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Study On Second Law Exploration In A Rectangular Slab With An Internal Thermal Production

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Abstract

In this work entropy production rates of thermal conduction in a slab with an internal thermal production has been carried out. It is considered that, the entire setup is in steady state and one dimensional. In this case, the rectangular slab exterior surfaces were subjected to two different thermal conditions. Symmetric and asymmetric boundary conditions are enforced on the rectangular slab. Here temperature distribution and entropy production in the rectangular slab was analysed graphically for various pertinent parameters. The observed result can be beneficial in manufacturing industry oriented procedures associated to conduction thermal transference

Keywords: Entropy production, Internal thermal generation, Second law analysis, Rectangular Slab.

Introduction

Every type of thermal transference processes in thermodynamic is associated with entropy generation. Everyone concentrates on first law of thermodynamics, but failed to analyze second law of thermodynamics. Irreversibility process related to calculation of entropy generation, which measures the extinction of existing work. Thermal entropy production as a result of the temperature differences is the most common analysis. Internal thermal production must be measured in the energy point of view. Thermal conduction through internal thermal production has been broadly applicable in many industry oriented presentations. Some of the important applications are thermal insulation, thermal cooling and metal casting.

As such, entropy generation is actually a measure of destruction of energy, thereby; higher entropy results in the failure of the system. Minimizations of entropy generation concepts were initially coined by Bejan [1-3]. He initiated the optimization method called entropy generation minimization. Investigation of 1-D thermal conduction in a slab with invariable internal thermal production related concepts like thermal conduction is most common. A steady state 1-D thermal conduction problem in a rectangular slab with asymmetric convective cooling investigated [4].

Least Entropy production rates occurrence aimed at a certain parameter are discussed. In [5], minimum entropy generation extended the results for 1-D, 2-D and 3-D problems. Similar type of content using irregular convective refrigeration to minimalize the entropy production rate in a thermal conduction problem was presented in [6] for a steady state case. They analyzed the Biot numbers and smallest entropy production rate for particular situations. Transient thermal transference in a slab with radiation effect was investigated [7]. Immediate internal thermal production effect in a dense solid is analysed by introducing a non-dimensional process. Detail analysis and importance of this study is given in [8-9], by considering internal heat generation.

So far no one considered the entropy in terms of internal heat generation. Therefore, this study is to carry out such an entropy analysis. Non-dimensional transformation is applied to convert basic equations. In addition, analytical approach is applied to get numerical solutions. In the direction of computing the entropy production value, we use the calculated temperature, and its gradients correspondingly. Graphs are plotted to show the influence of the various physical factors on distribution of temperature and entropy production. With these survey, no work is employed by considering entropy production in the energy point of view.

This work is organized as follows. Section II, consists of mathematical formulation and Section III consists of numerical method. Section IV consists of results and discussion. Finally, conclusion and future work is given in the last section.

Mathematical Formulation

Let us consider a rectangular slab made of a material with uniform properties with the assumption that the considered slab is facing uniform internal thermal production. Representation of the physical configuration can be seen in Fig.1. The considered rectangular slab is undergoing two thermal boundary conditions that is symmetric cooling and asymmetric cooling. Simplified set up can be seen in Fig.2.

Fig 1. Physical Configuration

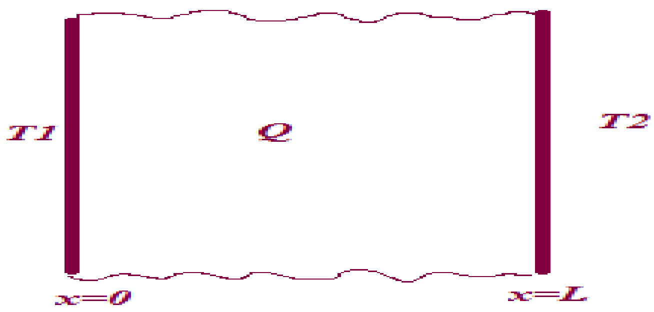

Fig.2. Cooling of a slab with internal heat generation.

The resultant one dimensional diffusion equation is given by

$$\frac{\partial^2 T}{\partial x^2}+\frac{\dot{q}}{k}=0\,,$$

With the boundary settings

$T=T_h$ at $x=0$ and $T=T_c$ at $x=L$ (Case 1- Asymmetric cooling)

$T=T_c$ at $x=0$ and $T=T_c$ at $x=L$ (Case 2- Symmetric cooling)

Entropy generation is given by

$$s_{gen}=\frac{k}{T^2}\left(\frac{\partial^2 T}{\partial x^2}\right)^2+\frac{\dot{q}}{T}$$

Most of the authors mainly concentrated on evaluating entropy by not considering heat generation. But ignoring internal generation would be result in improper results. This one is essential in the direction of considering the effect of internal thermal production in entropy generation evaluation process, which is introduced by Ting.et.al [10].

By introducing non-dimensional parameter,

$$X = \frac{x}{L}, \theta = \frac{T - T_c}{\Delta T}, Q = \frac{\dot{q}L^2}{k\Delta T}$$

Where $\Delta T = T_h - T_c$ for the situation of asymmetric cooling and $\Delta T = \frac{\dot{q}L^2}{k}$ for the situation of symmetric cooling.

The above governing equations which is also known as heat equation can be written in dimensionless form as follows,

$$\frac{\partial^2 \theta}{\partial X^2} + Q = 0$$

The dimensionless structure of entropy generation as follows,

$S_{Gen} = s_{gen} \frac{L^2}{k}$, implies

$$S_{Gen} = \frac{1}{(\theta + \mathrm{T})^2} \frac{\partial^2 \theta}{\partial X^2} + \frac{Q}{(\theta + \mathrm{T})}$$

Here $T = \frac{T_c}{\Delta T}$

Total entropy generation is considered by,

$$S_T = \int_0^1 S_{Gen} dX$$

Numerical Method

To solve the dimensionless form of the governing equation Runge-Kutta method for second order equation is utilized to draw the isolines of temperature and entropy contours. Libra office suit calc is used to draw the profiles of temperature contours and entropy contours.

With the purpose of finding the over-all entropy production, the value of the integral is calculated by using Simpson's Rule. Finally all the profiles are plotted for various pertinent parameters.

Results And Discussions

This work mainly focusses on the effects of uniform heat generation in the energy point of view. The results of asymmetric cooling and symmetric cooling effects are introduced and the results are represented in the graphs. Temperature profiles and entropy profiles are represented for various parameters and comparison has been made. Finally, with the help of entropy analysis, one can suggest the best method of cooling.

The temperature distribution as a function of axial coordinate is provided in fig. 3, which indicates that there exists a maximum temperature for various heat transfer parameters for both the cases, that is asymmetric and symmetric boundary conditions. The general parameters considers are Q= (0.5,1,23) are shown in the figure 3 and 4 respectively. it also demonstrations that the temperature linearly reduces through the axial region aimed at small values of Q, however, for higher values of Q there is a maximum temperature. And it additionally indicates that if Q increases then the temperature will also increase.

The figure 5 and 6 shows the discrepancy of local entropy production rate through the axial coordinate for different t values. A figure indicates the rate of local entropy production has a least significance at an assured X spot. Also, this least amount value is acquired due to the reason gradient of temperature is nil by the side of that X spot. It clearly shows that the allocation of non-dimensional rate of local entropy generation S_T as a X-function for various temperature ratio *T* and Q. Fig. 4 demonstrations that rate of the local entropy production increases linearly as X rises for large values of Q. Rate of local entropy generation declines and then grows with the value of X, i.e., a minutest S_T rate subsist nearer to the rectangular slab's left surface.

It can be ascertained that the rate of local entropy production is increasing linearly with the values of X for higher value of Q, also, here subsist a lowest value of S_T. Also, the picture illustrates that consequence of the temperature ratio *T* on the local entropy production and it can be observing that its effect is very strong. For minor values of T shows that the rate of local entropy production is superior than that for higher values of T. Total entropy generation is represented in a bar graph (See Fig. 7) and it is ascertained that the entire rate of entropy generation is happening maximally for the case of asymmetric cooling and minimally for the case of asymmetric cooling respectively

Conclusion

In this paper an elementary analysis of rate of local entropy production and rate of total entropy production for the case of thermal conduction in a rectangular slab with uniform internal thermal production has been done for the case of 1-D and steady state. Both symmetric and asymmetric, these two distinct boundary settings are imposed to analyse the effective cooling parameter. For the primary case, the slab outside sides were exposed to irregular chilling that is one border is hot and another is cold. For the secondary case, the slab exteriors are continued at constant cold temperatures. Dimensionless governing equation is solved analytically and the temperature profiles are represented graphically for various parameters.

The rate of local entropy production was also offered for various pertinent factors. The outcomes illustrate that there subsists a tiniest rate of local entropy production for the case of symmetric cooling. The outcome shows that maintaining the slab exterior surface temperatures maintained at cold temperatures result in acquiring a minimal rate of entropy production. This research will be helpful and valuable in industrial process such associated with thermal transference due to purely conductance. Further, this work can be extended by including the external effects such as magnetic, radiation and etc.

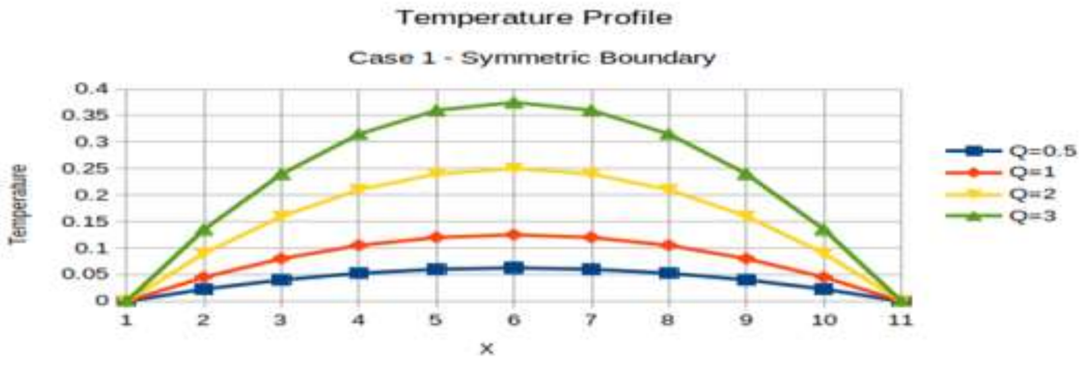

Fig. 3 . Profile of Temperature for the case of symmetric boundary

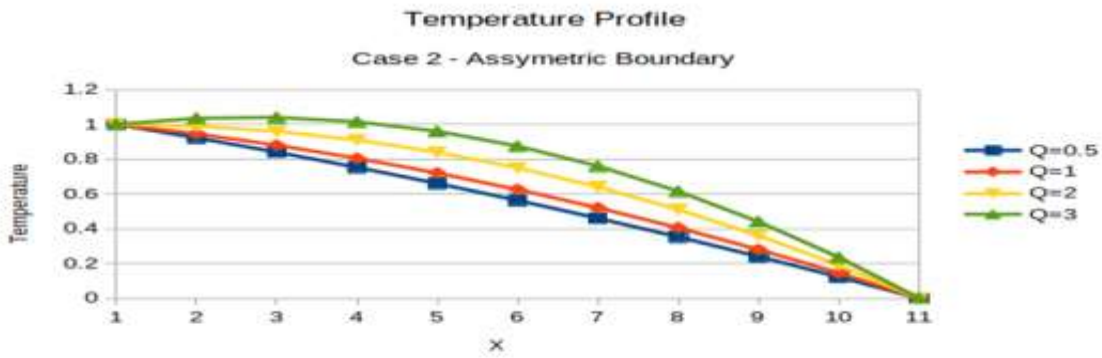

Fig. 4 . Profile of Temperature for the case of assymmetric boundary

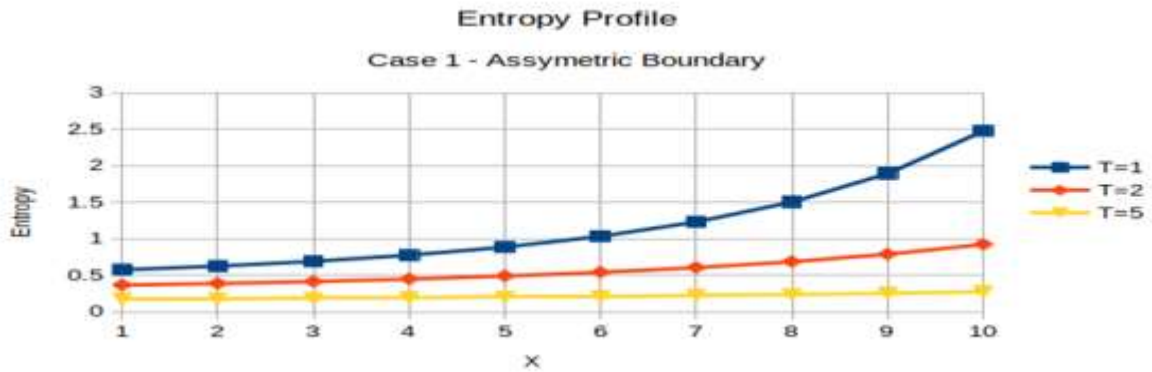

Fig. 5 . Entropy profile for the case of assymmetric boundary

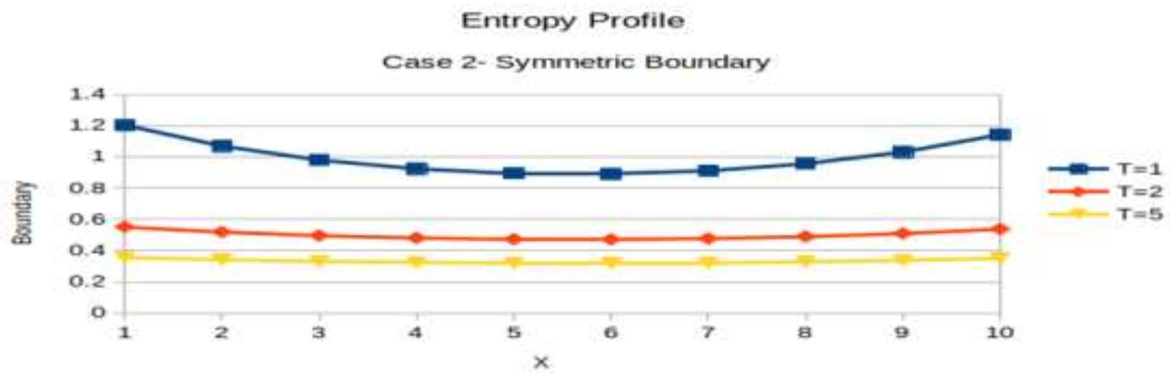

Fig. 6 . Entropy profile for the case of symmetric boundary

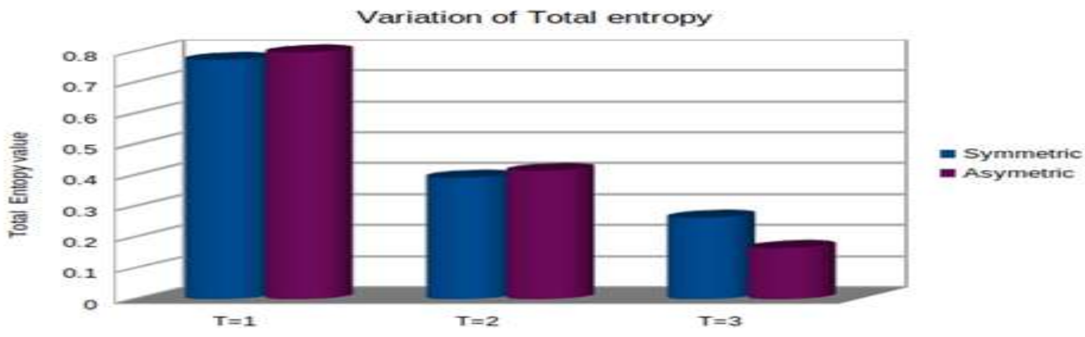

Fig. 7 . Total entropy comparison between assymetric and symmetric boundary.

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