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Electromagnetic study on HCCR TBM for ITER major disruption scenarios

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1. Introduction

Helium Cooled Ceramic Reflector (HCCR) Test Blanket Module (TBM) has been developed in Korea in order to experiment a breeding blanket module in ITER [1]. This TBM will verify the feasibility of tritium self-sufficiency in reactor and the extraction of high-grade heat suitable for electricity generation. Since various loads such as seismic load, electromagnetic (EM) load and heat load significantly affect the soundness of the TBM, a variety of analyses were carried out for design optimization [2]. The EM load is particularly one of main design drivers because large amount of magnetic energy in the plasma are transferred to in-vessel components including the TBM during plasma disruption. Because the TBM is located in equatorial port, major disruption (MD) among various plasma disruption scenarios causes the largest EM loads on the TBM.

2. Modeling

The HCCR TBM consists of four sub-modules. The components of each sub-module are first wall (FW), side wall (SW), and breeding zone (BZ). The four sub-modules are connected to a back manifold (BM), as shown in Fig 1.

The ANSYS model of HCCR TBM has removed complex coolant lines, and is divided by the conductors and non-conductors. The parts of conductor are FW, SW, BM, key and shield. The parts of non-conductor are breeder, multiplier and reflector.

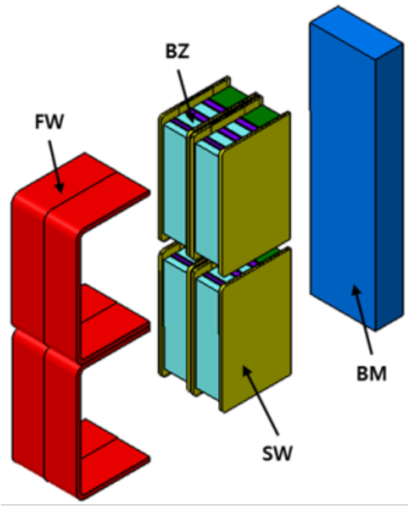

Fig. 1 The model of HCCR TBM

A 20 degree sector model for EM analyses has vacuum vessel, coils, plasma, blankets in addition to TBM. For the modeling of vacuum vessel, ribs connecting the double wall are removed. Considering the mutual inductance between the TBM and blankets, only the blankets surrounding the TBM are considered for this analysis. The lower port is removed for the simplification of model and the reduction of computational cost [3]. Fig. 2 shows 20 degree sector model. The coil and plasma are modeled as current-fed stranded conductors and the vacuum area is modeled as non-conducting region.

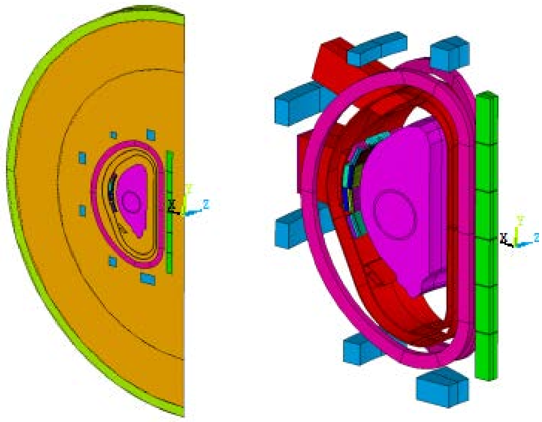

Fig. 2 Full geometry model for the 20 degree Sector of ITER and except the vacuum region

2. Material properties

Table 1 shows material properties of 20 degree sector model for EM analysis. A constant permeability is used instead of B-H curve for magnetic property of RAFM steel.

Table 1 Material properties of 20 degree sector model

Component		Material	Resistivity (Ωm)	Permeability
Vacuum Vessel		SS316LN	0.8e-6	1
TF coil				1
PF coil				1
CS coil				1
Blanket	FW Cu layer	Cu	0.27e-8	1
	FW SS layer	SS316LN	0.8e-6	1
	Shield block	SS316LN	0.8e-6	1
	Electrical strip	SS316LN	0.8e-6	1
Plasma		Air		1
TBM		RAFM	1.23e-6	1
Shield and Frame		SS316LN	0.8e-6	1

3. Meshing

The ANSYS mesh element types for EM analysis are solid 97 and INFIN 111. The degree of freedoms (DOF) of Solid 97 is magnetic vector potential ax, ay, az. When keyopt (1) is set as one, voltage is added to the DOFs. To deal with the far-field decay of magnetic flux, ANSYS element INFIN 111 is applied at the exterior region of the model. The full finite element model meshed with solid 97 is shown in Fig. 3. One layer of elements at the exterior is INFIN 111.

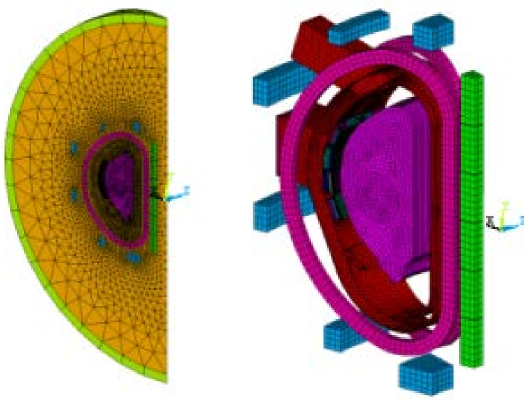

Fig. 3 Full finite element model for the 20 degree sector model and except the vacuum region

4. Boundary condition

The 20 degree sector model was repeated periodically per every 20 degrees. Therefore, all DOFs at both boundaries of sector model in toroidal direction were coupled for every two corresponding nodes of the same radial and vertical position. Flux parallel condition is applied to the ITER machine axis. The current of plasma and coils during disruption are extracted from DINA results. The current data at all-time steps were interoperated from DINA to ANSYS [4]. The 20 degree sector model was run for exponential 16 ms and 22 ms decay cases of major disruption downward scenarios.

4. Results

The eddy currents were derived on TBM and shield during disruption of plasma. In initial stage, most of the eddy currents were concentrated in TBM part. The eddy current moves then toward shield, as show in Fig. 4.

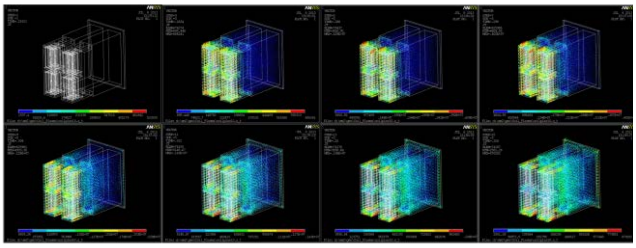

Fig. 4 The eddy current distribution on two TBMs and shield during the plasma disruption

The purpose of EM analysis was to calculate EM forces on HCCR TBM and shield. Fig. 5 and Fig. 6 show forces on the components of both TBMs and shield in the direction of radial, vertical and toroidal directions during the major disruption exponential 16 ms and 22 ms. Table 2 shows maximum values of EM force on HCCR TBM and shield. The values of EM force on TBM are higher than those acting on shield.

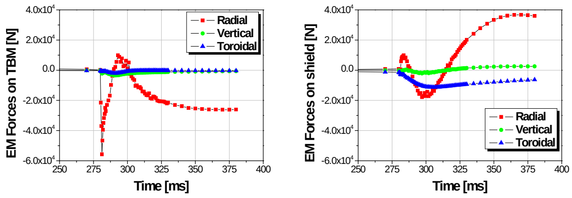

Fig. 5 Radial, vertical and toroidal component of electromagnetic force on TBM and shield during major disruption exponential 16ms

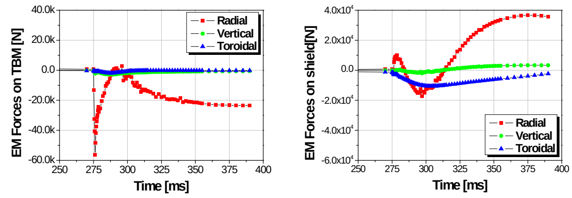

Fig. 6 Radial, vertical and toroidal component of electromagnetic force on TBM and shield during major disruption exponential 22ms

Table 2 Summary of maximum force on HCCR TBM and shield

	HCCR TBM (N)	Shield (N)
MD Down 16ms	-55,808	36,722
MD Down 22ms	-56,325	36,642

The EM analysis of HCCR TBM was successfully carried out by ANSYS-EMAG tool. The results will be utilized as input for the HCCR TBM design including back attachment. In the future, the additional calculation will be performed for the various scenario of the plasma disruption. In addition, the magnetic property such as B-H curve of RAFM steel will be used in the calculation for more practical purpose.

REFERENCES

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[4] D. Oh et al., Fusion Engineering and Design, 86, Issues 2–3 (2011)