Experimental investigation of toroidal eddy currents and poloidal halo currents during disruptions in the KSTAR tokamak

Jun Gyo Bak, Heung Su Kim, Sang Hee Hahn, Jay Hyun Kim, Jeong Won Lee, Hyun Sun Han, Eun Nam Bang and KSTAR team

Korea Institute of Fusion Energy (KFE), Daejeon, Korea

In the KSTAR tokamak, the toroidal eddy current (EC) was induced on the in-vessel conducting structures (IVCSs) used for the plasma facing component (PFC) during a plasma disruption, and the poloidal halo current (HC) also flowed through the supporting structures for the divertor as one of the IVCSs between plasma and the wall of the vacuum vessel during a vertical displacement event (VDE) eventually causing the disruption. The toroidal EC was directly measured by magnetic sensors (called as RCPPU/L) at the gap resistor between two adjacent sectors for the passive stabilizer (PS), and could be also evaluated by subtracting the discrete Rogowski coil (RC) measurement at the PFC from the RC measurement at the wall [1,2]. The poloidal HC, outgoing from the plasma to the wall and then incoming to plasma through the support structures during the VDE, was directly detected by magnetic sensors (called as HCMs) at the supporting structures for the PFCs and was also assessed by the divertor Langmuir probes (DLPs) in the lower divertor region during the downward VDE [3]. In addition, two coaxial poloidal loops at the wall for originally measuring the diamagnetic flux were utilized for estimating the toroidal magnetic flux due to the poloidal HC. Fig. 1 shows these sensors for investigating the toroidal EC and poloidal HC.

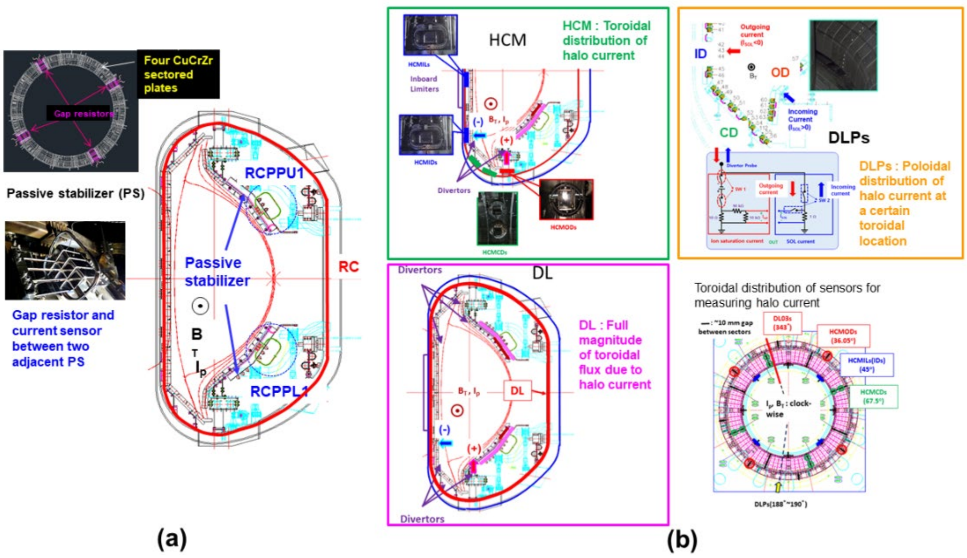

Fig. 1. Sensors for measuring and evaluating (a) toroidal EC and (b) poloidal HC.

Recently, the graphite tiles used for the PFCs in the lower divertors were upgraded to the tungsten mono-blocks (see Fig. 2(a)) for the purpose of being sustainable for the expected high heat flux (up to 10 MWm^2) in the divertor target region during a long pulse operation. The effective cross-sectional area of the new lower divertor was calculated as ~15 % of the area in the previous divertor. Thus, the characteristics of the toroidal EC and poloidal HC in disrupted plasmas due to the VDEs under the new tungsten environment were investigated in order to survey how much the two currents were affected by the new environment with the tungsten divertors at the lower side. The increase in the toroidal resistance of the new lower divertor was expected from the reduction of its cross-sectional area after its PFC was upgraded from the graphite tiles to the tungsten mono-blocks, which was confirmed by comparing the predictive simulation using the circuit model with the RC measurement during the blip without gas-puff for the graphite and tungsten divertors. The magnitude of the toroidal current from the RC measurement for the tungsten divertor is reduced to about 74 % of the value for the graphite divertor as shown in Fig. 2(b)

Fig. 2. (a) Photos and drawings showing the PFCs inside the vacuum vessel in the KSTAR tokamak before and after the lower divertor is upgraded, and (b) validation of the circuit model with vacuum experiments for the graphite and tungsten divertors.

The most probable value of the vertical growth rate $(\gamma_{Zj})_{MPV}$ became faster (from 102 s^{-1} to 136 s^{-1}) for the selected downward VDE shots during the experimental campaign after the graphite tiles were exchanged with the tungsten mono-blocks as the PFC in the lower divertor, while there was no clear change in the value of $(\gamma_{Zj})_{MPV}$ for the selected upward VDE shots during the two experimental campaigns before and after the lower divertor was upgraded with the tungsten mono-blocks (see Fig. 3). Firstly, it was found that the decay time of the toroidal EC measured at the lower PS in the downward VDE becomes faster (from 12.6 ms to 4.5 ms) under new tungsten environment, which can be validated from the comparison between two