4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Compatibility between a new LIMIT-style FLiLi and high confinement plasmas in EAST device

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A flowing liquid lithium limiter plate based on the LiMIT concept, i.e. using a thermoelectric MHD force to drive liquid Li flow along the surface channels[1], was successfully applied in EAST in 2020. Learning from the previous flowing liquid Li limiter (FLiLi) experiments [2-5], some upgrades were carried out to the non-plasma facing side of the plate. This includes brazing stainless steel (SS) cooling pipes into the TZM plate channels to avoid vacuum leaks in the cooling channels, connecting the distributor and Mo plate by three SS clips to eliminate reactions between the liquid Li and braze materials that were used for connection in the previous design (Cu and Ag), and designing a robust support to replace the original screw rods for obtaining an angled limiter plate inclined at ~15˚ to ensure the interaction between plasma and limiter occurs at the middle of limiter plate.

Based on these engineering upgrades, it was indeed found the main plasma interaction zone occurred in the middle of LiMIT plate located along the He cooling channels on the plate back side, and the limiter structure had no obvious visible damage viewed via CCD, IR cameras and EUV heavy impurity diagnostics during liquid Li operation. It is estimated from the videos that liquid Li covered ~70% of the Mo trench surface with flow along the vertical TZM trenches with about 0.5 mm depth ×2 mm width, which was clearly observed by a CCD camera. Furthermore, another experiment proved that a liquid Li limiter could be reused (e.g. flow was re-started) after sitting idle for about 20 hours, which is key to liquid Li application in future device. A 0-3 MPa He cooling pressure/rate scan was performed with liquid Li operation. With 3 MPa He cooling, there was an obvious lower temperature distribution in the center of the plate measured by the IR camera and thermocouples, and reduced Li efflux from the liquid Li limiter. Evidence includes a decrease in the Li line emission compared to what was observed without He cooling. In terms of the physics, the liquid Li could access H-mode in an upper single-null configuration with ion grad-B drift away from the active divertor, reduce the L-H transition threshold power and gradually increase H mode duration (P_{RF}~ 3.4 MW). By changing the toroidal magnetic field to make the ion grad-B drift toward the lower divertor, plasma confinement was significantly improved with liquid Li operation. ELM mitigation was observed, accompanied by enhanced edge coherent MHD mode (ECM) and an edge harmonic mode, which was similar with boron powder and impurity gas injection in EAST. With low magnetic field (Bt~1.9 T) and q_{95} ~ 4.2, by using liquid Li, large ELMs were effectively mitigated, i.e. increased ELM frequency and a decreased ELM size.

References

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