# Comparison study between the effects of different terms contributing to viscous dissipation in saturated porous media

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## Abstract

Some sort of controversy is associated with the problem of viscous dissipation in saturated porous media for which we try to present a comparison study between the influences of the different terms contributing to this phenomenon. We consider viscous dissipation by studying the case of semi-infinite flat plate embedded in saturated porous medium and is kept at constant, higher temperature compared with the surrounding fluid. The fluid is induced to move upwards by natural convection during which viscous dissipation is considered. The boundary layer assumptions are considered to simplify the treatment and to highlight the influencing parameters. The behavior of temperature, and velocity fields in the neighborhood of the vertical flat plate were used to highlight the effects of these parameters. Three terms were considered to contribute to viscous dissipation, namely Darcy's term, the Forchheimer term and Al-Hadharami's term. Although there are no unanimous agreements between researchers to include the Forchhemier term in the dissipation function, some researchers argued it might have an indirect effect and hence for this sake and for completion purposes, we include it in this comparison study. Dimensional considerations reveal that Darcy's term is influenced by Gebhart number, the Forchheimer term is controlled by the non-Darcy parameter and Al-Hadharami's term is influenced by Darcy's number. The governing, non-dimensional set of equations together with the imposed boundary conditions is numerically investigated by finite element method. The results for the details of the governing parameters are presented and investigated. It is found that the irreversible process of transforming the

kinetic energy of the moving fluid to heat energy via the viscosity of the moving fluid (i.e., viscous dissipation) is very much influenced by the relative magnitude of these dimensionless parameters.

## Highlights

► Numerical investigation of the phenomena of viscous dissipation in porous media is discussed. ► Three terms contributing to the viscous dissipation have been investigated. ► Comparisons between the effects of these terms are highlighted. ► The boundary layer approximations are used in this work. ► Finite element code is developed to consider this problem

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## Keywords

Viscous dissipation; Porous medium; Natural convection; Finite element method; Non-Darcy

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