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Progress on Long-pulse Steady-state High Performance Plasmas on EAST

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Significant progress has been achieved on EAST in the development of long-pulse steady-state advanced plasmas, and in the understanding of the related scientific and technical issues in support of ITER and future fusion reactors.

A thousand-second time scale (˜1056s) fully non-inductive plasma has been achieved on EAST at the end of 2021 with poloidal beta ˜1.5, a normalized confinement factor H89 ˜1.3 at DN configuration with full metal wall using an actively cooled ITER-like tungsten divertor. The total injected energy into the plasma is ˜1.73 GJ with Radio Frequency (RF) power. Key technical and scientific challenges have been addressed for steady-state operation. A robust plasma control is demonstrated to keep the equilibrium with good accuracy overcoming the challenge of drift in magnetic measurements over long pulses. An improved loop voltage control is key to sustain fully non-inductive CD. Meanwhile, new lower divertor can significantly mitigate the power exhaust challenge, enabling the handling of large divertor heat fluxes, up to 10 MWm-2, preventing impurities (particularly tungsten from the divertor) from contaminating and cooling down the plasma core, and maintaining good particle exhaust to ensure that the plasma density does not rise in an uncontrolled way. Taking advantage of synergistic effects has enabled fully non-inductive operation with RF driven current fraction fRFCD˜70% and bootstrap current fraction fBS˜30%: electron heating using on-axis Electron Cyclotron Heating (ECH) enhances the heating and current drive from Lower Hybrid Wave (LHW). A self-regulated system resulting from multiscale interaction between core MHD instabilities and electron temperature gradient (ETG) induced turbulence also contributes to the sustainment of the long pulse steady-state regime.

In support of steady-state high-performance operation for future fusion reactors, a long-pulse fully non-inductive regime with higher bootstrap current fraction and higher fusion performance is further explored in 2022. Recently, with the improved flexibility and capabilities, a duration of 310s H-mode plasma (H98y2>1.3, ne/nGW>0.6, fBS>50%) has been demonstrated at high density with zero torque on EAST. Higher density and poloidal beta increase the bootstrap current fraction and self-consistently broaden the current density profile, leading to a further increase in confinement. The key physics processes (e.g. RF synergy, confinement, transport, particle and heat exhaust etc.) of this steady-state regime will be illustrated. Extension of fusion performance with enhanced capabilities on EAST can offer unique contributions towards the successful operation of ITER.

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