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Modeling and Experimental Validation of Physics Enabled by W7-X Scraper Element Divertor Components

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A set of add-on components referred to as Scraper Elements (SE) were designed as a passive solution to a predicted heat flux overload of certain areas of the main Wendelstein 7-X (W7-X) stellarator divertor during long-pulse operation. W7-X will soon begin its first phase of operation using the first set of plasma facing components (PFCs) and a magnetic topology to realize an island divertor configuration (OP1.2). In an island divertor the core plasma is surrounded by an island chain with a helicity determined by the edge value of the rotational transform. The island chain is intersected by the PFCs, leading to heat and particle fluxes that typically manifest as a set of stripes with neutral baffling to guide recycled particles into pumping volumes. One challenge associated with stellarator island divertor configurations is to keep the edge rotational transform constant to maintain the desired topology. A net toroidal current evolving during a discharge will modify this transform unless it is opposed using applied driven current (e.g., ECCD) or by changing the toroidal field to maintain a fixed value. This issue is mitigated in W7-X as one of the optimization goals targeted during the design process was a low bootstrap current. However, this property is persistent only in certain configurations. In some long-pulse configurations of interest the steady-state toroidal current is predicted to be sufficient to modify the edge transform by ~10%. Such a current and thus boundary topology evolution, without mitigation, would sweep heat flux across regions of the divertor with a reduced rating, resulting in transient overload before the island divertor configuration is restored in steady-state.
We designed the SE as a passive solution to this problem. In the long-pulse, high-power operational phase (OP2) ten SE, one for each divertor unit, would be installed to intercept heat flux to the overloaded areas during the transient phase while receiving a load less than its 20 MW/m2 rating. Due to geometric limitations on the design, the SE continue to receive loading during the steady-state configuration, possibly leading to deleterious effects on pumping of neutral particles and impurity influx into the core plasma. To test both the positive and negative impacts, two inertially cooled SE will be installed in the middle of the OP1.2 campaign. Experiments both before and after the installation of SE will be used to determine if the predicted overload will exist, whether the SE protects the affected areas, and to assess any side effects associated with the SE. Special configurations will be used to mimic the effect of the OP2 configuration evolution, which is not directly accessible in OP1.2. The modeling associated with the design will be presented, along with the plans for validation using the W7-X diagnostic set. Details of the inertially cooled SE design and the finite element modeling performed to determine power and pulse length limitations will also be shown. Support from D.O.E. contracts DE-AC05-00OR22725, DE-AC52–06NA25396, DE-AC02-09CH11466.

Eligible for student paper award?

No

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