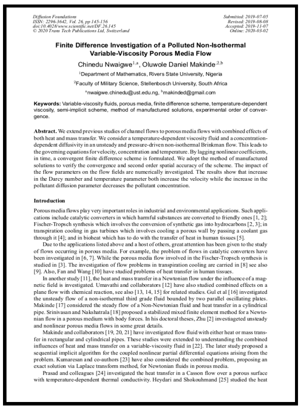
Method for computing unsteady flows in porous media

Longman Scientific & Technical - An Approximate Method for Computing Nonsteady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Finite Difference Investigation of a Polluted Non-Isothermal Variable-Viscosity Porous Media Flow

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Abstract. We extend previous studies of channel flows to porous media flows with combined effects of both heat and mass transfer. We consider a temperature-dependent viscosity fluid and a concentration-dependent diffusivity in an unsteady and pressure-driven non-isothermal Brinkman flow. This leads to the governing equations for velocity, concentration and temperature. By lagging nonlinear coefficients, in time, a convergent finite difference scheme is formulated. We adopt the method of manufactured solutions to verify the convergence and second order spatial accuracy of the scheme. The impact of the flow parameters on the flow fields are numerically investigated. The results show that increase in the Darcy number and temperature parameter both increase the velocity while the increase in the pollutant diffusion parameter decreases the pollutant concentration.

Introduction

Porous media flows play very important roles in industrial and environmental applications. Such applications include catalytic converters in which harmful substances are converted to friendly ones [1, 2]; Fischer-Tropsch synthesis which involves the conversion of synthetic gas into hydrocarbons [2, 3]; in transpiration cooling in gas turbines which involves cooling a porous wall by passing a coolant gas through it [4]; and in bioheat which has to do with the transfer of heat in human tissues [5].

Due to the applications listed above and a host of others, great attention has been given to the study of flows occurring in porous media. For example, the problem of flows in catalytic converters have been investigated in [6, 7]. While the porous media flow involved in the Fischer-Tropsch synthesis is studied in [3]. The investigation of flow problems in transpiration cooling are carried in [8] see also [9]. Also, Fan and Wang [10] have studied problems of heat transfer in human tissues.

In another study [11], the heat and mass transfer in a Newtonian flow under the influence of a magnetic field is investigated. Umavathi and collaborators [12] have also studied combined effects on a plane flow with chemical reaction, see also [13, 14, 15] for related studies. Gul et al [16] investigated the unsteady flow of a non-isothermal third grade fluid bounded by two parallel oscillating plates. Makinde [17] considered the steady flow of a Non-Newtonian fluid and heat transfer in a cylindrical pipe. Srinivasan and Nakshatrala [18] proposed a stabilized mixed finite element method for a Newtonian flow in a porous medium with body forces. In his doctoral theses, Zhu [2] investiageted unsteady and nonlinear porous media flows in some great details.

Makinde and collaborators [19, 20, 21] have investigated flow fluid with either heat or mass transfer in rectangular and cylindrical pipes. These studies were extended to understanding the combined influences of heat and mass transfer on a variable-viscosity fluid in [22]. The later study proposed a sequential implicit algorithm for the coupled nonlinear partial differential equations arising from the problem. Kumaresan and co-authors [23] have also considered the combined problem, proposing an exact solution via Laplace transform method, for Newtonian fluids in porous media.

Prasad and colleagues [24] investigated the heat transfer in a Casson flow over a porous surface with temperature-dependent thermal conductivity. Heydari and Shokouhmand [25] studied the heat

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