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Fishbone Modes in Plasmas with Dual Neutral Beam Injection Heating

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Neutral beam injection (NBI) is one of the important methods to heat plasmas in current tokamaks. However, fishbone instability induced by fast ions during NBI experiment is the main source for resulting in fast ion loss. Generally speaking, the density gradient of fast ions is the primary driving force to destabilize the fishbone modes. Therefore, it is possible to reduce the instability by eliminating the density gradient of the fast ions, employing dual neutral beam injection (DNBI) scheme in tokamak plasmas. The DNBI refers to two NBI lines heating plasma with one at the magnetic axis and the other (called off-axis NBI) at another radial position. With such tangential DNBI, a radial density profile of fast ions can be formed from superposition of dual Gaussian distributions. The dispersion equation for the fishbone instability is numerically solved for a density profile of fast ions of DNBI. A slowing down distribution with Gaussian pitch angle profile is used for each NBI. The dependences of the real frequency and growth rate of the fishbone modes on the parameters such as beta of hot ions (ratio of fast ions pressure/magnetic pressure), Delta (the distance between the axis and deposition position one of the off-axis NBI) and chi (ration of the on-axis NBI intensity and the off-axis one) are investigated in detail. The results show that the density distribution of fast ions from DNBI can bring about a stable window in the radial direction where the fishbone mode cannot be excited by fast ions. The width of the stable window increases linearly with radius increasing of magnetic flux surface of safety factor q=1. Besides, the width of the stable window increases with decreasing of density profile index of fast ions and keeps constant for large enough density profile index. The growth rates of fishbone modes dramatically decrease with the ratio of DNBI intensity and the critical beta values of fast ions increase with increasing of the ratio. The fishbone instabilities can be avoided with DNBI and may be an effective method to prevent fast ion loss resulted from fishbone modes.

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Author: Dr HE, Hongda (Southwestern institute of physics)

Co-authors: JIANG, H (Fujian University of Technology); Prof. DONG, Jiaqi (Southwestern Institute of Physics); ZHAO, Kang (Southwest University for Nationalities); HE, Zhixiong (Southwestern Institute of Physics)

Presenter: Dr HE, Hongda (Southwestern institute of physics)

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