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Neutronic analysis of ETSS with MCNP Monte carlo code for neutron transport

モンテカルロ粒子輸送コードMCNPによる周辺トムソン散乱計測システムの核解析

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Neutronic analysis was performed to reduce neutron flux in the interspace of the equatorial (EQ) port in ITER. The laser injection system of the Edge Thomson Scattering (ETS) system will be installed in the EQ port. However, the neutrons which pass through the Laser injection path and scattered by neutron dump significantly increase neutron flux in the interspace. Thus, by selecting the appropriate material and configuration of the neutron dump, the neutron flux can be reduced more than 40% from the original design.

1. Introduction

Neutronic analysis is very important to optimize the design of diagnostics system in ITER. In this study, neutronic analysis has been performed to optimize the design of the ITER Edge Thomson Scattering (ETS) system [1], which will be installed in the equatorial (EQ) port plug. From the view point of maintenance of diagnostics systems, reduction of neutron flux in the interspace region (the space between the port and the bio-shield.) is one of most important design items.

The ETS is the primary diagnostic system for measuring the electron temperature and density of the peripheral plasma in ITER. The ETS system consists of the laser injection and the collection optics systems as shown in Fig.1. The collection optics system can have a labyrinth structure in order to reduce streaming neutron from plasma to interspace region. On the other hand, in order to simplify the laser injection alignment and maintenance procedure, all optical components for the laser injection are required to be placed outside the port. Therefore a straight penetration in the port plug is necessary to inject laser beams into plasma and then it leads high flux of streaming neutrons to the interspace. Installing the additional shield effectively around the laser path are most important provisions to satisfy the Thomson scattering measurements in ITER.

In this work, the effect of the additional shield around the laser path and the neutron dump on neutron flux of the interspace was investigated through neutronic analysis.

2. Calculation method

To optimize the design of the laser injection system, we performed neutronic analysis with MCNP code (version of MCNP 5 [2] combined with the nuclear data library FENDL2.1). The geometry of the analytic model is shown in Fig 2. This model contains a plasma, port-plug, diagnostic first wall, interspace and the laser injection system of the ETS. The laser injection system consists of

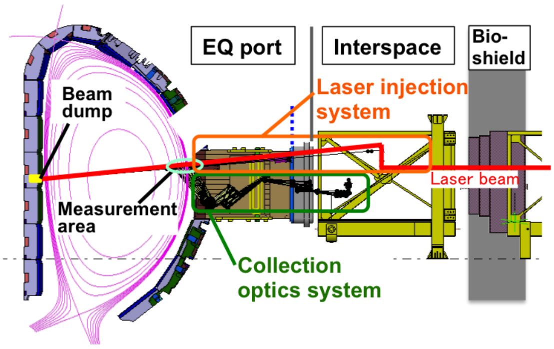

Fig.1. Schematic view of ETS system

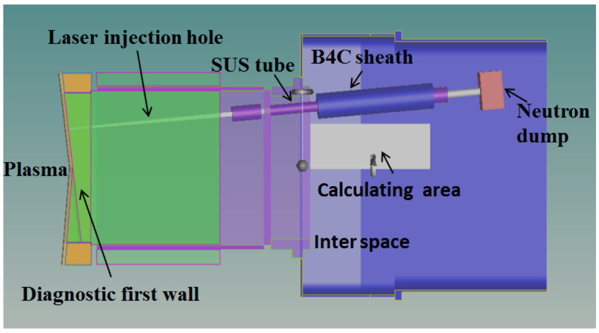

Fig.2. The image of calculation model of the laser injection system

the laser injection hole, SUS tube, boron-carbide (B_4C) sheath and Concrete neutron dump. The B4C sheath is used to shield neutrons which come from plasma through the laser injection hole. The model of the laser injection system is made with the software named MCAM4.8 professional edition [3], which can convert a CAD model to a MCNP input data. In this calculation, the neutron source is set as a toroidally symmetrical source with 14 MeV mono-energetic energy, and the neutron profile is set based on the ITER Inductive operation scenario (500MW fusion power).

3. Calculation results

3.1 Evaluation of the effect of B_4C sheath and SUS tube on neutron flux in interspace

In order to evaluate the shielding effect of B_4C sheath and SUS tube, neutron flux in interspace was calculated in the case of the model with and without B_4C sheath and SUS tube. As a result, the neutron flux in the interspace in the case the model with B_4C sheath and SUS tube is 10% smaller than that in the case of without. This result suggests that the contribution of neutron flux to interspace is small.

3.2 Design of neutron dump

The contribution of the neutron dump to increase of neuron flux in the interspace was evaluated. It was found that the neutron dump could significantly increase neutron flux in the interspace by scattering the neutrons from plasma. However, since the neutron dump is necessary for the laser injection system of the ETS in order to shielded neutrons from plasma region, it is important to reduce scattered neutrons from the neutron dump. In this work, appropriate material and configuration of the neutron dump for reduction of scattered neutrons was investigated through neutronic analysis.

The candidate of the material of neutron dump is Concrete and B_4C, because Concrete and B_4C has high shielding performance for neuron. As a result of the calculation, it was found that the neutron flux in the interspace in the case the neutron dump is B_4C can be reduced to 80% compared with the case of Concrete as shown in Tab.1.

For the configuration of neutron dump, the original design of the neutron dump is Cuboid shapes and the size is 50 × 50 × 30 cm. In order to reduce scattered neutrons more efficiently, the neutron dump was newly designed as shown in Fig.3. In the new design, the hole was made in neutron irradiation position of the neutron dump. The hole is cylindrical form and its radius is 5 cm and depth is 30 cm. It is expected that the scattered neutrons on the bottom face of the hole are

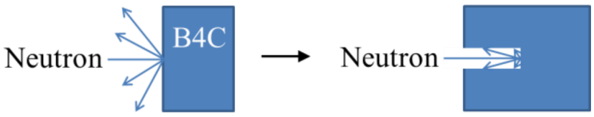

Fig.3. Schematic view of design change of the beam dump for effective reduction of neutron scattering

Table I. Neutron flux in the interspace calculated by each neutron dump model

Configuration	Material	Neutron flux in the interspace ($/cm^2 \cdot s$)	f.s.d
Cuboid	Concrete	5.2×10^5	0.09
Cuboid	B_4C	4.1×10^5	0.09
Cuboid with hole	B_4C	2.9×10^5	0.13

absorbed by the inside wall of the hole. The evaluated neutron flux in the interspace is shown in Table.1. The neutron flux can be reduced more than 40% from the original design.

Thus, it was found that the neutron flux in the interspace is significantly reduced by selecting the appropriate material and configuration of the neutron dump.

4. Summary

In this work, neutronic analysis was performed to reduce neutron flux in the interspace of the EQ port, where of laser injection system of the ETS will be installed. It was found that scattered neutrons by the neutron dump significantly increase neutron flux in the interspace. However, since the neutron dump of the laser injection system is necessary to shield high power neutron from plasma, the materials and the configuration of the neutron dump was investigated from the viewpoint of reduction of scattered neutrons. As a result, the neutron flux can be reduced more than 40% from the original design by selecting the appropriate material and configuration of the neutron dump.

References

[1] E. Yatsuka, M. Bassan, T. Hatae et al., J. Instrum. 8, (2013) C12001.

[2] X-5 Monte Carlo Team, "MCNP – A General Monte Carlo N-Particle Transport Code, version 5", LA-UR-03-1987, Los Alamos National Laboratory (2003).

[3] Y. Wu, FDS Team, Fusion Eng. Des. 84 (2009), 1987.