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Particle exhaust with the Wendelstein 7-X island divertor

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At the optimized stellarator Wendelstein 7-X (W7-X) an uncooled graphite test divertor unit (TDU) served as the main plasma wall interface in the last two operational phases. The 10 modules of the island divertor are mounted in stellarator symmetric positions, thus maintaining the five fold symmetry of the device. The island divertor is designed to conform to the magnetic field surfaces and can be operated under a variety of magnetic field configurations. Each divertor module is equipped with an island control coil which allows the local manipulation of the magnetic field topology inside of the divertor, further increasing operational flexibility. A divertor module intersects two magnetic islands of the 5/5 edge island chain, one with the horizontal and one with the vertical target plate, forming a pump gap in between. Hydrogen particle exhaust studies of the TDU, pumped with turbo molecular pumps and with a boronized wall are presented. Comparing the particle confinement time τ with the effective particle confinement time , reveals a global recycling coefficient R close to unity. Particles spend multiple plasma confinement times in the system until they are eventually exhausted. Only 1% - 3% of the particles arriving in the divertor are actually exhausted. While this is not a direct concern for hydrogen, it can be of concern for future reactors if these tendencies hold true for helium. While the overall exhaust efficiency is low, the divertor control coils are shown to be important actuators that are capable of changing the effective particle confinement time by a factor of 2.

Comparing the neutral pressure of upstream locations in the main chamber mid-plane with measurements in the divertor reveals the compression ratio. While in the standard magnetic field configuration, the divertor pressure was 20 times higher, than the main chamber pressure, this was significantly improved in the high iota configuration with a compression ratio of 100. While the neutral gas analysis could confirm the overall low exhaust efficiency, it allowed a more detailed assessment. While arround 3% of the neutralized incoming ions in the divertor are pumped through the pump gap, only a third of them actually gets exhausted through the turbo molecular pumps. As the divertor is not completely closed, 34% of the particles in the sub divertor region get exhausted. The rest flows back into the main chamber, coupling the midplane pressure with the sub divertor pressure.

In addition to the active pumping, the plasma facing components can absorb or release particles. The bound particle reservoir of the wall was analyzed via a gas balance. A wide range of operation regimes exists in varying wall conditions which either fill or deplete the wall with significant amount of hydrogen. Significant wall heating is key to mobilize retained gas in the carbon structures, while auxiliary fueling on low-heated walls leads to strong wall pumping.

References

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