Mechanical Responses of a Combined Support Structure for a Nb_3Sn Sextupole Magnet During Assembly and Temperature Cycle

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Introduction

At IMP in Lanzhou, China, a new fourth-generation ECR ion-source with frequency up to 45 GHz, designed with a Nb_3Sn superconducting sextupole-in-solenoid configuration, was built for the injected beam intensity requirements of the High Intensity Heavy Ion Accelerator (HIAF) . To accomplish the expected field range and warm bore size, an axial magnetic-field confinement is provided by four superconducting solenoids, and the plasma path is configured by the sextupole coils .

In this paper, a combined support structure was developed with an aluminum pre-tensioned shell, temporary bladders and load keys to generate a transverse pressure loading larger than 150 MPa on the six Nb_3Sn sextupoles. During the all pre-loading stages, the strain profile measured by low-temperature resistance strain gauges was obtained, which is compared to the FEM predictions. It was observed that a sufficiently high-pressure with fine homogeneity is produced over the coil surface. For comparison, **the stress/strain states of the sextupole structure restrainted with and without the combined support structure were also measured.**

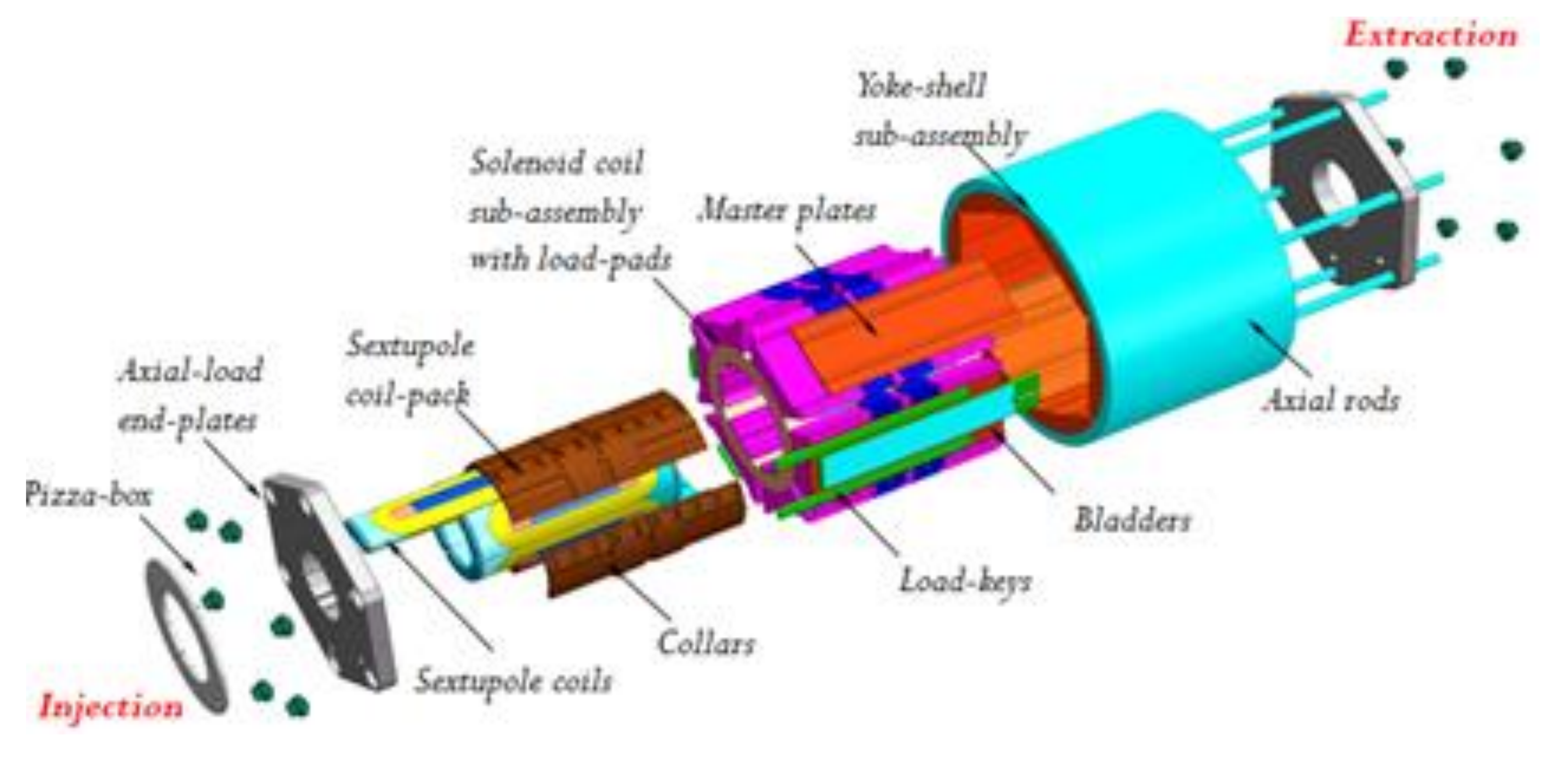


Fig 1. The combined support structure of sextupole-in-solenoid configuration and its assembly diagram

Fatigue performance test

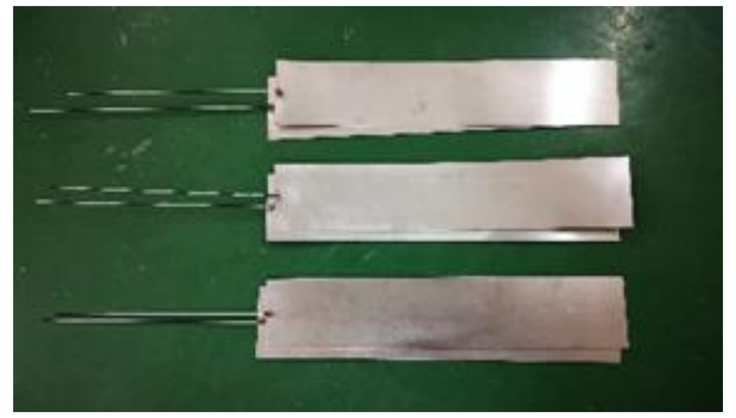


Fig 2. Home-made bladders with stainless-steel sheets by continuous laser welding

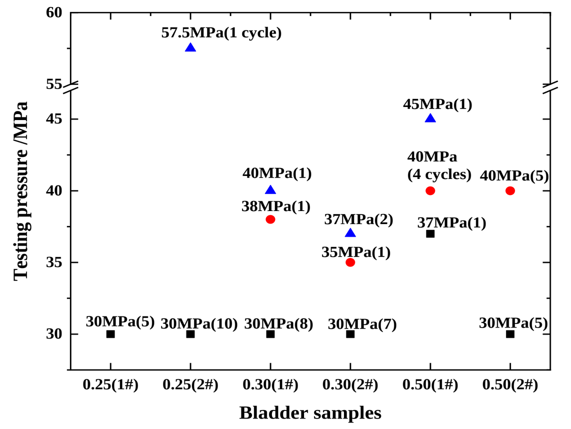


Fig 3. Fatigue properties of the bladder samples with different thickness for pressurization-deflated cycles

FEM Analysis and Assembly

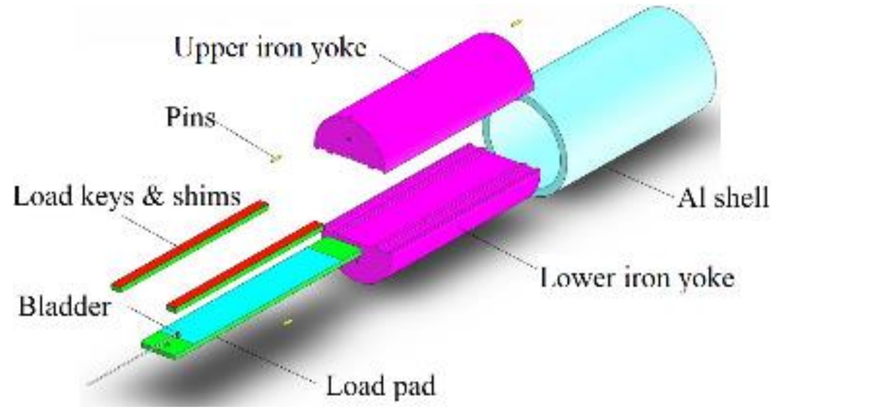


Fig 4. Assembly of support structure with iron dipole dummy structure

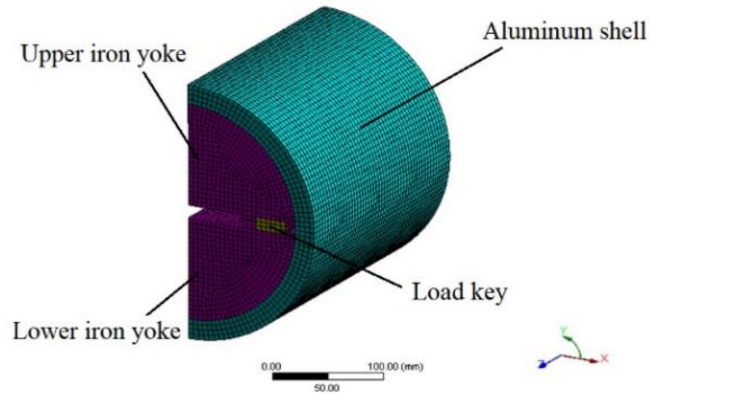


Figure 5. A 1/4 scale three-dimensional FEM model

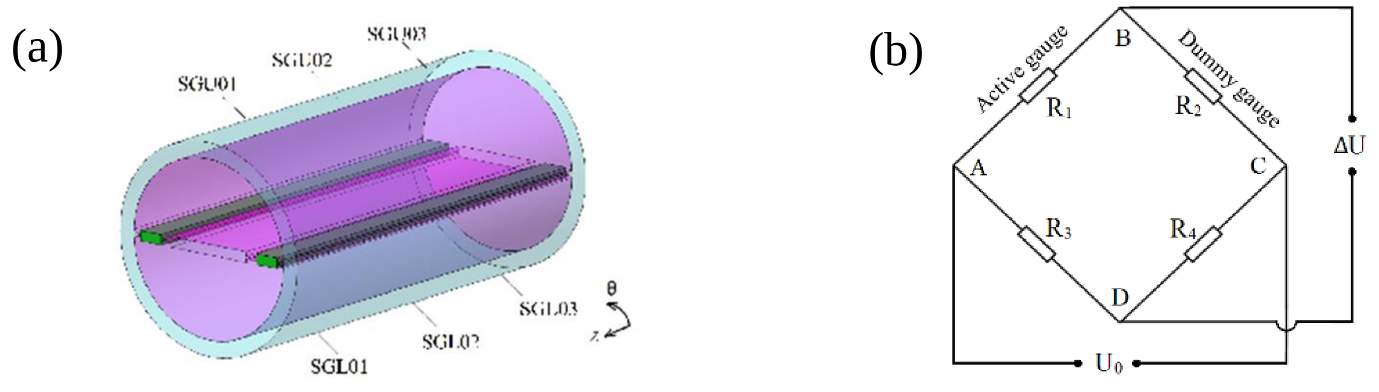


Fig 6. Schematic illustration of strain gauge sensors for aluminum shell(a), Wheatstone bridge circuit consisting of work gauges and compensation one (b).

Results and discussion

The experiment on the assembly process by the support structure with pre-loading from the temporary bladders and load keys were conducted. The measurements during the process and some predictions were presented in this section

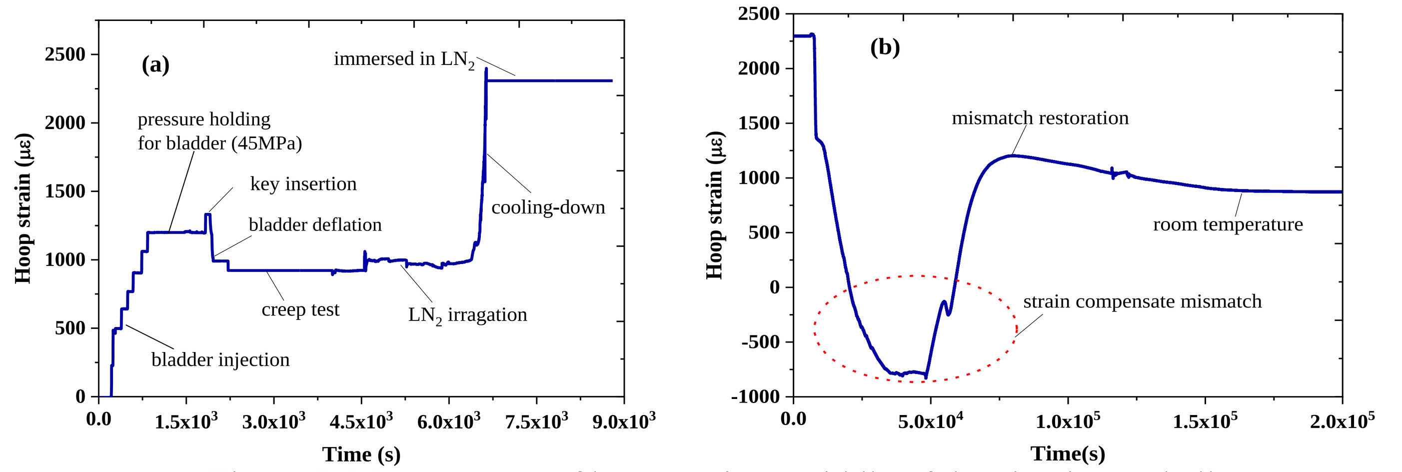


Figure 7. Measurement of hoop strain at middle of the aluminum shell: (a) during assembly process bladder injection, key insertion and bladder deflation and cooling-down; (b) during warming-up

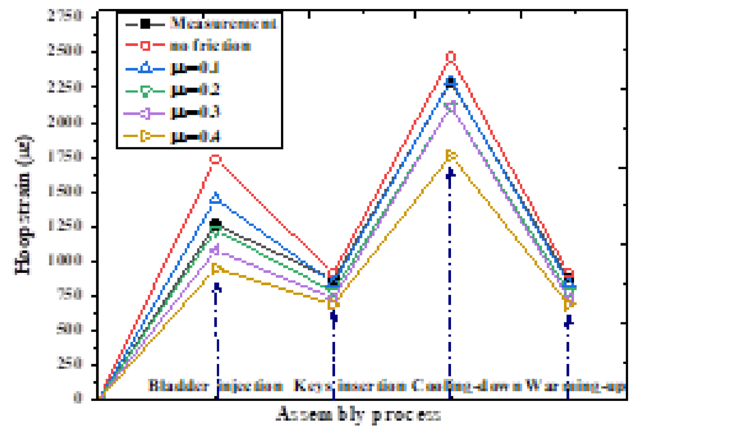
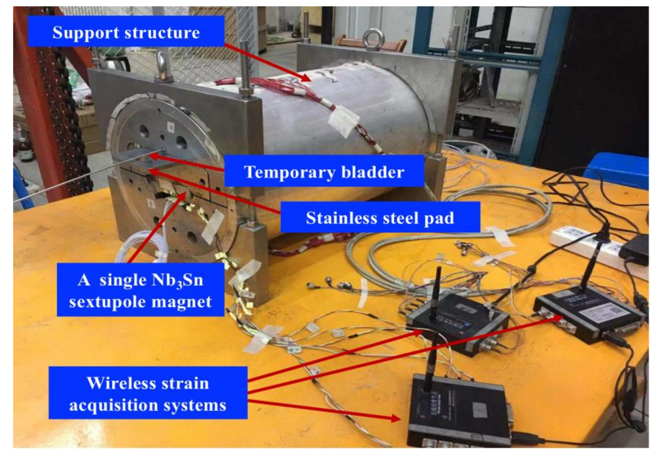


Figure8. Aluminum shell hoop strain during loading, cooling down and warming up with dummy coils



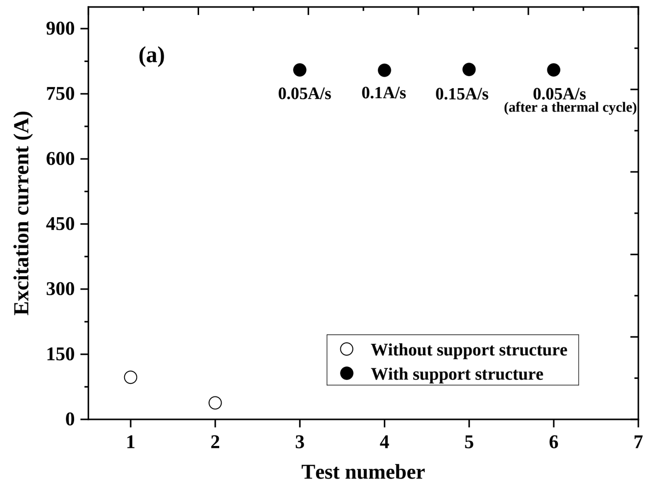


Figure.9 Operation current during a Nb3Sn sextupole excitation test for with and without the support structure

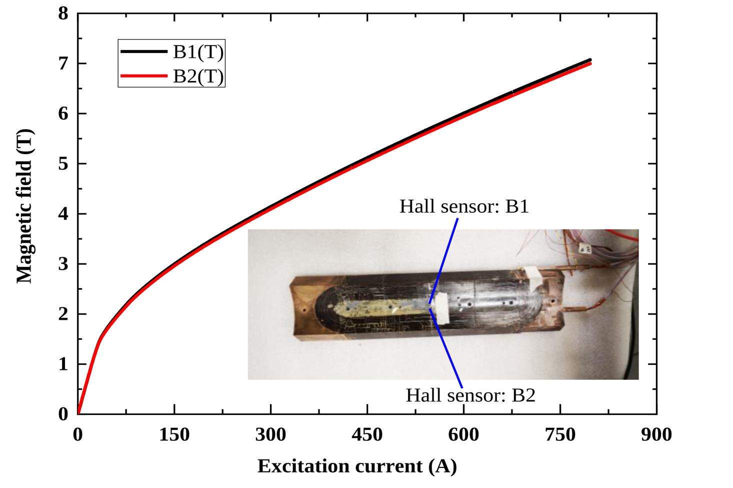


Figure 10 Operation current-magnetic field line during a Nb3Sn sextupole with the support structure

As a result of successive test, the **strain** on aluminum shell, during bladder operation, key insertion and bladder deflation, cool-down and warming up, was measured to estimate pre-stress state comparing with some key simulations.

Conclusion

In this paper, we show the design and test of a support structure for the sextupole magnet's assembly procedure and pre-stress operation. The use and anti-fatigue properties of home-made high-pressure bladders during the assembly and cooling down were also demonstrated. The technology based on a hydraulics system and bladder can carry out a well-controlled pre-stress level to magnet structure regardless of is tolerances. Targets for the room-temperature bladder operations and cooling down were carried out to prevent separation of the coils during operation and a quenching. As a result of successive test, the strain on aluminum shell, during bladder operation, key insertion and bladder deflation, cool-down and warming up, was measured to estimate pre-stress state comparing with some key simulations. The support structure has also been used to house a Nb_3Sn sextupole magnet under 20MPa pressure at room temperature. Then it was tested reaching expected field of 7 T@805A at 4.2K. The Nb_3Sn magnet with the support structure was also tested well at different excitation rate.

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