Development of the Helium Inlet for CFETR Central Solenoid Model Coil

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1. Introduction

CFETR (China Fusion Engineering Test Reactor) CS (Central Solenoid) model coil made with CICC (Cable in Conduit Conductor) superconductor had been developed in Institute of Plasma Physics, Chinese Academy of Sciences. The highest field of CS model coil is 12T when the running current is 47.65KA at 4.5K, and the largest magnetic field change rate is 1.5 T/S. CS model coil mainly consists of one Nb3Sn inner coils, one Nb3Sn outer coils and three NbTi coils cooled by supercritical He flow. There are totally 10 helium inlets & outlets distributed in CS model coil. Due to the geometrical discontinuity within the helium inlet & outlet, the helium inlet area is one of the regions where high stresses can be expected in the CFETR CSMC.

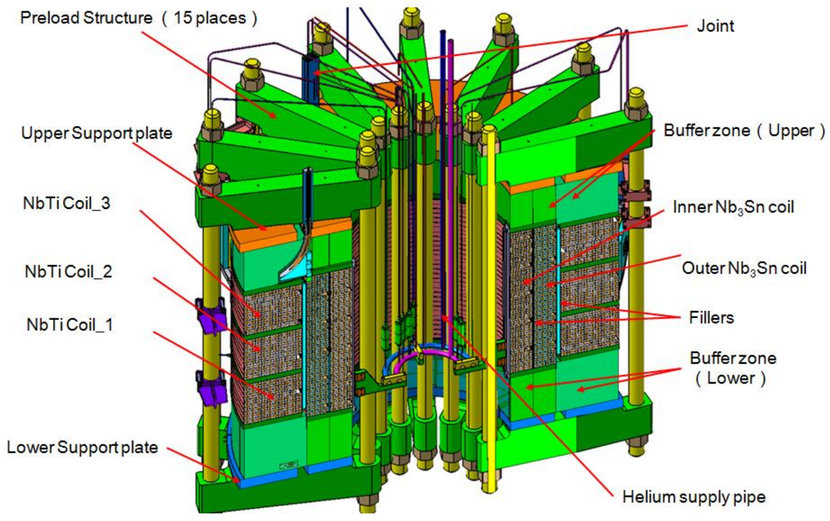

Figure 1. CFETR CS Model Coil Configuration

2. Structure of helium inlet

We design the weld groove of helium inlet as shown in Fig.2, it is a full penetration weld. In it's simplest form, delivering He flow to the ID turn is achieved by drilling a hole through the conduit wall, and reinforcing the hole with a heavy-wall boss.

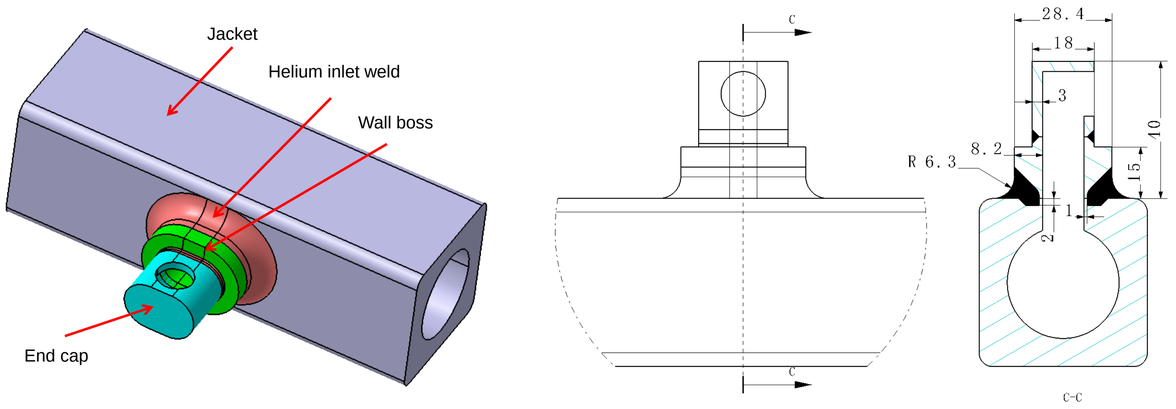

Figure 2. Main size and feature of CSMC

3. FEA model

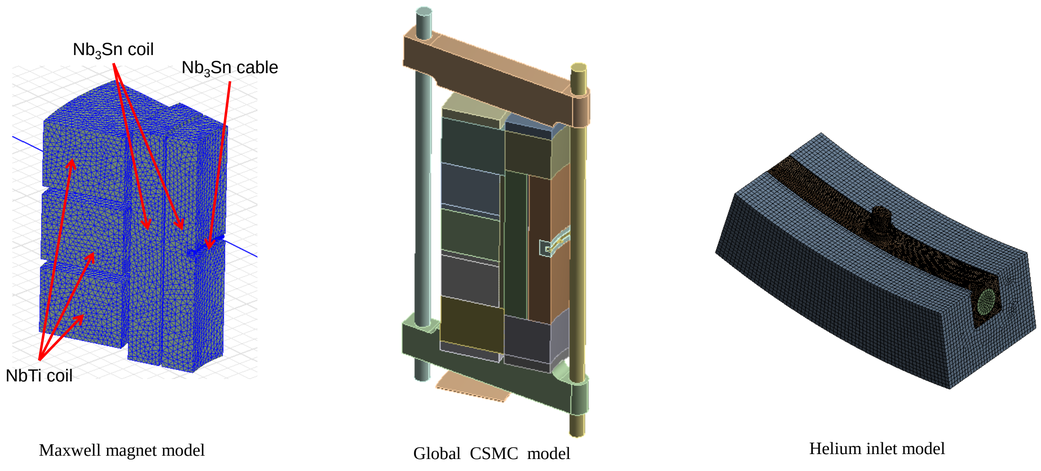

Figure 3. Finite element model of CSMC

To investigate the mechanical property such as static and fatigue assessment, the FEA model of helium inlets located in the highest magnetic field were created based on ANSYS in which the sub-model technique was used. The electromagnetic load in the WP and cable were calculated by the 1/15 magnet model with Ansoft Maxwell.

4. Static assessment

Table 1 The assessing criterion and stress limits

Tresca stress	Symbol	Limits
Membrane (local)	Pl	1.3*Sm
Membrane + bending	Pm+Pb	1.5*Sm
Total	Pm+Pb+Q	1.5*Sm

Generally, there is Sm =2/3Sy. The yield stress of 316LN at 4.2 K is 900 and 600 MPa respectively. The maximum stress intensity is 661.8 MPa and occurs in the bottom of the helium hole in the jacket. The maximums stress occur in weld toe is about 402 MPa. Stress linearization was performed at the location with the highest intensity. PL is 195.6 MPa, Pm+Pb is 434.4 MPa and P+Q is 661.6 Mpa. All linearization stress can meet the allowable values.

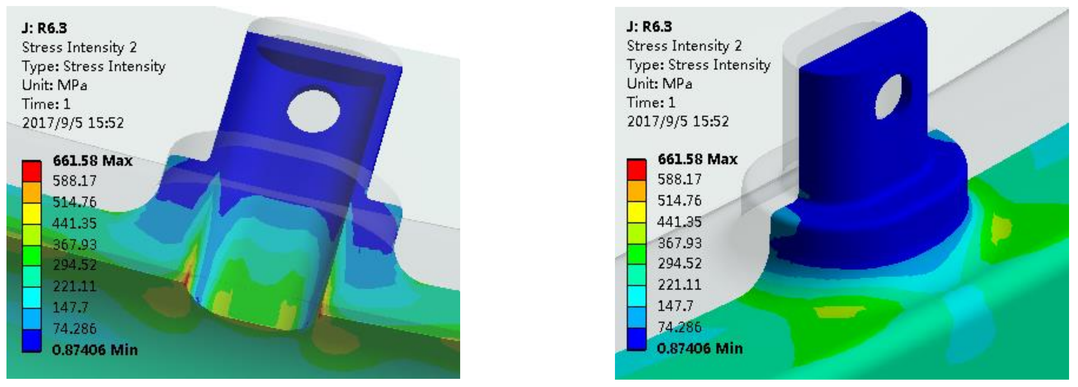

Figure 4. Stress intensity of helium inlet

5. Weld R&D

In weld R&D activities, helium inlet hole drilling and stainless steel wrapping removal were carried out. Helium inlet welding with full penetration by manual argon arc welding was performed, temperature measurement during welding was implemented and was under 250℃. Penetrant test, x ray test and leak test were applied to ensure no defect was exist.

A. Weld trails

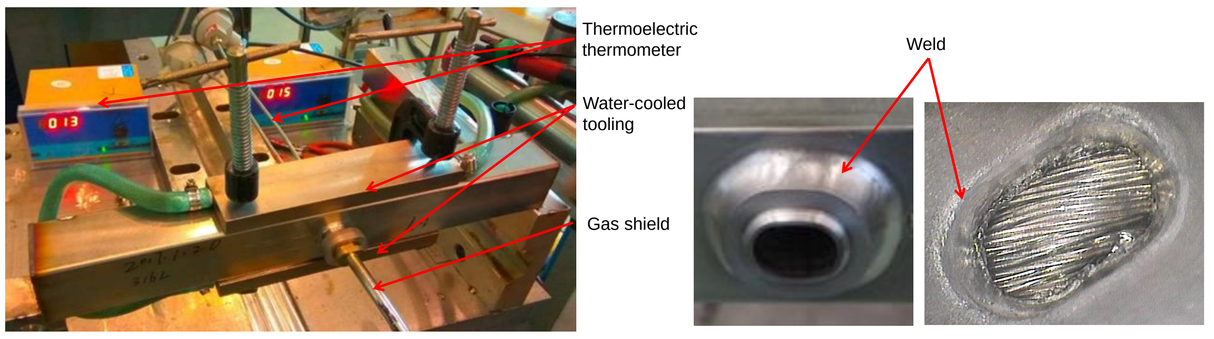

Figure 5. Sample welding and visual appearance

Welding trials of 316LN and 316L samples were carried out and welding parameter is determined. Three weld samples of 316LN and 316L were welded respectively.

B. Weld certification

Figure 6. Tensile and bend test

Table 2 Tensile test result

	316LN sample 1#	316LN sample 2#	316L sample 1#	316L sample 2#
UTS(MPa)	581	577	563	552

According to ASME IX QW451, tensile and bending test need to be carried out to assess weld. A groove-weld was used to instead the fillet welds to carry out the tensile and bending test based on ASME IX QW202.2. For tensile test, fractures occur at the weld. Ultimate tensile strength of all samples can meet ASMEⅡSA-213 (485 MPa for 316L and 515MPa for 316LN at RT). For bending test, all of specimens are no defects. The welds are qualified.

C. R&D of X ray test

To verify whether the feasibility of x-ray test scheme, the x-ray trials on the standard sample with two types artificial defects (φ0.5*1mm hole and 2*1*0.5mm rectangular slot) have been carried out.

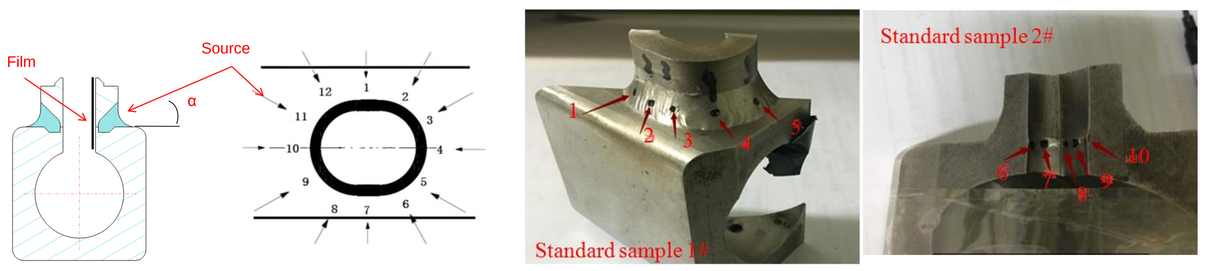

Figure 7. Schematic diagram and standard sample for x ray test

Film is inserted into helium hole as shown in above. In order to test the whole circle weld, every weld need to be X- rayed 12 times. The all artificial defects can be found in the film after the trails.

6. Conclusion

A reasonable design of helium inlet for CSMC is presented based on static assessment. The welding R&D activities, including welding trails, destructive test and NDE were carried out successfully to develop welding technology for helium inlet.

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