Development of Digital Twin Technologies for Fusion Research

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Recent progresses in the development of Virtual KSTAR (V-KSTAR) are reported [1]. As an attempt to apply the digital twin technologies for fusion research, the V-KSTAR development is focused on the integration of fusion simulation into the virtualized KSTAR main device based on the fast graphic engines such as Unity and Unreal. For the systematic processing of various data, which are generated either from KSTAR experiment or simulation, a new data framework is developed based on ITER-IMAS and HDF5 technologies. Currently, V-KSTAR is being developed for two primary goals. The first goal is to provide a 3D virtual platform to monitor the status of machine operations along with plasma experimental results, from which researchers can more intuitively understand and analyze key machine status e.g. 3D distribution of the first wall temperatures, proximity of superconductors to quench etc. Figure 1 shows the real time monitoring system implemented by utilizing aforementioned technologies. As shown in the figure, EFIT reconstructed equilibrium magnetic fields can be visualized with the first wall tiles which have thermocouples indicated by blue color.

The second goal is to provide a comprehensive platform for fusion simulations. The digital twin technologies combined with conventional simulation technologies enable efficient detection and recording of the interactions of complex 3D data. Based upon these, three simulations are integrated into the V-KSTAR platform: 1) Monte-Carlo NBI simulation, 2) ECH ray tracing simulation, and 3) RMP magnetic field perturbation simulation. In Figure 2, a snapshot of the NBI particle trajectories are visualized with their loss patterns on the first walls.

In the presentation, we will present the details how these new developments are applied for KSTAR machine operation and experimental analyses. Also, we will discuss long term perspectives of the V-KSTAR development.

References

[1] Jae-Min Kwon et al, Fusion Eng. Des. 184, 113281 (2022).

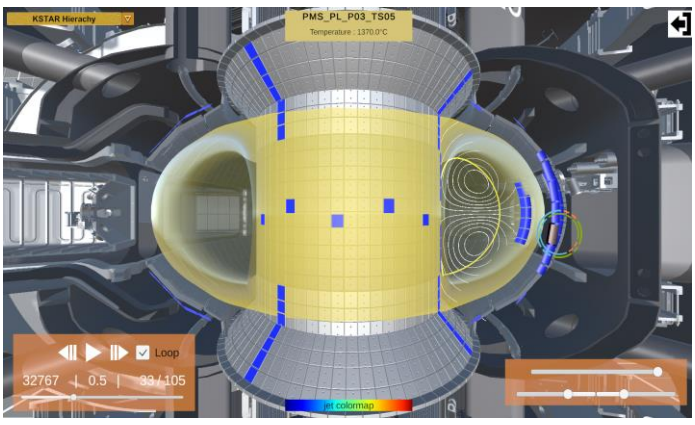

Figure 1. The real time monitoring of EFIT reconstructed equilibrium magnetic fields and the first wall temperatures. The blue colored tiles indicate those with thermocouple.

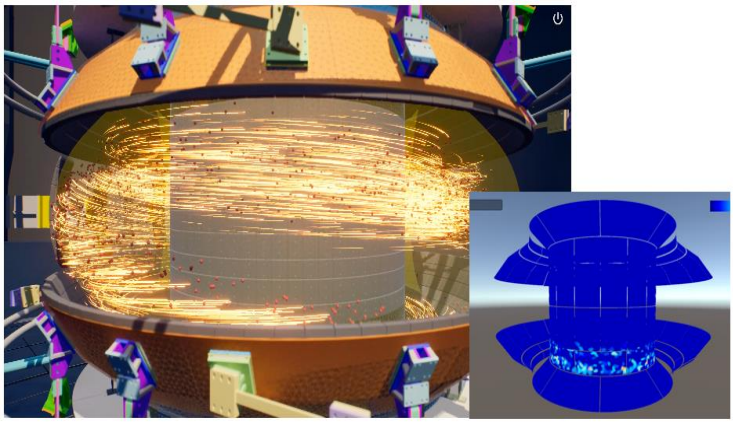

Figure 2. Visualization of NBI particle trajectories in the virtualized KSTAR. The right bottom figure shows the recorded results of the NBI particle losses on the first walls.