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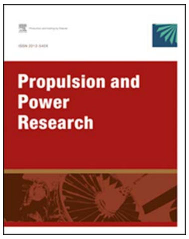

ORIGINAL ARTICLE

Application of differential transformation method (DTM) for heat and mass transfer in a porous channel

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Abstract In the present paper a differential transformation method (DTM) is used to obtain the solution of momentum and heat transfer equations of non-Newtonian fluid flow in an axisymmetric channel with porous wall. The comparison between the results from the differential transformation method and numerical method are in well agreement which proofs the capability of this method for solving such problems. After this validity, results are investigated for the velocity and temperature for various values of Reynolds number, Prandtl number and power law index.

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1. Introduction

The problem of non-Newtonian fluid flow has been under a lot of attention in recent years. Various applications in different fields of engineering specially the interest in heat transfer problems of non-Newtonian fluid flow, such as hot rolling, lubrication, cooling problems and drag reduction was the main reason for this considerable attention. Debruge and Han [1] Q3 studied a problem concerning heat transfer in channel flow, which can be considered as an application of the previous works reported by Yuan [2], White [3] and Treill [4]. Q4 Increasing the resistance of the blades against the hot stream around the blades for cooling was interested. However the cooling process gives rise to excess energy consumption which leads to largely decrease of turbine efficiency.

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Nomenclature

A, B	symmetric kinematic matrices
C	specific heat
C_n	blade-wall temperature coefficients
f	velocity function
F	transformation of f
x_k	general coordinates
K_r	rotation parameter
$\overline{k}$	fluid thermal conductivity
n	power law index in temperature distribution
p	fluid pressure
$q_n(\eta)$	temperature function
Pr	Prandtl number
Re	injection Reynolds number
T	temperature
u_r , u_z	velocity components in r, z directions, respectively
V	injection velocity
r, θ, z	cylindrical coordinate symbols
$\frac{\delta v_m}{\delta x_n}$	velocity gradients
$\frac{\delta a_m}{\delta x_n}$	acceleration gradients

Greek symbols

ρ	fluid density
τ_{ij}	stress tensor component
ϕ_k	viscosity coefficients
φ	dissipation function
η	dimension less coordinates in z direction
ψ	stream function

Most of phenomena in our world are essentially nonlinear and are described by nonlinear equations. Nonlinear differential equations usually arise from mathematical modeling of many physical systems. Some of them are solved using numerical methods and some are solved using analytic methods such as perturbation. Perturbation techniques are based on the existence of small or large parameters, this is called perturbation quantity. Unfortunately, many nonlinear problems in science and engineering do not contain such kind of perturbation quantities. Therefore, same as the HAM [5,6], HPM [7–10], ADM [11,12] and OHAM [13,14] can overcome the foregoing restrictions and limitations of perturbation methods. One of the semi-exact methods which does not need small parameters is the differential transformation method. This method constructs an analytical solution in the form of a polynomial. It is different from the traditional higher-order Taylor series method. The Taylor series method is computationally expensive for large orders. The differential transform method is an alternative procedure for obtaining an analytic Taylor series solution of differential equations. The main advantage of this method is that it can be applied directly to nonlinear differential equations without requiring linearization, discretization and therefore, it is not affected by errors associated to discretization. The concept of DTM was first introduced by Zhou [15], who solved linear and nonlinear problems in electrical circuits. Chen and Ho [16] developed this method for partial differential equations and Ayaz [17] applied it to the system of differential equations. Jang et al. [18] applied the two-dimensional differential transform method to the solution of partial differential equations. Sheikholeslami et al. [19] used this method to solve the problem of nanofluid flow between parallel plates considering Thermophoresis and Brownian effects. Sheikholeslami and Ganji [20] applied DTM to solve the problem of nanofluid flow and heat transfer between parallel plates considering Brownian motion. They concluded that Nusselt number increases with augment of nanoparticle volume fraction, Hartmann number while it decreases with increase of the squeeze number. Natural convection of a non-Newtonian copper–water nanofluid between two infinite parallel vertical flat plates is investigated by Domairry et al. [21]. They conclude that as the nanoparticle volume fraction increases, the momentum boundary layer thickness increases, whereas the thermal boundary layer thickness decreases. New analytical and numerical method has been developed in recent year in different field of science [22–56].

In this study, the purpose is to solve nonlinear equations via DTM. It can be seen that this method is strongly capable for solving a large class of coupled and nonlinear differential equations without tangible restriction of sensitivity to the degree of the nonlinear term.

2. Mathematical formulation

2.1. Flow analysis

This study is concerned with simultaneous development of flow and heat transfer for non-Newtonian viscoelastic fluid flow on the turbine disc for cooling purposes. The problem to be considered is depicted schematically in Figure 1. The r-axis is parallel to the surface of disk and the z-axis is normal to it.

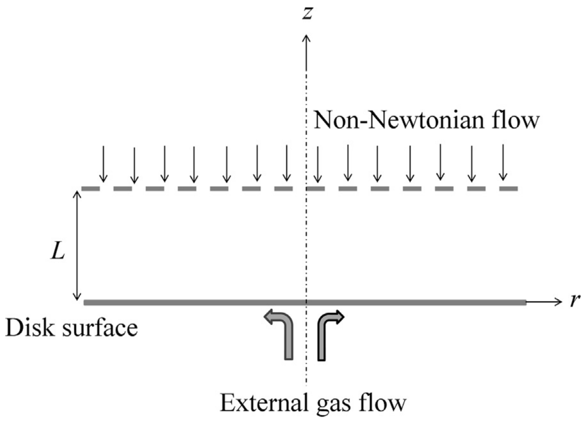

Figure 1 Schematic diagram of the physical system.

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