Recent progress on the equilibrium and stability properties of NT tokamaks

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There is continuing interest in investigating negative triangularity (NT) tokamaks. Here, we report the results of two investigations: first, we examine the effects of rotation on the MHD stability in NT; Second, we examine the effects of X point position on the equilibrium, stability, and transport in NT scenario in comparison with the positive triangularity (PT) case.

For the MHD stability analyses, we use the AEGIS and DCON stability codes to investigate the DIIID-like equilibria constructed by EFIT, VMEC, etc.We found that, although NT configurations may be more unstable for low-n modes than the PT case, for intermediate-n modes the situation is reversed. The NT configuration becomes more stable for intermediate n modes (n = 3-10) [1]. This is consistent with the experimental observation that shows the NT configuration usually has a lower turbulence transport level [2].

We then extend the studies to include the effects of rotation to see how the resistive wall modes in the NT configuration are affected as compared with the PT configuration. This is particularly motivated by noting that the wall interface with the plasma is quite different between the NT and PT configurations. The geometrical differences condition the effects of plasma rotation on the low n modes. We find that, although low-n ideal MHD modes are more unstable in the NT case, the rotation stabilization of the resistive wall modes is more effective in the NT case than in the PT case [3].

We also study the X point effects on equilibrium, stability, and transport in the NT scenario as compared with the PT one. We note that the positions of X points are quite different between the NT and PT cases. The X points locate in the high field side in the PT case, while in the low field side for the NT case. With the analytical Solovev solutions we are able to show that the NT configuration always gives lower safety factor value than the PT case [4] even without taking into account the bootstrap current, which has been pointed out to drive the q value even lower in the NT case due to larger trapped particle population [5]. We also examine the local q distribution along the magnetic field line. We found that the high local q region accumulates near the X point in the NT case, while being broader in the PT case. This leads us to examine further how these features affect the equilibrium, stability, and transport.

In the equilibrium, we previously obtained the asymptotic solution of vacuum field at the X point tip with a conformal transformation [6]. We find that, while there is no solution for an equilibrium with an X point on the plasma-vacuum interface, the hyperbolic plasma-vacuum boundary does give the solution with the new X point in the vacuum. This indicates that one has to chip off a thin layer in order for an MHD equilibrium with X points to exist. Due to the difference in the accumulation of high q value along the magnetic field between the NT and PT cases, chipping off a thin layer can cause a large difference of edge q value between the NT and PT cases. The difference consequently affects the edge stability and transport.

In the stability study, we developed the coordinate system with dual-regional q values. This is shown to be more suitable to study the system with X points. It extracts the extreme high local q region at the vicinity of the X points from the global MHD stability studies. In view of the non-existence of an equilibria with X points on plasma edge, we then are able to investigate the edge chipping off effects on the peeling/ballooning modes in both NT and PT scenario.

In the transport studies, we have shown that with the X points sitting in the low field side, the NT configuration turns out to be less effective in confining the trapped particles at plasma edge as compared to the PT case [7]. We will further study the edge chipping-off effects on the transport to see how deep the confinement of trapped particles is affected. The aspect ratio and elongation effects will also be discussed.

References

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