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Assessment of electromagnetic loads for EAST magnets using interaction matrix method

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HIGHLIGHTS

- A new technology–interaction matrix method is applied to assess EM loads of EAST magnet system.
- The interaction matrices of EAST magnet system are obtained.
- The application validated the efficiency and accuracy of the method.
- Results indicate that the approach can be conveniently used for multi-scenario EM loads assessment for EAST current-carrying components.

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ABSTRACT

An approach for assessing the electromagnetic (EM) loads of the main current-carrying components in tokamaks has been proposed recently [1,2]. It is mainly based on the interaction matrix and the method is general. This paper explores on the application of the new technology to EAST magnet system. Firstly, the interaction matrices of EAST magnet composed of bilateral interaction forces between separate components at unit current are calculated, then the EM loads are obtained by a linear transform of given currents using the interaction matrix. The application validated the efficiency and accuracy of the method, which is useful for the systematic assessment of Tokamak EM forces. Results indicate that the approach can be conveniently used for multi-scenario EM assessments and parametric studies of the EM loads for EAST current-carrying components, and a specialized force-calculating module for real-time simulating will be developed in the future.

1. Introduction

Experimental Advanced Superconducting Tokamak (EAST) is a fully superconducting tokamak which has been built in ASIPP CAS, aiming at investigating physical issues of steady-state advanced tokamak operation. The core of EAST project consists of the superconducting magnet systems, a non-circular cross-section of the vacuum vessel and actively cooled plasma facing components. There are two superconducting magnet systems in the tokamak machine. Firstly the superconducting toroidal field (TF) magnet system consists of sixteen D-shaped coils which are disposed toroidally and spaced 22.5 apart. Secondly the superconducting poloidal field (PF) magnet system consists of fourteen superconducting coils, including a stack of 6 central solenoid coils (CS) and 8 poloidal coils (PF). The CS and PF systems are supported on the TF magnet assembly [3]. Fig. 1 has shown the main components of EAST magnet system. Tables 1 and 2 have list the design parameters of these coils separately [3,4].

How to calculate the electromagnetic (EM) load on magnets accurately and quickly is one of the key techniques for engineering design of tokamak devices. A new theoretical method was proposed to assess the electromagnetic load on each magnet at various scenarios quickly [1,2]. Considering the linear relationship between the currents and corresponding EM loads, the method firstly calculates the interaction matrices for main Tokamak current-carrying components, which reflects parameters of pair-wise load interactions between separate coils at unit currents. The computed unit current interaction matrices are fundamental scenario-invariant properties of the system. They enable immediate purely-algebraic calculation of all individual interaction forces and torques between the components by given currents. Once the matrices are gained, the full set of loads of the current-carrying components at different scenarios can be simulated in few seconds by simple linear matrix operations [1,2].

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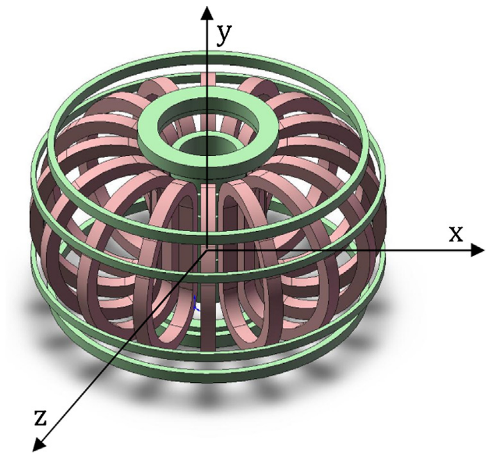

Fig. 1. Main components of EAST magnet system.

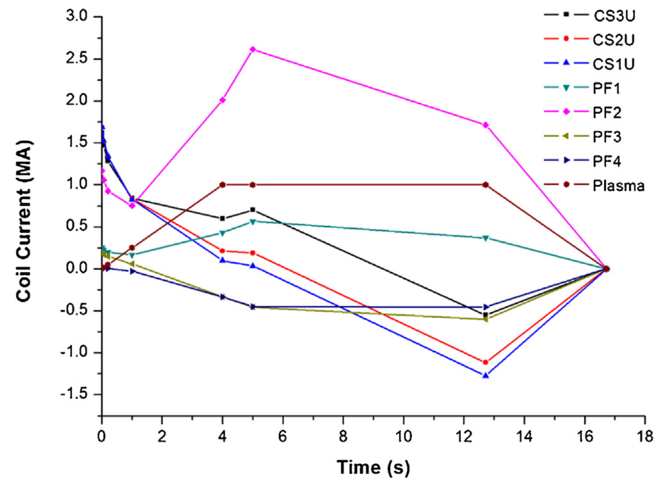

Fig. 2. Currents on toroidal coils with time.

Table 1
Design parameters of EAST TF coils.

Number of Coils	/	16
Number of turns per coil	/	130
Operating current	kA	14.3
Magnetic field at the plasma center(B_t)	T	3.5
Maximum field at the coil(B_{max})	T	5.8
Total stored energy	MJ	300

Table 2
Design parameters of EAST CS and PF coils.

	Position of coil centre		Coil size without ground insulation		
Coils	R(cm)	Z(cm)	dR(cm)	dZ(cm)	Turns
CSU3	62.866	125.66	16.078	45.177	140
CSU2	62.866	75.396	16.078	45.177	140
CSU1	62.866	25.132	16.078	45.177	140
CSL1	62.866	−25.132	16.078	45.177	140
CSL2	62.866	−75.396	16.078	45.177	140
CSL3	62.866	−125.66	16.078	45.177	140
PF1	107.217	175.37	24.694	9.769	44
PF2	113.679	194.09	37.618	27.473	204
PF3	294.558	159.07	12.844	21.256	60
PF4	326.98	90.419	8.896	17.188	32
PF5	326.98	−90.419	8.896	17.188	32
PF6	294.558	−159.07	12.844	21.256	60
PF7	113.679	−194.09	37.618	27.473	204
PF8	107.217	−175.37	24.694	9.769	44

In this paper we apply the method to EAST magnets. The EM load interaction matrices for EAST magnets are calculated in Section 3. Then the loads on each EAST magnet are evaluated at various scenarios for the time-depending multi-point data sequences, corresponding to plasma transient events in Section 4.

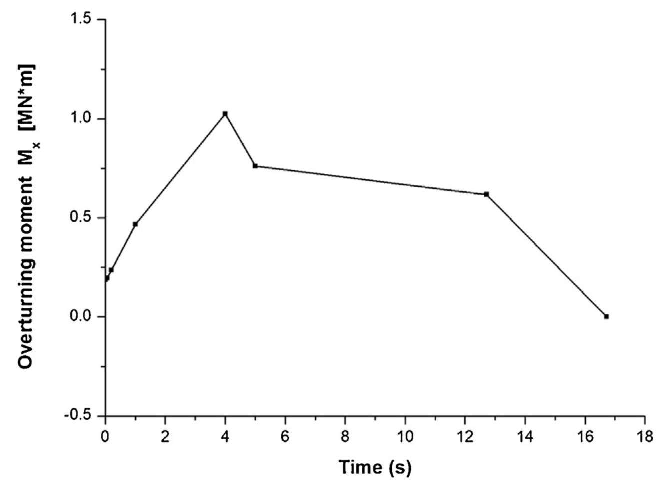

Fig. 3. Overturning moment on a TF from all toroidal coils.

2. Method

2.1. Interaction matrix

According to the method present in [1,2], at the low-frequency domain, the calculation of magnetic field by known currents is substantially a static problem. Then the Lorentz forces, acting on a current-carrying component, are result of interaction of currents in the conductor with the magnetic field, which is the total field of all sources superimposed. So the basic problem can be formulated as a problem of pair-wise interactions between all currents. The two currents: source current I_i and current in the loaded structures I_j consist of a minimum considered system. The Lorentz force acting

Table 3
Specified quantities as parameters of interactions.

Parameter	Description	The load on:	The load from:
$F\ F_R$	Radial force	TF	TF
$F_{tor}^{(1)}$	Out-of-plane force	TF	TF
M_y	Moment of the out-of-plane force about the main axis	TF	TF
$F\ F_{y-hlaf}$	Vertical total force on the upper-half coil	TF	TF
$F_{tor}^{(2)}$	Out-of-plane force	TF	CS/PF/Plasma
M_x	Overturning moment of the out-of-plane force about radial axis	TF	CS/PF/Plasma
${}_v\ F_v$	Vertical total force	CS/PF/Plasma	CS/PF/Plasma
$F\ F_{hoop}$	Hoop force	CS/PF/Plasma	CS/PF/Plasma