Gyrokinetic simulation of turbulence driven geodesic acoustic modes in edge plasmas of HL-2A tokamak

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(Received 13 May 2010; accepted 7 September 2010; published online 29 November 2010)

Strong correlation between high frequency microturbulence and low frequency geodesic acoustic mode (GAM) has been observed in the edge plasmas of the HL-2A tokamak, suggesting possible GAM generation via three wave coupling with turbulence, which is in turn modulated by the GAM. In this work, we use the gyrokinetic toroidal code to study the linear and nonlinear development of the drift instabilities, as well as the generation of the GAM (and low frequency zonal flows) and its interaction with the turbulence for realistic parameters in the edge plasmas of the HL-2A tokamak for the first time. The simulation results indicate that the unstable drift wave drives strong turbulence in the edge plasma of HL-2A. In addition, the generation of the GAM and its interaction with the turbulence are all observed in the nonlinear simulation. The simulation results are in reasonable agreement with the experimental observations. © 2010 American Institute of Physics. [doi:10.1063/1.3496981]

I. INTRODUCTION

Anomalous cross field particle, momentum, and energy transport in tokamak plasma are generally believed to arise from the microturbulence excited by drift wave instabilities, such as ion/electron temperature gradient driven modes and trapped electron mode (TEM). Identifying the underlying mechanism and searching for the ways to suppress the turbulence is one of the key topics in magnetic fusion studies. One of the major progress made in this field in recent years is the identification of zonal flows (ZF).1 ZFs are self-generated large scale coherent structures, resulting from parametric instabilities and regulating the turbulence. It plays a crucial role in setting the level of turbulence and associated transport and has been under intensive investigation in magnetically confined fusion plasmas in the past decades. It is widely accepted that there are two types of zonal flows: one is the low frequency ZF, the other is the higher frequency oscillation called the geodesic acoustic mode (GAM).2 The experimental identification and characteristics of ZFs and GAMs have recently been reported in a variety of toroidal fusion devices.3 The structure in poloidal cross section and characteristics of the flows were studied at the edge in the DIII-D tokamak and in the core of the JIPP-TIIU tokamak plasma.4–7 The radial and poloidal structures of the GAM oscillations were investigated in ASDEX and in T-10 device.8,9 Recently, the toroidal symmetry (n=0) of the GAM/ZFs has been identified in the edge plasmas of the HL-2A tokamak.10 Strong correlation between the high frequency microturbulence and the low frequency GAM has also been observed,11 suggesting the possibility of GAM generation by turbulence and turbulence modulation by GAM.12 Much experimental research has been done to explore the physics mechanism leading to turbulent transport, ZF generation, and its role in transport reduction in the HL-2A tokamak.13–16 However, simulation study about ZFs and turbulence of the HL-2A experiments has not been performed.

In this work, we use the gyrokinetic toroidal code (GTC),1 which has been effectively used for studies of turbulent transport and zonal flow in tokamak plasmas, to simulate the linear and nonlinear development of the drift wave instabilities, such as ion/electron temperature gradient driven modes and TEM, as well as the generation of GAM (and low frequency zonal flows) and its interaction with the turbulence for realistic parameters, including steep pressure gradients and large safety factor q in edge plasmas of the HL-2A tokamak for the first time. In the GTC linear simulation without collision effect, we find that the TEM is strongly unstable in the edge plasma of the HL-2A tokamak. The TEM instability is driven by the electron density and temperature gradients. Meanwhile, the GAM structure and its regulation of the turbulence are found in the nonlinear simulation. The frequency of the GAM from the simulation is about tens of kilohertz, which is close to the experimental observations and theoretical value. The properties of the GAM, such as the radial wavenumber and frequency spectrum, are investigated and compared with the observations of the HL-2A experiments.

The remainder of this paper is organized as follows. The simulation model is described in Sec. II. The simulation results are given in Sec. III. Finally, Sec. IV is devoted to the conclusions.

II. SIMULATION MODEL

In the electrostatic gyrokinetic particle simulations using GTC,1 the plasma is treated as a set of computational particles interacting with each other through self-generated elec-