The H-mode density limit at the ASDEX Upgrade tokamak

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The high confinement mode (H-mode) is the operational scenario foreseen for ITER, DEMO and future fusion power plants. At high densities, which are favourable in order to maximize the fusion power, a back transition from the H-mode to the low confinement mode (L-mode) is observed. In present tokamaks, this H-mode density limit (HDL) occurs at densities on the order of, but below, the Greenwald density [1].

For carbon covered devices the HDL is reported to be radiation induced [2]. Since the radiation characteristics change significantly with the wall material, the HDL is revisited in the fully tungsten covered ASDEX Upgrade tokamak (full-W AUG). In gas ramp discharges, four distinct operational phases are identified in the approach towards the HDL. These four phases are reproducible, quasi-stable plasma regimes and provide a framework in which the HDL can be further analysed. In the presented work, the observation of the four phases is explained by a coupling of two effects: A fuelling limit and an increased energy loss at the plasma edge.

The first of the four phases is a stable H-mode regime, where the central plasma density increases at stationary confinement, expressed by a constant energy confinement time. This is followed by a degrading H-mode, where the increased energy losses set in, reducing the confinement. Meanwhile the fuelling limit leads to a built up of a plateau of electron density in the scrape-off layer (SOL) at a fixed density in the core. In the third phase, the breakdown of the H-mode, the overall electron density remains constant and the confinement decreases further, leading, finally, to an L-mode. Here, the energy losses do not further degrade of the confinement and the observed fuelling limit appears to be inactive, leading to a density increase until the disruptive L-mode density limit is reached.

In this work, two mechanisms are proposed, which might lead to the observed effects. The fuelling limit is most likely correlated to an outward shift of the ionization profile as observed in one-dimensional modelling. The additional energy loss channel is presumably linked to a regime of fast radially propagating filaments in the SOL. The SOL and divertor plasmas play a key role for both mechanisms, confirming the previous hypothesis that the HDL is edge-determined.

The well-known extension of the good confinement at high density with high triangularity is reflected in this scheme by extending the first phase to higher densities.

The four phases are also observed in carbon covered AUG, although the HDL density exhibits a different dependency on the heating power and plasma current. This can be attributed to a replaced energy loss channel, which is most likely caused by the changed radiation characteristics in a carbon device.

References