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Numerical Analysis of the Effect of Configurations of Double Rotating Cylinders on Heat Transfer Enhancement Hybrid Nanofluid Flow in a Vented Cavity

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ABSTRACT: In this paper, the effect of configurations of rotating cylinders in a vented cavity with inlet and outlet port on the flow field and heat transfer enhancement of forced convection of Al2O3/Cu-water hybrid nanofluid flow in the laminar regime is numerically investigated. In this study, the influence of parameters as configurations of cylinders (A, B, C, and D), as well as the rotational velocity of cylinders (from -10 to +10), Reynolds number (from 100 to 500), and the volume fraction of nanoparticles (from 0.5% to 3%) on the flow field and heat transfer are studied. Results indicate that the average Nusselt number and the Performance Evaluation Index for configuration D are higher than other configurations. Also, it is obvious that by increasing the rotational velocity of cylinders, Reynolds number, and the volume fraction of nanoparticles, the Performance Evaluation Index increases. Also, by rotating the cylinders in the counterclockwise rotation direction with respect to the clockwise rotation direction, the η increases about 1.30. The results show that Al2O3/Cu-water hybrid nanofluid causes heat transfer enhancement compared to the Cu-water nanofluid and it increases the Performance Evaluation Index compared to the Al2O3-water nanofluid.

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1- Introduction

Fluid flow and heat transfer in the vented cavity are implemented in a wide range of technological applications in various fields. Costa and Raimundo [1] numerically investigated the effect of rotating cylinders on the mixed convection heat transfer in a cavity. They revealed that increasing the rotational velocity of the cylinder increases the heat transfer rate. On the other hand, hybrid nanofluids are an efficient way to improve heat transfer and thermal performance. Even though numerous studies have been performed on proposing and investigating the cavities with inlet and outlet ports from the position of ports [2], and the number of ports [3] standpoints, less research has been dedicated to using simultaneous rotating cylinders in the cavities with inlet and outlet ports for heat transfer enhancement. One of particular relevance here is the work of Selimefendigil and Öztop [5], who conducted a numerical study on a 2D laminar forced convection heat transfer of hybrid nanofluid flow in a vented cavity with rotating cylinders. They investigated the effects of Reynolds number, nanoparticle volume fraction, rotational velocity, size, horizontal and vertical locations of cylinders on the hydrothermal performance. In this regard, the four novel configurations of rotating cylinders in a vented cavity in the presence of hybrid nanofluid are proposed and then analyzed from a heat transfer enhancement perspective, extending to helping the design of the thermal proposed systems.

2- Geometry

Fig. 1 represents a schematic view of the computational domain used for the present study.

The governing equations of the hybrid nanofluid flow, thermal, and species fields including continuity, momentum energy equations are as follows:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{1}{\rho_{hnf}}\frac{\partial P}{\partial x}+\frac{\mu_{hnf}}{\rho_{hnf}}\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right) \tag{2}$$

$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-\frac{1}{\rho_{hnf}}\frac{\partial P}{\partial y}+\frac{\mu_{hnf}}{\rho_{hnf}}\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right) \tag{3}$$

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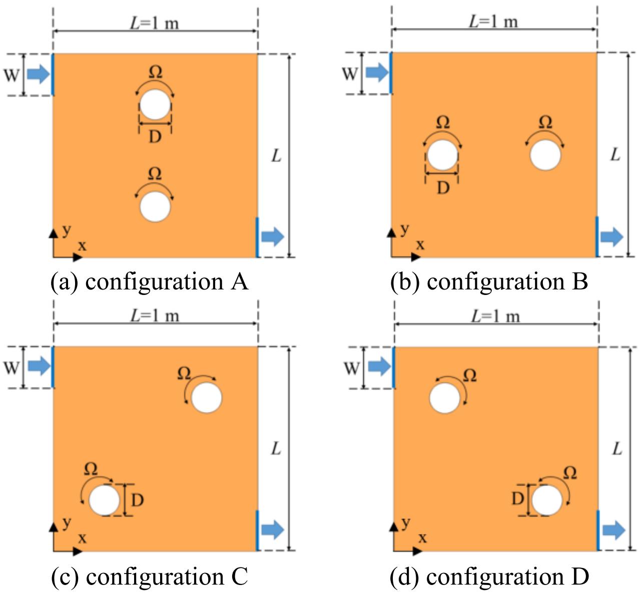

Fig. 1. Schematic view of the computational domain.

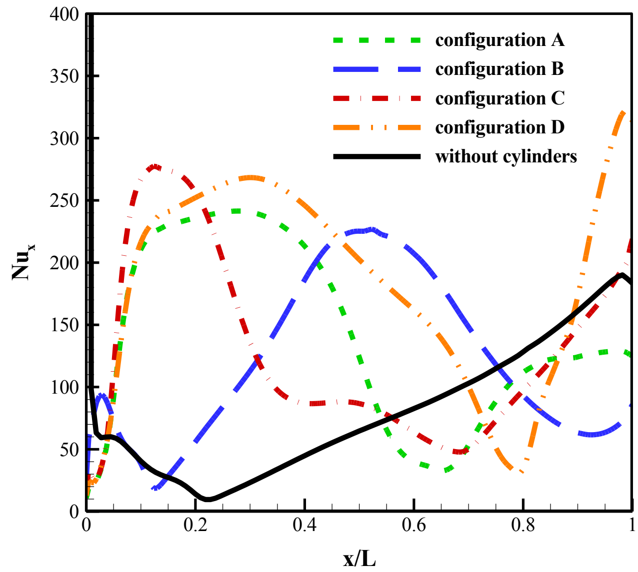

Fig. 2. Longitudinal evolution of the Nusselt number on the bottom wall of cavity for different configurations (φhnf =0.01, Re=500, Ω=+5)

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{K_{hnf}}{(\rho c_P)_{hnf}}\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right) \quad (4)$$

The thermo-physical properties of hybrid nanofluid are expressed as follows [4]:

$$\rho_{hnf}=(1-\varphi_{hnf})\rho_f+\varphi_1\rho_{p1}+\varphi_2\rho_{p2} \quad (5)$$

$$(\rho c_P)_{hnf}= (1-\varphi_{hnf})(\rho c_P)_f+\varphi_1(\rho c_P)_{p1}+\varphi_2(\rho c_P)_{p2} \quad (6)$$

$$\mu_{hnf}=\frac{\mu_f}{(1-\varphi_{hnf})^{2.5}} \quad (7)$$

$$K_{hnf}= K_f\left[\frac{\left(\frac{\varphi_1K_{p1}+\varphi_2K_{p2}}{\varphi_{hnf}}\right)+2K_f+2(\varphi_1K_{p1}+\varphi_2K_{p2})-2\varphi_{hnf}K_f}{\left(\frac{\varphi_1K_{p1}+\varphi_2K_{p2}}{\varphi_{hnf}}\right)+2K_f-(\varphi_1K_{p1}+\varphi_2K_{p2})+\varphi_{hnf}K_f}\right] \quad (8)$$

This study employs the simpleFoam module in the OpenFOAM. Divergence, gradient, and laplacian terms in Eqs. (1) to (4) are discretized separately in OpenFOAM by using proper discretization schemes.

3- Results and Discussion

To express the effect of the configuration of rotating cylinders on the flow field and heat transfer enhancement in a vented cavity, the local Nusselt number for configurations A, B, C, and D are shown in Fig. 2 at φ_{hnf} =0.01, *Re*=500, and *Ω*=+5. It is clear that changing the configuration cause considerable heat transfer enhancement. Also, it is obvious that the peak value of the Nusselt number for configuration C is higher than others. Moreover, the ratio of the average Nusselt number on the bottom wall of the cavity and performance evaluation criteria for different configurations of rotating cylinders are tabulated in Table 1. According to this table, the results indicated that in presence of rotating cylinders, the η is higher than 1 for all cases, and it is clear that the presence of rotating cylinders is effective on the thermal efficiency of the cavity. It is clear that the average Nusselt number and the Performance Evaluation Index for configuration D are higher than other configurations.

Impacts of rotational velocity on the average Nusselt number and η of configuration D at φ_{hnf} =0.03 and *Re*=250 are also shown in Fig. 3. It can be argued that the behavior of Nu_m/Nu_{m0} and η are nearly the same at different rotational velocities. In addition, the minimum of both parameters occurs in the stationary cylinders cases. It is found that the rotation of the cylinders (clockwise (CW) and counterclockwise (CCW) direction) acts in a way to enhance the average Nusselt number and η. The results show that the CCW rotation direction of the cylinders must be more beneficial than the CW rotation direction.

Table 1. The ratio of average Nusselt number on the bottom wall of cavity and performance evaluation criteria for different configurations of rotating cylinders in the cavity (φhnf =0.01, Re=500, Ω=+5)

Configuration	Nu_m/Nu_{m0}	η
A	1.68	1.62
B	1.46	1.35
C	1.54	1.41
D	2.29	1.83

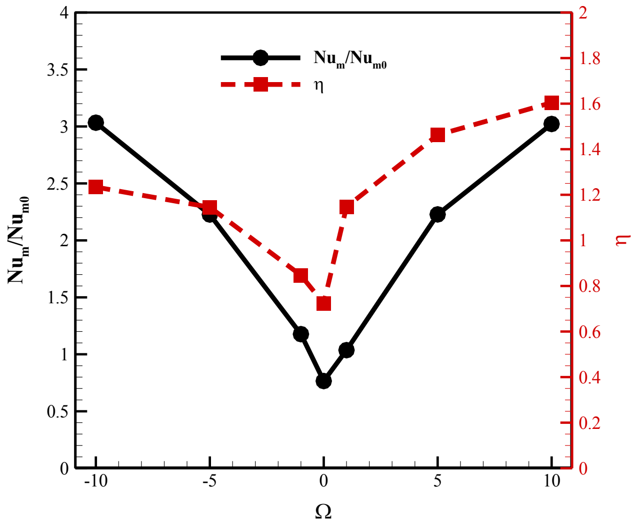

Fig. 3. The ratio of average Nusselt number on the bottom wall of cavity and performance evaluation criteria for the different rotational velocity of rotating cylinders for configuration D (φhnf =0.03, Re=250)

4- Conclusions

In this study, the effect of configurations of two rotating cylinders in a vented cavity in the presence of Al_2O_3/Cu-water hybrid nanofluid flow in a hydraulically laminar regime was numerically investigated. The effects of effectiveness parameters as Reynolds number, rotational velocity, configuration of rotating cylinder, and volume fraction of the nanofluid were studied for evaluation of the heat transfer enhancement. Results indicate that by increasing the rotational velocity of cylinders, Reynolds number, and the volume fraction of nanoparticles, the Performance Evaluation Index increases. Also, by rotating the cylinders in the counterclockwise rotation direction with respect to the clockwise rotation direction, the η increases about 1.30.

References

[1] V. Costa, A. Raimundo, Steady mixed convection in a differentially heated square enclosure with an active rotating circular cylinder, International Journal of Heat and Mass Transfer, 53(5-6) (2010) 1208-1219.

[2] L. Koufi, Z. Younsi, Y. Cherif, H. Naji, Numerical investigation of turbulent mixed convection in an open cavity: effect of inlet and outlet openings, International Journal of Thermal Sciences, 116 (2017) 103-117.

[3] S. Balaji, S. Lakshminarayanan, Improved design of microchannel plate geometry for uniform flow distribution, The Canadian Journal of Chemical Engineering, 84(6) (2006) 715-721.

[4] F. Selimefendigil, H.F. Öztop, Effects of a rotating tube bundle on the hydrothermal performance for forced convection in a vented cavity with Ag–MgO/water hybrid and CNT–water nanofluids, Journal of Thermal Analysis and Calorimetry, (2020) 1-18.

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