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Analysis of ITB and ETB Formations in Tokamak Plasma Using Bifurcation Concept

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The formation of transport barriers, including both ETB (edge transport barrier) and ITB (internal transport barrier), in tokamak plasma is investigated using bifurcation concept. A set of heat and particle transport equations with both neoclassical and anomalous effects is used to represent the plasma in slab geometry. The neoclassical coefficients are assumed to be constant, while the anomalous coefficients, taking effect only above critical gradients, are assumed to be locally driven by gradients of pressure and density. The transport suppression is assumed to occur only in the anomalous channel with flow shear and magnetic shear as suppression mechanisms. The flow shear, presented in term of coupling pressure and density gradients, is assumed to nonlinearly suppress the transport, whereas the magnetic shear plays a more complicated role in the suppression of the transport and reduction of the flow shear strength. Both transport equations are analytically and numerically solved for local plasma gradients in order to examine ETB and ITB formations. It is found that the results exhibit bifurcation nature when mapped onto fluxes versus gradients space in which abrupt jumps in the gradients can be observed at both transport barrier locations. ETB appears to form only if the critical flux is reached regardless of the magnetic shear profile, while ITB formation is possible only with a reversed magnetic shear profile. In addition, with a suitable magnetic shear profile, the minimum flux criterion is not needed for ITB formation, though the abrupt jumps in the gradients become smoother at lower flux. ITB location and width are also found to be correlated to the nature of q-profile. In particular, the location is in the vicinity of where q-profile reverses its direction and the width appears to be inversely proportional to its curvature.

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