Single-helicity states in compressible magnetohydrodynamics simulations of the reversed-field pinch with anisotropic thermal conductivity

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The reversed-field pinch (RFP) is a toroidal machine for the confinement of plasma, where the magnetic field is mainly generated by currents flowing in the plasma. The possibility of realizing the RFP configuration in the SH state, where the dynamo effect is provided by the growth of a single unstable mode, is important for plasma confinement because it results in well conserved magnetic surfaces, which ensure better confinement properties with respect to multiple-helicity states. RFP experiments have shown a clear tendency of the plasma towards a single-helicity states for increasing plasma currents [1]. We present compressible magnetohydrodynamics (MHD) simulations of the reversed-field pinch, including anisotropic thermal conductivity. In a fusion plasma, the thermal conductivity in the direction parallel to the magnetic field is much larger than in the perpendicular direction, so that magnetic field lines tend to become almost isothermal. We developed a multiple-time-scale method to solve the MHD equations with a large parallel thermal conductivity [2]. The system shows the formation of both multiple helicity and quasi-single helicity states. Single helical axis (SHAx) states are also observed in the simulations. We find a relation between temperature distribution and magnetic field topology similar to the experimental results, with larger temperature gradients in quasi-single-helicity states. We find that when the resistivity has a radial profile sharply increasing close to the wall single-helicity states are formed. On the contrary, a uniform resistivity produces multiple-helicity states. A radially increasing resistivity profile is determined in RFP experiments by the temperature difference between the plasma core and the wall. The results of our simulations are an indication that quasi-single helicity states observed in experiments with high toroidal currents may be a consequence of the resistivity profile determined by the high temperature reached in the plasma core in high-current discharges.