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Electrical testing and performance evaluation of 1:1 prototype JET ELM control coils☆

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HIGHLIGHTS

- An appropriate 1:1 prototype Small and Large ELM coils for JET have been successfully manufactured using indigenous technologies.
- ELM coils have been tested extensively to verify and validated their performance with respect to operational requirement of JET.
- The test results confirm and validate the electrical performance of ELM coils.

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ABSTRACT

Magnet Technology Development Division at Institute for Plasma research is engaged in extensive R & D for appropriate technologies towards manufacturing of Edge Localized Mode (ELM) magnets for Large Tokamak such as Joint European Torus (JET) as well as for Steady State Superconducting Tokamak (SST-1). Under this project, manufacturing of 1:1 prototype of Large and Small JET ELM control coils (CC) is completed incorporating indigenously developed manufacturing and insulation technologies. Performance evaluation of both the types of coil has been completed for its current carrying capability and insulation resistance as required by various operational scenarios of JET. Experimental setups, test procedures and measurements for electrical characterization of both type of ELM control coil has been discussed in this paper.

1. Introduction

Resonant Magnetic Field Perturbations (RMP) is identified as most promising method to suppress edge localized modes (ELM) and has been successfully demonstrated in various tokomaks [1–4]. The RMP coil configuration for JET consists of 32-coil array arranged in two toroidal belts around the plasma, an upper one with 8 Large coils and a lower one with 24 small coils. Both the rows are located above the mid-plane, as shown in Fig. 1 [5,6]. The coils are mechanically grouped in eight sets, each set consisting of one Large and three small coils, straddling adjacent octants and centred on the boundary between them, as shown in Fig. 1. The overall dimensions of Large ELM control coil (ELM CC) measures ~1.3 m × 0.4 m, while the small coil measures ~0.6 m × 0.4 m.

The ELM CC must withstand vacuum vessel bake out at elevated temperatures (350 °C) for extended periods, and must operate with the vessel at 200 °C. Pulsed coil heat loads due to joule heating of the conductors and radiation from the plasma must be handled during its operation. The coils are passively cooled means pulsed heat loads between pulses are getting removed by radiation to the vacuum vessel walls. Thus, their operation is restricted to 8 s pulses in every 30 min as shown in Fig. 2 [5,6] (Table 1).

Fig. 3 shows basic configuration for both type of ELM CC. The design of 1:1 prototype Large and Small ELM CC is finalized on the basis of feasibility report, conceptual design, remote handling constraint, lead orientation and fabrication feasibility. The winding pack is identical for both the ELM coils having 48 turns arranged in matrix of 6 × 8 as shown in Fig. 4.

ELM coil has winding pack consists of CuCrZr as conductor; Glass fiber as coil wrap with indigenously developed cynate-ester based high temperature insulation and Inconel 625 as casing material. The pumping pipe is also incorporated in winding pack to pump

☆ The views and opinions expressed herein do not necessarily reflect those of the JET organization.

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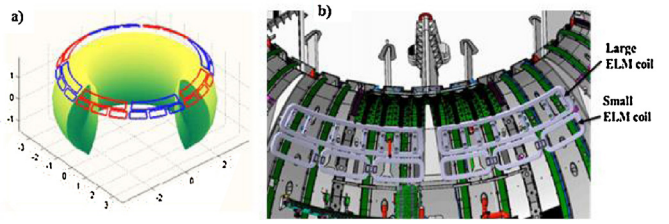

Fig. 1. JET ELM coils configuration.

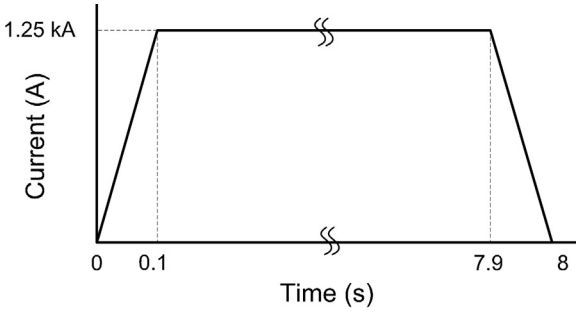

Fig. 2. Shape of current pulse during operation of ELM control coil.

Table 1
Major design parameters of Large and Small ELM coils.

Parameters	Values/details
Cross-section of conductor	6.35 mm × 6.35 mm
Nos. of turns	48
Total conductor length -in Coil	~124.6 m (Large coil) ~68.9 m (Small coil)
Turn to turn insulation	0.5 mm
Ground insulation	2 mm
Casing material	Inconel 625
Total cross section area -of Winding Pack	~0.001935 m^2
Rated current	1250 A DC
Nos. of current pulses	8
Duty cycle of each pulse	8 s ON, 30 min OFF

down any residual gas emitted during operation. The entry and exit lead of conductor are coming towards inside approximately at the middle position of coil along winding pack as required by current lead routing in JET.

2. Performance evaluation tests

The manufacturing of 1:1 prototype for both type of ELM CC is completed with development of indigenous technology in collaboration with Indian industries and has been presented [7].

For performance evaluation of ELM coils, various tests have been performed for its rated parameters which are tabulated in Table 2. The detailed experimental test setup, test procedure and their results are discussed in subsequent sections.

2.1. Resistance measurement

The resistances of the Small and Large ELM coils have been measured with the help of Nano-voltmeter and 200 A DC power supply. Voltage drop across the coil has been measured for various currents from 20 A to 80 A. The average value of the measured resistance has been considered as the coil resistance and it agrees well with the analytically calculated resistance.

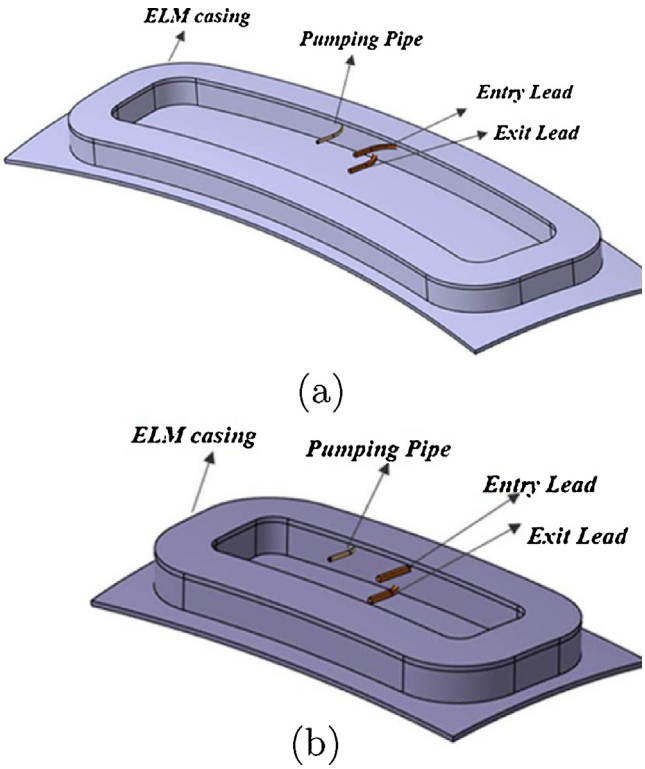

Fig. 3. (a) Large ELM coil, (b) Small ELM coil.

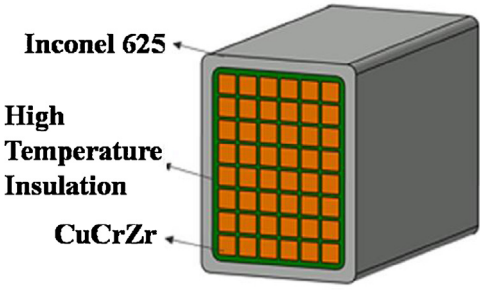

Fig. 4. Cross section of Large ELM CC and Small ELM CC.

Table 2
Test parameters of Large and Small ELM coils.

	Test parameters	Required values
1	Resistance measurement	37 mΩ for Small coil 70 mΩ for Large coil
2	Current carrying test (DC)	Thermal profile of the coil at 1375 A current
	Nos. of pulses	8
	Duty cycle	8 s ON/30 min OFF
	Rise time	100 ms
	Fall time	100 ms
3	Current carrying test (10% sinusoidally varying current with DC offset)	120 A(10%), 10 Hz Sine wave, 1200 A DC offset
4	Insulation testing	Up to 1 kV
5	Magnetic field measurement	Magnetic field profile at various points of the ELM coils

The fabricated ELM coils have been connected to the DC power supply through copper blocks. A proper arrangement has been done to ensure tight and perfect joint between the two components.

Analytically the resistance of the Small ELM coil has been calculated to be 37.08 mΩ for conductor length of 68.9 m with