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On the effect of mixed impurity seeding on occurrence and stability of the X-point radiator in fusion reactors

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The X-point radiator (XPR) plasma regime displays favorable properties with regard to power exhaust in tokamaks. An H-mode-like confinement quality, a detached divertor, and the suppression of type-I ELMs are achieved simultaneously. XPR scenarios may also pave the way for more compact and cheaper divertor solutions, as demonstrated on ASDEX Upgrade [3]. The XPR regime was realized on different tokamaks including JET [1]. XPR stability and the fraction of powerdissipated by radiation can be actively controlled through impurity seeding and neutral gas fuelling [2]. The control parameter is the XPR height, which represents its vertical extension above the X-point. Controlling the XPR height is also important to prevent marfes and consecutive disruptions.

This contribution focuses on the prospects of XPR scenarios in tokamak fusion reactors and the appropriate choice of impurity species. The investigations indicate that XPRs should be more accessible in a reactor than in smaller tokamaks, i.e., at lower neutral and impurity densities. This is consistent with results from SOLPS-ITER transport code simulations [4]. Among the impurities investigated (B, C, Ne,
N, Ar), argon is most efficient at radiating height power. For EU-DEMO, argon seeding resulted in an XPR height of 50 cm, which corresponds to a dissipation of 90 % of the 150 MW heating power. However, the XPR height depends strongly on impurity concentration, which could make control difficult. Neon, on the other hand, requires higher concentrations to radiate the same amount of power, but the XPR hight changes more slowly with concentration. Therefore, an impurity mixture
could be advantageous, with argon carrying the base load of radiation losses and neon being used for control. Under the model assumptions made, there are indications that carbon and, to a certain extent, nitrogen have a negative effect on XPR stability, while too much boron may lead to unstable XPRs.

These results were obtained from a reduced power and particle balance model [5] and an extension of it [6] which estimates the XPR height, the dissipated power, and the coupling to the upstream profiles. The calculated reduction in the pedestal gradient is consistent with the experiments [8] and could explain the process of ELM
suppression.

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