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Dynamics of the breather waves, rogue waves and solitary waves in an extend Kadomtsev-Petviashvili equation☆

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Abstract

Under investigation in this work is an extend Kadomtsev-Petviashvili (eKP) equation, which appears in the study of multi-component plasmas. By considering Bell's polynomials, an effective and straightforward way is presented to succinctly derive its bilinear form and soliton solutions. Moveover, the homoclinic breather limit method is employed to construct the breather wave and rogue wave solutions of the equation. Finally, the dynamic behaviors of breather waves, rogue waves and solitary waves are discussed with graphic analysis. It is hoped that our results can be useful for explaining and enriching the dynamic behavior of these KP-type equations.

Keywords: An extend Kadomtsev-Petviashvili equation, Breather wave, Rogue wave, Solitary wave, Homoclinic breather limit method.
2010 MSC: 35Q51, 35Q53, 35C99, 68W30, 74J35.

1. Introduction

It is well known that nonlinear evolution equations (NLEEs) can depict many important phenomena in physics and other related fields. As mathematical models of these phenomena, it is very necessary to seek exact solutions for NLEEs in mathematical physical. In the past few years, there exists a mass of methods to deal with NLEEs, including Lie group method [1], inverse scattering transformation (IST) [2], Darboux transformation(DT) [3], Hirota bilinear method (HBM) [4], etc. Particularly, it is very necessary to indicate that the HBM is one of the most direct and effective methods to search the solitary wave solutions of NLEEs. Recently, Rogue waves (RWs) (alias monster waves, killer waves, extreme waves) have attracted a growing amount of attention on both experimental observations and theoretical predictions. These giant wave phenomenons had been found in different fields as the plasmas, deep ocean, Bose-Einstein condensates (BECs), nonlinear optic, biophysics and even finance etc [5]-[12]. The first-order rational solution of the nonlinear Schrödinger equation (NLSE) is first investigated by Peregrine to depict the RWs phenomenon [13]. Very recently, by using DT method and HBM, there are a number of work to study breather wave (BW) and rogue wave (RW) solutions of NLEEs and NLSE [14]-[29].

The Kadomtsev-Petviashvili (KP) equation is a nonlinear partial differential equation (PDE) in two spatial and one temporal coordinate, which can describe the evolution of nonlinear, long waves of small amplitude with slow dependence on the transverse coordinate. Kadomtsev and Petviashvili relaxed the restriction that the waves be strictly one-dimensional, to construct the completely integrable KP equation in the following form

$$(U_t + 6UU_x + U_{xxx})_x + \sigma U_{yy} = 0, \ \ \sigma = \pm 1, \tag{1.1}$$

which can be used to describe the evolution of quasi-one-dimensional shallow-water waves when effects of the surface tension and the viscosity are negligible. A variety of modified and extended KP equations has been presented in [30]. Particularly, in this work, we will focus on an extend (3+1)-dimensional Kadomtsev-Petviashvili (eKP) equation

$$u_{xt} + a\left(uu_{xx} + u_x^2\right) + bu_{xxxx} + c\left(u_{xy} + u_{xz} + u_{yz}\right) + d\left(u_{xx} + u_{yy} + u_{zz}\right) = 0, \tag{1.2}$$

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