Configuration of DEMO Reactor and the environment for plasma diagnostics
原型炉の構造と計測環境

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As an introduction to plasma diagnostics in DEMO, constraints and difficulties in DEMO are summarized from the aspects of radiation conditions, port allocation, in-vessels components, electromagnetic property, operational program and safety relevant to diagnostics.

1. Introduction

There is no doubt that plasma diagnostics in DEMO will face more difficulty or constraints because of torus configuration and operational conditions than those of ITER. Diagnostics-relevant features of DEMO are presented along Ref. [1] by contrast with ITER.

2. Torus configuration and conditions of DEMO

Neutron flux and the induced γ-rays in the the vacuum vessel (VV) of DEMO will be several times higher than that of ITER. The resulting neutron fluence is anticipated to be two orders of magnitudes higher in DEMO because of steady state operation. Such radiation conditions can be a tight restriction in the selection of diagnostics for DEMO. In addition, a high coverage of breeding blanket in the VV imposes tremendous constraints on the field of view and instrumental arrangement of diagnostics. As to magnetic probes installed in the VV, eddy currents induced in various in-vessel components by transient variation of plasma and coil currents could be a disturbance in the detection of plasma position and shaping.

Figure 1 illustrates a schematic view of the torus configuration of tokamak DEMO. Basically, helical reactor has the similar configuration regarding vessel/in-vessel components. Main vessel/in-vessel components are breeding blanket, divertor, neutron shield and VV. Furthermore, conducting shell is installed in-between the blanket and shield for plasma vertical stability and high beta access. The blanket module typically has a dimension of 1-2 m (W) × 1-2 m (H) × 0.6-0.9 m (D) and a clearance of about 0.02 m between the neighboring blanket modules for installation with remote equipment. The shield is composed of a combination of steel and water (steel : water = 70-60% : 30-40%) and has an additional function for supporting blanket modules.

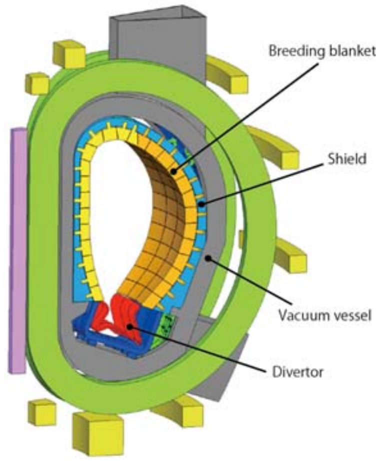

Fig.1 Schematic view of DEMO reactor

3. Radiation conditions

Radiation field in tokamak and helical DEMO during operation was calculated for the average neutron wall load of 1.5 MWm^{-2}. The wall load corresponds to a a tokamak reactor with a major radius (R_p) of about 8 m and fusion power (P_{fus}) of about 2 GW, and a FFHR-d1[2]-like helical reactor with R_p = 14.1 m and P_{fus} = 3 GW. The calculations produced the approximately same results as shown in Fig. 2, indicating fast neutron flux (E > 0.1 MeV) of around 2×10^{13} $cm^{-2}s^{-1}$ on the back surface of blanket and around 5×10^{10} $cm^{-2}s^{-1}$ on the back surface of shield, albeit dependent on breeding materials. In the case of the tokamak calculation, the induced γ-ray flux is comparable (around 10^{13} $cm^{-2}s^{-1}$) with the neutron flux on the back surface of blanket and the resulting dose rate is roughly 10^{10}

Gy/year.

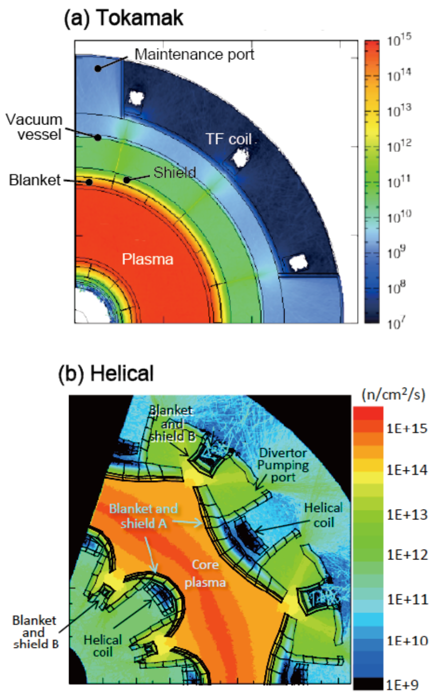

Fig.2 Calculated fast neutron flux (E > 0.1 MeV) on the mid-plane for (a) tokamak and (b) helical reactor

4. Port allocation for diagnostics

For self-sufficient production of tritium, the total area of diagnostic ports needs to be minimized to increase breeding zone as possible. Although there is no reasonable explanation for defining a numerical value of the port allocation, 5-10 m^2 seems to be acceptable for diagnostics. In the case, the reduction of tritium breeding ratio (TBR) is estimated to be only 1% or lower. Incidentally, diagnostics need not necessarily to share-ride on the shield plug of a maintenance port. If needed, dedicated ports should be considered for diagnostics.

5. Electromagnetic property

In the VV, there are a lot of various conductive components with different thicknesses and sizes. Time constant of induced eddy current in some components can be as long as 0.1 s. Pattern and time evolution of eddy current in the conductive components are dependent on the mutual inductance of multiple components, a current path determined by electrical contacts of components and so on. Here, special attention needs to be paid to the fact is that magnetic probes should hide behind blanket or something far from the plasma in order to survive more than a few years in severe radiation environment of DEMO. This leads to difficulties in the magnetic measurement in that the distance from the plasma tends to weaken the probe signals due to plasma displacement and the closeness to blanket or other components makes magnetic probes susceptible to a disturbance due to eddy currents. Thus it is never taken for granted that magnetic probes with which every tokamak has been always equipped as an essential diagnostic, is applicable to DEMO, as well. In order to confirm its applicability, intensive considerations are required on the basis of calculations using an elaborate code.

6. Use of phased operation

As planned in ITER, phased operation will be adopted in DEMO. In the commissioning, low power and/or low duty operation phases, most of diagnostics used in ITER should work. These phases can be used for cross calibration of different diagnostics. In contrast, in power-up and full power phases, the number of diagnostics that survive until the next replacement should be limited. In this sense, the early operation phases should be used for systematic development of diagnostics to derive information as much as possible using a limited number of diagnostics in preparation for the late phases. In addition, it must be noted that in-situ calibration is practically impossible in DEMO except in the comissioning phase.

7. Safety aspect

When using a dedicated diagnostic port, the port and a part of diagnostic components can be regarded as the first barrier for the confinement of tritium and radioactive materials. Then, as considered in ITER, each diagnostic system requires redundant isolation valves to limit the amount of radioactive materials released through one failed component.

Acknowledgements

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References

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