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Natural Convection around Heated Circular Cylinder Placed Inside Triangular Enclosure

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Abstract—*This paper investigates the natural convection phenomena with a heated circular cylinder placed inside the triangular enclosure by applying 2D approach. The Prandtl number for the analysis is (Pr=0.71). The problem was solved using ANSYS FLUENT 15 and governing equations follow Boussinesq approximation. Natural convection is observed in the triangular enclosure in which horizontal and vertical walls are adiabatic and hypotenuse wall is cold, offset from the center a heated circular cylinder is placed. Simulation is affected by the various parameters such as Rayleigh number (Ra) ranging from 10^3 to 10^6, aspect ratios (0.75 to 2), the dimensionless height of circular heater, the dimensionless location of the circular heater. The study is formulated in terms of temperature distribution, streamlines and mean Nusselt number variation along the heated cylinder and surface of the triangular enclosure.*

1. INTRODUCTION

Yesiloz and Aydin [1] investigated right-angled triangular enclosure for natural convection where bottom wall is heated, the sidewall is kept at a lower temperature, while hypotenuse, is kept adiabatic. Water is filled in the enclosure. The experimental analysis focuses on flow visualization studies while numerical study used the fluent software. With the increase in Rayleigh number, thermal stratification becomes more intensive close to surfaces where heat transfer takes place. Experimental and numerical results are in good agreement with each other fairly well. Ra is increased, thermal stratification is more intensive near the heat transfer surface, and fluid motion becomes active at the tip zones. Ridouane and Campo [2] investigated transient convection in isosceles triangular cavity air filled. Triangular base is heated and inclined walls of the triangle are kept at lower temperature. Saha [3] analyze heat transfer and fluid flow inside an enclosure made in triangular shape where instantaneous heating is provided on the inclined walls. Kent [4] numerically analyzed isosceles triangular cross-section enclosure for natural convection. Inclined walls of triangle enclosure are heated and the base is kept at lower temperature. A study took on different Rayleigh number and varying base angles from 15^0 to 75^0. Higher heat transfer is observed from the lower surface of the enclosure with small aspect ratio. Triveni and Panua [5] investigated water filled isosceles right-angled triangular enclosure for laminar natural convection. The base of the triangle contains a caterpillar (C)-curve shape wavy wall. Width and aspect ratio are varied for analysis. The base wall is heated and inclined walls are cooled. The study observed that the heat transfer rate improved by introducing caterpillar curved shape wavy wall. Sahu and Singh [6] analyze square enclosure filled with air in which equilateral triangular cylinder heater is placed. Vertical walls of the enclosureis at a lower temperature while horizontal walls taken as adiabatic. Aspect ratio is varied with the different size of the triangular heater. Heat transfer is more at the upper area of vertical walls. Bhardwaj and Dalal [7] investigated numerically undulated porous enclosure shaped a right-angled triangle. The base wall is provided with sinusoidal temperature while vertical and hypotenuse wall is maintained at isothermal lower temperature. Heat transfer increases with increasing Darcy number. Mansour and Ahmed [8] analyzed inclined triangle having Cu-water which is porous in nature. The heater is placed onthe base wall of the enclosure and left wall while the inclined wall is at a lower temperature. With the increase in volume fraction of the nanoparticle, average Nusselt number increases.

NOMENCLATURE	
g Gravitational acceleration, m/s^2	T_H Higher temperature of inside body, ^oC
Gr Grashof number	U, V Dimensionless velocity components in X- and Y-directions
h Convective heat transfer coefficient W/m^2-K	x, y Rectangular coordinates
K Thermal conductivity, W/m-K	X, Y Dimensionless rectangular coordinates
L Length of triangular enclosure, m	A Aspect ratio (H/L)
Nu Surface averaged Nusselt number	**Greek Symbols**
Pr Prandtl number	α Thermal diffusivity of the fluid
p Pressure, Pa	β Coefficient of volumetric expansion Of the fluid
P Dimensionless pressure	ν Kinematic viscosity of the fluid
u, v Velocity components in x-and y -direction, m/s	θ Dimensionless temperature Ψ Non Dimensional Stream function
T_L Lower temperature of enclosure wall, ^oC	r Radius of circular cylinder Ω Non Dimensional vorticity

2. PROBLEM STATEMENT AND GOVERNING EQUATION

Fig. (1) shows the computational domain of the problem in which heated circular cylinder is placed inside a triangular enclosure at distance of c=L/3 and center is H/3 from the base. The radius of the cylinder is r=L/6, inclined wall behaves like a cold wall and remaining walls are adiabatic. Fig. (2) shows mesh generation in the computational domain.

Dimensionless governing equations in streamline-vorticity:

$$X = \frac{x}{L}, Y = \frac{y}{L}, \Psi = \frac{\Psi Pr}{v}, \theta = \frac{T-T_c}{T_h-T_c}, U,V = \frac{(u,v)L}{\alpha}, \Omega = \frac{w(L)^2 Pr}{v} \quad (1)$$

$$\text{u}= \frac{\partial\Psi}{\partial y}, \text{v}= -\frac{\partial\Psi}{\partial x}, \omega = \left(\frac{\partial v}{\partial x} - \frac{\partial v}{\partial x}\right), \quad (2)$$

$$Ra = \frac{\beta g(T_h-T_c)L^3 Pr}{v^2}, Pr = \frac{v}{\alpha} \quad (3)$$

Governing equations

$$-\Omega = \frac{\partial^2\Psi}{\partial X^2} + \frac{\partial^2\Psi}{\partial Y^2}, \quad (4)$$

$$\frac{\partial^2\Omega}{\partial X^2} + \frac{\partial^2\Omega}{\partial Y^2} = \frac{1}{Pr}\left(\frac{\partial\Psi}{\partial Y}\frac{\partial\Omega}{\partial X} - \frac{\partial\Psi}{\partial X}\frac{\partial\Omega}{\partial Y}\right) \text{ - Ra}\left(\frac{\partial\theta}{\partial X}\right),$$

$$\frac{\partial^2\theta}{\partial X^2} + \frac{\partial^2\theta}{\partial Y^2} = \left(\frac{\partial\Psi}{\partial Y}\frac{\partial\theta}{\partial X} - \frac{\partial\Psi}{\partial X}\frac{\partial\theta}{\partial Y}\right), \quad (5)$$

Local Nusselt number

$Nu_n = -\frac{\partial\theta}{\partial n}$(6) at inclined wall

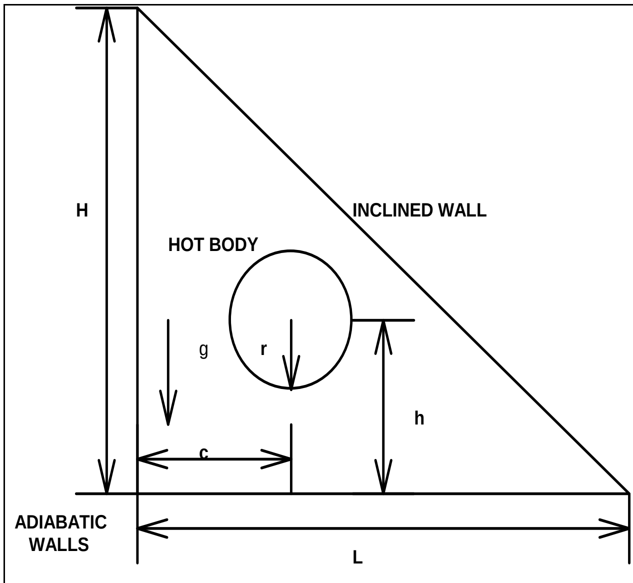


Fig. 1: Computational Domain

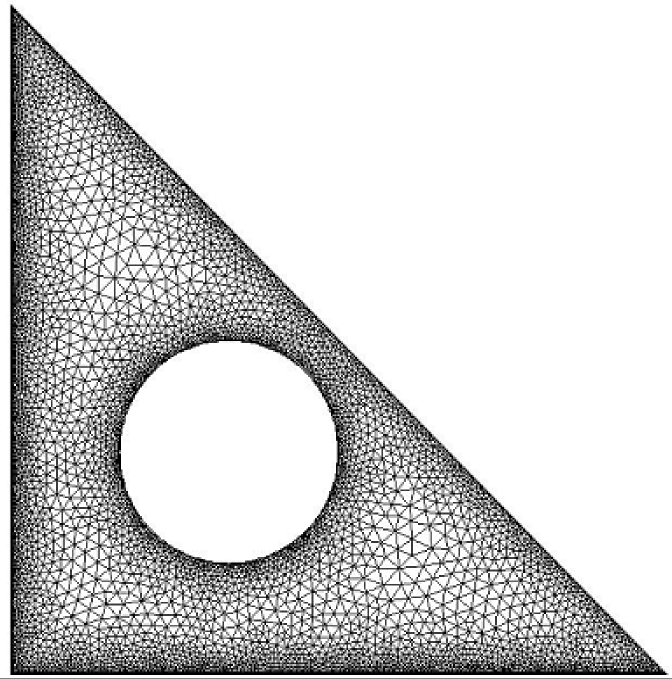


Fig. 2: Mesh Generation

3. RESULT AND DISCUSSIONS:

Ra	Surface average Nusselt no plot at Hot cylinder			
	A.R=0.75	**A.R=1.0**	**A.R=1.50**	**A.R=2.0**
10^3	16.711	6.518	9.235	8.656
10^4	15.527	11.546	9.585	9.388
10^5	17.601	14.487	14.354	15.095
10^6	39.004	35.717	35.809	36.962

Ra	Surface average Nusselt no plot at cold wall			
	A.R=0.75	**A.R=1.0**	**A.R=1.50**	**A.R=2.0**
10^3	13.995	4.824	5.362	4.052
10^4	12.995	8.540	5.563	4.392
10^5	14.745	10.727	8.338	7.069
10^6	32.664	26.438	20.778	17.282

Flow and temperature fields are simulated using the given parameters such c (distance from the vertex to one-third of the base length), L length of the base, Height of the enclosure. Flow visualization can be seen from Ra=10^3 to 10^6. Three vortices are formed for all Rayleigh number, a vortex is formed on the left side of the circular heater which rotates in an anticlockwise direction. The other two are forming in top and right side of the circular heater and rotate in clockwise direction. Because the hot air moves from heated cylinder to top of the inclined wall, The shape remains approximately constant for Ra=10^3 to 10^5 because conduction effect remains dominated. For higher Ra=10^6 faster speed convection takes place which leads to turbulences in the domain.

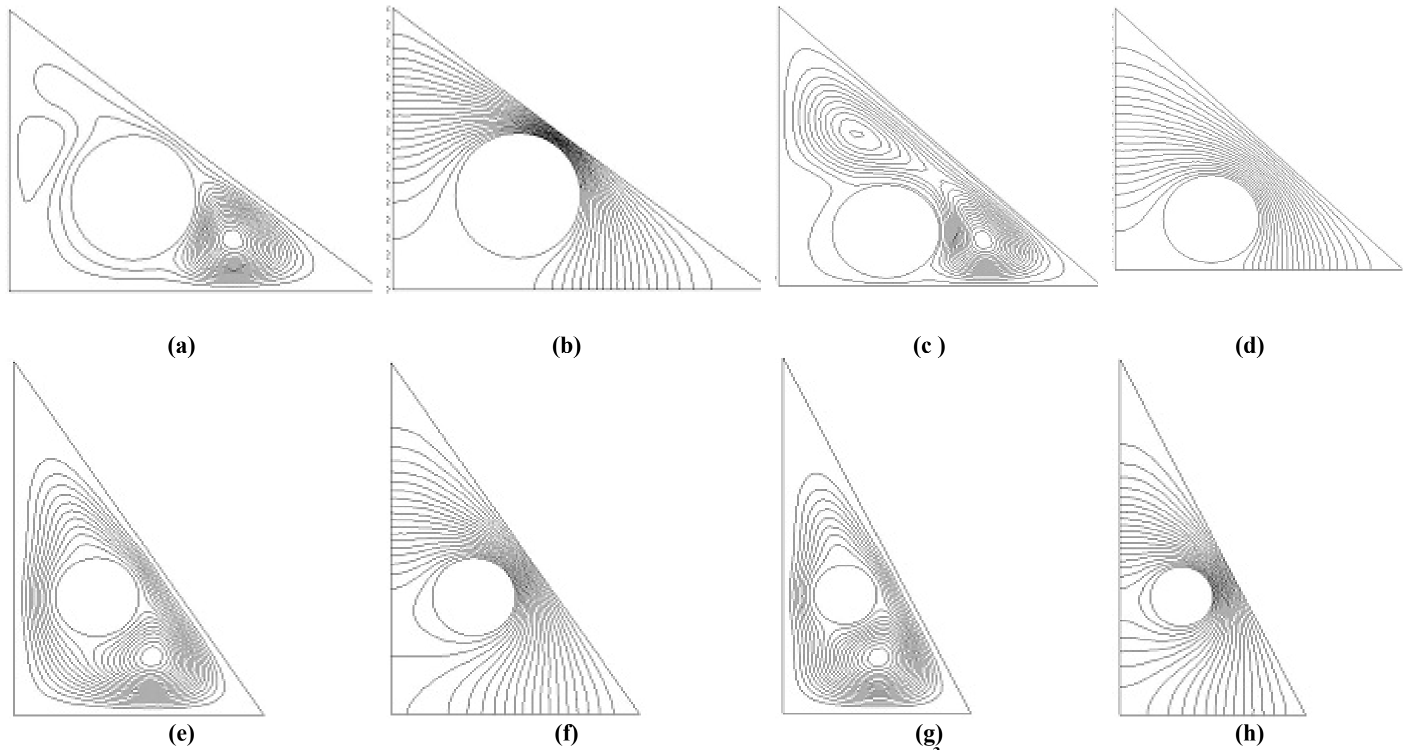


Fig. (3) Streamline & Isotherm for Ra =10^3

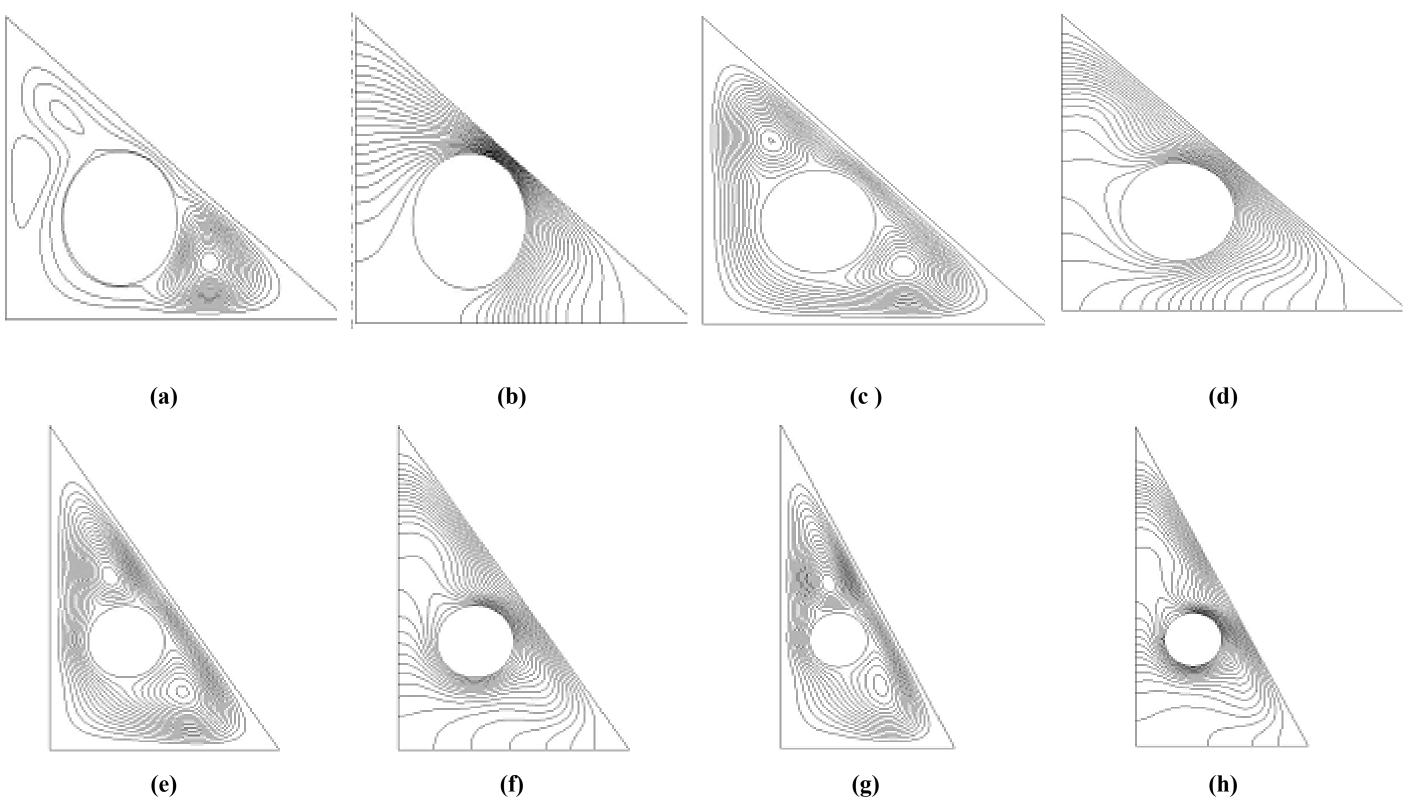
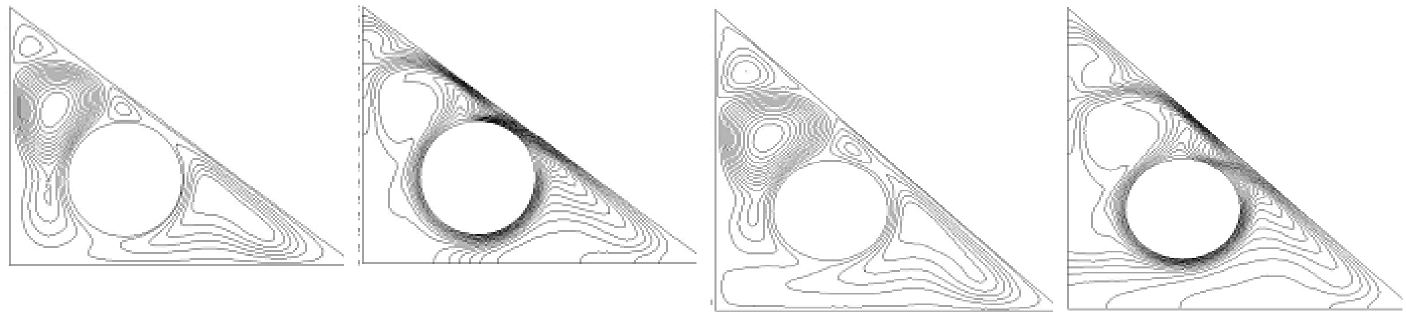
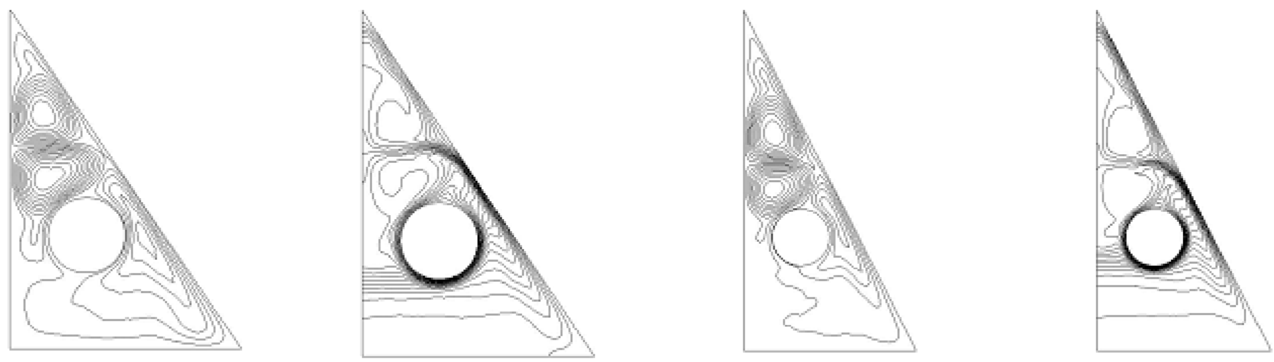


Fig. (4) Streamline and Isotherm for Ra=10^5



(a) **(b)** **(c)** **(d)**



(e) **(f)** **(g)** **(h)**

Fig. (5) Streamline and Isotherm for Ra=10^6

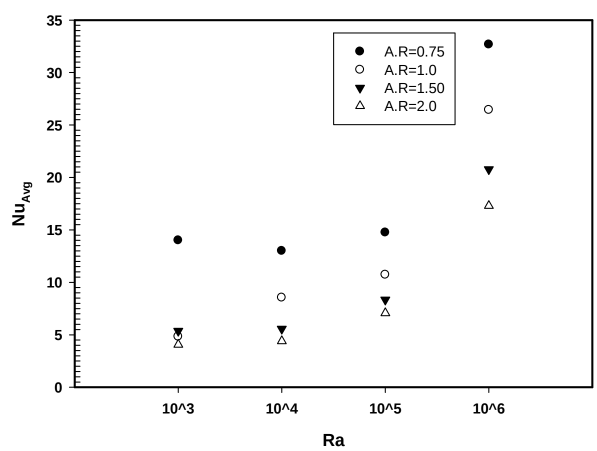


Fig. 6: Average Nusselt no plot at cold wall

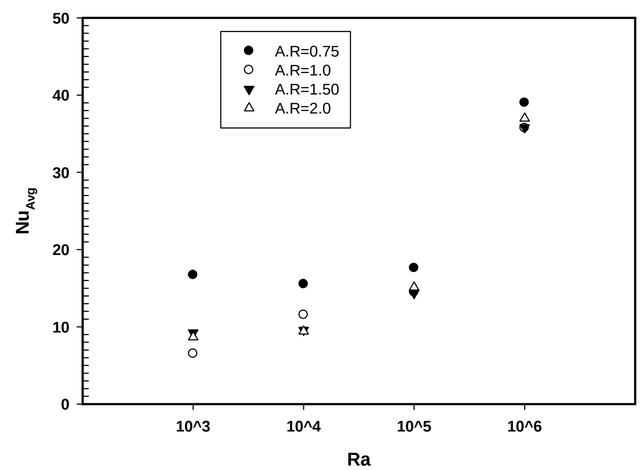


Fig. 7: Average Nusselt no plot at hot body

In the Fig. (6) shows the variation of the average Nusselt number at the inclined wall. For Ra=10^3 to 10^4 average Nusselt number is constant due to the conduction dominance but at A.R=0.75 average Nusselt number is maximum due to the height variation of the triangle enclosure, gap of the heated cylinder and cold inclined wall. As the Rayleigh number increases average Nusselt number also increases and becomes maximum at Ra=10^6. In Fig. (7) merging of aspect ratios 1.5 & 2 occurs due to the turbulence in the domain.

4. CONCLUSION

Numerical simulation of natural convection inside the heated circular cylinder was performed with the important parameters such as Rayleigh number, hot cylinder radius and aspect ratios. Following conclusions were found which are listed below:

1).Initially for lower Rayleigh number Nusselt number remains almost constant due to conduction effect but as the Rayleigh number increases the value of Nusselt number also increases.

2).Variation in the aspect ratio provides maximum values of the Nusselt number.

3). It is observed that variation in the aspect ratio also leads to changes in the height of the enclosure i.e heat transfer rate decrease due to the minimum distance between hot cylinder and cold wall.

4).Streamlines become weak at higher aspect ratio and due to increasing distance between hot cylinder and cold wall.

5. ACKNOWLEDGEMENT:

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REFERENCES:

[1] Gurkan Yesiloz, Orhan Aydin," Laminar natural convection in right-angled triangular enclosures heated and cooled on adjacent walls," International Journal of Heat and Mass Transfer,60, pp 365-374, 2013.

[2] E.H. Ridouane, A. Campo, Formation of a pitchfork bifurcation in thermal convection flow inside an isosceles triangular cavity, Phys. Fluids 18 (2006). 074102(1-8).

[3] S.C. Saha, Unsteady natural convection in a triangular enclosure under isothermal heating, Energy Build. 43 (2–3) (2011) 695–703

[4] E. Fuad Kent,Numerical analysis of laminar naturalconvection in isosceles triangular enclosures for the cold base and hot inclined walls, Mechanics Research Communications 36 (2009) 497–508.

[5] Manoj Kr. Triveni and Rajsekhar Panua, "Numerical simulation of natural convection in a triangular enclosure with caterpillar (C)-curve shape hot wall," International Journal of Heat and Mass Transfer 96 (2016) 535–547.

[6] K. B. Sahu and Ravi Kumar Singh, "Analysis of heat transfer and flow due to natural convection in theair around heated triangular cylinders of different sizes inside a square enclosure", 10th International Conference on Mechanical Engineering, ICME 2013, Procedia Engineering 90 (2014) 550 – 556.

[7] Saurabh Bhardwaj and Amaresh Dalal, "Analysis of natural convection heat transfer and entropy generationinside porous right-angled triangular enclosure,"International Journal of Heat and Mass Transfer 65 (2013) 500–513.

[8] M.A. Mansour and Sameh E. Ahmed, "A numerical study on natural convection in porous media-filled an inclined triangular enclosure with heat sources using nanofluid in the presence of heat generation effect", Engineering Science and Technology, an International Journal 18 (2015) 485-495.