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Stability analysis of a new lattice hydrodynamic model by considering lattice's self-anticipative density effect

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Abstract: In this paper, a new lattice hydrodynamic model with consideration of the density difference of a lattice's current density and its anticipative density is proposed. The influence of lattice's self-anticipative density on traffic stability is revealed through linear stability theory and it shows that lattice's self-anticipative density can improve the stability of traffic flow. To describe the phase transition of traffic flow, the mKdV equation near the critical point is derived by using nonlinear analysis method. The propagating behavior of density wave in the unstable region can be described by the kink-antikink soliton of the mKdV equation. Numerical simulation validates the analytical results, which shows that traffic jam can be suppressed efficiently by considering lattice's self-anticipative density in the modified lattice hydrodynamic model.

Key words: Traffic flow, lattice hydrodynamic model, self-anticipative density, nonlinear analysis

1 Introduction

Traffic congestion is a serious problem in our modern society and it affect our daily lives importantly. In order to uncover the intrinsic mechanism of traffic congestion, Traffic modeling is one of underlying works which can explain many real traffic phenomena mathematically. Generally, the existing traffic models can be categorized into the microscopic models [1-8] and the macroscopic models [9-18]. The microscopic models mainly study the dynamic behavior of individual vehicle, while the research of the macroscopic models is focus on the macroscopic traffic characteristics of the road.

As the lattice hydrodynamic model, it was firstly proposed by Nagatani [19]. It was constructed by discretizing the hydrodynamic model built by Kerner et al. [10] with the idea of car-following theory. Due to the superiority of the lattice hydrodynamic model that it can reproduce many real traffic phenomena with a simple differential equation, it was widely extended by many researchers subsequently. Among them, some were conducted by considering the traffic information like the density difference effect [20], the current difference effect [21,22], the backward looking effect [23], traffic interruption effect [24-26], different road condition [27,28] and different kind of driver's behaviors [29-34] in single lane highway, the others were extended to the two-lane or two-dimensional traffic systems [35-40]. Also the lattice hydrodynamic model is researched by some scholars with control method [41,42].

In Ref.[20], Tian et al. assumed that the density difference information of two consecutive lattices could affect the stability of traffic flow and they constructed a

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