/s^2)
H height of the vertical wall (m)
K thermal conductivity (W/$m.k$)
K_B Boltzmann constant
L Horizontal length of the cavity (m)
Nu Nusselt number
Pe number Pklt
Ra Rayleigh number
Re Reynolds number
T is the temperature (k)
V Velocity (m/s)

Symptoms Greek

β thermal expansion coefficient (1/k)
μ Dynamic viscosity ($kg/m.s$)
θ dimensionless temperature
ρ density (kg/m^3)

Φ Particle volume fraction

Subtitles

dr drift
ffe effective or equivalent
eq equivalent
f the fluid
max is the maximum
m mixed and moderate
nf nanofluid
p particles and secondary phases
q Initial Phase

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