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Application of homotopy perturbation method for a conductive–radiative fin with temperature dependent thermal conductivity and surface emissivity

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Abstract This work aimed at studying the effects of environmental temperature and surface emissivity parameter on the temperature distribution, efficiency and heat transfer rate of a conductive–radiative fin. The Homotopy Perturbation Method (HPM) being one of the semi-numerical methods for highly nonlinear and inhomogeneous equations, the local temperature distribution efficiencies and heat transfer rates are obtained using HPM in which Newton–Raphson method is used for the insulated boundary condition. It is found that the results of the present works are in good agreement with results available in the literature.

1. Introduction

The fins are extended surface which are used to dissipate heat from the primary surface to the surrounding environment [1]. In recent years the demands for fins in space exploration are increasing. Every satellite has different electronic subsystems which generate heat in different sections. In order to control the thermal performance of electronic subsystem of satellite in proper limits, heat has to be lost to the space medium and modes of heat transfer are conduction combine with the radiation only. The space temperature can be maintained either at absolute zero or at nonzero sinks temperature. The Naumann [2] analyzed the radiation conduction problem on

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Nomenclature

N_r	radiation–conduction parameter
C	constant that represents the temperature
k	temperature dependent thermal conductivity, W/(m K)
k_a	thermal conductivity corresponding to ambient condition, W/(m K)
ε_s	the surface emissivity corresponding to radiation sinks temperature, T_s
T	temperature, K
P	fin perimeter, m
T_b	fin's base temperature, K
T_a	sink temperature corresponding to k_a, K
T_s	sink temperature for radiation, K
b	length of the fin, m
x	axial co-ordinate of the entire fin, m
A_c	cross-sectional area of the entire fin, m^2
X	dimensionless axial co-ordinate
A	thermal conductivity parameters
B	the surface emissivity parameters

Greek symbols

α	slope of the thermal conductivity-temperature curve, K^{-1}
β	slope of the surface emissivity-temperature curve, K^{-1}
θ	dimensionless temperature of the fin
θ_a	dimensionless sink temperature of the fin corresponding to k_a
θ_s	dimensionless radiation sinks temperature
σ	Stefan–Boltzmann constant
ε	emissivity

the basis of constant thermal conductivity as well as constant surface emissivity in order to reduce the mathematical complexity of the problem. The majority of work reported on space radiating fins is on the basis of environmental temperature maintained at absolute zero [3,4]. The governing equation of conduction–radiation heat transfer phenomena can be expressed in differential equation along with relevant boundary condition. Arslanturk [5] evaluated the optimum dimension of space radiative fin with variable thermal conductivity with constant emissivity while sink temperature maintained at absolute zero using Adomian decomposition method (ADM). Hosseini et al. [6] obtained the temperature distribution of space radiative fin with variable thermal conductivity with constant emissivity while environmental temperature maintained at absolute zero using Homotopy perturbation method (HPM). Baratas and Sellers [7] provided the efficiency curves of a heat rejecting system consisting of parallel tubes joined by web plates that serve as extended surface. Torabi et al. [8] applied the differential transform method (DTM) to a radiative fin with temperature dependent thermal conductivity and heat generation while environment temperature maintained at nonzero sink temperature. Roy et al. [9] analyzed the effect of environmental temperature and heat generation number on the temperature distribution of a convective–radiative straight rectangular using Adomian decomposition method (ADM). Torabi and Yaghoobi [10] obtained the temperature distribution of a step fin using both differential transform method (DTM) and variation iteration method (VIM) and the results are compared with finite difference method (FDM). Akbar and Khan [11] analyzed the effects of different flow parameters for a two dimensional stagnation-point flow of carbon nanotubes toward a stretching sheet with water as the base fluid under the influence of slip effects and convective boundary conditions using a homogeneous model. Noreen Sher Akbar [12] obtained the heat transfer characteristics and flow parameters for peristaltic flow with carbon nanotubes in an asymmetrical channel. Double-diffusive natural convective peristaltic flow of a Jeffery nanofluid in a two dimensional porous asymmetric channel has been studied by the same author [13]. Akbar and Butt [14] carried out investigation to analyze the effect of heat transfer in a flexible tube with ciliated walls and carbon nanotubes. Bhowmik et al. [15] applied both decomposition and differential evolution method for predicting dimensions of rectangular and hyperbolic fins with variable thermal properties. Singla and Das [16] predicted the heat generation number and fin tip temperature using Adomian decomposition method and Genetic Algorithm (GM). Arslanturk [17] evaluated the fin efficiency of a conductive-convective straight fin with variable thermal conductivity using ADM. Aziz and Torabi [18] presented numerical analysis of straight rectangular fin with simultaneous variation of thermal conductivity, heat transfer coefficient and surface emissivity. Mallick et al. [19] determined the thermal stresses of annular fin with variable thermal conductivity using Homotopy perturbation method (HPM). The previous studies are based on the constant surface emissivity parameter of space radiative fin and sink temperature maintained at absolute zero. But in some of the cases the surface emissivity changes with temperature along with the simultaneous variation of other thermal properties [20,21]. Again in some real situation the sink temperatures are also changing from nonzero value to any higher temperature for stationary fin [9]. The literature indicates that, the study of simultaneous variation of thermal conductivity and surface emissivity parameters of space radiative fin along with nonzero sink temperature is not available. Therefore the present works are undertaken to

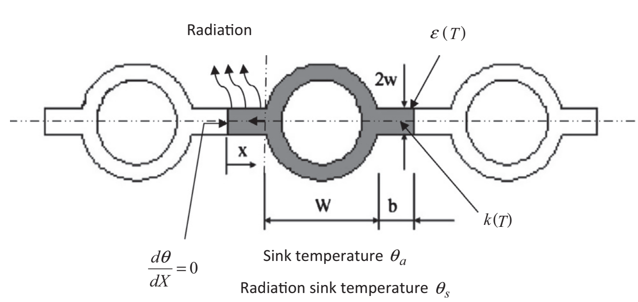

Figure 1 The geometry of heat pipe/fin space radiator.