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Optimization of the large-area RF negative ion source for long-pulse and high-power operation on CRAFT NNBI test facility

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To explore the key technology of negative-ion-based neutral beam injection (NNBI), a NNBI test facility is under construction in the frameworks of the Comprehensive Research Facility for Fusion Technology (CRAFT). During the second experimental campaign of the CRAFT NNBI test facility, the 100 seconds and megawatt-class negative hydrogen beams have been repeatably achieved via a dual-driver RF negative ion source. The parameters of the best long-pulse shot were 135 keV, 10.6 A (~ 180 A/m2), 110 s. When pursuing a long-pulse shot with higher power (>2 MW), the leading-edge element of the neutralizer was damaged and lead to serious water leaking. In addition, during the disassembly and maintenance, some obvious heating erosions were found on the supporting frame of ground grid electrode. Hence, a multi-physics coupling model has been upgraded to study the acceleration of negative ions within the full-size extraction system, including the particle-gas and particle-solid interaction. The simulation results showed that, the over-focusing of multi-beamlet was the main reason of the damage on the downstream neutralizer, and the erosions on the supporting frame without cooling were consistent with the hot spots induced by the stray secondary electrons. Accordingly, the optimizations on the field shaping plate and the electron deflection magnetic field were proposed and estimated, which will be tested in the following experimental campaign.

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