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New Compact Torus Injection System on KTX reversed field pinch device

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The compact torus (CT) plasma is a self-organized plasmoid used for fuelling and providing external helicity and momentum. Recent research has shown that central fuelling greatly improves the tritium breeding ratio, which is a key parameter in tritium fusion devices [1]. As the most promising fuelling solution for future fusion devices, such as ITER and CFETR, CT plasma can achieve an ultra-high velocity of over 100 km/s to penetrate a strong magnetic field with magnetic reconnection processes to realize central fuelling. The main requirement for CT penetration is governed by the empirical condition: $\frac{1}{2}\rho_{ct}\nu_{ct}^2 > B^2/2\mu_0$, which the physical image shows the initial directional kinetic energy density of CT plasma must be higher than the magnetic energy density at the penetration position [2].
A new compact torus injector (KTX-CTI) has been developed on Keda Torus eXperiment (KTX) [3], which is a medium size reversed field pinch (RFP) device. The three-meter long coaxial injector, shown in Fig. 1(http://staff.ustc.edu.cn/~lantao/Fig.1.jpg), is designed to inject CT plasmoid into KTX. In the engineering commissioning, the maximum injection mass of CT is over 50 μg for hydrogen, which is about 30% of the KTX plasma particle inventory, and the electron density of CT can reach 10^{22} m^{-3}. The CT plasma can be accelerated to a directional speed higher than 100 $\mathrm{km/s}$ though strong $\mathbf{J} \times \mathbf{B}$ force. At the same time, KTX-CTI is equipped with various in-situ and compact diagnostics for the operation and physics research such as optical fiber interferometer, spectrometer, Rogowski coil, magnetic field probe and Langmuir probe array.
After the commissioning, KTX-CTI is installed to KTX in the middle plane. Since the maximum toroidal magnetic field of KTX is about 0.2 T, a CT plasmoid with electron density greater than 3×10^{21} m^{-3} and a velocity above 80 $\mathrm{km/s}$ can easily reach the central region of KTX. The penetration position will be directly viewed from the Hα array in the top diagnostic port of KTX. The injection angle can be adjusted from 0° to 25° with respect to the major radius direction at the CT entry location in the middle plane shown in Fig.2 (http://staff.ustc.edu.cn/~lantao/Fig.2.jpg). When the injection angle is set to a none-zero angle, the CT will introduce a net tangential momentum, and it is possible to induce and sustain toroidal rotation of the KTX plasma due to external momentum transfer from the CT to KTX plasma bulk. In addition, a small amount of helicity carried by rolling CT can also be introduced to KTX plasma.
It is the first time that the CT plasma is injected into a RFP device, and it is significant to study the interaction between CT and RFP, especially the impact of CT on RFP confinement. Just as the confinement was improved through CT injection in the tokamak experiments [4,5], it is expected to be successful in the confinement research of RFP, especially in the single helicity mode (SH) research. In advance, KTX-CTI will become a pre-research platform to test the high-frequency and long-distance injection, including the injector machine and power supply, for future fusion device such as ITER and CFETR.
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