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Study on the Numerical Investigation of the Natural Convection of an Elliptical Enclosure with a Hot Curved Triangular-Shaped in Different Orientation

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ABSTRACT

This study investigates natural convection in a cold elliptical enclosure that is around an equilateral triangle with curved vertices, which represent the hot walls (T_h) at five different triangle location cases. The oval shell surrounding the hot curved triangles fills with air. This study primarily investigates how arcs enhance natural convection by examining their impact on streams and isothermal lines at various locations within a curved triangle. However, the main parameters carried out in this work are the Rayleigh number, triangle location, and Nusselt number. The Rayleigh numbers used in this work are varied by the interval $10^4 \leq Ra \leq 10^6$, which was applied for all locations of a curved triangle. The Ansys 2020 R1 software has been used to analyse the concept of natural convection by solving the governing equation using the finite volume method with the presented Boussinesq approximation. Furthermore, the high Rayleigh number (10^6) results in a significant and clear breakthrough. On the other hand, the Nusselt number's minimal value occurs on the middle arc of the inner curved triangle in most cases of curved triangle locations. Also, it reveals that the bottom location of a curved triangle is optimal since it has the maximum Nusselt number at the middle arcs of the triangle.

1. INTRODUCTION

Heat by natural convection is a basic method of heat transferring from many engineering technology applications. Many engineering applications can be seen that used enclosure technology with different models like design of building and cooling systems. However, the circular enclosure is a very useful shape in the fields of mechanical engineering and manufacturing [1]. The horizontal circular annulus is a frequently seen geometric shape in many applications such as heat exchangers, water distillation vapor condensers, solar collector-receiver systems, subterranean electrical transmission cables, and food processing equipment. Multiple technological applications carried out to examine the phenomenon of natural convection inside the enclosures.

Because of the wide application of heat transfer by natural convection, several researchers have investigated it numerically [2, 3]. While some of these investigations were concentrating on a natural convection between inner body containers. Others, were conducted inside containers of both simple and complex designs. Where, Abouei Mehrizi et al. [4] conducted a numerical study using the Lattice Boltzmann method to study laminar flow and natural convection in a flat ring-shaped area between a heated triangular inner cylinder and outer cylinder represented by a cold elliptical with various Rayleigh numbers. The study found that a rise in the Nusselt number that occurs when the aspect ratio drops and/or the Rayleigh number increases, and a vertically placed ellipse has a higher heat transfer rate. Dogonchi and Tayebi [5] conducted a study on the heat transfer due to natural convection with in square enclosure having a wavy circular heater under a magnetic field and nanoparticles. In a similar context, Moraveji and Hejazian [6] investigated the natural convection heat transfer in rectangular enclousure with an oval-shaped heat source filled with Fe_3O_4/water nanofluid. The average Nusselt numbers are presented for several Rayleigh numbers values with multiple heat source sizes. The study reveals that the concentration of nanoparticles, heat source geometry, and Rayleigh number values significantly impact the behavior of average Nusselt numbers, highlighting the importance of heat source configuration. Also, Bouhalleb and Abbassi [7] performed a study of the two-dimensional steady laminar natural convection in an inclined rectangular enclosure filled with CuO-water nanofluid through numerical simulations. They revealing that heat transfer initially increases and then decreases with increasing inclination for aspect ratios equal (1) or greater. On the other hand, it consistently increases for aspect ratios less than 1.

Moreover, Nithyadevi et al. [8] examined laminar natural convection heat transfer in a two-dimensional rectangular enclosure with discrete heaters. Increasing values of Prandtl number lead to increased fluid flow and heat transfer, thereby forming hydrodynamic and thermal boundary layers, respectively. For his part, Al-Farhany and Abdulkadhim [9] analyzed conjugate natural convection heat transfer in a partially heated square porous enclosure. They Results indicated that increasing the modified Rayleigh number increased heat transfer, leading to an increase in the local Nusselt number for both fluid and solid phases. In addition, Torki and Etesami [10] investigated the natural convection heat transfer of SiO_2/water nanofluids in a rectangular enclosure at different inclination angles. Results showed that the heat transfer coefficient decreased with tilt angle and had a more pronounced effect on the Nusselt number at low concentrations. Also, Graževičius et al. [11] revealed that natural convection occurs above the heater rod, while water is thermally stratified below. Heat from the higher and lower regions is transferred via conduction. Thermal stratification disappears after the water temperature reaches saturation and boiling begins.

In 2010, Xu et al. [12] conducted a study on the convection heat rate between a heated inner cylinder and an outer triangular enclosure. The system maintains consistent temperatures, and the control equations are located along the bottom wall. The study found that raising Rayleigh numbers causes the streamline contours' symmetry to break, focusing the isotherm contours in the upper regions, specifically within gaps. Sheikholeslami et al. [13] investigated the effect of a magnet field in the space that existed between an elliptical internal body and an elliptical container filled with Nano fluid. Dogonchi [14] embed the Fe_3O_4-filled internal rhombic structure into a wavy casing using a finite element approach and a new viscosity model dependent on a magnetic field. The study considered various parameters like aspect ratio, radiation parameters, Rayleigh and Hartmann numbers, and nanoparticle form factors for various shapes. The results showed that increasing the aspect ratio decreases heat transfer transmission rate by maintaining a constant Hartmann number in the magnetic field.

Many of studies on convective heat transfer using elliptical enclosures having various geometric, circumstances and boundary values that have been examined in the previous literature [15-19]. Bouras et al. [15] conducted a numerical study on the effects of the square geometry ratio and Rayleigh number on natural convection heat transfer and Newtonian fluid flow in a horizontal circular area. They used Fluent-CFD to simulate a mathematical model. Results showed that the Rayleigh number increased the intensity of natural convection, while lower geometry ratios created more free space, promoting modest convection transfer. Conversely, as this ratio grows, average Nusselt number likewise increases. Also, Tayebi et al. [16] investigated the effect of hybrid Nano fluid, natural convection, and entropy formation on heat transfer rate in an elliptical annular cavity. The study used finite volume method to solve the CFD problem, demonstrating that the highest heat transmission rate occurs when heat absorption reaches its maximum amount.

The ways in which eccentricity affects open-ended square rod annular heat transfer characteristics and the influence of heat power and eccentricity on the mean Nusselt number are examined experimentally by El-Maghlany et al. [17]. The findings indicated that the convection heat transfer coefficient exhibited a decrease when the eccentricity increased in both directions. In addition, it was discovered that the midway region between the two ends has the lowest rate of heat transfer, resulting in the highest surface temperature. In 2022, Shah et al. [18] investigated the characteristics of a low-temperature cylinder that undergoes natural convection inside an equilateral triangular hollow. The fluid exhibits non-Newtonian behavior and is incompressible with a laminar flow system. The study was conducted in a two-dimensional setting and solved numerically using Comsol Multiphysics. Results showed that the heat flux coefficient increased with increases in Rayleigh and Prandtl numbers, but as the Rayleigh number increased, the velocity profile became faster. In 2024, Hameed et al. [19] conducted a study on the horizontal magnetic field on mixed convection flow in an oval-shaped enclosure with a non-Newtonian Nano fluid. They used the Galerkin finite element technique to solve for a heated inner circular cylinder, a cylindrical, heated inner wall, and a chilly outer one. The study examined properties like n-index, nanoparticle volume ratio, Mahammed et al. [20] investigated how water-based Al_2O_3 Nano fluid behaves in a triangle cavity under MHD-forced convection, with a right-angle corner having a quarter-circle porous medium maintained at a consistent elevated temperature. The findings demonstrate the influence of the magnetic field on heat transfer and the amplifying effect of the Rayleigh number. Fayz-Al-Asad et al. [21] conducted a numerical study on the impact of a rectangle heat starting to translate in a confined environment by the natural convection flow via a triangle hollow. The analytical solution was validated using a finite element technique using numerical methods. The findings obtained have verified that the rate of thermal oscillation in the triangular cavity rises as the Rayleigh number increases. In a study conducted by Abdel-Kazem [22], the process of generating and absorbing internal heat through natural convection heat transfer was examined. The experiment involved a heated circular inner cylinder and an oval envelope filled with a mixture of copper and water nanoparticles, which was cooled. Additionally, a horizontal magnetic field was present during the experiment. The findings suggest that heat transmission is more efficient under heat absorption circumstances than to heat generating situations.

In Jalili et al. [23] conducted a study to examine the impact of cylindrical barriers of varying quantities and dimensions inside a triangular hole contain a Nano fluid by natural convection. The researchers used a finite element approach for their investigation. The analysis revealed that the inclusion of several cylindrical barriers increased the velocity range of the Nano fluid inside the cavity. This, in turn, led to higher Rayleigh numbers, rebound forces, and heat transfer levels within the triangular cavity.

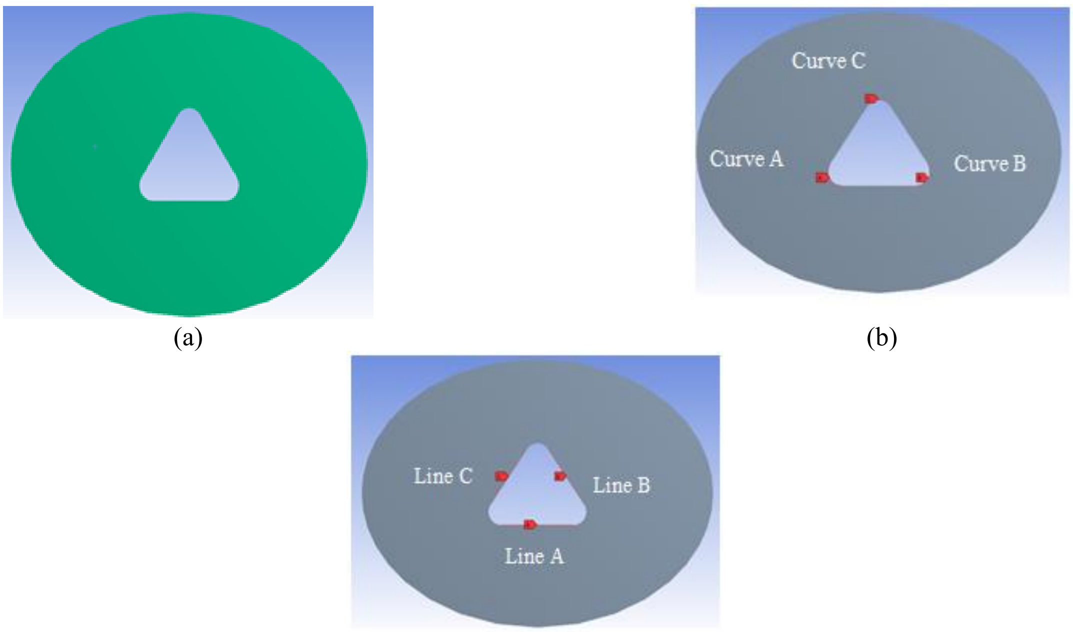
In 2023, Mohammed et al. [24] conducted a study on the heat transfer caused by laminar steady-state natural convection of air within cold circular cage produced by a heated equilateral triangular inner cylinder placed in the ratio of four radii at the enclosure's center as well as four inclination angles based on the findings, the vortex center moves upwards towards the central plane of the enclosure, and the streamlines along the walls become more focused as the Rayleigh number grows. Furthermore, the positions of these peaks resulting from the torsion of the thermopile do not impact the inclination angle of the triangle cylinder or the maximum values of the Nusselt number at that location along the interior surface of the annular cylinder. In 2024, Behtarinik and Mehryar [25]

Conducted many shapes of enclosure (trapezoidal, triangle, rectangular and innovate polygon (twelve lines) shape. They study numerical natural convection due hot one side of the enclosure shape and other side is cold with constant temperature. They observed that clear influence and connected between Nusselt number and Rayleigh number not only the changing of shape but also to which cold and hot side in the shape of enclosure.

This paper employs the Ansys 2020 R_1 commercial code for numerically solving the heat-free convection heat transfer within the elliptical walls of a cold enclosure (T_c) and an equilateral curved triangle hot wall (T_h) across five different triangle location cases. Both the heated inner triangle and the outer elliptic enclosure are maintained at constant temperatures. As shown from previous authors, many methods for solving numerically the natural convection with in oval shape rounded several hot shapes like square, triangles or other shapes. Despite the multiplicity of shapes studied using appropriate hypotheses, there is a weakness in studying the sudden change in the basic shape resulting from adding an arc at the corners. This change, despite its simplicity, has a clear effect on improving heat transfer by convection and the possibility of adding it to many important engineering applications. This research aims to investigate the impact of a curved line that is connected between two adjacent lines with a triangular cylinder located within, as seen in Figure 1. Moreover, the location or orientation of the smooth hot triangle and its heat transfer rate are carried out in detail with different types of Rayleigh numbers. This value of the Rayleigh numbers changes from the laminar situation ($Ra=10^4$) until the turbulent situation ($Ra=10^6$). More details about the case studies are presented in the next sections. The manuscript has arranged as following section 2 outlines a description of the physical model. Section 3 presents the governing equations and boundary conditions. Section 4 introduces numerical formulation and code validation. Section 5 is about results and discussion. Section 6 introduces conclusions. Section 7 is the references, and section 8 is nomenclature.

2. MODEL OF ENCLOSURE

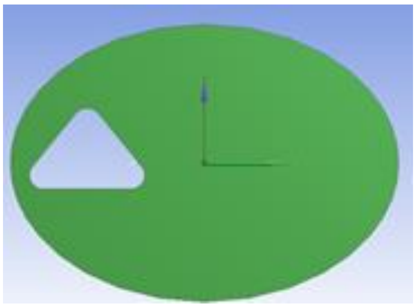
Elliptical enclosure geometry was carried out with an equilateral triangle that has a curvature in all vertices, as shown in Figure 1. The outer wall of the enclosure kept at temperature (T_c), whereas the curved equilateral triangle wall is hot with constant temperature (T_h). The curved triangle was placed in a middle position inside the ellipse to investigate the heat convection inside the cavity that containing air as a working fluid. The operating conditions are steady and laminar, with air presented as incompressible. The parametric variables were Rayleigh numbers $10^4 \leq Ra \leq 10^6$. Also, five position cases of a hot equilateral curved triangle are taken for natural convection investigation, as shown in Figure 2.



(a) (b) (c)

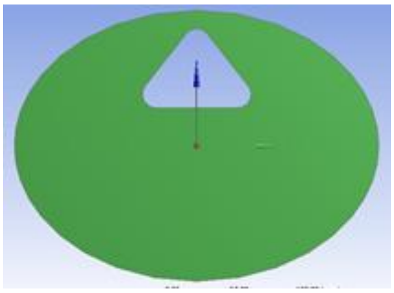
Figure 1. The schematic diagram of the physical model under investigation where: a) the general shape under investigation, b) the location of arcs, and c) straight lines location

a) Case I b) Case II



c) Case III

d) Case IV



e) Case V

Figure 2. The cases under investigation of curved triangle at multiple locations inside elliptical enclosure

3. THE GOVERNING EQUATIONS AND BOUNDARY CONDITIONS

The case study is a laminar, two-dimensional steady state that neglects viscous dissipation, heat generation, and radiation. For analysis the cold elliptical enclosure with cold curved triangle applied the continuity, momentum, and the energy governing equations may be expressed in a dimensionless form, which can be written as:

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

$$\rho(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y})=-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right) \tag{2}$$

$$\rho(u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y})=-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+\rho g\beta(T-T_c) \tag{3}$$

$$\rho c_p(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y})=\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right) \tag{4}$$

The velocity analysis parts in the x and y-direction have expressed by symbols u and v respectively. T refers to the fluid's temperature, whereas p represents the pressure. There are many physical properties have contained inside these equations can be reviewed in the nomenclature. The dimensionless forms of these governing equations have been specified as follow:

$$\mathrm{X}=\frac{\mathrm{x}}{\mathrm{Lc}},\mathrm{Y}=\frac{\mathrm{y}}{\mathrm{Lc}},\mathrm{U}=\frac{\mathrm{uLc}}{\alpha},\mathrm{V}=\frac{\mathrm{vLc}}{\alpha}, \quad Pr=\frac{pL_c^2}{\mu\alpha},\theta=\frac{T-T_c}{T_h-T_c}, \tag{5}$$

The dimensionless form presents the continuity, momentum, and energy governing equations as follows:

$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}=0 \tag{6}$$

$$U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}=-\frac{\partial P}{\partial X}+\left(\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}\right) \tag{7}$$

$$U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}=-\frac{\partial P}{\partial Y}+\left(\frac{\partial^2 V}{\partial X^2}+\frac{\partial^2 V}{\partial Y^2}\right)+RaPr\theta \tag{8}$$

$$Pr(U\frac{\partial \theta}{\partial X}+V\frac{\partial \theta}{\partial Y})=\left(\frac{\partial^2 \theta}{\partial X^2}+\frac{\partial^2 \theta}{\partial Y^2}\right) \tag{9}$$

where, $Ra=\frac{g\beta(T_h-T_c)L^3}{\alpha v}$, $Pr=\frac{v}{\alpha}$.
where, Lc refers to the thermal characteristic length that suggested by each case under investigation.

U and V refer to the stream function velocity components, which describe the flow inside the annular space between the ellipse and curved triangle. Since, the flow is in 2D in this investigation, the velocity components and the stream function as presented below can be used.

$$U=\frac{\partial \Psi}{\partial Y},V=-\frac{\partial \Psi}{\partial X},\text{and }\frac{\partial^2 \Psi}{\partial X^2}+\frac{\partial^2 \Psi}{\partial Y^2}=\frac{\partial U}{\partial Y}-\frac{\partial V}{\partial X} \tag{10}$$

The average Nusselt number is determined by using the following equations. locally for around the all parts of curved triangle, as shown below:

$$Nu_L=\frac{\partial \theta}{\partial n} \tag{11}$$

$$Nu_{ave}=\frac{1}{2\pi}\int_0^{2\pi}Nu_L(\theta)d\theta \tag{12}$$

A mathematical formulation known as the heat function serves as the basis for the heat line expression.

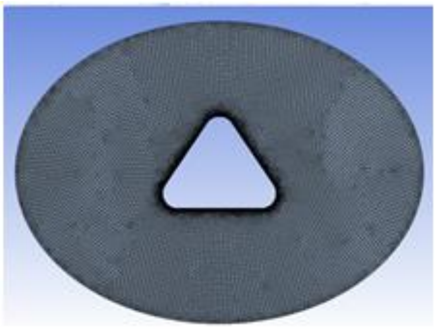
The above equations describe the two-dimensional laminar flow in this elliptical cavity. The fluid (air) must adhere to the assumptions of being incompressible, stable, and satisfying the Boussinesq approximation. The study of this particular scenario is conducted using the ANSYS 2020 R1 program, as stated before.

For high Rayleigh number (10^6) the turbulent flow has been taken in account to satisfy the special case of flow behaviour. The turbulent flow that comes from high Rayleigh number will occur at Low-Reynold number. Moreover, the turbulent model has been presented to include the swirl effect, which is formulated by the thermal effect on fluid viscosity. Since, the RNG k-ε model was choosn with in ANSYS 2020 R1 software and to apply in this case with the following assumptions:

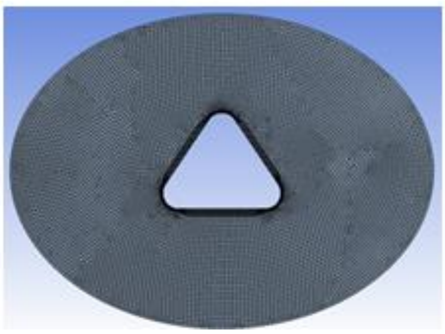
1. $\partial\varepsilon/\partial y=0$ at the wall of hot curved triangle.
2. No slip of boundary layer around curved triangle.
3. Steady and mutually dominate between viscouse force and buoyancy force that comes from temperature distribution within fluid and around the hot curved triangle.
4. The air viscosity has been struggled by thermal effect producing turbulent behavior.
5. The ellipse has constant lower temperature Tc while the triangle has constant hot temperature Th.
6. The main force producing flow is Bouyncy force due to heating fluid (air) at the vinicity region of the curved hot triangle.

4. MESH GENERATION AND VALIDATION

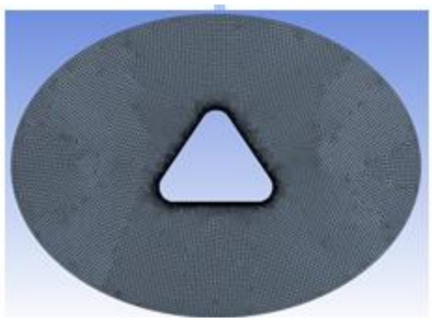
Numerically, analyses have computed the equations provided are dimensionless and regulate the system. However, the above equations have been solved by using the finite volume method based on Fluent ANSYS 2020 R1 after inserting the boundary conditions. Figure 3 describes the mesh generation in the confined fluid between the curved triangular shape and outer ellipse for five cases in this work.



(a) No. of nodes 30451
No. of element 29602

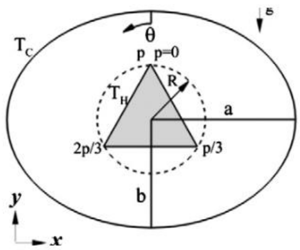


(b) No. of nodes 11881
No. of element 11620



(c) No. of nodes 19183
No. of element 18721

Figure 3. (a, b, c) Mesh generation for four cases



Model of Reference [4]

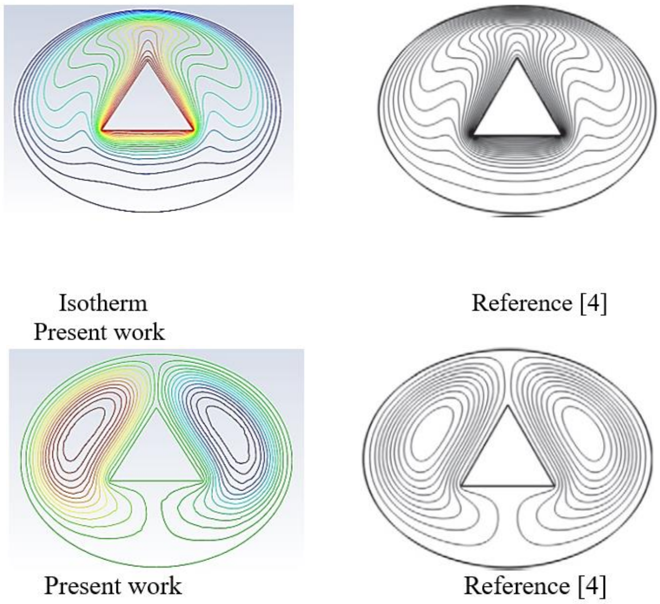


Figure 4. Validation the present work with that of Abouei et al. [4] at Ra=10^4

To check the number of element that required getting optimal mesh of the grid generation, multiple types of the grids was tested (coarse, normal, fine, finer). Table 1 exhibited the number of elements with Nu. It has been seen that averaged Nu becomes independent on mesh at finer mesh and the error percentage is getting equal to 0.0021%.

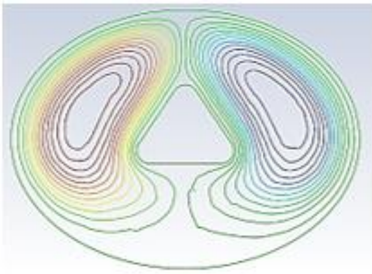
Table 1. The grid independency at Ra=10^5

Grid Types	Coarse	Fine	Finer
Number of elements	11620	18721	29602
Nu	10.89	11.0432	11.0411

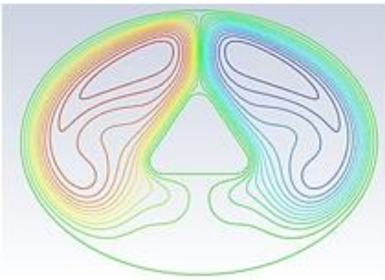
Abouei Mehrizi et al. [4] present a comparison with the previous authors' work to validate the work's findings. Abouei et al. [4] provide a comparison of the current situation at b/R=2, as depicted in Figure 4. As shown in this figure there is a good agreement in results at Ra=10^4.

5. RESULTS AND DISCUSSION

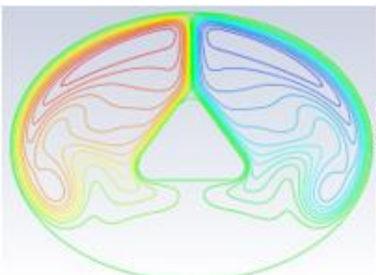
The manuscript examines how a hot curved triangle alters natural convection, but it also uses Ansys software 2020 R1 to investigate a numerical method that analyses the heat transfer rate, which is dependent on natural convection because of buoyant force. The method of analysing the steady air flow depends on the assumption that the fluid is incompressible and satisfies the Boussinesq approximation. Moreover, its show how positioning of a curved triangular hot cylinder inside a cold elliptical enclosure enhancing the thermal effect on heat convection rate. The findings indicate that an increase in the Rayleigh number will result in an increase in the local Nusselt number at the triangle points. significantly influence the thermal rate effect. Where, the Nusselt number will be max on the terminal curves (A and B) and falls down at curve C see Figure 2. On the other hand, the Nu number will be at its minimum in most locations of the triangle, specifically at the middle curve, or curve C.



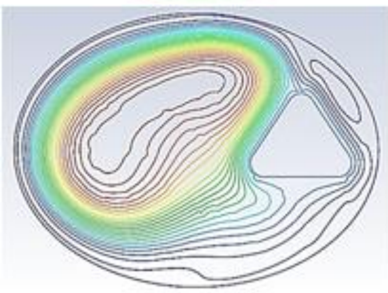
Case I
Ra=10^4



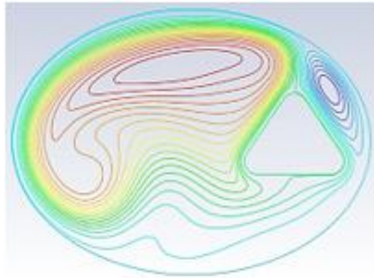
Case I
Ra=10^5



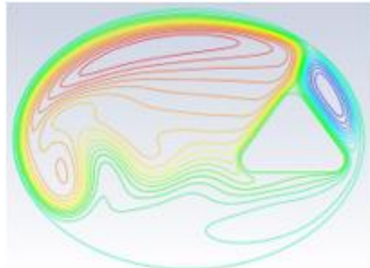
Case I
Ra=10^6



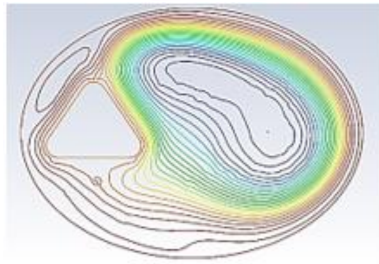
Case II
Ra=10^4



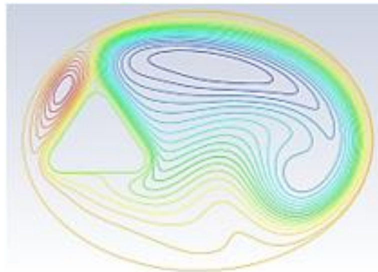
Case II
Ra=10^5



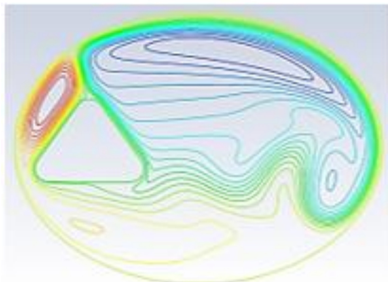
Case II
Ra=10^6



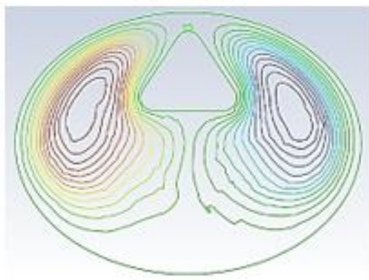
Case III
Ra=10^4



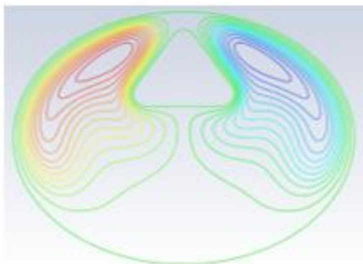
Case III
Ra=10^5



Case III
Ra=10^6



Case IV
Ra=10^4



Case IV
Ra=10^5

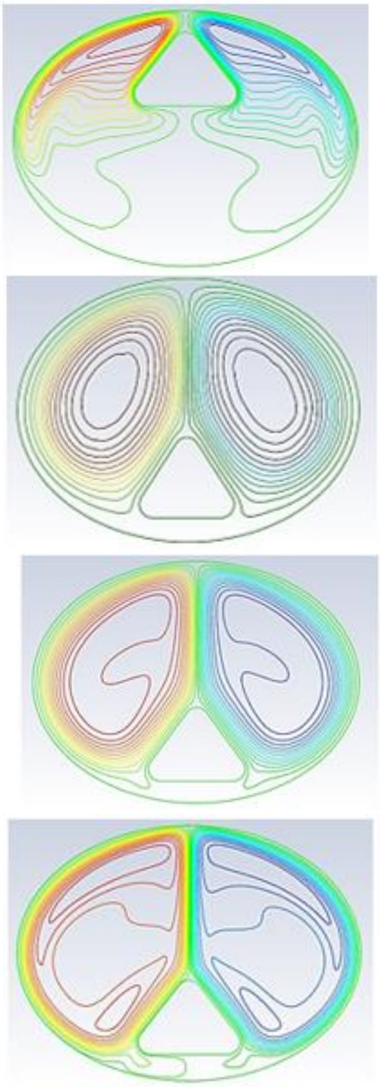
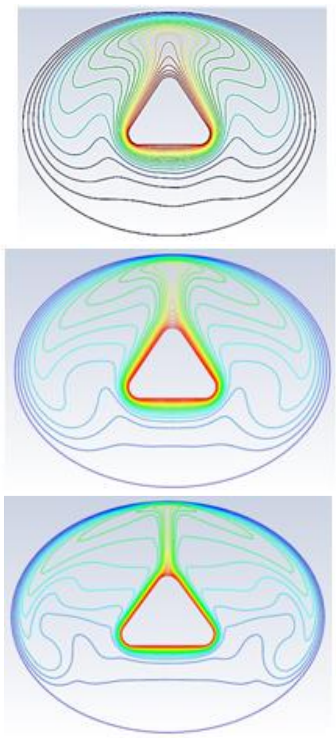
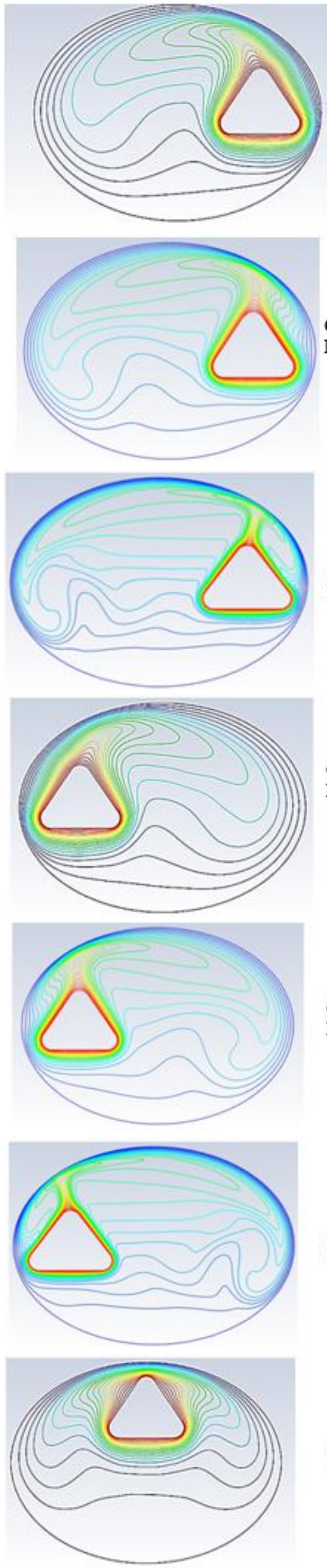


Figure 5. Steam function for multiple location of curved triangle and Rayleigh number





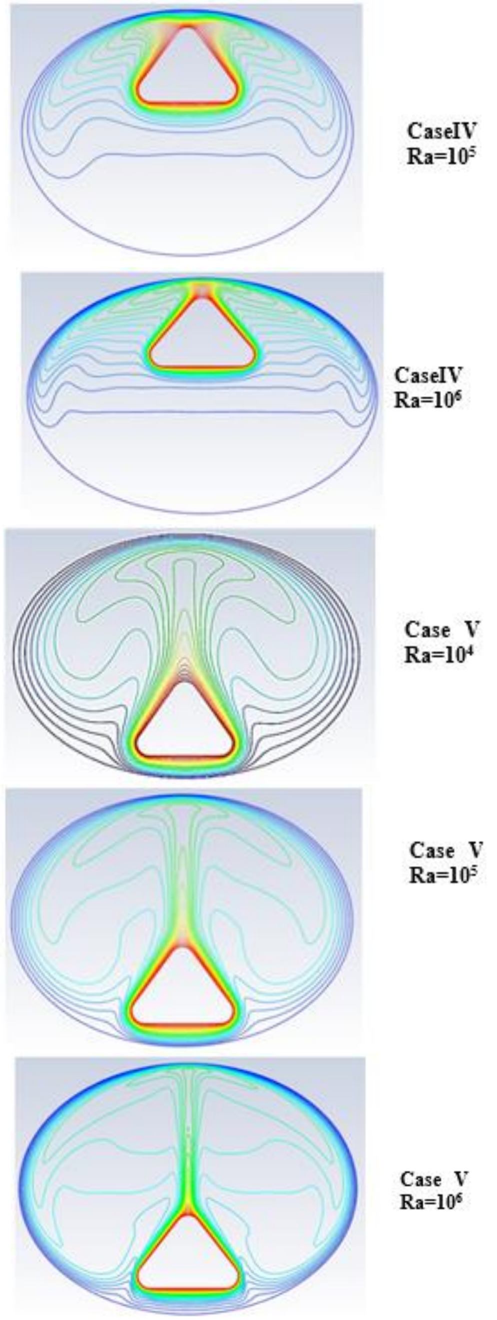
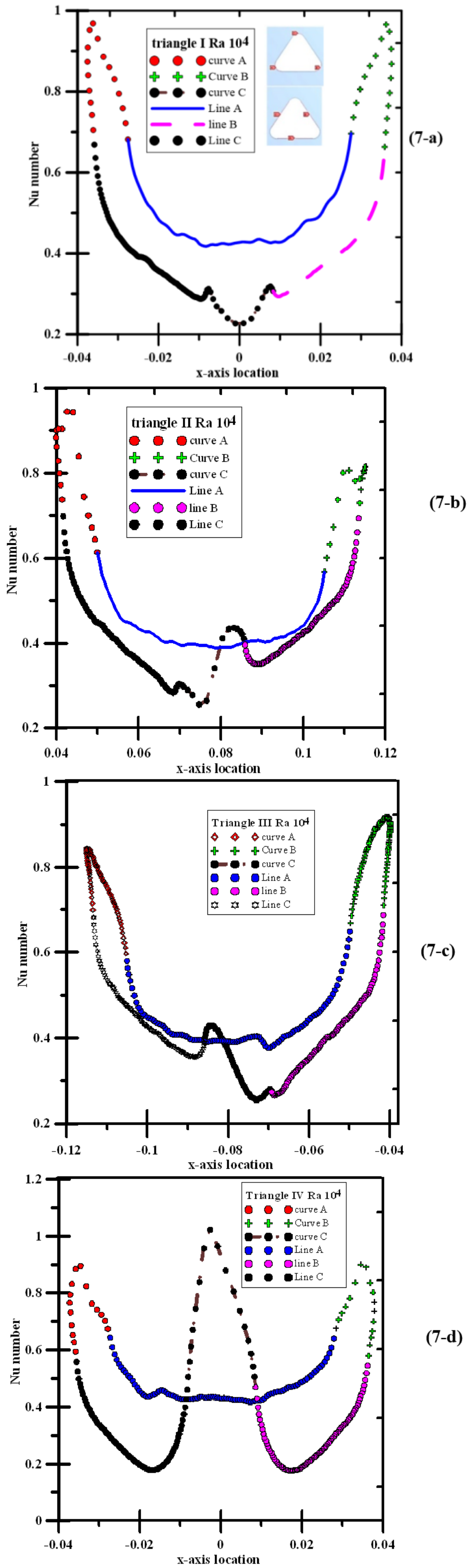
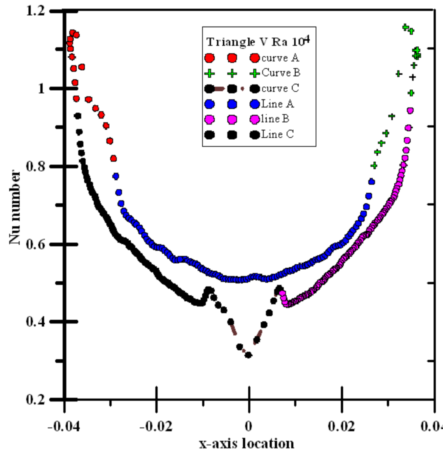


Figure 6. Isotherm for multiple location of curved triangle and Rayleigh number

Figure 5 illustrates the variation of streamlines at the location of triangles and the Rayleigh number. As shown in this figure, the triangle location changes from middle position to left, right, up location, and down location inside the elliptical outer cover of cavity, respectively. Nevertheless, the variety of streamlines remains very consistent when the position shifts from left to right (cases II and case III) for all values of the Rayleigh number. This means that these locations have the same flow features. The bottom location (case V) exhibits a clear and distinct change that significantly enhances the swirl formation process. This effect intensifies as the Raleigh number increases, particularly at Rayleigh number 10^6. Furthermore, at Rayleigh number 10^6, all locations experience fluid movement disturbances and sharp changes, generating turbulent flow and enhancing heat transfer.

Figure 6 illustrates the variation in the isotherm at the locations where triangles vary, along with the Rayleigh number. The isotherm lines clearly illustrate the distribution of temperatures within the enclosure, as well as the buoyant forces that generate fluid movement due to density variations. Curved vertices clearly alter the boundary layer on the inner triangle cylinder for all cases at varying Rayleigh numbers in both Figures 5 and 6, demonstrating their impact.

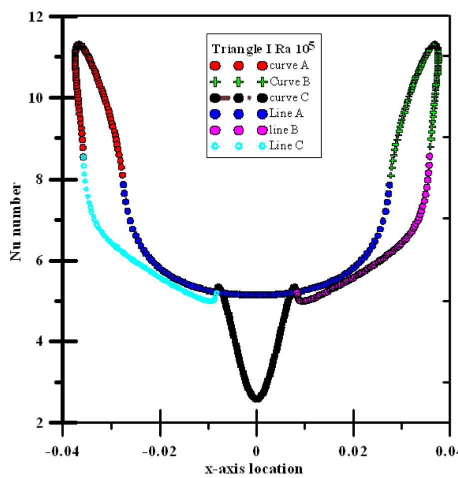




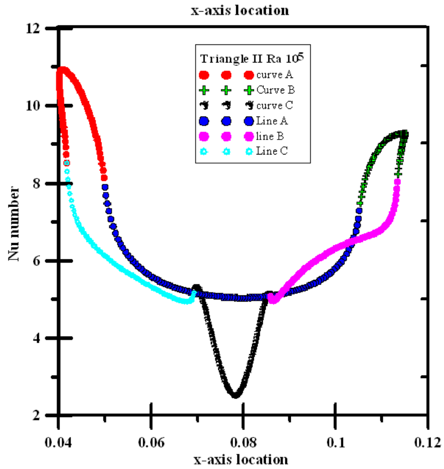
(7-e)

Figure 7. Variation the Nu number with location of the curved triangle at Ra number equal 10^4

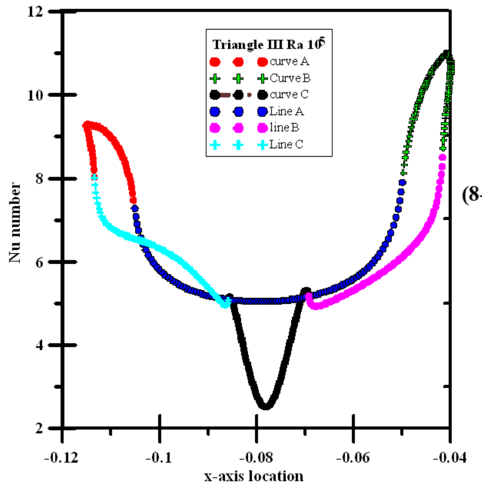
Figure 1 illustrates the locations on the triangle where the curves and lines are a, b, and c. that have examined these locations in Figures 5 to 8 with laminar dominate while Figure 9 the turbulent dominant. Figure 7 illustrates the relationship between the Nu number and the placement of triangles at a Ra number of 10^4. The several cases, labeled as a) case I, b) case II, c) case III, d) case IV, and e) case V, are shown. The impact of the curves on the Nu number and hence on the heat transfer rate is readily apparent in this diagram. Furthermore, it can be seen that the peripheral curves exhibit much higher Nusselt values compared to the central curve, with the exception of case IV where the lowest Nusselt values are found. Case IV, in the triangle's location, exerts a greater influence than the middle curve, enhancing turbulence and fostering enhanced heat transfer through natural convection.



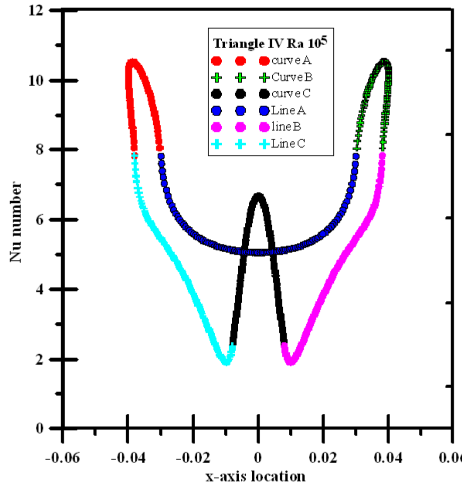
(8-a)



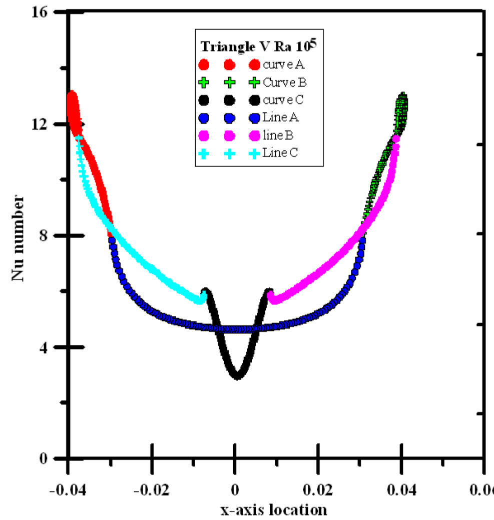
(8-b)



(8-c)



(8-d)

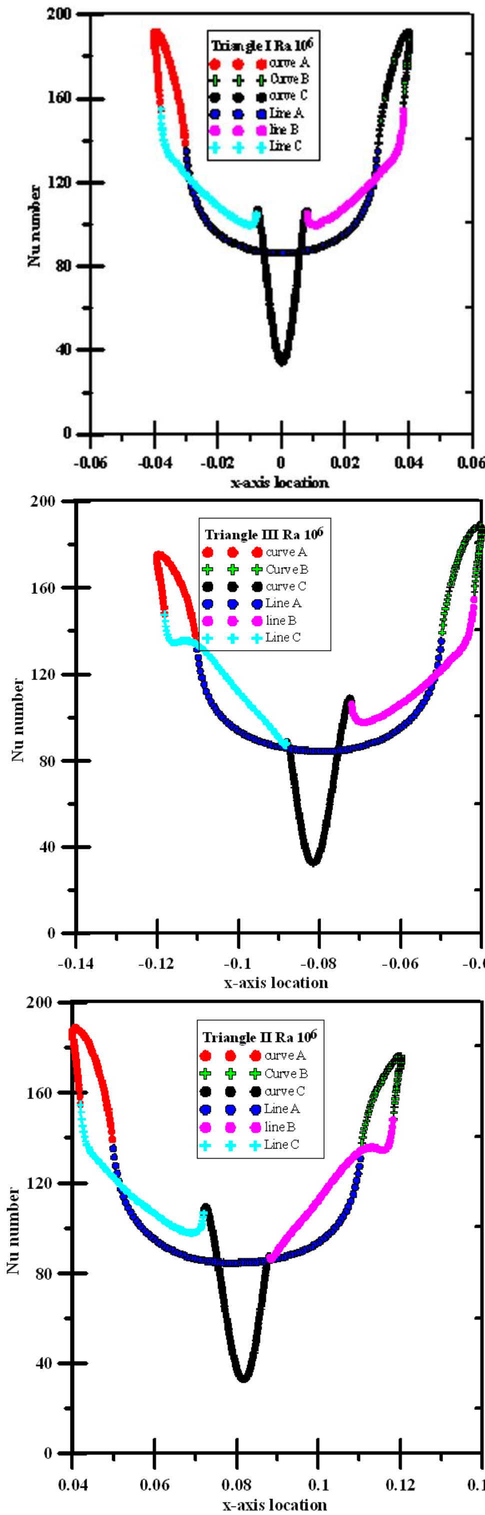


(8-e)

Figure 8. Variation the Nu number with location of the curved triangle at Ra number equal 10^5

Figure 8 illustrates how the Nu number varies when triangles are positioned at Ra number equal to 10^5 in five different cases as shown in this figure. The flow at this Rayleigh number will still be laminar, and the change results come from the shape, arches, and location, of the inner triangular hot cylinder, in addition to the external oval shape only. Consequently, this figure demonstrates a significant convergence in the change and variations, in contrast to Figure 7, where the Ra number equals 10^4 and the Nusselt number increases moderately.

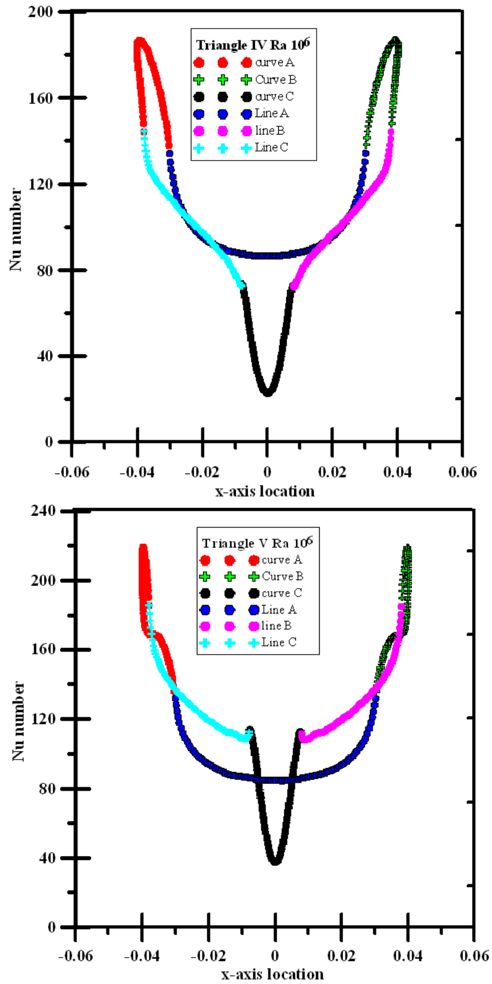
Figure 9 shows a qualitative leap in the Nusselt values as a result of the flow transitioning to a turbulent state. The impact of the arcs and the location change is less pronounced than in the case of laminar flow, despite a noticeable increase in heat transfer rates. This work is the development and improvement of Abouei et al work that presented by Abouei Mehrizi et al. [4] and Mohammed et al. [24] by changing the shape and adding curves instead of vertices of the triangle, with an extensive study of the effect of the new locations of the curved hot triangle in this new shape form. But there has been a big improvement and growth in the rates of heat transfer, and now there is also a study of what happens when there is turbulent flow because of the heat transfer analysis at Rayleigh number 10^6 values. Where, there is a large mutation in the magnitude of Nesslt number.



(9-a)

(9-b)

(9-c)



(9-d)

(9-e)

Figure 9. Variation the Nu number with location of the curved triangle at Ra number equal 10^6

6. CONCLUSION

This manuscript's innovation is to numerically study the effect of small arcs at the corner of a hot triangle surrounding a cold elliptical shell on the natural enhancement of heat transfer rate. This paper numerically investigates, using air as the working fluid, the effect of a curved line connecting two adjacent lines with an inner hot triangle surrounding a cold elliptical enclosure. Five different curved triangle and location cases are presented at varying Rayleigh numbers: $10^4 \leq Ra \leq 10^6$.

Here's a summary of the findings:

For $Ra=10^4$ and 10^5, there are clear changes in heat transfer rates due to the shape and location of the triangle inside the elliptical enclosure.

The three arcs on the corners of the hot triangle have a big effect on the magnitude of the Nu number and then heat transfer rate. The arc situated at the top vertices of the triangle, where the sides meet, inhibits the increase in heat rate, with the exception of case IV.

In this instance, the triangle's location exerts a greater influence than that of the arcs. This refers to the fact that location has a greater influence on heat transfer than shape.

When $Ra=10^6$, a qualitative shift results in the locations and rates of heat transfer due to the flow changing from laminar to turbulent.

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NOMENCLATURE

Cp	Specific heat at constant pressure, kJ. kg^{-1}. K^{-1}
Lc	Characteristic length, m
k	Thermal conductivity, W/m^{-1}. K^{-1}
Nu	Local Nusselt on hot cylinder, dimensionless
K	The turbulence kinetic energy
U	Dimensionless velocity component, x-direction
u	Velocity part in x-direction, $m.s^{-1}$
V	Dimensionless velocity component, y-direction
v	Velocity component part in y-direction, m/s^{-1}
Pr	Prandtl number, (dimensionless)
Ra	Rayleigh No. (dimensionless)
T	Temperature, K

Greek symbols

θ	Small distance part of the curved triangle, m
ε	Rate of dissipation
α	Thermal diffusivity, m^2/s^{-1}
μ	viscosity, $kg.m^{-1}$
ρ	Density, kg/m^3
Ψ	Dimensionless stream function

Subscripts

c	Cold
h	Hot