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PII: S0301-9322(14)00145-1
DOI: http://dx.doi.org/10.1016/j.ijmultiphaseflow.2014.07.013
Reference: IJMF 2085

To appear in: *International Journal of Multiphase Flow*

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Abstract

Darcy's equations are frequently used as a coarse-grained numerical expedient for modeling multiphase flow through complex porous materials. In some applications, the porous material may be quite thin, allowing the possibility of further simplification of the equations. In this paper we derive a reduced-order shell finite-element model for flow through thin porous materials using an approach similar to that taken to derive the Reynolds' lubrication equation. We advance first a formulation that addresses generalized unstructured porous materials and then specialize the equations for certain structured cases. We also extend the model to account for multiphase, confined lubrication flow in an adjoining layer and gas transport within the pores. We apply the model to several problems of topical interest in micro- and nano-manufacturing processes.

Keywords: porous media, lubrication, reduced-order model, shell element, finite element method, nano-manufacturing

1. Introduction

Building predictive computer-aided models for multiphase flow through a porous medium is a multiscale challenge, with most work focused on the largest scales by invoking the theory of interacting continua [1]. The most common approach on this scale is to deploy what is known as Darcy's law [2, 3]. Darcy flow simulations in three-dimensions are used extensively in geologic applications (groundwater flows) [4, 5] and in chemical process modeling [6]. The underpinning concept of the Darcy formulation is that the flow is pressure driven and its

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