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Group properties of the extended Green-Naghdi equations

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Abstract

The group analysis method is applied to the extended Green-Naghdi equations. The equations are studied in the Eulerian and Lagrangian coordinates. The complete group classification of the equations is provided. The derived Lie symmetries are used to reduce the equations to ordinary differential equations. For solving the ordinary differential equations the Runge-Kutta methods were applied. Comparisons between solutions of the Green-Naghdi equations and the extended Green-Naghdi equations are given.

Keywords: the Green-Naghdi equations; Lie group classification; Invariant solution; Exact solution
Subject Classification (MSC 2010): 76M60, 35R10
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1. Introduction

The Green-Naghdi equations, also known as the Serre or Su-Gardner equations, model the fully nonlinear and weakly dispersive surface gravity waves on a fluid of finite depth. Although the Green-Naghdi equations only approximate the Euler equations for irrotational flows, they inherit several remarkable features of them. It should be noted that a large number of works have been devoted to the study of the Green-Naghdi equations from both analytical and numerical points of view. Recently, the equations of an extended Green-Naghdi shallow water model which incorporates the arbitrary higher-order dispersive effects while preserving the full nonlinearity were derived [1]. As an illustrative example of approximate model equations, a higher-order model that is accurate up to the fourth power of the dispersion parameter in the case of a flat bottom topography were derived there. This system of equations is the generalization of the equations derived first by Serre [2] and later by Su and Garden [3], and then by Green and Naghdi [4] to describe the one-dimensional propagation of fully nonlinear and weakly dispersive surface gravity waves.

1.1. The studied equations

The conservation form of the extended Green- Naghdi equations, accurate up to the fourth power of the dispersion parameter, is [1]

$$h_t + \varepsilon(hu)_x = 0, \tag{1}$$

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