On the physics of divertor detachment and detachment stability

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Detached or semi-detached divertor operation is the primary operational scenario for the ITER divertor (we define a divertor detachment as a "roll over" of plasma flux which in experiment is often observed with increasing plasma density). However, surprisingly so far there is no consensus on the physics mechanism(-s) of detachment. To this moment, a few plausible mechanisms of plasma detachment were suggested.

In Ref. 1 the reduction of plasma flux to the target was attributed to the plasma momentum loss due to plasma-neutral coupling (friction). As a result of this friction force plasma flow to the target is slowing down, which could cause the reduction of plasma flux to the target.

In Ref. 2 the detachment was explained by the increase of energy loss (associated with both impurity and neutrals), which reduces the energy flux available for neutral ionization, and/or by the onset of plasma recombination, which literally extinguishing the plasma in front of the target simultaneously reducing the plasma flux to the target and spreading the heat load to the targets by the fast cross-field neutral transport.

Finally, in Ref. 3 it was demonstrated that, for the SOL width comparable and smaller than the ion poloidal gyro-radius, the interplay of the ExB drifts and the parallel plasma dynamics in the plasma momentum balance equation can produce a strong variation of plasma pressure along the magnetic field lines and, therefore, alter plasma fluxes to the targets.

We note that detached regime can be unstable [4] causing a jump of detachment front from the target to X-point following the MARFE formation, which, potentially, can cause disruption of the discharge.

Here we discuss basic physics of diverter detachment and detachment stability. Based on available scalings of the width of the heat flux to the target we derive the scalings for the onset of detachment.

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