One-dimensional transport analysis of divertor detachment

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Detachment of divertor plasma is one of key physics to be understood for divertor heat handling in International Thermonuclear Experimental Reactor (ITER) and a succeeding demonstrating fusion power plant (so-called DEMO). Detached divertor regimes have been confirmed in most large diverted tokamak experiments. On the other hand, qualitative and quantitative attempts of modelling have not yet reproduce these experimental results. Most of such attempts have been based on two-dimensional (2D), multi-component plasma fluid codes coupled to neutral particle Monte Carlo codes [1].
Complexity of these codes makes it necessary to interpret simulation results in simpler physical model. Particularly, it would be important to understand what is a multi-dimensional effect and/or what phenomenon can be explained by such simpler model. A one-dimensional (1D) model, apparently simpler than the complex 2D codes, can be expected to provide physical insight and qualitative information that are useful for interpretation of experimental results and improvement of the 2D codes.
The purpose of this study is to qualitatively understand under what conditions detachment divertor plasma can occur and "thermal fronts" [2, 3] of several plasma parameters can be stabilized. For this study we use 1D transport equations along the field lines for detached divertor plasmas coupled to a simple analysical model for neutral particles. These transport equations consists of the effective parallel viscosity term, particle and heat sources into the scrape-off-layer from the core plasma, radiation loss, effective friction of the charge-exchange collisions of neutrals, and power loss due to three-body and radiative recombination. In the previous 1D model [3], elastic collision of neutrals and presence of fast neutrals, emitted in the charge-exchange collisions, were not taken into account. We newly introduce these terms into the 1D transport equation. Moreover, in the previous study [3] a scan in impurity content for occurrence of detachment has not been performed.
In the presentation we particularly discuss

(i) the effect of the impurity content (or "Z effective") and

(ii) the effect of the plasma momentum loss due to elastic collisions of neutral hydrogen atoms and molecules

on the occurrence of divertor detachment and the thermal fronts.

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