3D Mechanical Design and Stress Analysis of LPF2: a 12-T Hybrid Common-coil Dipole Magnet

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Abstract

The Institute of High Energy Physics (IHEP, China) has been engaged in the development of shell-based dipole magnet with Common-Coil configuration for the pre-study of Super proton-proton Collider (SPPC) project. The first subscale magnet named LPF1, with two Nb_3Sn coils and four NbTi coils, reached a bore field of 10.2 T at 4.2 K. Then a higher safety margin model has been proposed as LPF2, which has six Nb_3Sn coils and two NbTi coils to reach a 12-T main field in both apertures with an operating current of 5300 A. The pre-loaded method of LPF2 is : using Bladder & Key technology to overcome the Lorenz force in horizontal and vertical direction and pre-tightening six aluminum rod to pre-load the coil packs in the axial direction. While, the strain gauges are applied at the surface of the aluminum shell to monitor the pre-loading effect. The main design parameters and stress analysis results will be presented.

Magnet Design

Details about the electromagnetic design and coils fabrication of LPF2 will be reported in :

Tue-Mo-Or7-05: *<u>Electromagnetic design, fabrication and test of LPF2: a 12-T hybrid common-coil dipole magnet with inserted IBS coil.</u>*

TABLE I
MAIN DESIGN PARAMETERS OF LPF2 MAGNET

Parameter	Unit	Value
Designed operating current	A	5300
Safety margin	%	22
Operating temperature	K	4.2
Peak coil field	T	12
Outer diameter of magnet	mm	620
Outer diameter of yoke	mm	500
Spacing between two bores	mm	180
Lorenz force F_x for 1/8 coil model	kN	786
Lorenz force F_y for 1/8 coil model	kN	173
Lorenz force F_z for 1/8 coil model	kN	115

Mechanical Structure

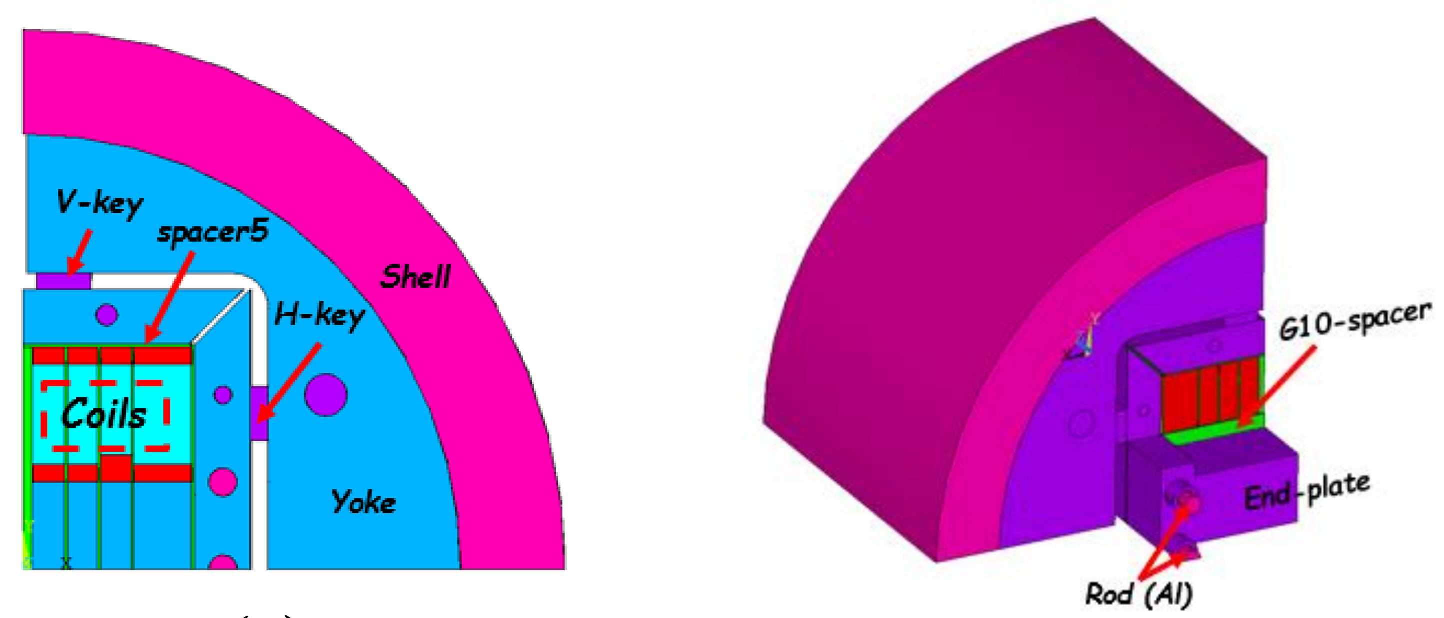
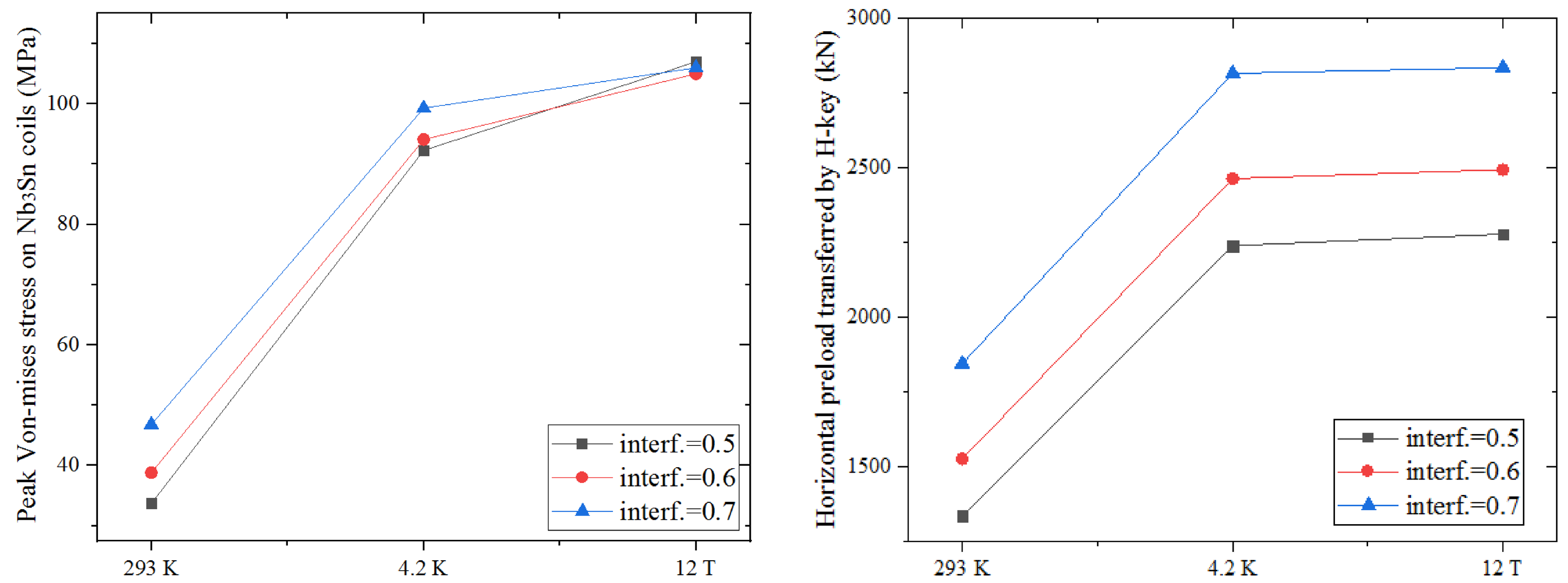


Fig. 1 (a) cross-section of LPF2 magnet; (b) 1/8 mechanical FEA model

Mechanical Analysis

Interference contact pair is created between yoke & H-key to compute the Bladder & Key pre-tightening process; sliding contact pair is created between the yoke and shell to reflect the shrinking of the aluminum shell during the cooling down process.

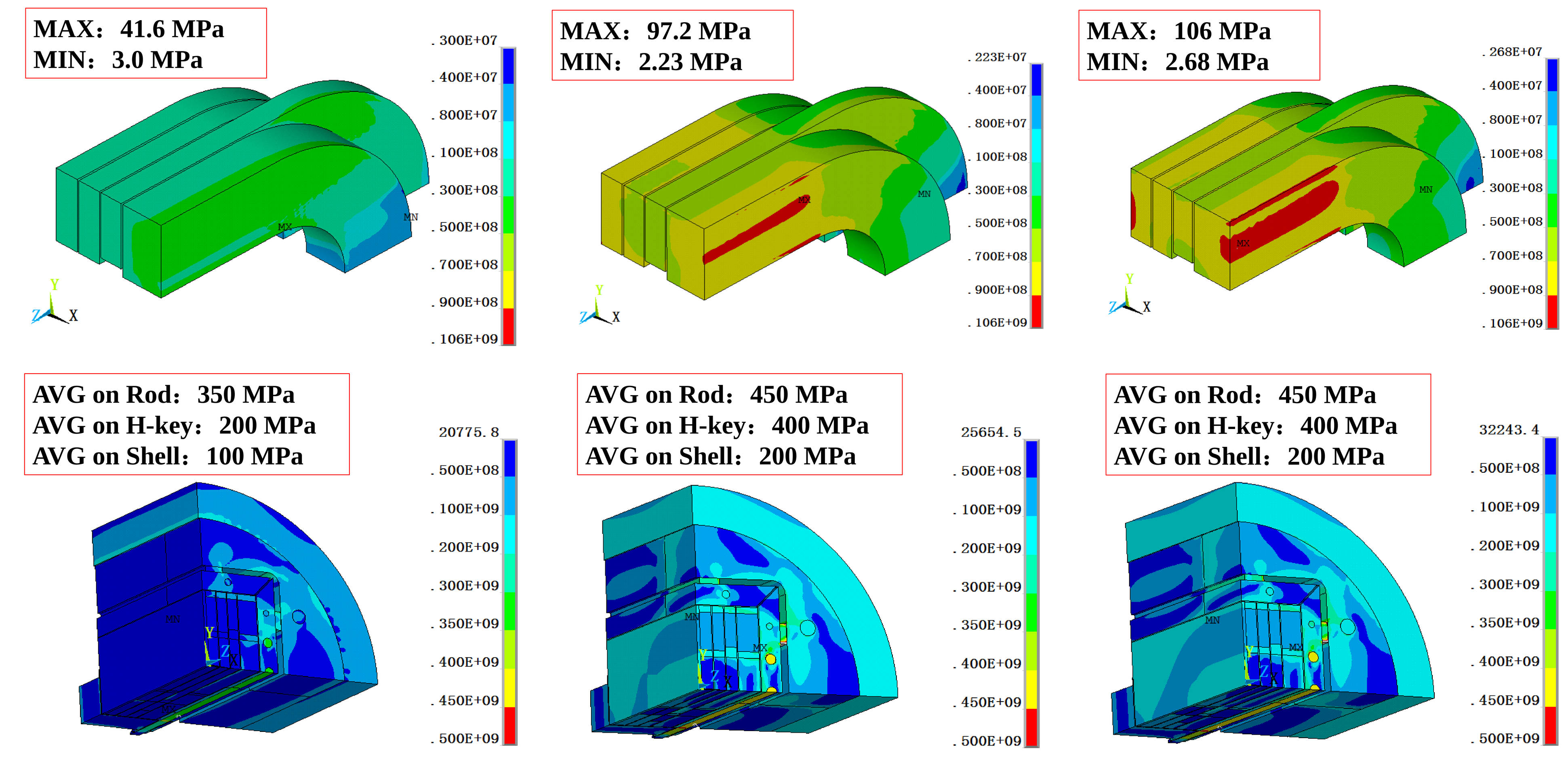


(a) **(b)**

Fig. 2. (a) Peak Von-Mises stress in Nb_3Sn coils under different interference value; (b) Horizontal preload transferred by H-key under different interference value.

TABLE II
SIMULATED PRE-LOAD FORCE AT EACH STEP(INTERF.=0.6 MM)

	Assembly	Cooling down	Excitation
Horizontal preload force transferred by H-key	1,528 kN	2,464 kN	2,494 kN
Vertical preload force transferred by V-key	708.4 kN	1,033 kN	1,039 kN
Axial preload force provided by AL-rod	91.5 kN	123 kN	124 kN



Assembly **Cooling down** **Excitation**

Fig. 3. Von-mises stress on Coils and magnet at each step (interference=0.6 mm)

Table II and Fig.3 shows the calculation results at each step of one selected simulation case: the interference value of 0.6 mm is defined between H-key and yoke. The pre-stress force of each direction after cooling down step is enough to overcome the Lorenz force. The forces change little after excitation, which is another proof of applying enough pre-loading force to the coils. The stress level on Nb_3Sn coils is acceptable, and stresses on other assembly parts are within limits.

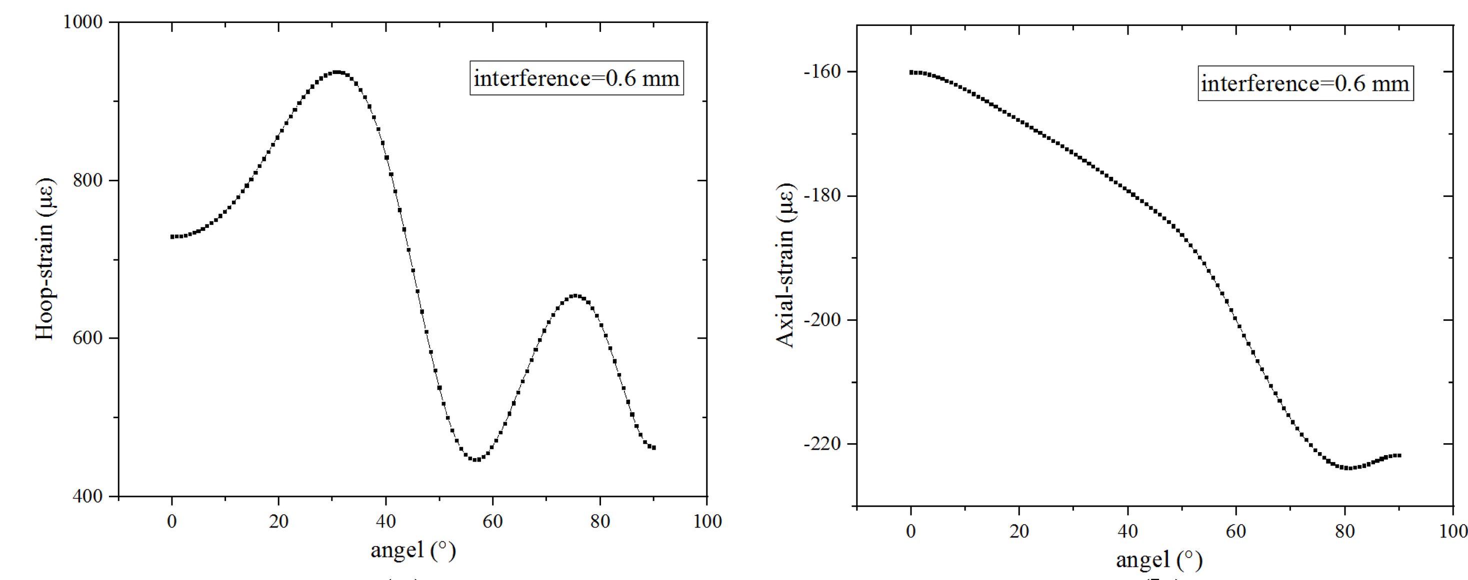


Fig. 4. (a) Simulated Hoop-Strain results at the mid-plane with the interf.=0.6 mm; .

(b) Simulated Axial-Strain results at the mid-plane with the interf.=0.6 mm;

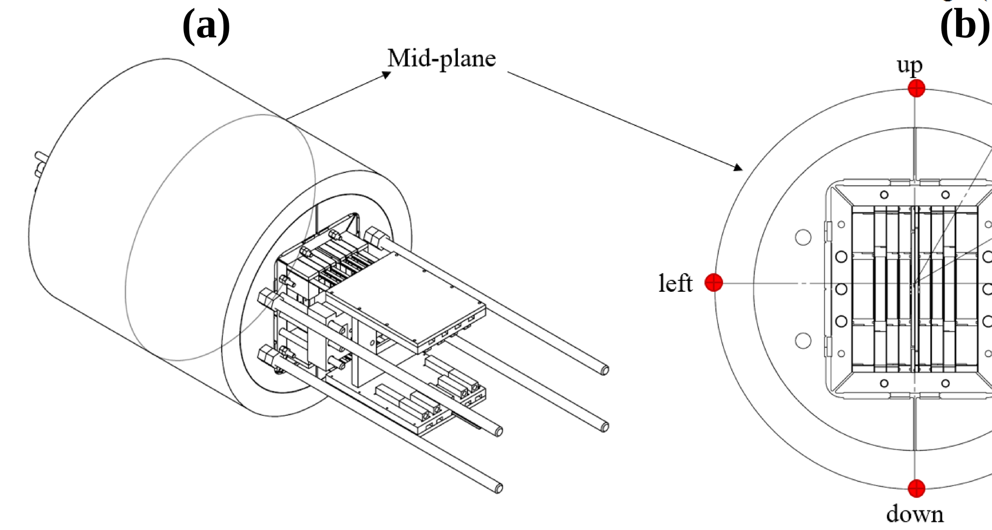


Fig.5 Strain measurement positions.

summary

A new shell-based dipole magnet LPF2 with Common-Coil configuration has been proposed. Stress analysis has been made, the proper pre-load force can be given by the Bladder & Key technology and the stress distribution on coils and other assembly parts are reasonable.

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