First-order shift formula of stable and unstable manifolds under perturbation and its application in magnetic confinement fusion

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In the established theory [1, 2] of the global structure of three-dimensional (3D) magnetic fields, we had derived *the first-order shift formula of X/O-cycles under perturbation* ($\delta\mathscr{B}$), based on which we further deduce *the first-order shift formula of stable and unstable manifolds under perturbation*. These two formulae provide a new perspective for controlling the shape of magnetically confined plasma by applying them to the vacuum magnetic fields induced by various magnetic coils. Moreover, it is feasible to control the width of chaotic layers at the plasma edge and island chains. Of particular importance among all the "perturbing" fields, the time derivative of a realistic field, $\partial\mathscr{B}/\partial t$, can be considered a peculiar one in the formulae (*i.e.*, substituted for the perturbing field $\delta\mathscr{B}$), which yields the shift velocities of X/O cycles, stable and unstable manifolds. It should be noted the perturbation field $\delta\mathscr{B}$ does not need to be axisymmetric and the field to be perturbed does not need to be divergence-free.

For a typical divertor configuration, the connection lengths of magnetic field lines in the scrape-off layer (SOL) are greatly influenced by the Jacobian matrix eigenvalues of the Poincaré map of the outmost X-cycle(s). The Jacobian matrix is denoted by DP^m for a cycle of m toroidal turns, where P denotes the Poincaré map of one toroidal turn. Adjusting the eigenvalues of DP^m of the X-cycle(s) to be close to unity can significantly increase the connection lengths in the SOL. The first-order change of DP^m under perturbation is revealed by a formula deduced in the same manner as that of X/O-cycles and (un)stable manifolds. It is expected that pushing the two eigenvalues of DP^m towards unity will facilitate the achievement of edge plasma detachment due to the resulting increase in radiation loss from the longer connection lengths.

References

[1] Wenyin Wei and Yunfeng Liang, "The chaotic nature of three-dimensional magnetic topology revealed by transversely intersecting invariant manifolds", Poster presented at EPS48 (online), 2022, Poster P5b.110.

[2] Wenyin Wei and Yunfeng Liang, *Invariant manifold growth formula in cylindrical coordinates and its application for magnetically confined fusion*, Preprint CSTR:32003.36 (2022) available at ChinaXiv:202211.00236.