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Numerical Simulation of a Leaking Buried Pipe in Semi-infinite Saturated Porous Medium

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Abstract

Numerical simulation for a leaking species migration from a heat source buried into a fluid saturated porous medium is demonstrated. Heat and mass transfer from a source buried into a saturated porous medium are relevant to nuclear waste disposal and crude oil transport. Here, the porous medium surrounding the source is heated/polluted and the resulting temperature/concentration difference drives the flow. For simulating a buried pipe in porous media we used a 2D geometry, and the governing equations base on Dupuit-Forchheimer model solved numerically by finite difference method.

A parametric study is carried out for different Peclet and Rayleigh numbers and location of the Leaking hole. Two locations of leakage are considered in this study. The results show that the leaking hole place has a significant effect on migration of the Third component into the porous medium.

Keywords: Porous media, buried pipe, Heat and Mass Transfer, Buoyancy, Finite difference

Introduction

Coupled heat and mass transfer due to buoyancy in saturated porous media has many important applications in energy related engineering problems, for example, the migration of moisture in fibrous insulation, the spreading of chemical pollutants in saturated soil, and the underground disposal of nuclear wastes. The engineering application that is closely related to this study is the transportation of crude oil through buried pipelines. In order to reduce the pumping load and cost, crude oil is often heated to a higher temperature to reduce its viscosity for transport. In the event of a leak developed from the pipeline, one would be interested in predicting the spreading patterns of the crude oil from the accident site to the surrounding environment and also it is practical for spreading of any fluid which is transformed by buried pipeline such as water supplies. Another application related to the present study is the usage of waste heat for soil heating. Sometimes it is desirable to let water seep through a buried pipe to provide subsurface irrigation and maintain the moisture level in the soil. For either application, a prior knowledge of the flow, temperature and concentration distributions would certainly improve the effectiveness in confining the pollutants or providing subsurface heating and irrigation.

Despite the importance of this transport phenomenon in engineering applications, only limited reports are available in the literature that deal with double diffusive convection from a buried cylinder. One of the pioneering studies was performed by Poulikakos [1] as he tackled the problem with perturbation method using a heat and concentration point source in an infinite porous medium. Later, Cheng and Lai [2], Yih [3] as well as Chamkha and Quadri [4] investigated the double-diffusive transport phenomena from a buried cylinder and their studies did not consider a leakage from the pipe. In 2006, Ngo[5] presented buoyancy induced in a porous media near buried pipe base on Darcy law.

The objective of the present paper is to investigate the coupled heat and mass transfer by mixed convection induced by a leakage from a cylinder buried in a porous medium base on Dupuit-Forchheimer equation for porous media which is more exact solution for Problems in porous media especially for larger velocity magnitude. It is expected that the solutions thus obtained will have useful applications in practice and will serve as a complement to the existing literature.

Analysis and Mathematical Formulation

For modeling a pipe in a semi-infinite porous media the beneath configuration (figure 1) is considered. The dimensions for representing the semi-infinite porous media are selected base on [5] which state that the proper ratio of width to radii equal to representing the semi-infinite porous media is 1/30.

The geometry considered is a horizontal pipe With a radius of r_i embedded in a saturated porous medium at a depth of d ($d/r_i = 5$ for the present study) beneath the top surface. A crack developed on the pipe is assumed to have an angular span of 9^o to produce leakage from the pipe. Two locations of the leakage are considered in the present study: one is on top and another at the bottom of the pipe. The fluid is assumed to discharge from the horizontal pipe at a radial velocity of U_R and a higher concentration of C_h. The impermeable top surface is maintained at a lower temperature T_c and concentration C_c while the pipe itself is maintained at a higher temperature T_h.

For describing momentum conversation in the porous media there are some ways. The most fundamental equation governing fluid flow in porous media was derived by Darcy[6].