GLOBAL EVALUATION OF PROMPT DOSE RATES IN ITER USING FW-CADIS

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INTRODUCTION

Assessment of the dose rates throughout ITER is necessary to determine personnel accessibility, ensure occupational safety, and guide possible reactor building design changes. Due to the immense size and the complexity of the ITER structure, calculation of the radiation dose rates, especially outside the bioshield, has always depended on coupling the final 3-D analysis with 1- or 2-D analyses[1]. These approaches ignore critical geometric details such as the large diagnostics ports. This paper shows how the Forward Weighted Consistent Adjoint Driven Importance Sampling (FW-CADIS) method[2] can enable the full 3-D modeling of large and geometrically complex problems such as ITER.

METHODOLOGY

The ITER 3-D model, Alite03, was used in the form of an MCNP5[3] input file representing a 40° sector of the ITER device[4]. The fusion evaluated nuclear data library (FENDL-2.1)[5] was used in this analysis. A multigroup 46-neutron/21-gamma FENDL-2.1 library was used for the deterministic calculations while continuous energy data was used in the MC calculations.

The ADVANTG (AutomateD VAriaNce reducTion Generator) code[6] was used to develop weight-window maps for subsequent MC simulations. For problems with complicated geometries such as ITER, the manual creation of an equivalent 3-D input file for the deterministic calculation is extremely difficult. One of the main advantages of ADVANTG is the automatic generation of the deterministic input file from the MC model. The ADVANTG package uses a modification of MCNP5-1.40 to map materials from the combinatorial geometry onto a user-defined orthogonal mesh. It drives the Denovo 3-D discrete ordinates (S_N) code to generate approximate forward and/or adjoint S_N solutions[7]. Using the CADIS or FW-CADIS methods, ADVANTG then generates weight-window and source-biasing parameters in formats directly usable by MCNP5/X (i.e., as a WWINP file and SDEF cards, respectively).

RESULTS

The dose rates at the bioshield were found to be strongly affected by the neutrons and photons streaming through the ITER ports. Figure 1 shows the dose rate map on the central plane of the model and on a plane rotated 20° from the central plane.

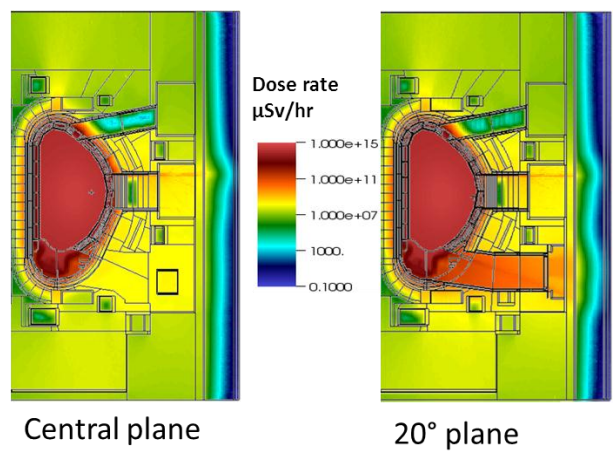

Figure 1. Dose rates at two planes in ITER.

The central plane passes through the center of an upper diagnostics port and the center of an equatorial port. The rotated plane passes through the centers of an upper port, an equatorial port, and a divertor port. The effect of the upper port on increasing the dose rate at the bioshield is not apparent because it is fully plugged by 5 m of shielding in the Alite model. The equatorial port, which is only plugged by 2 m of shielding, has some effect on the dose at the bioshield especially at the 2 cm gap between the port wall and the shielding plug. The divertor port does not have any shielding plugs and hence it strongly affects the prompt dose rate at the bioshield.

Behind the divertor port, the dose rate at the back surface of the bioshield is 240 µSv/hr. The maximum dose rate at the centeral line of the back surface of the bioshield is 94 µSv/hr. This occurs 100 cm above the center of the equatorial port opening corresponding to the

2 cm gap between the port plug and the upper wall of the port. At the same azimuthal and axial position, the dose rate in front of the bioshield is 204 Sv/hr. The effect of the bioshield in decreasing the prompt dose rate is a factor of 2×10^6 at this position. Similar degrees of attenuations due to the bioshield were found at other positions.

CONCLUSION

The ability of performing full 3-D MC analysis for problems with the overall size and complexity of ITER using the hybrid MC/deterministic techniques has been demonstrated. The 2 m biological shield (bioshield) reduces the total prompt operational dose by six orders of magnitude. The divertor port results in a peaking factor of 120 in the prompt operational dose rate behind the bioshield of ITER. The equatorial port, plugged by 2 m of shielding, increases the prompt dose rate behind the bioshield by a factor of 47. The peak values of the prompt dose rates at the back surface of the bioshield were 240 µSv/hr and 94 µSv/hr corresponding to the regions behind the divertor port and the equatorial port, respectively.

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