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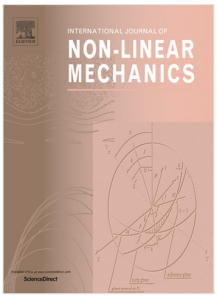

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Acceleration waves in a nonlinear Biot theory of porous media

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Abstract

We extend a theory of Biot to be applicable to nonlinear deformations of an elastic body which contains pores saturated by a fluid. A detailed acceleration wave analysis is presented for the full nonlinear theory.

Keywords: acceleration waves, porous media, nonlinear deformations

1. Introduction

There is much interest in the propagation of waves in porous and related media which allow acoustic wave propagation, see e.g. Biot [1], Brunnhuber and Jordan [2], Christov [3], Christov and Jordan [4], Christov et al. [5], Ciarletta and Straughan [6–8], Jordan [9–14], Jordan and Puri [15], Jordan and Saccomandi [16], Jordan et al. [17, 18], Paoletti [19], Rossmanith and Puri [20, 21], Wei and Jordan [22]. This interest is driven by the many real life applications this topic has.

Many of the early articles dealing with wave propagation in porous media were based on linear theories developed by Biot, see e.g. Biot [1].

To develop a fully nonlinear theory of acoustic wave propagation in a porous medium Jordan [10] used what may be termed an equivalent fluid theory and showed that we could analyze such propagation in a completely nonlinear framework by using an acceleration wave analysis, see also Ciarletta and Straughan [6]. These works assume the solid skeleton remains stationary.

In order to accommodate nonlinear wave motion in a porous medium with the skeleton allowed to deform or vibrate, two approaches have been employed. One is to employ a theory of a mixture of a fluid and of a solid, see e.g. De Boer and Liu [23]. The other is to employ a theory of nonlinear elasticity where the body includes voids, see e.g. Iesan [24], Ciarletta and Straughan [7, 8]. Biot [25] is critical of employing a mixture theory approach due to inherent difficulties with interacting continua based on a Eulerian description. He writes such a theory... "*lacks the required sophistication to account for all significant and essential properties of porous media.*" Chen [26] also raises doubts about the validity of acceleration wave analysis in mixture theories.

In this work we wish to address the issue of nonlinear wave motion in a porous body where we allow the body to undergo a finite deformation with an approach which is consistent with the original linear theory of Biot [1]. In order to achieve this we commence with work of Biot [25] where he develops a fully nonlinear theory for a porous medium by incorporating an equation for the pressure inside the pores in the material. Biot presents his theory in the quasi-static and isothermal context, and in particular he neglects the acceleration term in the momentum equation for the elastic body. However, he writes that his theory brings the mechanics of porous media... "*to the same level of development of the classical theory of finite deformations in elasticity.*" In this paper we generalize Biot [25] work and include the acceleration into the momentum equation.

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