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The effects of transient heat flux on the tube in contact with the natural convection, on enthalpy and entropy generation, for developed laminar flow of fluid with high Prandtl number

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ABSTRACT

Heat flux is passed through the tube wall with natural convection in a tube wall of developed laminar flow. Tubes are used to find the best case with the minimum enthalpy and entropy generation. Process of heat flux pass is simulated with natural convection in several cases through the wall. By varying heat flux along the tube kept in touch with natural convection, temperature, entropy generation and enthalpy of each case change. Tubes are studied distribution of temperature, entropy generation and enthalpy along the radius and distribution of entropy generation and enthalpy along the cylinder axis, via different diagrams. Entering heat flux to the tube wall, temperature, entropy generation and enthalpy of the fluid increase significantly along the radius. The contact of heat flux to the tube wall in the direction of fluid movement, entropy generation decreases in the flow direction. Heat flux is applied to the tube wall, in parts of the tube being a heat flux, enthalpy increases in the direction of the tube wall. enthalpy is reduced in the tube wall in parts that are associated with the natural convection. The electric coil is wrapped on the tube as heat flux in tubes that are in contact with convection, the implications of this paper is used.

1. Introduction

Enthalpy and entropy generation are obtained by applying constant heat flux on different parts of the tubes, compared to the convective heat transfer in various amounts. Different parts of tube are applied entropy generation and enthalpy variation in radially and axially. In industry, in order to achieve the most economical efficiency, minimum entropy generation for the length and radius of the tube as well as the least amount of enthalpy in the tube at different ratios is considered. The high amount of heat is applied to wall boundary layer because the fluid in the tube has a high Prandtl number. Laboratory tests are executed for heat flux in vertical, horizontal and spiral tubes [1-16], critical heat flux (CHF) has been tested in horizontal tube in addition [13, 15]. Critical heat flux has been investigated in some cases in helical tubes [2, 5]. temperature possessing uniform has been provided a method to predict bulk temperature, using the tube wall outer wall heat flux, [17]. Critical heat flux model has been shown based on support vector machine (SVM) in concentric-tube, by Jiejin cai [18]. Convective heat transfer of molten salt in tubes copper-coated with uniform heat flux has been employed by shen et al [19]. Critical heat flux of boiling cold water flow with no internal twisted bar under high mass flux has been studied by Yan, et al. [20]. Analysis of entropy generation of turbulent convection has been provided with constant heat flux in the wall of a circular tube by Bianco, et al[21]. The effects of wall heat flux are exhibited on entropy generation during the turbulent convective heat transfer, for tubes with different characteristics, by Mohseni, et al [22]. Non-uniform heat transfer have been studied numerical and experimental studies of heat transfer in solar thermal

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absorber tubes with by chang et al [23]. Experimental studies are carried out on critical heat flux in vertical tube under oscillatory flux at low pressure by Zhao, et al [10]. Experimental studies have been achieved on heat transfer in supercritical water flow in a circular tube with high heat flux by Gu, et al [11]. Mohammed, et al, has assayed convection heat transfer for a fixed heat flux in a vertical tube [20]. Non-uniform heat flux has been used in tube in several ways [9, 14, 19, 24, 25]. Natural convection has been utilized in CFD simulation in order to study the effect of condenser tube dip, by Minocha, et al [26]. Analysis of the minimum entropy generation has been investigated on the tube in different situations [27-36]. Entropy generation of forced convection have been studied on a horizontal oval tube by Esfahani, et al [37]. Convective heat transfer at the supercritical pressure of tube, on the fluids, has been reviewed by Huange, et al [38]. Minimum entropy generation in the boundary layer as well as natural and forced convection has been demonstrated by Bejan, Jlji, Incropera, et al [31, 46, 47]. Entropy generation and energy conversion rates in a tube with magnetic field have been represented by Akbar, et al [39]. Entropy generation of mixed convection in a square cavity containing a rotating drum has been studied by Wang, et al [40]. Entropy generation of forced convective flow on a horizontal oval tube has been represented by Esfahani, et al [37]. Entropy generation in a vertical tube with solar heat flux has been shown by Zhang, et al[41]. Chen, et al have investigated entropy generation of forced convection [44]. Mixed convection in a horizontal cylinder has been tested by Elsherbiny, et al[42]. The effects of natural convection of channel, in helical tube, have been studied by Heo, et al [43]. Some experimental and numerical methods have been suggested to obtain natural convective heat transfer and characteristics of tubes [35, 38, 43, 44]. Numerical investigations of convective heat transfer and entropy generation of laminar flow in helical tube by Kumai, et al [45]. Effect of non-uniform temperature distribution on entropy generation and enthalpy for the laminar developing pipe flow of a high Prandtl number fluid is shown by Reza kakulvand [48]. Effect of non-uniform convection distribution on entropy generation and enthalpy for the laminar developing pipe flow of a high Prandtl number fluid with high Prandtl number is investigated by Reza kakulvand [50]. The effects of transient radiant flow on pipe in contact with natural convection, for developed laminar flow of fluid with high Prandtl number, on enthalpy and entropy production by Reza kakulvand is presented [49]. Investigation of drag coefficients in gas – liquid tower and boundary conditions on pipes is obtained by Reza kakulvand [51].

The heat flux and constant convective heat transfer are investigated developed laminar flow of tube, by applying in the different parts of tube wall for several cases. There are shown the effects of different ratios of heat flux and convective heat transfer along the tube wall in different cases. In each case temperature distribution, enthalpy as well as entropy is studied. The optimized conditions for enthalpy and entropy are applied.

2. Physical model

Tube geometry has been designed as follows: Diameter: 0.025m, Length: 1m, and 5 sections. Transient heat flux changes on convective heat transfer in 6 cases are investigated. The fluid velocity in the tube is fixed and steady-state conditions prevail. Due to the constant convective flow changes and heat flux, the temperature fluctuates. Specifications of tube and fluid properties are extracted from table 1.

Table 1,

pipe geometry specifications and Fluid properties are shown.

Fluid properties	Variable	value
Specific heat transfer at constant pressure	$C_p\,(j/kgk)$	1845
Thermal conductivity	$k\,(w/mk)$	0.146
Density	$\rho(kg/m^3)$	889
Viscosity (at T_{ref})	$\mu(NS/m^2)$	1.06
Prandtl number , pr		13400
Inlet axial fluid velocity	$V_i\,(m/s)$	0.02
Inlet fluid temperature T_i**(k)**		273.15
Reference temperature, T_{ref} **(k)**		288.16
geometry of pipe		
Pipe length	$D(m)$	0.025
Pipe diameter	$L(m)$	1

In high Prandtl numbers, incompressible fluid, symmetry of tube and laminar flow, steady-state condition prevails. Prandtl number of fluid is 13400 and a material indeterminate. A schematic of tube geometry that heat flux and convective heat transfer enter to, is displayed in Figure 1. In simulation, mesh with 30×300 is used for the tube length and width.

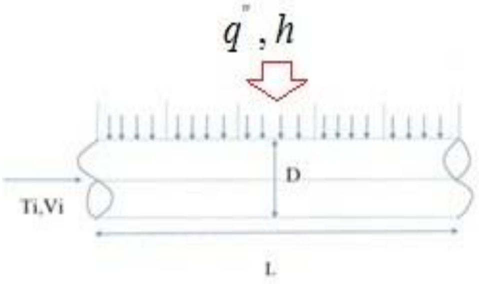

Figure1; A schematic of the pipe convective heat transfer and heat flux

3. The governing equations

In bejan's heat transfer, the governing equations in the two-dimensional tube coordinates x, z, are as follows:

Continuity equations:

$$\frac{\partial \upsilon_r}{\partial r}+\frac{\upsilon_r}{r}+\frac{\partial \upsilon_z}{\partial z}=0$$

Momentum equations:

$$\rho\left(\upsilon_r\frac{\partial \upsilon_r}{\partial r}+\upsilon_z\frac{\partial \upsilon_r}{\partial z}\right)=-\frac{\partial P}{\partial r}+\mu\left\{\frac{\partial}{\partial r}\left[\frac{1}{r}\frac{\partial}{\partial r}(r\upsilon_r)+\frac{\partial^2\upsilon_r}{\partial z^2}\right]\right\}$$

$$\rho\left(\upsilon_r\frac{\partial \upsilon_r}{\partial r}+\upsilon_z\frac{\partial \upsilon_z}{\partial z}\right)=-\frac{\partial P}{\partial z}+\mu\left\{\frac{1}{r}\frac{\partial}{\partial r}\left[r\frac{\partial \upsilon_z}{\partial r}\right]+\frac{\partial^2\upsilon_z}{\partial z^2}\right\}$$

Energy equations:

$$\rho C_p\left(\upsilon_r\frac{\partial T}{\partial r}+\upsilon_z\frac{\partial T}{\partial z}\right)=k\left\{\frac{1}{r}\frac{\partial}{\partial r}\left[r\frac{\partial T}{\partial r}\right]+\frac{\partial^2 T}{\partial z^2}\right\}+\mu\phi$$

Where the energy loss term is:

$$\phi=2\left[\left(\frac{\partial \upsilon_r}{\partial r}\right)^2+\left(\frac{\upsilon_r}{r}\right)^2+\left(\frac{\partial \upsilon_r}{\partial r}\right)^2\right]+\left(\frac{\partial \upsilon_r}{\partial z}+\frac{\partial \upsilon_z}{\partial r}\right)^2$$

Enthalpy and entropy generation:

$$\dot{S}'''_{gen}=\frac{k}{T^2}\left[\left(\frac{\partial T}{\partial r}\right)^2+\left(\frac{\partial T}{\partial z}\right)^2\right]+\frac{\mu}{T}\phi$$

According to the high heat flux of walls and high Prandtl number of fluid with no slip in the tube wall, high amounts of enthalpy and entropy generation are created. The amounts of enthalpy and entropy generation, in uniform heat flux, are dramatically more than the amount of convective heat transfer. Entropy generation consists of two semesters dependent on thermal conductivity and temperature gradient along the radius and axis and semester dependent on loss and viscosity.

4. Problem definition

The aim of this article is to find the minimum amounts of enthalpy and entropy generation created by passing the constant heat flux through the tube wall. Different values of enthalpy and entropy generation are obtained for various cases that are dependent on the amounts of heat flux and convective heat transfer along the tube. The amounts of uniform heat flux and convective heat transfer are 25000 (W/km^2) and 20 (W/m^{2}k), respectively.

Temperature distribution along the radius as well as entropy generation and enthalpy along the wall as a result of transient heat flux on the tube have been shown in figures 3-7. In addition, simulation has been displayed for 6 cases. In the first case constant convective heat transfer has been applied to the tube wall and in the 6th, there is uniform heat flux on the tube.

5. Results and discussion

When the fluid enters the cylinder, the heat enters too, and therefore, velocity and temperature distribution profiles are created in the tube. Due to the prevailing the steady state, velocity distribution profile is fixed, but, profiles of temperature distribution, enthalpy and entropy generation along the tube are variables because of changes in boundary conditions of heat flux and convective heat transfer. In all cases, the temperature at the center of the tube and the radius of 0.004 meter is almost constant and temperature changes along the radius in the range of 0.004 meter begin. In the first case, only convection along the tube wall is restored. In the first case, temperature at the beginning of the tube to the end is an upward trend.

In the cases 2-4, entering the heat flux to the cylinder, the concavity of curves varies. Approaching the wall along the radius, along with changes in temperature, for flow lines with the similar radial sizes, when concavity is downward, the temperature at the beginning of the tube is higher than the temperature at the end of the tube. When the concavity is upward, in lines closer to the wall, temperature at the end of the tube is less than the temperature at the beginning of one. In the cases 2-5, due to the higher temperature of the heat flux than convective heat transfer. Heat flux significantly increases the tube temperature more advanced heat flux along the tube, the fluid temperature is increased. In the case 6, the temperature at the bottom of the tube is more than the beginning. Temperature changes along the radius in different parts of the wall are shown in Figure 3.

Entropy generation in the central tube lines, up to the specified radius, Changes very little. In the first case, entropy generation is slightly distributed along the radius. In the first case, each of profile, possess two upward and then downward cavities. In cases 2-6, entering heat flux to the wall, entropy generation increases along the radius. Manufacturing of entropy profiles with border thermal flux possess several milestones. As thermal flux on the wall goes on, entropy generation at the beginning of the tube is more than the end. Entropy generation changes are shown along the radius in Figure 4. In figure 5, enthalpy changes diagrams along the radius are illustrated. In the first case, approaching the tube wall leads to increases enthalpy. In cases, 2-5, entering heat flux to the wall, under convective heat transfer boundary conditions, enthalpy increases significantly.

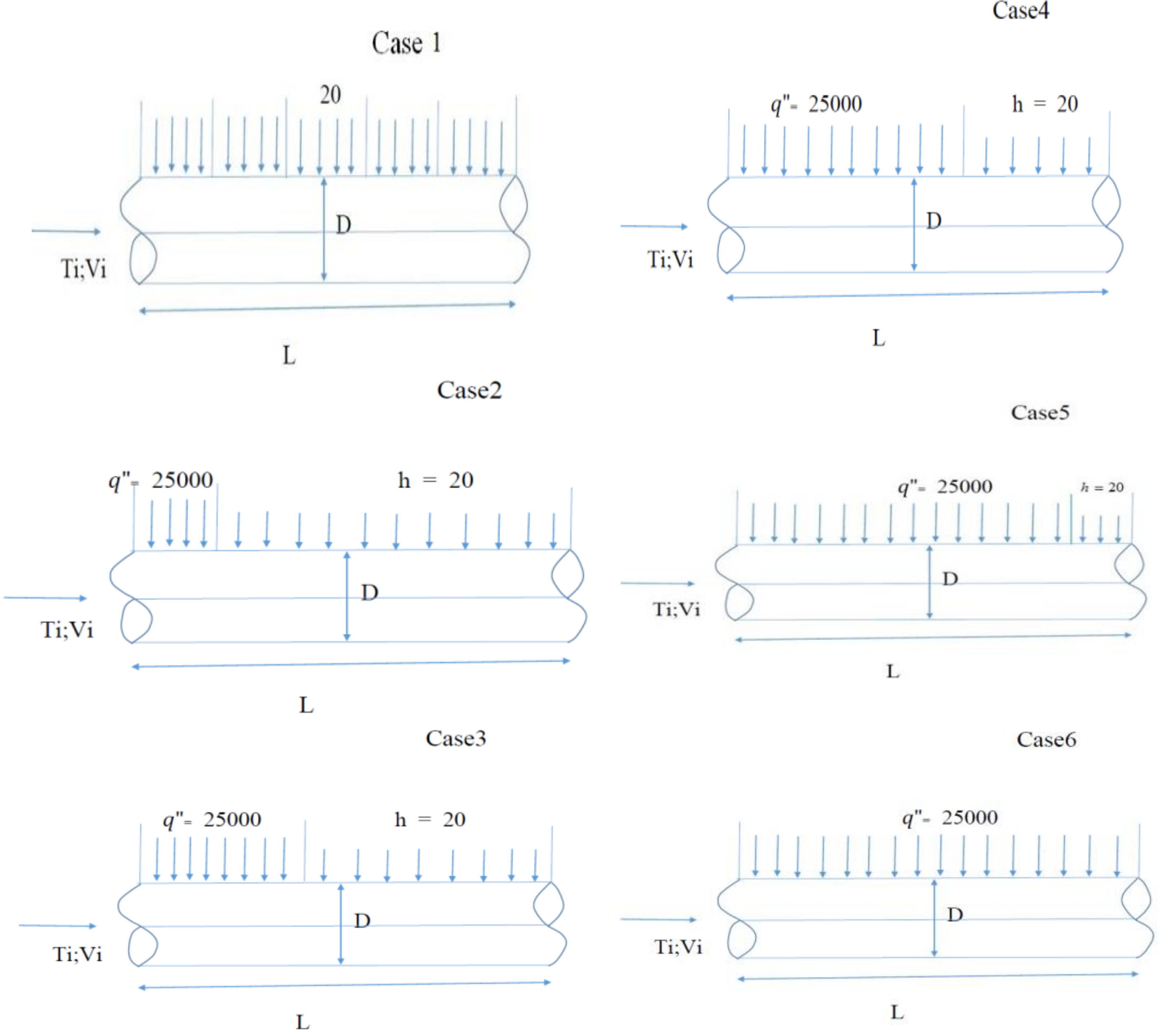

Figure 2. Convective heat transfer and heat flux in contact with the wall for 6 case

As heat flux increases, the amount of enthalpy in the end of tube precedes the beginning. In the case 6, the enthalpy value increases near the wall.

In the cases 1, 5 and 6, the amount of enthalpy increases along the tube. In Figure 6, enthalpy change is observed along the wall. In the first case, there is only convective heat transfer and so, enthalpy changes along the wall are upside. With the arrival of the heat flux, in the next case due to the large amount of enthalpy under heat flux than convective heat transfer, diagram of enthalpy versus wall length under heat flux is ascending and under convective heat transfer boundary conditions is descending.

In the maximum point of enthalpy versus wall length, convection is replaced with heat flux. This observed trend is observed for other cases. In case 6, a constant heat flux is applied to the wall and then, enthalpy is increasing. In figure 7, for the first case with low heat as a result of convective heat transfer, entropy generation is almost constant.

Under heat flux boundary conditions, entropy generation along the wall reduces downward. Due to the higher heat flux than convective heat transfer, entropy generation, at the point where the boundary conditions change, suddenly decreases. In the case 6, Heat flux boundary condition is applied only.

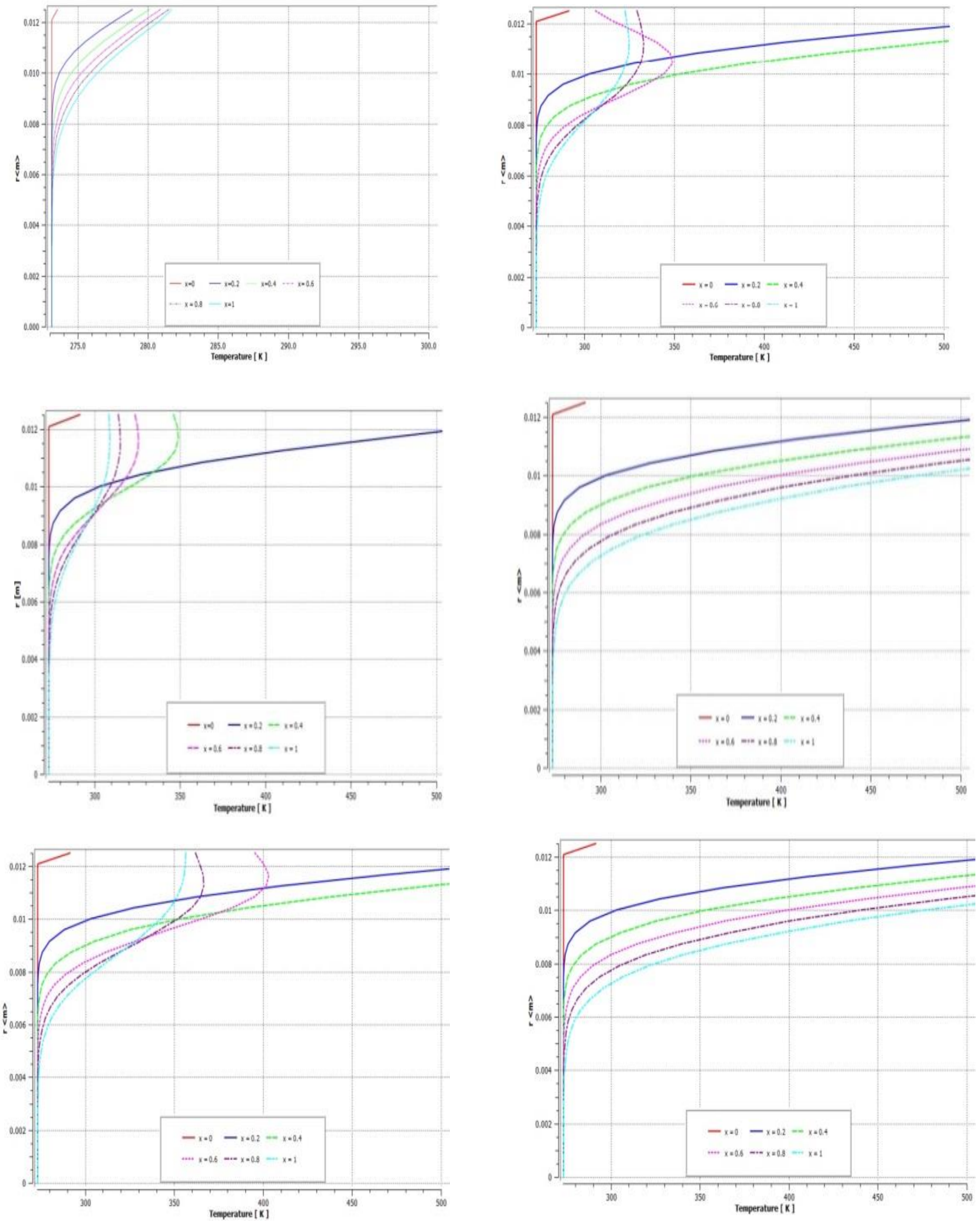

Figure 3. Temperature changes along the radius in 6 cases, at heat flux boundary conditions and convective heat transfer

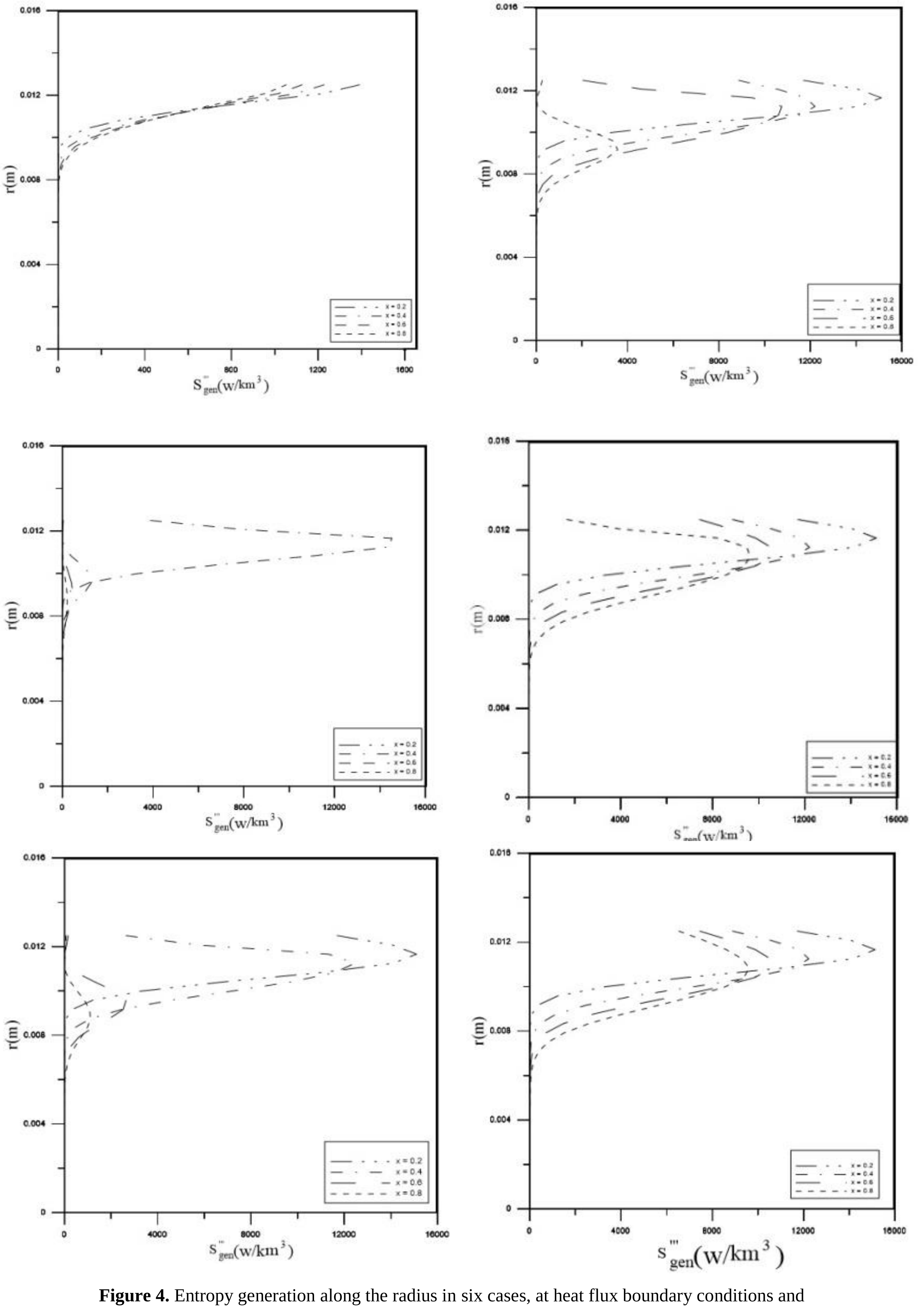

Figure 4. Entropy generation along the radius in six cases, at heat flux boundary conditions and convective heat transfer

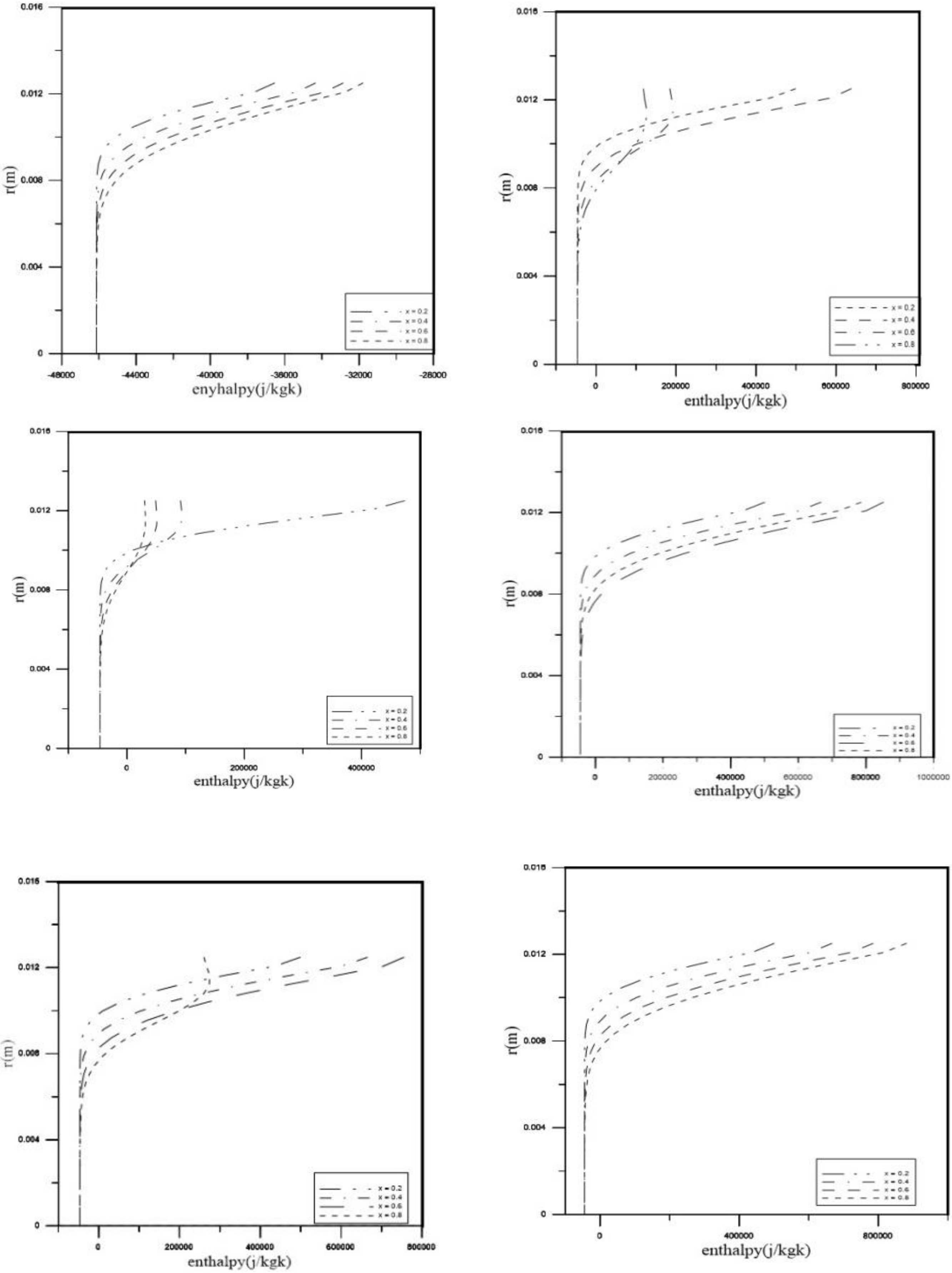

Figure 5. Enthalpy along the tube radius in six cases, at heat flux boundary conditions and convective heat transfer

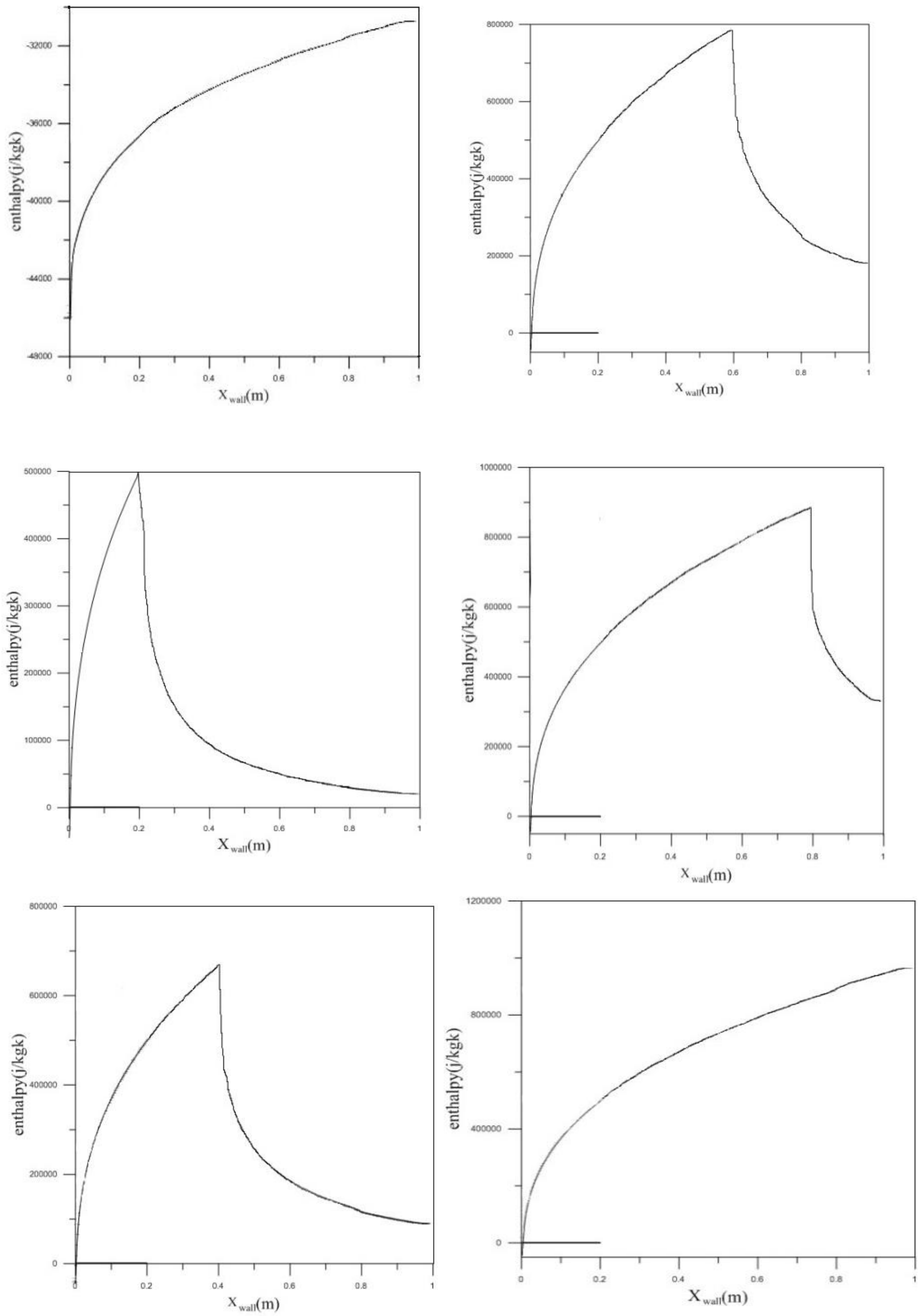

Figure 6. Enthalpy along the tube wall in six cases, at heat flux boundary conditions and convective heat transfer

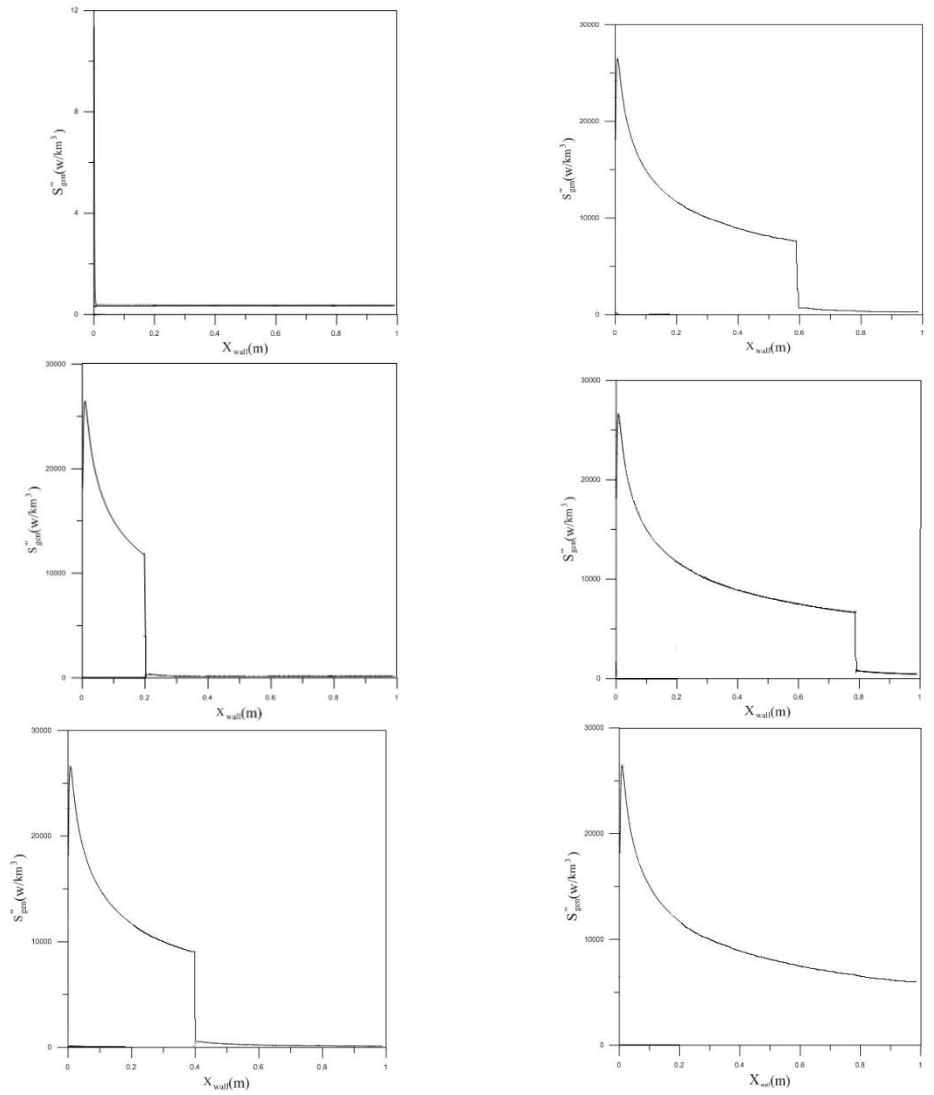

Figure 7. Entropy generation along the radius in six cases, at heat flux boundary conditions and convective heat transfer

6. conclusion

The results of this work are applicable to constant heat flux, for electrical coils in which heat flux is transferred to the channel or tube (the first case), as well as convective heat transfer in environments with natural or forced convection (case 6). As a result of a tube or channel bearing heat flux, in contact with the environment of natural convection, the cases 2-5 emerge the pipe is passed through environments with different. Minimum entropy generation is in all cases at the end of the tube. application are used in tubes contact with convection and various fluids and air in convective heat transfer in environments with natural or forced convection the electric coil is wrapped on the tube as heat flux. Applications of convection distribution tubes electric and diesel furnace, solar water heaters, refrigerant tube. In the border areas of the pipe, the temperature varies; so the dramatic fluctuations were observed in the entropy generation. The results of this article is created on the channel wall channels that are passed through different environments. Electric and diesel furnace, solar water heaters, refrigerant tube and tubes in hot and cold weather. Minimum entropy generation are investigated electric and diesel furnace, solar water heaters, refrigerant tube.[25,48,49,50,51]

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