

Helium ash removal in DEMO-FNS

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In this paper the integrated modelling for the steady-state regime of a fusion neutron source DEMO-FNS ($R/a=3.2\text{m}/1\text{m}$, $B=5\text{T}$, $I_p=4\text{-}5\text{MA}$) [1] is complemented by the helium balance in the divertor and core plasma. The model describes the power and particle balances consistently in the divertor and core plasmas according to approach [2] and finds the condition to fulfill the global requirements on: neutron source value $S_{\text{neut}} > 1019/\text{s}$, maximal peaking heat load is limited by $q_{\text{pk}} < 10\text{MW}/\text{m}^2$, keeping up-down symmetry and avoidance of deep detachment, $\mu < 1$, condition for plasma current overdrive $I_{\text{pl}} \leq I_{\text{BS}} + I_{\text{CD}}$, when the plasma current I_{pl} is generated by the noninductive methods from neutral beam ICD and from the bootstrap current IBS and on a source by pellets $S_{\text{pel}} > f_{\text{T}}/(1-f_{\text{T}})S_{\text{NB}}$, that control the tritium fraction $f_{\text{T}} = n_{\text{T}}/(n_{\text{T}} + n_{\text{D}})$ in a core, where S_{NB} is the D source from neutral beam, S_{pel} is the pellet source of D and T.

The energy and particle balances in the core plasma are modelled with transport equations in the ASTRA code [3] using ITER IPB(y, 2) [4] with prescribed H-factor, ratio of main ions and helium confinement times to the energy confinement time $\tau_{\text{p}}/\tau_{\text{E}}$, $\tau_{\text{He}}/\tau_{\text{E}}$, tritium fraction, f_{T} , electron averaged density $\langle n_{\text{e}} \rangle$ (maintained by the pellet source S_{pel}) and density at the pedestal (see Table 1). Model for the pedestal poloidal beta and the pedestal width is taken from [5,6].

The state of divertor plasma is determined by the values of the incoming heat flux $PSOL$, the neutral pressure in divertor volume p_{n} , the concentration of the neon impurity C_{Ne} and the pumping speed C_{pump} to pump out the helium ash produced by the fusion reaction (see Table 2). Results of SOLPS4.3 [7] series runs are approximated by analytical dependencies (scalings) in order to install the boundary conditions and heat and particle fluxes through the separatrix into the core plasma.

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Self-consistent modeling of central and divertor plasma for DEMO-FNS [8] allows to determine the acceptable window of the divertor parameters p_{n} and C_{Ne} where the global requirements are fulfilled (see Figure). It should be noted that in comparison to the modelling without helium balance [1] the acceptable parameter window become significantly constricted. The neutron yield is weakly reduced but remained to be at the reasonable level $S_{\text{neut}} = 1.1 \cdot 1019/\text{s}$. As one of the neutron reduction factor is the decrease of the tritium fraction in the core plasma in order to fulfill the requirement to tritium fraction control with pellet source (see Table 3). The up-down symmetry requirement ($\mu < 1$ red line in Figure) become a strong factor in the divertor neutral pressure p_{n} limit. We need to make an accurate investigation of a single X-point configuration as it can be more efficient to mitigate the power load to divertor plates.

References

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Table 1 Set of core plasma parameters

$\tau_{\text{p}}/\tau_{\text{E}}$, $\tau_{\text{He}}/\tau_{\text{E}}$ 4
 H-factor 1.3
 f_{T} 0.5
 I_{pl} , MA 4.5
 $n_{\text{ped}}/\langle n_{\text{e}} \rangle$ 0.7
 $\langle n_{\text{e}} \rangle$ 1019/m³ 7

Table 2 Set of divertor plasma parameters

$PSOL$, MW 37.5
 p_{n} , Pa 2

Cpump, m3/s 20
CNe= Σ NNe/ne 0.025
qpk, MW/m² 9.7
 μ 0.87

Table 3 Result global values

Sneut 1019/c 1.1

IBS, MA 1.7

ICD, MA 2.8

PDT MW 31

PDT_pp /PDT_bp 1.8

SpelT,1019/s 58

SpelD,1019/s 21

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