1LP3-21

EUCAS 2017

Numerical Multi-Scale Model for AC Loss Calculation of Large-Scale HTS Solenoid Magnet

Z. Zhang, L. Ren, Y. Xu, Z. Wang, Z. Wang, Y. Tang

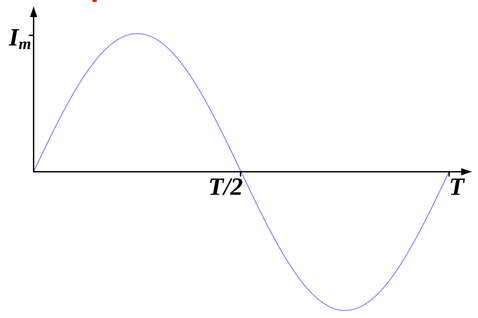
State Key Laboratory of Advanced Electromagnetic Engineering and Technology, Huazhong University of Science & Technology, Wuhan, China

I. Simulation Parameter

Table I Parameters of the magnet

Designation	Parameter
Inner radius	50 mm
Number of turns	100
Thick of tape	0.1 mm
Width of tape	4 mm
Thick of isolation	0.15 mm
Number of double pancake	4
Type of tape	Superpower 4050
Critical current of tape at 77K	104.5 A
Critical current of magnet	33.4 A

Transport current characteristic



Test Cases: $I = I_m$*sin(100*pi*t), I_m = 13 A, 17 A, 21 A, T = 0.02 s.

Contact information:

Scan the QR code to add me on WeChat.

Email: 2567248470@qq.com

II. Modeling Methodology

Diagram of the reference H-formulation model

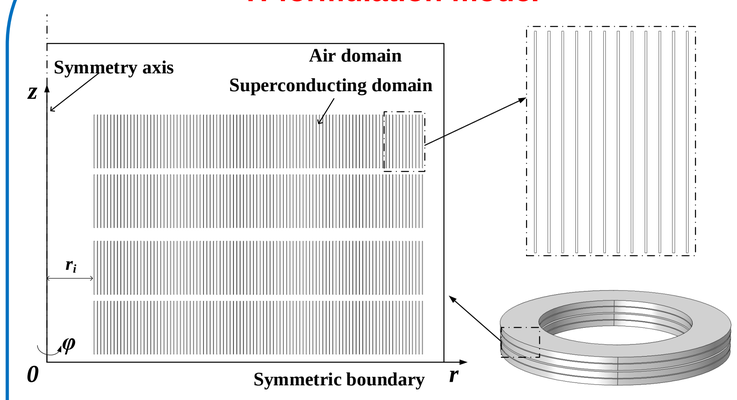


Diagram of the Homogenization model

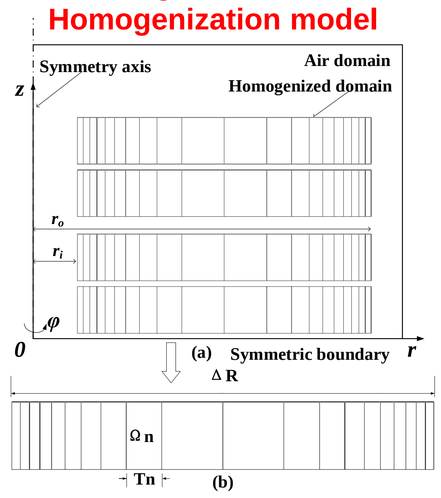
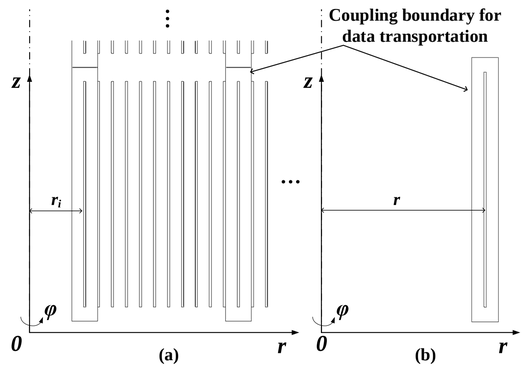


Diagram of the Multi-scale model



H-formulation model: All tapes are modeled respectively.
Homogenization model: Equivalent anisotropic bulk is used.
Multi-scale model: Break the calculation domain into (a) coil model and (b) tape model.

Flow diagram of the iteration background field method

Coil model with uniform current distribution → Tape model for current distribution → Coil model with corrected current distribution → Tape model for AC loss calculation

J_0 uniform method: Estimate the background field with uniform current.
Iteration method: Estimate the current distribution with J_0 uniform method. Estimate the background field with the corrected current distribution.

III. Result and Discussion

Figure of the instantaneous AC loss of (a) 13A, (b) 17A and (c) 21A test cases

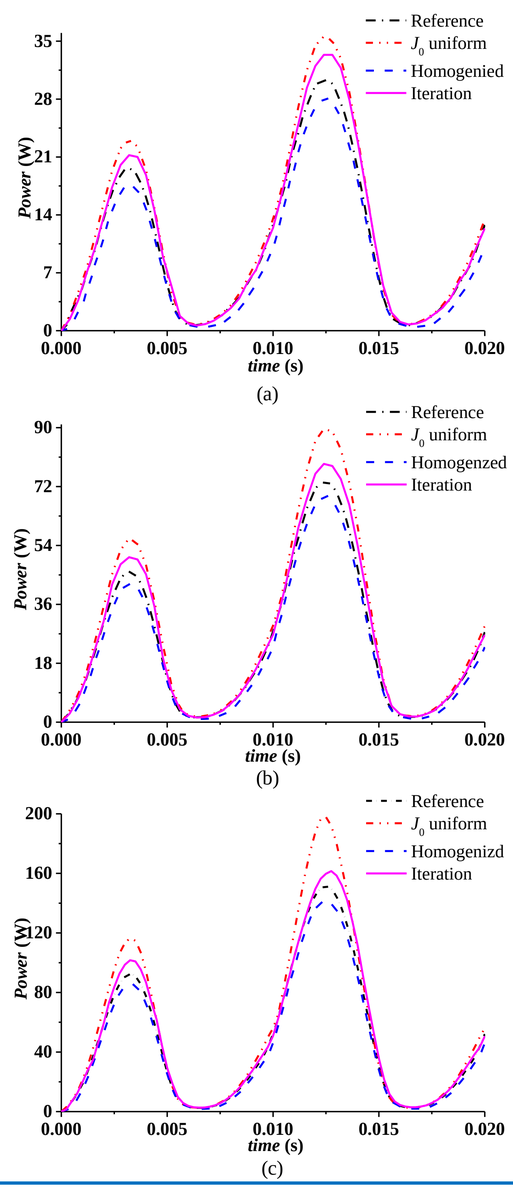


Table II Result of the reference model

	13 A	17 A	21 A
Mean value of AC loss (W)	13.01	30.53	61.44
Peak value of AC loss (W)	30.41	73.57	151.35
Total calculation time	11h 10min	19h 48min	22h

Table III Result of the J_0 uniform method

	13 A	17 A	21 A
Mean value of AC loss (W)	15.02(15.48%)	30.56(19.76%)	73.13(19.03%)
Peak value of AC loss (W)	35.58(16.99%)	89.62(21.82%)	197.8(30.69%)
Total calculation time	31min 16s	40min 58s	50min 24s

Table IV Result of the homogenization model

	13 A	17 A	21 A
Mean value of AC loss (W)	11.55(11.18%)	27.95(8.64%)	56.91(7.38%)
Peak value of AC loss (W)	28.086(7.65%)	69.19(5.95%)	142.35(5.95%)
Total calculation time	1h 15min	1h 38min	2h 4min

Table V Result of the iteration method

	13 A	17 A	21 A
Mean value of AC loss (W)	14.27(9.66%)	33.02(8.17%)	65.57(6.71%)
Peak value of AC loss (W)	33.66(10.66%)	79.09(7.5%)	160.36(5.95%)
Total calculation time	1h 27min	1h 36min	1h 45min

(1) The iteration method is more accurate than the J_0 uniform method.
(2) The J_0 uniform method dramatically accelerate calculation.
(3) The homogenization model is superior in AC loss peak value calculation. The iteration method is good at average AC loss calculation.
(4) The iteration method catches up with the homogenization model in accuracy of AC loss peak value calculation and total calculation time cost.

IV. Conclusion

AC loss of a HTS solenoid magnet is calculated and performance of homogenization model and multi-scale model has been compared:
(1) The iteration method greatly improves the accuracy of multi-scale model and still has good performance in calculation speed. The J_0 uniform method dramatically accelerate the calculation.
(2) The iteration method is superior to the homogenization model in average AC loss calculation.
(3) The iteration method trends to catch up with the homogenization model in speed and accuracy of AC loss peak value estimation with the increase of computational complexity.