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Physics assessments on the requirement of heating, current drive and rotation drive to sustain CFETR steady-state scenarios

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The Chinese Fusion Engineering Testing Reactor (CFETR) is the next device in the roadmap for the realization of fusion energy in China [1, 2]. In the past two years several steady-state scenarios for China Fusion Engineering Test Reactor (CFETR) have been developed by integrated modeling for core plasma [3, 4]. Based on the self-consistent equilibrium and profiles in these scenarios physics assessment on the requirement of heating and current drive (CD) by neutral beam (NB) and RF are performed in this work.

In the NBCD dominated scenario with good confinement the equilibrium calls for far off-axis current drive to help sustain reversed magnetic shear and thus reduce the demand of high energy NB. Confinement enhancement by low energy neutral beam rotation drive has been demonstrated in previous integrated modeling [5]. The assessment of this power requirement is also performed to reduce the risk due to fixed rotation profile for the high performance scenario.

In the RFCD dominated steady-state scenario strong reversed magnetic shear at large radius produces internal transport barrier (ITB) in electron energy channel at rho~0.5 [see Figure 1(a)]. The ITB prevents the high-harmonic fast wave (HHFW) penetrating through the ITB [see Figure 1(b)], while the flat temperature and density profiles outside the ITB make lower hybrid wave being able to drive current at rho~0.7 where large-radius ITB could be produced like that demonstrated in DIII-D experiments with off-axis NBCD [6]. Optimization of electron cyclotron wave (ECW) for current drive and localized electron heating are performed to demonstrate the potential on control of safety factor profile and electron temperature profiles. Since the penetration of RF waves depends on the profiles and equilibrium sensitively, the compatibility of the optimized RFCD method with the evolving profiles before the steady state is being checked by integrated modeling.

These simulations with 2D modeling provide more consistent information about auxiliary heating and current drive, which are being used to update of 0D system code and reduce the risk on design of both scenarios and heating and current drive systems.

References

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Figure 1. (a) Temperature profiles by integrated modeling for the steady state scenario sustained by HHFW and ECW. (b) Current profiles driven by different methods while the equilibrium and kinetic profiles are from HHFW and ECW sustained by HHFW and ECW. LHCD and FWCD are almost determined by the kinetic profiles.