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Steady state control of fuel recycling for long pulse discharges in EAST tokamak with full metal first wall

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Fuel recycling is one of the key issues for long pulse operation for tokamaks. During long pulse operation in tokamaks, the accumulation of fuel particles on the first wall leads to a decreasing of wall pumping capability, and eventually the wall changes to outgassing from pumping due to the accumulation of fuel retention and the increasing of surface temperature. This enhances fuel recycling and may leads to uncontrollable plasma density, and further plasma confinement would be deteriorated, or even plasmas would be disrupted. To some extent, the capability of long pulse operation of a tokamak depends on fuel recycling control.
Various methods have been studied in EAST tokamak for recycling control. Lithium coating and real-time lithium injection are very effective to control recycling, and the wall pumping rate is almost proportional to the Li-II emission intensity. The Divertor Dα emission is proportional to divertor neutral pressure in a wide range of auxiliary heating power of 0 –11 MW, and control of divertor neutral pressure by divertor cryopumps is very important for recycling control. Moreover, a short distance between strike point on divertor plate and pumping slot could improve the particle exhaust. The global recycling coefficient was decreased notably with Resonant Magnetic Perturbation (RMP) coil current, but the plasma stored energy was also decreased.
1056 s long pulse discharge was achieved in EAST tokamak, with heating power of 1.5 MW, plasma density of 1.8×1019 m-3 and Double Null (DN) configuration. Both divertor cryopumps and real-time lithium powder injection was employed. Plasma density was controlled very well during the whole discharge. Particle balance analysis shows that the pumping rate of divertor cryopumps was ˜ 2.0×1020 D/s. The wall pumping rate became almost zero since 60 s, and it was kept at zero until 800 s. After that the wall outgassing was gradually increased but was limited to a low value of ˜0.4×1020 D/s. The H/(H+D) ratio from spectrometry diagnostics increases from ˜700 seconds. This means that the outgassing from some part of the first wall was enhanced since ˜ 800 seconds, due to the gradual increase of the first wall temperature. However, the total outgassing rate was limited due to the continuous real-time injection of lithium powder, and the divertor cryopumps provided ˜ 5 times higher exhausting rate than the wall outgassing. Therefore, the fuel recycling was well controlled during the whole discharge of 1056 s, the global recycling coefficient was kept in the range of 0.95 - 0.97. The successful control on fuel recycling during long pulse discharge of over thousand seconds provides valuable references on the steady state operation of future fusion reactors, such as ITER.

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