Collisional transport of heavy impurities with flux-surface density variation in stellarators

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Due to their ability to cause intolerable radiation losses, heavy impurities cannot be allowed in the core of a magnetic fusion reactor. In addition, heavy impurities can have observable density variations on flux-surfaces due to their sensitivity to any flux-surface variations in electrostatic potential. Such density variations have been analytically shown to significantly affect the collisional impurity transport in tokamaks [1, 2], while their importance in stellarators have mainly been investigated numerically [3].

We have included impurity density flux-surface variations in an analytic calculation for a stellarator in the mixed-collisionality regime, building on recent analytical results in stellarator impurity transport [4, 5] – and have thus generalized the calculation in Ref. [2] to stellarator geometry. Specifically, we have derived an expression for the radial transport of a heavy impurity, using a mass-ratio expanded ion-impurity collision operator. In contrast to both the general tokamak case, and the stellarator case with flux-function impurity density, the neoclassical flux includes an *electrostatic flux* term [6], which must be retained.

We have found the neoclassical transport to be sensitive to the distribution of impurities over the flux-surface in simple test cases with a W7-X vacuum field – even changing sign compared to the homogeneous case when the impurity density becomes sufficiently localized around extrema in the magnetic field strength. Interestingly, for these test cases, this effect on the neoclassical transport is overshadowed by classical transport, which appears to be the dominant collisional transport mechanism for a collisional species in W7-X. Work is currently being carried out to investigate in which scenarios classical transport is relevant.

References

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