Operation of HL-2A Tokamak

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***Abstract*—The operation conditions have been improved via developing new technologies and improving the hardware on HL-2A tokamak in recent years. The ECRH system has been upgraded to 3 MW/68 GHz, the supersonic molecular beam injection (SMBI) fuelling technique has been developed further, and clusters can be formed in the SMB by cooling the gas to around liquid nitrogen temperature, so that deeper penetration can be achieved. Moreover, there are about 30 kinds of diagnostics developed on HL-2A to measure the plasma parameters. These diagnostic systems include magnetics, microwave reflectometry, charge exchange recombination spectroscopy, Thomson scattering, FIR interferometer. Some of them were specially designed for the physics experiments. For example, a novel design of Langmuir probes was developed to study the 3-D structure of zonal flows. With these hardware development and improvement, new experimental results have been achieved in the fields of turbulence, transport, MHD instabilities, and energetic particle dynamics. In particular, the edge localized mode (ELM)y H-mode has been achieved by combining the auxiliary heating of NBI and ECRH, SMBI is beneficial for the L-H transition and the H-mode operation on HL-2A, and suitable for studying particle transport and controlling the ELMs during H-mode discharges due to its deep and local injection features and good controllability. In addition, the 3-D spectral structures of the low-frequency zonal flow and quasi-mode, which were predicted by theory and simulation, have been observed simultaneously. The beta-induced Alfvén eigenmodes (BAEs), excited by large magnetic islands (m-BAE) and by energetic electrons (e-BAE), are investigated, these phenomena are under further study.**

***Index Terms*—electron cyclotron resonance heating (ECRH), ELM mitigation, HL-2A tokamak, H-mode, lower hybrid current drive (LHCD), neutral beam injector (NBI), pellet injection (PI), supersonic molecular beam injection (SMBI), wall conditioning.**

supply system [3]–[5] is equipped with two identical 90 MVA flywheel motor generator (MG) sets and one 125 MVA MG set. The former provides power for 16 D-shaped toroidal field (TF) coils to obtain the toroidal magnetic field $Bt = 2.8$ T with a flat-top of $3 \sim 5$ s, the latter provides power for 52 poloidal field coils and auxiliary heating systems. The waveform of the current through the TF coils is controlled by adjusting the exciting current of the two generators. Since the first plasma on HL-2A in 2002, there have been more than 30 kinds of diagnostics developed on HL-2A to measure the plasma parameters, or to perform special physics experiments. The electron density profile is measured by an 8-channel hydrogen cyanide laser interferometer [6], a reciprocating probe system [7] and O-mode reflectometer [8]. Electron temperature profile can be measured by Thomson scattering diagnostic [9], fast electron cyclotron emission (ECE) radiometer [10] and energy spectrum analyzer of soft X-rays [11]. Ion temperature is given by the charge exchange recombination spectroscopy [12] and multichannel energy spectrum of neutral particles. Plasma radiation can be measured by four bolometer arrays, five soft X-ray arrays, hard X-rays, vacuum ultraviolet spectrometer [13], visible spectrometer, and so on. The electron temperature and density profiles at divertor target plates are given by seven fixed Langmuir probe arrays, and the temperature of outer target plate is monitored by an FIR camera. Various fuelling techniques (extruded pellet injector with 40 pellets per discharge, normal gas puffing (GP), supersonic molecular beam injection—SMBI) and heating systems (NBI of 1.0 MW/45 keV, ECRH/ECCD of 3.0 MW/68 GHz, LHCD of 1.0 MW/2.45 GHz), are developed