Modelling of Merging-Compression Formation of High Temperature Tokamak Plasmas
A. Nicolai, M. Gryaznevich
Tokamak Energy Ltd., 173 Brook Drive, Milton Park, Abingdon, OX14 4SD, UK

The merging-compression formation method is used in spherical tokamaks (STs) to produce high temperature plasmas without using flux from a central solenoid. Plasma rings are formed around two in-vessel poloidal field coils (MC-coils) and merged via magnetic reconnection into one plasma ring. The ring is then radially compressed to form the ST configuration.

This method is used to form plasma in a small tokamak ST40 (design parameters: \(R/a=0.4/0.25\) m, \(B_t=3\) T, \(I_{pl}=2\) MA pulse duration 1-2 sec, \(P_{aux}\) up to 4MW) and \(I_{pl} \approx 400\) kA and \(T_i \approx 1-2\) keV have been recently achieved without use of auxiliary heating or central solenoid /1/. The modelling of merging-compression in ST40 has following aims:

1. To determine the deposition profile \(D(r)\) of the ions accelerated to Alfvén speed during magnetic reconnection by means of the fast particle code NFREYA.
2. To calculate the ion temperature after the reconnection heating and compression.
3. To estimate the electron ohmic heating power, Ampère’s law is applied to the current sheet formed at the X-point of the reconnecting rings.

The TSC describes the plasma behaviour using \(D(r)\) for ions and ohmic heating for electrons.

The following results have been obtained:

1. Assuming flux conservation in TSC simulations, the ramp-down of the current in MC-coils from \(I_{MC} \approx 600\) kA to zero produces plasma current of \(\sim 1\) MA. After acceleration of ions to the Alfvén speed in the electric field produced by the reconnection, the corresponding Alfvén energy of fast ions is \(\sim 10\) keV. In ST40, lower values of the plasma current of 400 kA have been obtained using swing of current in MC coils \(\sim 450\) kA. The overestimation of the induced plasma current in simulations is due to the presence of losses of the poloidal flux in passive structures of the tokamak, not accounted for in TSC simulations.
2. Since the reconnected ions are released in the vicinity of the X-point and run in co-direction /2/ with a small spread (\(\sim 10\) degrees) in pitch angle, the deposition profile is peaked at the plasma boundary and was found to have a width of \(\sim 5\) cm.
3. Assuming in TSC a reconnection heating power of 20 MW with the deposition \(D(r)\), a temperature of \(T_i \sim 1\) keV was obtained in a rough agreement with the ST40 findings /1/.
4. Using Spitzer resistivity (which underestimates the heating), the central electron heating power is around 0.5MW. With the central deposition, \(T_e \sim 600\) eV was obtained in simulations.