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Electromagnetic dynamic response of HL-2M vacuum vessel under plasma disruption considering the electromagneto-mechanical coupling effect

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HIGHLIGHTS

- A 1/5 numerical model is established and validated for HL-2M vacuum vessel.
- The Lagrangian approach used for treating the EM-mechanical coupling problem is introduced.
- The EM field and structural dynamic response of HL-2M VV during plasma disruptions are simulated by using the Lagrangian strategy.
- The dynamic responses of the VV of HL-2M are compared to clarify the effect of the EM-mechanical coupling under the MD and VED conditions.
- The results present a basis for the safe operation of the HL-2M VV device.

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ABSTRACT

During plasma disruptions (PDs), transient eddy currents are induced in the HL-2M vacuum vessel (VV) which is a D-shaped, double thin-wall structure. Under the circumstance of high magnetic field, the resulting electromagnetic (EM) forces during PDs are large and the dynamic response of related structures may be violent. In this complicated EM circumstance, the EM-mechanical coupling effect may also have a great influence on the dynamic response of VV structure. In this paper, the EM field and structural dynamic response of HL-2M VV during PDs are simulated by adopting a numerical code of the Lagrangian approach. The Lagrangian approach is on the basis of the Maxwell equations in the Lagrangian description, which treats the coupling behavior of magnetic damping effect without explicitly using the velocity term. This approach can be easily applied to actual structures by updating FEM meshes and reforming coefficient matrices before calculating EM field at each time step. In this work, the disruption plasma currents of operating conditions are simulated by using the DINA code and then the dynamic responses of displacements and stresses of the VV of HL-2M are obtained for both cases with and without considering the coupling effect. The numerical results show that stresses under the disruptions (MD and VDE) are not significant and the coupling effect does not significantly affect the peak dynamic response for the HL-2M problem.

1. Introduction

HL-2M, which can realize relative complicated divertor plasma configuration, is an experimental Tokamak device designed by the Southwestern Institute of Physics (SWIP) of China. The major design parameters of HL-2M are 2.5 MA plasma current, 2.2 T toroidal magnetic field, 1.78 m major radius, 0.65 m minor radius, 14 Vs flux swing, 1.8–2.0 elongation, bigger than 0.5 triangularity and 5 s plasma duration time [1–3]. During the design and construction periods, much attention has been devoted to the electromagnetic (EM) force problem to ensure its structural integrity, especially at the situation of disruption.

During plasma disruptions (PDs), strong transient eddy currents can be induced in the first wall and the vacuum vessel (VV).

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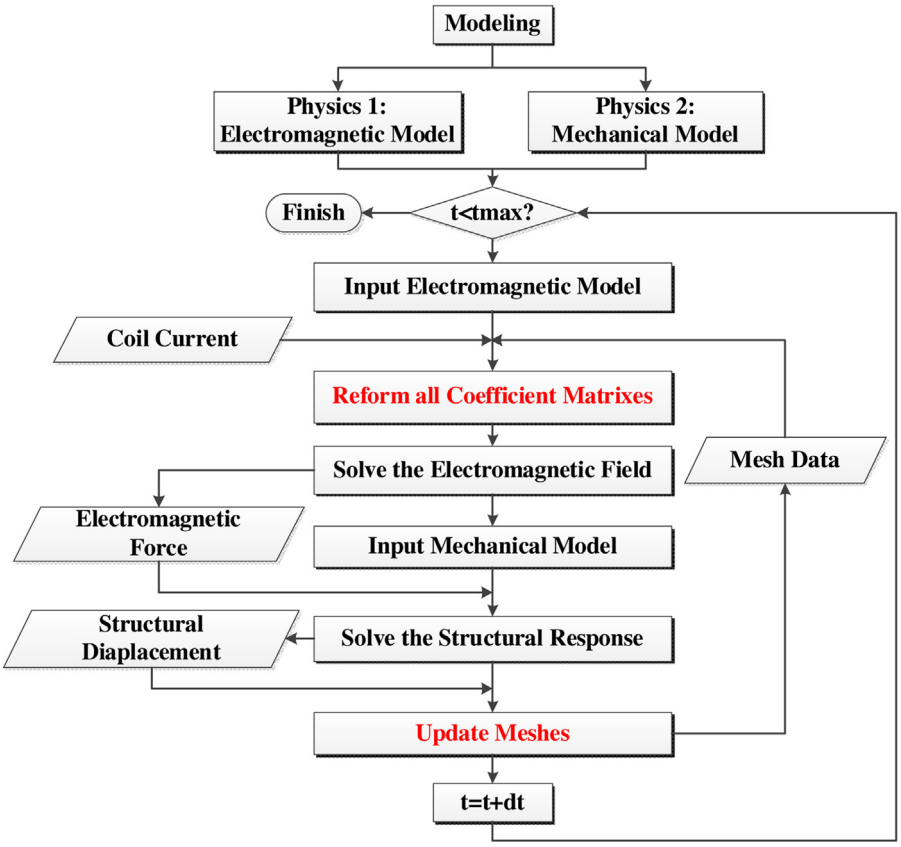
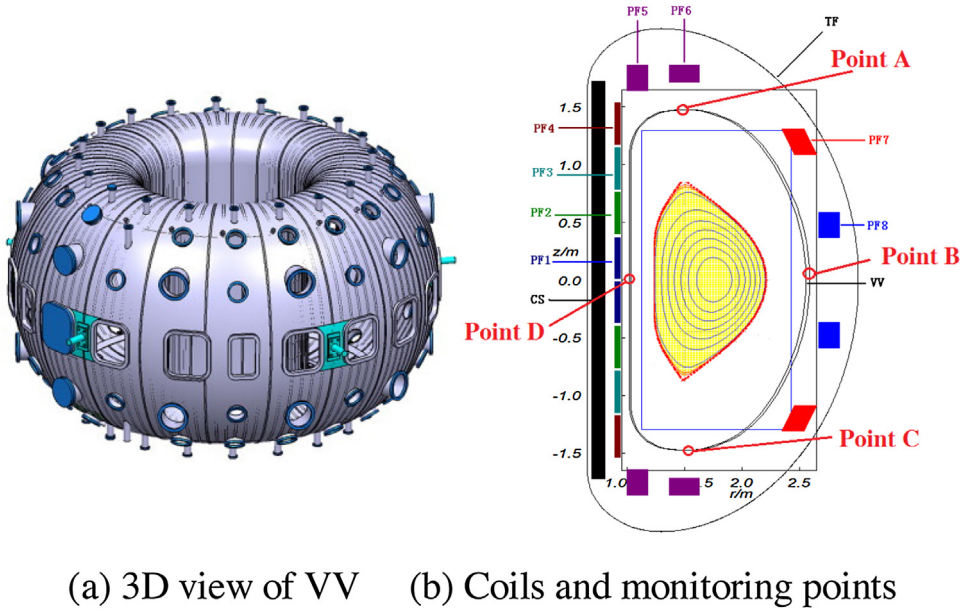


Fig. 1. Flowchart of the EM-mechanical coupling code.



(a) 3D view of VV (b) Coils and monitoring points

Fig. 2. The VV of HL-2M and locations of coils [1].

Table 1
The material constants of Inconel 625.

Electric conductivity γ/S m^{-1}	Density ρ/kg m^{-2}	Young's modulus E/GPa	Poisson ratio ν	Allowable stress σ_s/MPa
0.78×10^6	7860	0.189	0.3	414

Interacted with the high confinement magnetic field, the eddy current may causes large EM forces and the corresponding dynamic responses of related in-vessel structures may be violent. In such a complex EM field environment, the EM-mechanical coupling effect

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