Current Initiation and Sustainment in Spherical Tokamaks*

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Current initiation, ramp-up and sustainment are key issues for low aspect ratio Spherical Tokamaks (ST). A reliable, totally noninductive system to supply the plasma current would enable a ST option devoid of a central solenoid, allowing more space in the inboard side for toroidal field generation or neutron shielding. This would increase the ultimate performance of the machine as a fusion reactor. In this work we examine the physics and feasibility of achieving totally noninductive operation. Plasma current ramp-up is achieved using bootstrap current overdrive. This requires starting with a low plasma current and high β_P together with density control to maximize the boostrap current relative to the total current. The efficiency depends on which particle species is being heated and the resistive diffusion time. Both electron cyclotron heating and ion-ion hybrid mode-conversion are plausible schemes for heating electrons at low temperatures. Also, the stability of the plasma to MHD modes during the dynamic evolution has to be maintained. It is shown that current exceeding 1 MA can be attained with a rate of approximately 0.5 MA/s. Although most of the current at steady-state can come from the bootstrap current, some external current drive is required for profile control. High harmonic fast waves are absorbed off-axis because of the high beta of ST's, and should be considered only for off-axis current drive, whereas the low frequency fast waves (below ion cyclotron frequency) can penetrate with a centrally peaked absorption profile and can be considered for central current drive. Based on these findings, transformless operation for ST's appears promising.

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