Neutronics Design of Helical Type DEMO Reactor FFHR-d1

National Institute for Fusion Science, Japan

Helical type DEMO reactor FFHR-d1

Neutronics requirements and issue

Cross sections of FFHR reactors

Neutronics requirements:
1. Tritium fuel breeding (Tritium Breeding Ratio (TBR) > 1.0)
2. Radiation shield for coil systems (Operation for >10 years)

Issue in FFHR-d1:
Core plasma shifts to inboard side.
Limited inboard blanket space.

Neutronics design study
with MCNP5 code and JENDL-3.3 library.
Keeping consistency with Plasma, In-vessel, Superconducting coil, Blanket and System Integration designs.

Configuration of reactor components and plasma parameters of FFHR-d1:
Enlargement and extrapolation from LHD. 
Enhancement of feasibility, early demonstration.

Neutronics investigation with torus model (first step)

Example of design window analysis


Configuration of inboard blanket, shield and helical coil

700 mm for blanket

Inboard blanket space: 70 cm
First candidate blanket: 
Flibe+Be/ Ferritic steel (FS) (Fully-covered TBR: 1.31)

Neutronics evaluation with 3-D model (second step)

Meshing of cross section ➔ 3-D model according to numerical equations.

Neutron transport and shielding

(a) Vertical distribution
Fast neutron flux (>0.1 MeV) (n/cm²/s)

Fast neutron flux in helical coil at inboard side: ~2 x 10¹⁰ n/cm²/s.
(at ★ mark) Nuclear heating: ~0.6 mW/cm³
Could be operated for >10 years.

(b) Horizontal distribution
Fast neutron flux (>0.1 MeV) (n/cm²/s)

Neutron wall loading

3-D model Blanket A
Simulation of helical neutron source

Neutron wall loading distribution

Design parameters of FFHR-d1
- Fusion power: 3GW
- Averaged neutron wall loading: 1.5 MW/m²

Evaluated maximum neutron wall loading:
~2.0 MW/m² at inboard
~1.5 MW/m² at outboard

Conclusion

3-D evaluations of
- Tritium breeding with Flibe blanket
- Neutron wall loading
- Radiation shielding
 indicate that the FFHR-d1 design would be feasible from the neutronics point of view.

Neutronics study is continued for further detailed 3-D design of FFHR-d1.
Consistency with other design factors is a key point of this study.

- Helical divertor can be placed behind blanket and shield.
- Suppression of radioactivity and irradiation damages of divertor materials.
- Coolant ducts from blanket could also be placed behind radiation shield.