Plasma Current Ramp-up in a D-^{3}He ST Reactor

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In a high temperature deuterium and helium 3 fuel tokamak reactor, the non-inductive plasma current ramp-up without central solenoid needs a very long time due to a large resistive decay time. On the other hand, a plasma current ramp-up could be achieved in a shorter time by the heating power and the vertical field and it might be suitable to a high temperature and high beta D-^{3}He tokamak reactor with a large plasma current. Recent progress of experimental and numerical studies on the plasma current ramp-up by the heating power and vertical field in various tokamaks without central solenoid, such as JT-60U, MAST and NSTX, encourages the further study on the current ramp-up in a D-^{3}He spherical tokamak reactor.

Initially, we survey the parameter regime for ignition in a proposed D-^{3}He ST reactor using the zero-dimensional power and particle equations assuming the time constant plasma current of $I_p > 58$ MA. Machine parameters are assumed to be the major radius of R = 5.6 m, the minor radius a = 3.4 m, the aspect ratio A = 1.65, the toroidal field $B_t = 4.8$ T and the elongation of $\kappa = 3$. Ignition is possible for the confinement enhancement factor γ_{HH}>2.0~2.5 over IPB98(y,2) scaling, fuel ratio of $n_D : n_{He3} = 2 : 1$, the external heating power of 300 MW, parabolic density and temperature profiles with $T_i(0) \sim 114$ keV, $n(0) \sim 2.5 \times 10^{20}$ m^{-3} and $\tau_E \sim 7$ sec.

Based on above study, we have explored the plasma current ramp-up scenario by the heating power and the vertical field. With application of 300 MW heating power and good confinement factor of $\gamma_{HH} = 2.5$, the plasma temperature is initially increased to ~ 100 keV and the plasma current is ramped up to ~ 50 MA. After switching off the heating power in the ignition phase, the plasma current is further ramped up to 80 ~ 100 MA in 250 sec with the fusion power of 3 GW without any non-inductive means. This large plasma current may provide the wide operation regime, such as larger ^{3}He density than deuterium density to decrease the neutron wall loading and allow flatter density profile, etc.