Plasma Physics and Fusion Science by Virtual-Reality System

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1 Introduction

Scientific visualization analysis by virtual-reality (VR) technology has a clear advantage compared with an analysis on a two-dimensional display because the technology can immerse a researcher totally in the VR space. National Institute for Fusion Science (NIFS) introduced a CAVE-type VR system[1] in 1997 to analyze simulation results, such as magnetohydrodynamics (MHD) simulation results for MHD dynamo and spherical tokamak, molecular dynamics simulation results for chemical sputtering of plasma particle on a diverter, and particle simulation for magnetic reconnection.

In the analysis of the magnetic reconnection, we clearly displayed the relationship between the complex three-dimensional (3D) structures of magnetic fields, flow velocity of ion, distribution of ion temperature and ion trajectories in the VR space[2].

Recently, we succeeded to visualize integrally a simulation result and experimental device data, and analyzed equilibrium plasma in the Large Helical Device (LHD) of NIFS [3, 4]. In this paper, we report one of the recent applications of VR technology to investigate plasma physics and fusion science in NIFS.

2 Visualization of Equilibrium Plasma in Experimental Device

Equilibrium plasma in LHD is calculated by the MHD simulation code HINT[5], in which each coil is assumed to be a filament outside the computation box. The visualization software Virtual-LHD visualizes an isosurface of plasma pressure, a streamline of magnetic-field, and an orbit of drift particle of an LHD plasma in the VR space[6]. By visualizing this equilibrium LHD plasma simulation data integrally in the experimental vessel, in which the devices, such as divertor plates, ion and electron cyclotron heating antennae, are located in the same positions as those in the actual vessel according to CAD data[3, 4], it is possible to trace the magnetic-field line and particle trajectory to examine whether they strike against the wall or divertor plate, and to check the plasma pressure isosurface to check an interference with the wall or antennae.

The integrated VR visualization is realized by EasyVR and FusionSDK, which can capture OpenGL graphic data created by different visualization software and fuse together the data into one graphic data in one VR space[7, 8].

In the previous paper[9], we visualized an LHD equilibrium simulation data by HINT2[10, 11], in which the coil currents existed in the computation region, and it became much easier to use the code in practical applications for evaluation of the equilibrium of actual non-axisymmetric configurations. In order to check the visualization of HINT2 data, we excluded the divertor region.

In this paper, we succeed to visualize the HINT2 simulation data including the divertor region, and show some results in the next section.

3 Analysis of Equilibrium Plasma in Experimental Device

Figure 1 is a scientific visualization of a HINT2 plasma simulation result by Virtual LHD in the VR space. Green line shows the stream line of magnetic-field. The starting point is given by Wand in the 3D space. We can visualize various field lines. The black plates are the divertor plates. Top and bottom panel in Fig. 1 shows the same magnetic-field line from the different view point. In this way, we can trace it in the immersive 3D VR space. Since this HINT2 data includes the divertor region, it is possible to analyze the magnetic structure there. It is found that the streamline strikes the divertor plate in the top panel of Fig. 1, and that another end of the line also strikes the wall as shown in the bottom panel.

Figure 2 shows the other magnetic structure. Since the HINT2 code can treat consistently the net toroidal current effects (Ohmic and Neoclassical) and the full torus configuration with the coil currents in the computation region, the stochastic magnetic structure can be displayed in the periphery region. The structure is complex as shown in Fig. 2. However, this structure cannot be clearly-identified as the stochastic. The Poincare map is one of the available tools, and we will add a function of drawing the map in the VR space.

Figure 3 displays the drift particle trajectory in the divertor region. We can put any points and pitch angles as an initial condition for the equation of motion by Wand in the 3D space. Because the HINT2 data takes in the divertor region, we can analyze the orbit there. In the Fig. 3, it is found that the particle moves along the divertor plates or the wall with a complex orbit.

4 Conclusion

Streamline of magnetic-field and orbit of drift particle of equilibrium LHD plasmas by HINT2 simulation code were demonstrated in the LHD vessel in the immersive 3D space by the VR system. The HINT2 simulation data included the divertor region. It became possible to investigate the magnetic-field structure and the particle orbits in

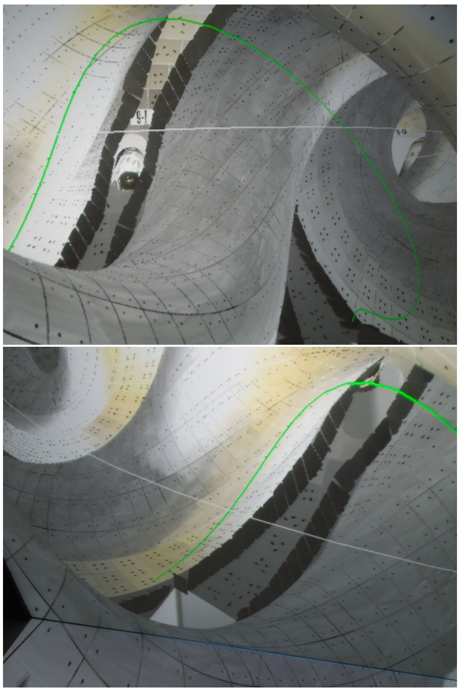

Fig. 1. Scientific visualization of the Large Helical Device (LHD) plasma by Virtual LHD in the LHD vessel in the VR space. Green line shows the stream line of magnetic-field. The black plates are the divertor plates. Top and bottom panels show the same magnetic-field line from the different view point.

the divertor region. It is hard to recognize the stochastic structure of magnetic-field as shown in Fig. 2. In order to confirm the existence of the magnetic islands and stochastic regions in the periphery and divertor region, Poincare map is useful. In the near future, we will add a function of drawing the Poincare map of the magnetic-field structure simultaneously to Virtual LHD.

VR technology is powerful equipment for analyzing simulation data. We believe that the buildup in this paper will boost up the research of the plasma physics and fusion plasmas.

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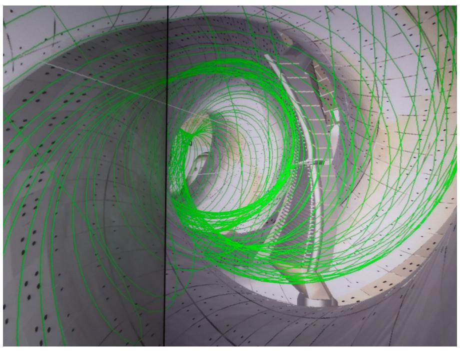

Fig. 2. Magnetic field structure. The starting point of the streamline is different from that in Fig. 1.

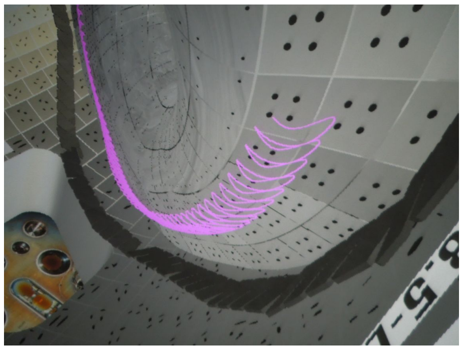

Fig. 3. Tracing of the particle trajectory in the divertor region. The magenta line shows the particle trajectory.

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