Operational Margins and Impact of Particle Exhaust in DEMO

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Physics requirements for particle throughput for steady state DEMO inductive operation are assessed;

A new DEMO conventional divertor configuration with different height of the dome position and the size of pumping port is investigated in respect to pumping efficiency and D₂ macroscopic quantities in the private flux region and divertor volume.

Physics requirements for particles throughput

DEMO: 2GW fusion power ~ 2hr pulse, D. Ward 2015

- Fuel replenishment due to burn-out & particle loss ~ 40 Pa·m³/s
- Particle loss due to ELMs ~ 75 Pa·m³/s
- Fuel replenishment for He removal at 30% enrichment ~ 160 Pa·m³/s
- Divertor control (dust puff to facilitate detachment) ~ 75 Pa·m³/s

- In steady state particles throughput through fuelling and pumping systems must be essentially the same
- In DEMO steady state operation particle throughput is estimated as ~ 360 ± 160 Pa·m³/s for 2hr pulse. This amount of gas must be pumped out in divertor. (Yu. Igitkhanov, TOFE 2016)

Model for the conventional divertor DEMO design [1]

Fig. 1: 3D model of DEMO divertor cassette with vertical divertor plates and with & w/out possible DOME structure.

$\xi = 0.1$

$\xi = 0.6$

Pressure contours and streamlines for maximum and minimum dome height and large and small pumping port size.

- Pressure is higher for the max. dome height configuration
- No outflow across the lateral sides
- The vortices below the dome are observed only at low values of $\xi$

Effect of the dome height and pumping port size

Fig. 3: Pressure contours and streamlines for maximum and minimum dome height and large and small pumping port size.

- In the case of the small pumping port size, the flow pattern and vortices are similar, while quantitatively the sub-divertor pressure for all cases is higher.

Results

- Physics requirements for particles throughput are assessed for DEMO steady state operation in the range of 360-160 Pa·m³/s.
- A new DEMO divertor configuration is investigated in respect to pumping efficiency required for pumping out particles throughput.
- The DIVGAS code calculations show that it is preferable to have DOME with maximum height and with the large pumping port size.
- The calculations show that the neutral gas entering the PFR from both HFS and LFS flows homogeneously to the pumping port
- No strong vortices impeding pumping and creating gas outflow to the SOL is found in contrary to the ITER-like DEMO divertor
- The gas pressure is higher in the configuration with the maximum dome height and small value of sticking coefficient, whereas it is independent on the pumping port size
- The gas temperature is lower and the gas density is higher in configuration with dome. For low dome height both the density and temperature are, in general, lower at any value of sticking coefficient.
- In the new divertor configuration without the dome, a strong outflow of the molecules towards the core and the reduced pumping flux is found.
- For an open divertor, namely without dome, the particle exhaust can only be insured with a pumping system of high efficiency and probably on the limit of the current technological level.
- It is found that in the new DEMO divertor configuration the max. dome height and pumping duct size are favorable in reaching the higher pumping flux.

For the case of the large pumping port, the solid and dashed lines intersect at around $\xi = 0.2$, which means that for an open divertor, namely without dome, the particle exhaust can only be insured with a pumping system of high efficiency and probably on the limit of the current technological level.

Fig. 7: Normalized D₂ outflow and pumped flux vs $\xi$ for large and small pumping port size.

Fig. 4. Pressure contours and streamlines for maximum and minimum dome height and large and small pumping port size.

1) EU DEMO Design Configuration Definition (EDC_D_2) v4.1, 2015.