

EFFECT OF SPATIAL MOMENTUM CHANNELLING OF ENERGETIC IONS ON PLASMA ROTATION

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In this work, the plasma momentum transport that occurs during the spatial channelling (SC) [1,2] is studied. When an eigenmode with a non-zero toroidal mode number n transports energy from one flux surface to another, it always transports toroidal angular momentum. This means that when the spatial regions where the mode is destabilised and damped are separated in space, the mode applies opposite torques to both these regions. Here, we derive relationships between the radial flux of the ions destabilising the wave and the power accepted by the mode. The torques that result from the resonant interaction of trapped and passing energetic ions with an eigenmode are calculated and compared. At a fixed power channelled by the mode, the resulting torque is proportional to n ; note that TAEs (toroidicity-induced Alfvén eigenmodes) with $n \sim 10-15$ are expected to be dominant in ITER [3]. The shearing rate of the toroidal flow that arises when an eigenmode transports toroidal angular momentum from the excitation region to the damping region is evaluated. The possibility that this flow can contribute to turbulence suppression is discussed.

When the AE (Alfvén eigenmodes) is excited by trapped particles, it is mainly the thermal plasma that receives the torque resulting from the wave radiation. In the case of destabilisation by passing energetic ions, they can take a certain fraction of this torque and undergo longitudinal acceleration. This fraction is small for low-frequency AE modes (TAEs, BAEs (beta-induced Alfvén eigenmodes) and RSAEs (reversed-shear-induced Alfvén eigenmodes) with $n \gg 1$. However, this inequality may not hold for low-frequency modes with $n \sim 1$ and for high-frequency modes excited via cyclotron resonance.

Fast ions are known to affect plasma turbulence [4], see an overview in [5]. Several mechanisms are proposed to explain this effect; zonal flows (ZF) generated by fast-ion-excited AE – TAEs, RSAEs or BAEs – are among these mechanisms. Generation of zonal flows by AEs and EPMs (energetic particle modes) has been observed in numerical experiments [6-8]. In several works involving experimental observations and numerical simulations, the suppression of turbulence by AEs via shear flow formation was demonstrated [9, 10]. Analytical theories for the ZF generation by AEs have been developed [11, 12]; they treat this phenomenon in terms of nonlinear wave–wave interaction between an AE and a ZF. The aim of our analysis was to point out momentum channelling (MC) as a possible mechanism for the shear flow generation. We have estimated the rotation shear generated by the momentum SC. We found that a shearing rate created by a mode with $n=10$, $\gamma_{\text{drive}}/\omega = 5 \times 10^{-2}$, $\tilde{B}/B = 5 \times 10^{-4}$ can reach the order of magnitude required for turbulence suppression. It should be taken into account that our estimate does not allow for the effect of the mode on the turbulence suppression; actually, the flow shearing rate can be higher.

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