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Anomalous plasma transports during the ohmic breakdown in a tokamak

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An ohmic breakdown, as a kind of the electrical breakdown, is widely used to produce the plasmas from the neutral gases in a tokamak. The toroidal electric fields are induced by the time-varying currents of the central solenoids to accelerate the seed electrons in the tokamak along the magnetic field lines. The heated electrons ionize the neutral gas molecules successively which result in an electron avalanche. At the same time, the stray magnetic fields in the RZ plane are produced by the central solenoids and the eddy currents in the vessel wall, so that the magnetic field lines are open to the vessel wall segments. Since the electron avalanches tend to propagate along the magnetic field lines, long connection lengths of the open magnetic field lines are required to achieve a large number of ionizations. For that purpose, the stray magnetic fields are canceled out by the poloidal field coils with appropriate current wave forms. As a result, time-varying complex electromagnetic structures are produced in the device during the ohmic breakdown [1].

The physical mechanism of the ohmic breakdown in the complicated situation is not clearly revealed due to the topological complexity and a lack of observations of the cold rarefied initial plasmas. Previous works adopted the simple Townsend avalanche theory [2] by assuming that the plasma responses are negligible during the ohmic breakdown. Based on the Townsend theory, various external field estimation methods, such as empirical conditions [3] and field-line-following analysis [4], were proposed to expect breakdown condition qualitatively. However, it was reported experimentally 30 years ago that the strong self-electric fields could be produced by the space charges in the plasma as the plasma response [5]. In spite of the experimental evidence, the self-electric fields have been paid very little attention so far and their importance and roles has been shrouded in mystery.

To understand the physical mechanism of the ohmic breakdown considering the plasma response, we have focused on the fundamental plasma physics in the presence of the open-field magnetic fields and external toroidal electric fields. As a result, we found that the self-electric fields play crucial roles in the ohmic breakdown above a critical plasma density. For the parallel dynamics to the magnetic fields, the self-electric fields cancel out the external electric fields which results in a loss of heating power and then a significant reduction of the plasma growth rate. For the perpendicular dynamics, turbulent ExB vortices are produced by the strong self-electric fields which result in dominant anomalous transports along and across the vertical magnetic fields. We address the unique characteristics of the ExB transport mechanism in the ohmic breakdown which are very different from the other open magnetic fields system such as ECH pre-ionized plasma with vertical magnetic fields [6] and the blob in the SOL [7]. In addition, the roles of the field-null region near the X-point and secondary electrons from the wall are newly revealed. The detail ohmic breakdown physics including plasma response are well captured by the particle simulation. The particle simulation also well reproduce the mysterious experimental results in KSTAR which have not been understood before.

References

[1] Y. Gribov, D., *et al.*, "Plasma operation and control" Nuclear Fusion, vol. 47, p. S385, 2007.
[2] J. Townsend, "Electricity in Gases, Clarendon," ed: Oxford, 1915.
[3] A. Tanga, *et al.*, "Tokamak start-up" vol. 159, ed: New York: Plenum, 1986.
[4] E. Lazarus, *et al.*, "Using a multipole expansion for startup in the DIII-D tokamak," Nuclear fusion, vol. 38, p. 1083, 1998.
[5] M. Valovič, "Convective losses during current initiation in tokamaks," Nuclear fusion, vol. 27, p. 599, 1987.
[6] S. H. Muller, et al., "Effects of a vertical magnetic field on particle confinement in a magnetized plasma torus," Phys Rev Lett, vol. 93, p. 165003, Oct 15 2004.
[7] S. I. Krasheninnikov, "On scrape off layer plasma transport," Physics Letters A, vol. 283, pp. 368-370, May 21 2001.