Mechanical responses of a semi-open split NbTi superconducting magnet reinforced with cantilever structure

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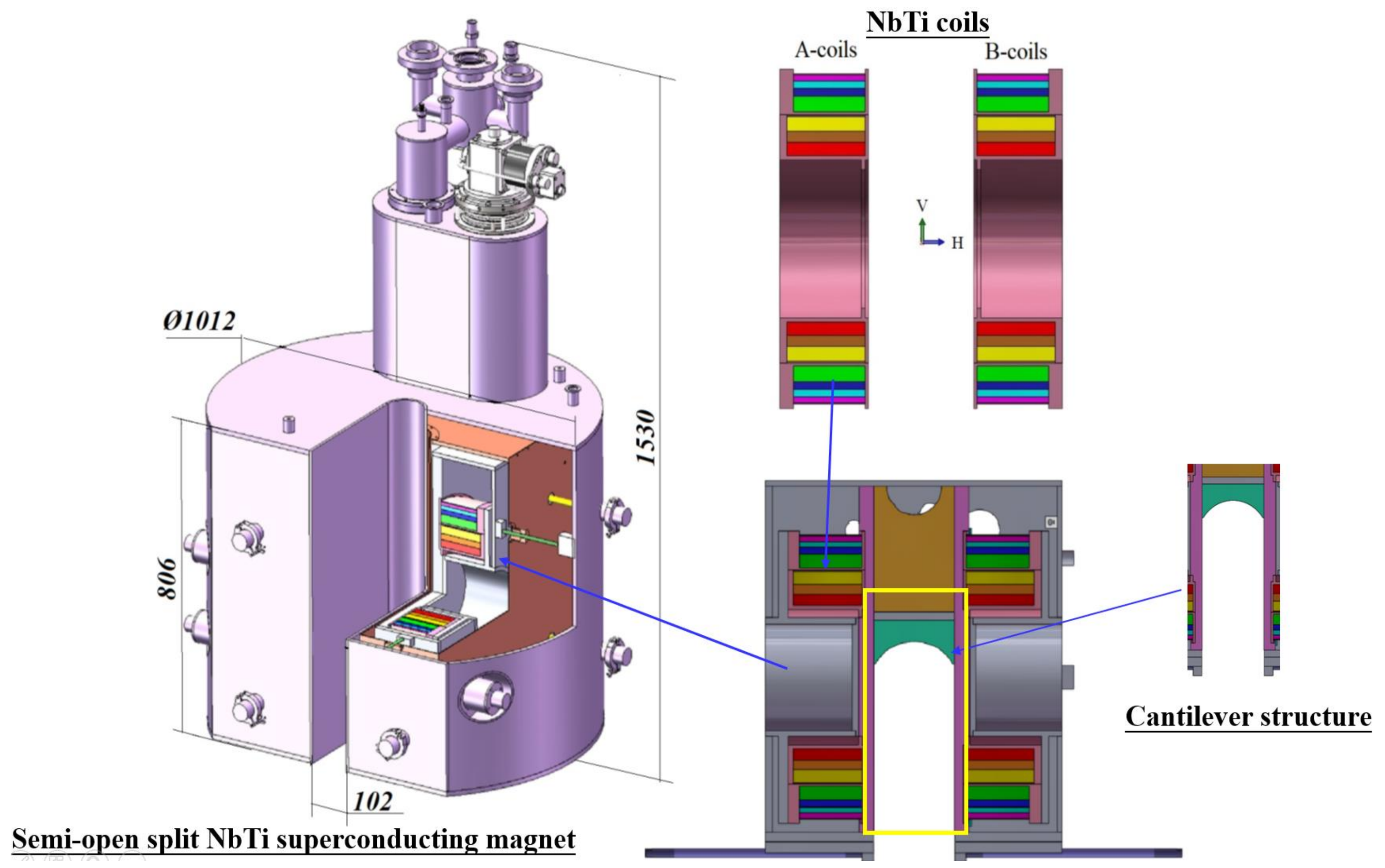
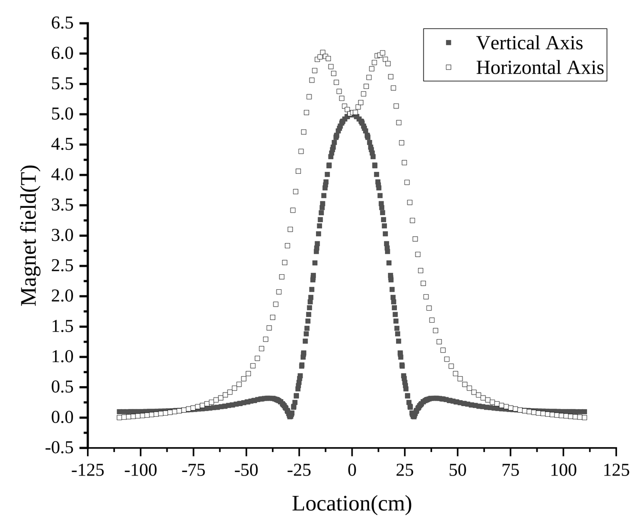
Introduction

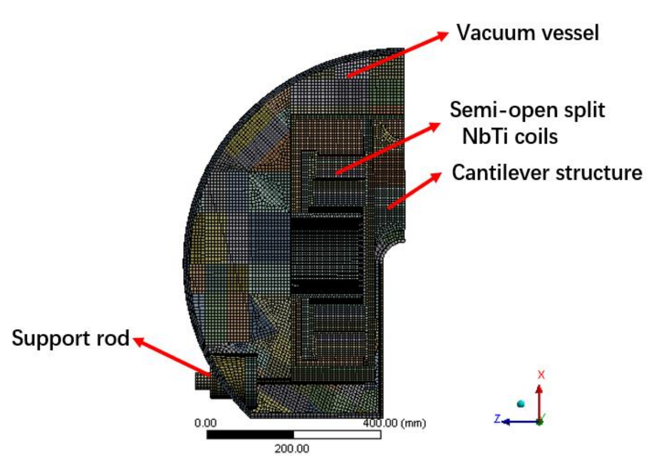
Aiming to a versatile multi-field test facility, Lanzhou University, in collaboration with the Institute of Modern Physics of Chinese Academy of Science, has designed and constructed a facility capable of providing cryogenic-electro- magnetic multifield in 2018. A superconducting racetrack magnet is manufactured to generate a background field up to 3.5 T. Recently, we updated the superconducting magnet for a high background field up to 5 T, which was a novel design for providing a high field based on a semi-open split NbTi superconducting magnet. A relatively large space for samples under a transverse high field was achieved, it also makes feasible for a non-contact optical technology of DIC for full-field deformation measurements. However, when the semi-open split superconducting magnet is exposed to a high field, the large deformation against attraction from electromagnetic forces arises due to its configuration without any external support rod. A big challenge is confronted to propose a support structure for bearing the large attraction and keeping a stability configuration under operation conditions within its tolerable deformations to prevent a quenching.

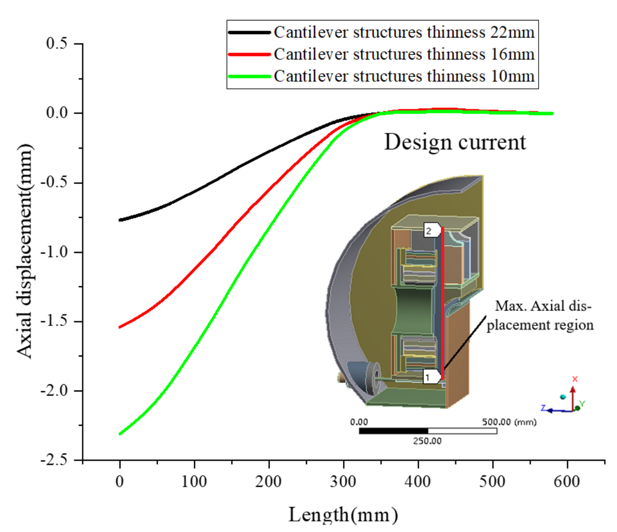


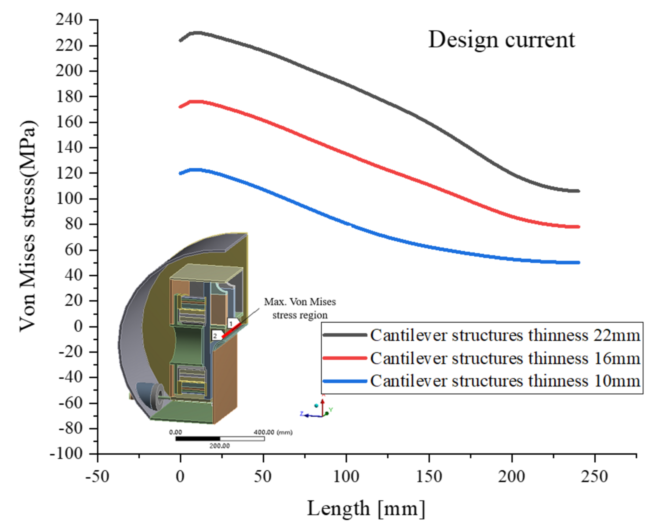
The schematic drawing and specifications of semi-open split NbTi superconducting structure

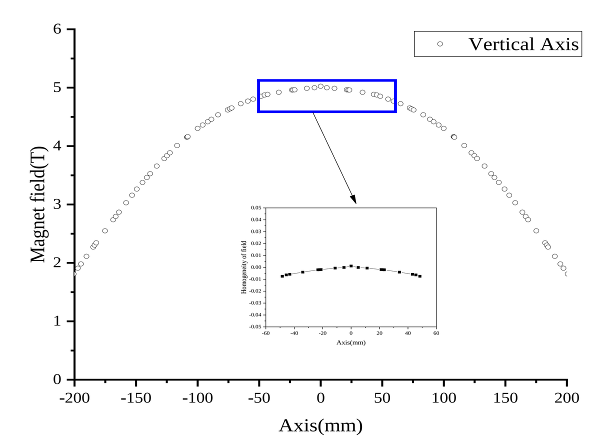
Numerical modeling and Experimental detail

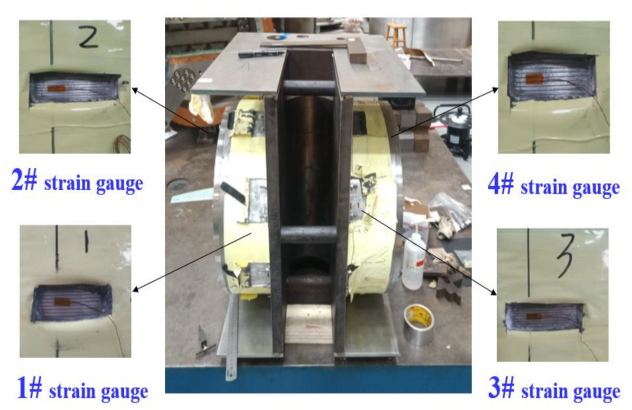


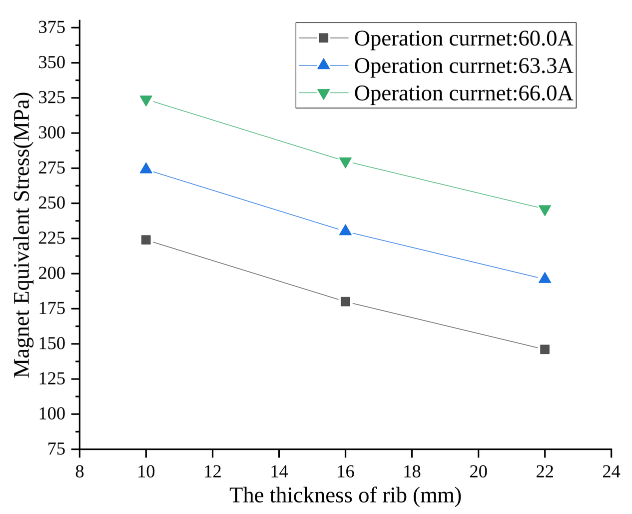


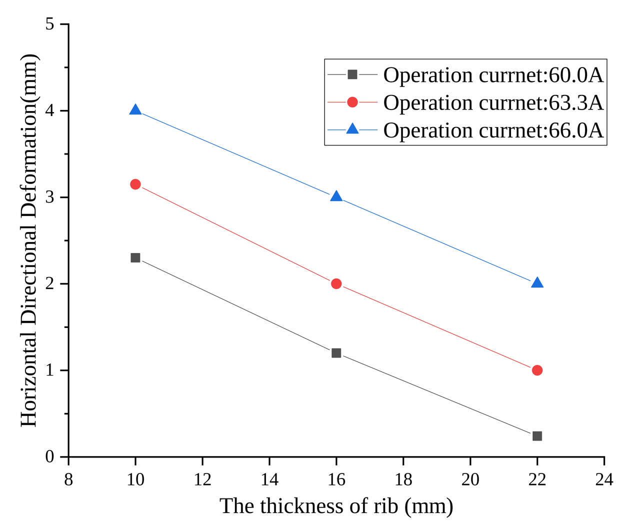




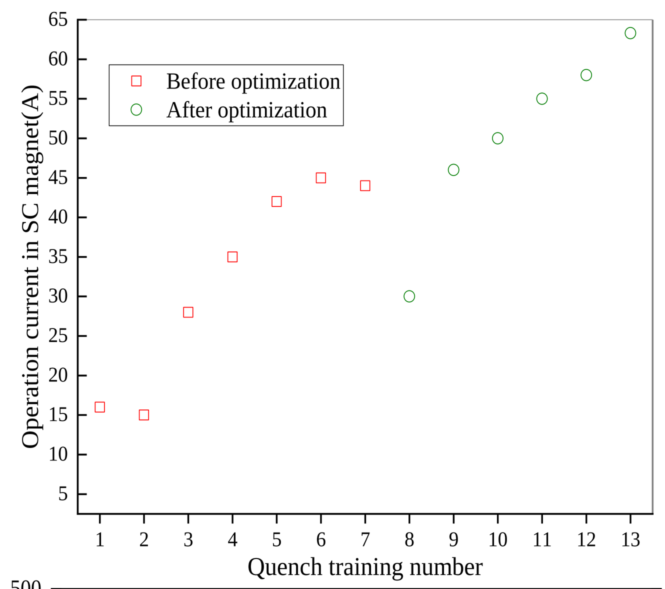


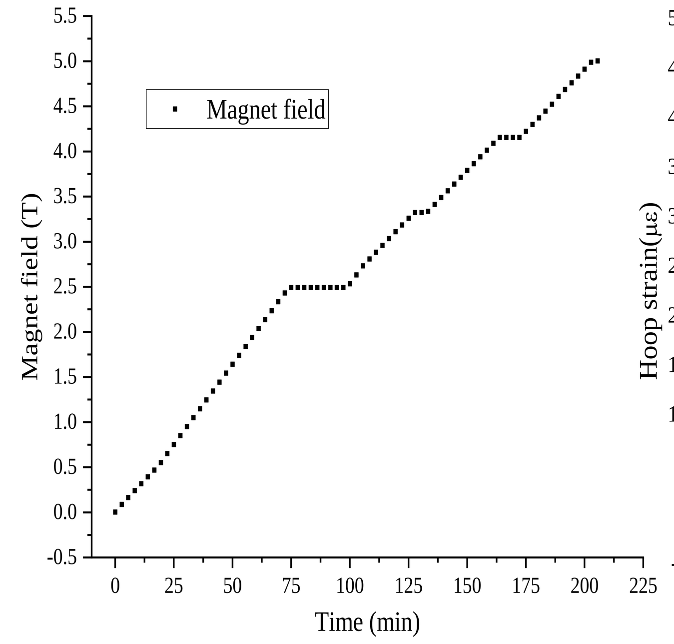


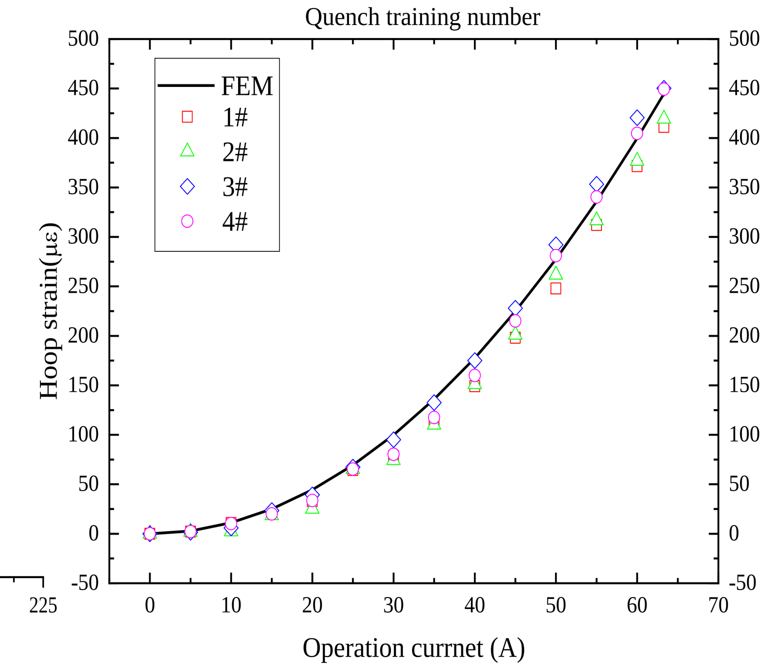




Measurements and discussion







In order to investigate performance of the coils with and without internal stainless-steel cantilever structures, the whole superconducting magnet were tested in a bath of LHe for quench training. When the structure without internal stainless-steel cantilever structures,

The strain measurements at the four positions at the four at the four positions show good consistency due to axisymmetric deformation of the solenoid during its excitation, this is because their deformation is axisymmetric, the hoop strains at four locations showed similar responses. During the excitation process, the FEM simulations also give quite good predictions and are a little lower than experiment measurements due to the internal turn-to-turn friction of superconducting coils. This phenomenon can be clearly demonstrated that the new reinforcing structure is effective in reducing the axial deformation and increasing magnet's stability during its assembly and excitation

Conclusion

In this paper, we show a new deformation sharing structure for the full open split superconducting magnet system which was used for a versatile multi-field test facility. Based on finite element method considering contact nonlinearity, the structural analysis was performed to clarify the mechanism of the deformation sharing between the coil winding and reinforcing internal cantilever structures. The numerical simulations show the proposed internal reinforcing cantilever structure can share effectively structure's stress and axial displacements, the maximum electromagnetic stress and axial displacements on the split magnet structure are reduced to 35% and 75%, respectively, due to the existence of stainless-steel cantilever structures. We also analyze in detail the effects of stainless-steel cantilever structures thinness on structural peak axial deformation in the split superconducting magnet for its assembly. Finally, the optimized split superconducting magnet was assembled and tested. After 12 times quenching training, it can reach successfully central field of 7.8T@ 63.3A. During the transport current excitation process, the FEM simulations on hoop strain also give quite better predictions comparing with measurements. This phenomenon can be clearly demonstrated that the new reinforcing structure is effective for increasing the split superconducting magnet's stability during its operation.

Acknowledge

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