Tokamak residual zonal flow level in near-separatrix region*

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Residual zonal flow level is calculated for tokamak plasmas in the near-separatrix region of a diverted tokamak. A recently developed method is used to construct an analytic divertor tokamak configuration. It is shown that the residual zonal flow level becomes smaller but still keeps finite near the separatrix because the neoclassical polarisation mostly due to the trapped particles goes larger in this region.

Keywords: residual zonal flow, divertor configuration
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1. Introduction

The $E \times B$ zonal flows are generally recognized to be significant for the reduction of turbulent transport either in tokamaks or in other toroidal plasma confinement systems.[1–9] This is an issue closely relevant to the confinement mode transition from low mode (L-mode) to high mode (H-mode), and the standard transition usually appears in the near-edge region. For most tokamak devices, such a transition happens in an equilibrium with divertor configuration.[10] Previously, Rosenbluth and Hinton provided an analytic study of the ion-temperature gradient (ITG) turbulence for tokamak plasmas and obtained an analytic formula for the residual zonal flow that is suitable for large aspect ratio circular tokamak plasma.[1] Later, non-circular shaping and arbitrary aspect ratio effects were considered[11,12] by using a simple analytic equilibrium model, the so-called Solov'ev configuration. However, for more relevant experimental cases, the residual zonal flow level in the divertor configuration is still not considered. Very recently, we suggested to use a semi-analytic simple model to describe the tokamak equilibrium model, the so-called Solov'ev configuration. In this model, the poloidal flux $\psi(R,Z)$ can be simply described by only two terms of separable solutions of the original Grad–Shafranov equation as follows:

$$\psi(R,Z) = \psi_0 g_k(x) \cos(ky) + c_0 g_0(x).$$ (1)

The poloidal magnetic field is determined by

$$B_p = \nabla \psi \times \nabla \zeta.$$ (2)

And $(R, \zeta, Z)$ is the cylindrical coordinates while $x = R/R_0$ and $y = Z/R_0$, with $R_0$ being the major radius of the equilibrium configuration. Function $g_k(x)$ is the solution of the following homogenous ordinary differential equation:

$$\frac{d^2 g_k}{dx^2} = \frac{1}{x} \frac{d g_k}{dx} + (\eta \alpha + \eta \beta x^2 - k^2) g_k = 0,$$ (3)

while $g_0(x)$ is the solution of the following equation

$$\frac{d^2 g_0}{dx^2} - \frac{1}{x} \frac{d g_0}{dx} + (\eta \alpha + \eta \beta x^2) g_0 = 0.$$ (4)

Equations (3) and (4) will be solved numerically in range $0 < x_1 \leq x \leq x_2$. Within this range, these ordinary differential equations are regular. We usually set $g_k(x_{10}) = 0$ and $g_k'(x_{10}) = s_k$. The value of $s_k$ is determined by such a condition as $\max\{g_k(x)\} = 1$. Similarly, Eq. (4) is solved by setting $g_0(x_{11}) = 0$ with

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