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Conceptual Mechanical Design and Analysis of CEPC Detector Magnet

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Abstract

A large-scale low-temperature superconducting magnet is proposed for the future detector of Circular Electron Positron Collider (CEPC) at the Institute of High Energy Physics, Chinese Academy of Sciences (IHEP,CAS). The central magnetic field of the magnet is 3 Tesla, the length, inner and outer diameter of the magnet is 9.05 m, 7.07 m and 8.47 m， respectively. The weight of the cold mass is about 185 t. This poster presents the mechanical design of the support structure of the cold mass and the cryostat of the magnet.

Introduction

The Circular Electron Positron Collider （CEPC）is a large scientific project proposed by the Institute of High Energy Physics, Chinese Academy of Sciences (IHEP,CAS) in China. The detector of the CEPC needs a 3 Tesla central magnetic field superconducting solenoid. The coil of the magnet is supported by an aluminum alloy cylinder and cooled indirectly by liquid helium to an operating temperature about 4.5 K. Aluminum stabilized NbTi/Cu Rutherford cable is choosed to wind the coil. A room temperature bore is required with 7.07 m in diameter and 9.05 m in length. This poster presents the mechanical design of the magnet.

3D Structure Design

The mechanical structure of the detector magnet consists of vacuum tank, thermal shield, cold mass support. Figure 1. shows the structure of the magnet. Figure 2. shows the internal detailed structure of the magnet. Some parameters of the detector magnet are listed in Table 1. The vacuum tank, made of stainless steel, is installed in the barrel yoke. It houses and supports the superconducting coil.

Two chimneys are situated near the top of the vessel. Their purpose is the following:

i) the smaller chimney contains the cryogenic lines, maintaining the solenoid below 5 K during operation.

ii) the bigger one, contains the electrical leads, and is also used as the main pumping and venting line.

The thermal shield, made of 5083 aluminum, encloses the superconducting coil inside the vacuum tank.

The coil is suspended in the vacuum tank by titanium alloy rod. In order to ensure that the magnet operates stably, the heat leakage should be minimized.

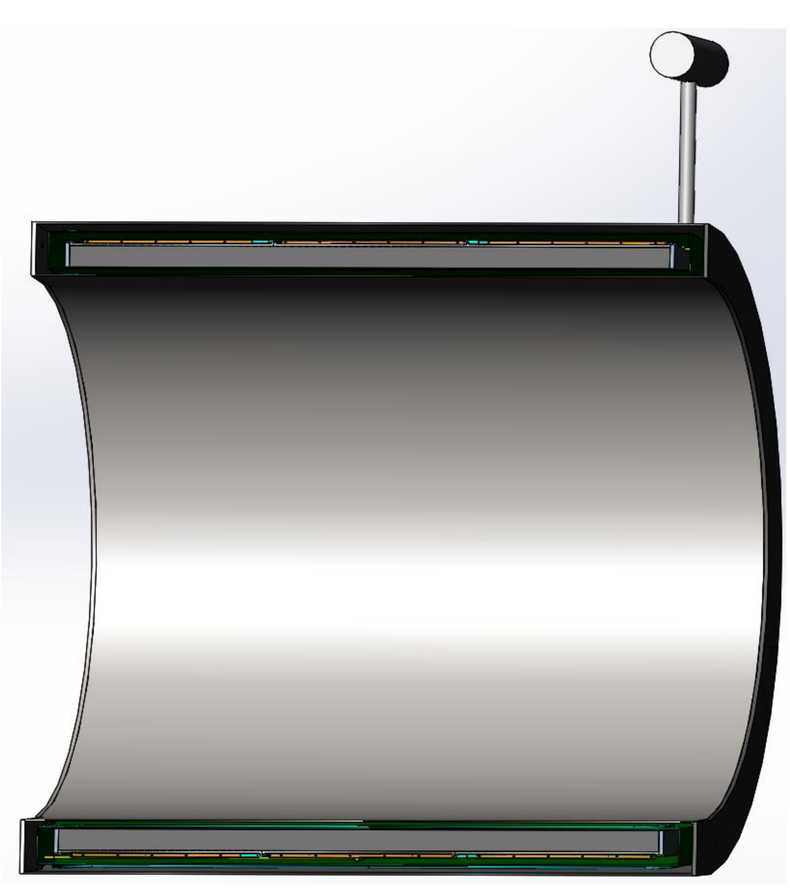


Fig. 1. Structure of the detector magnet

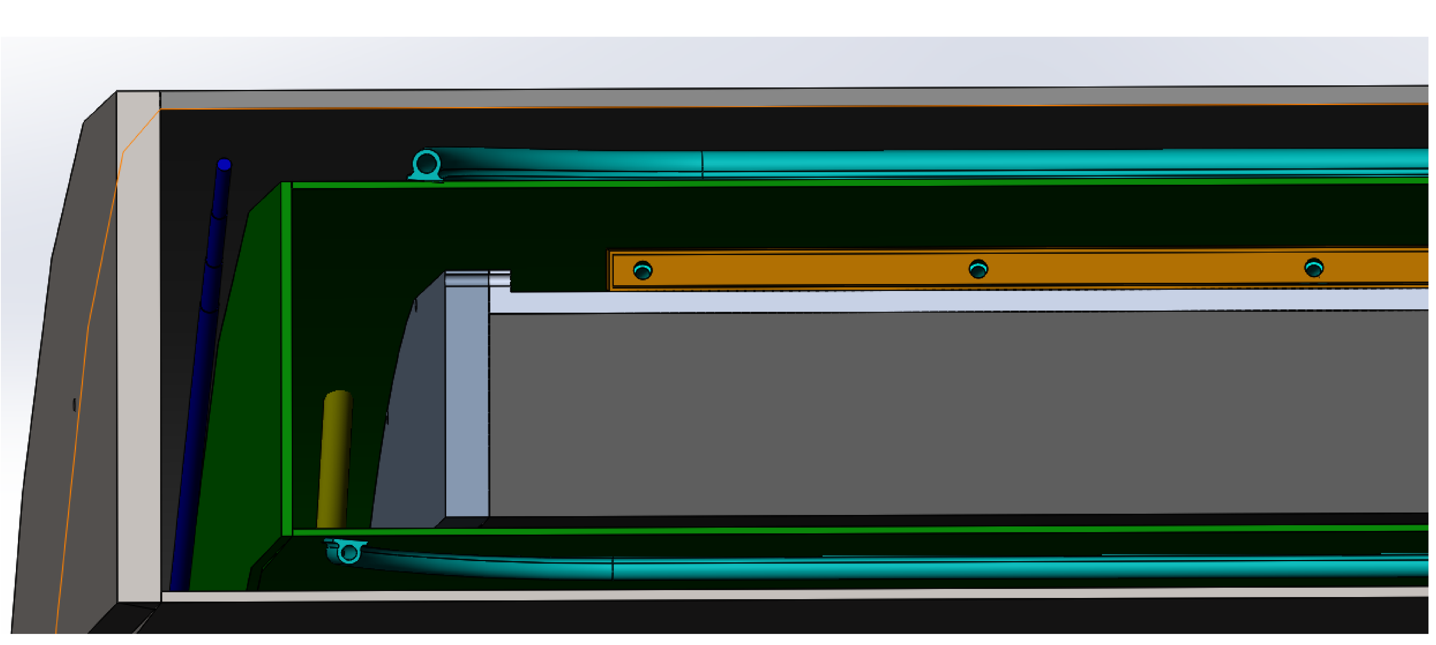


Fig. 2. Internal detailed structure of the detector magnet

Table 1. Parameters of the detector magnet

	Inner Diameter (mm)	Outer Diameter (mm)	Length (mm)
Vacuum tank	7070	8470	9050
Coil	7300	7916	8150

Suspending structure of coil

The coil suspend system has to ensure a precise and stable suspension of the cold mass inside the vacuum tank. The loads are the self-weight of the cold mass，the magnetic forces due to the decentering of misalignment of the coil with respect to the return yoke. The suspend system consists of a set of rods made of titanium alloy There are a total of 28 radial and axial rods, half at each end. Figure 3. shows the layout of the rods and the cold mass. Table 2. lists the parameters of the titanium alloy rods.

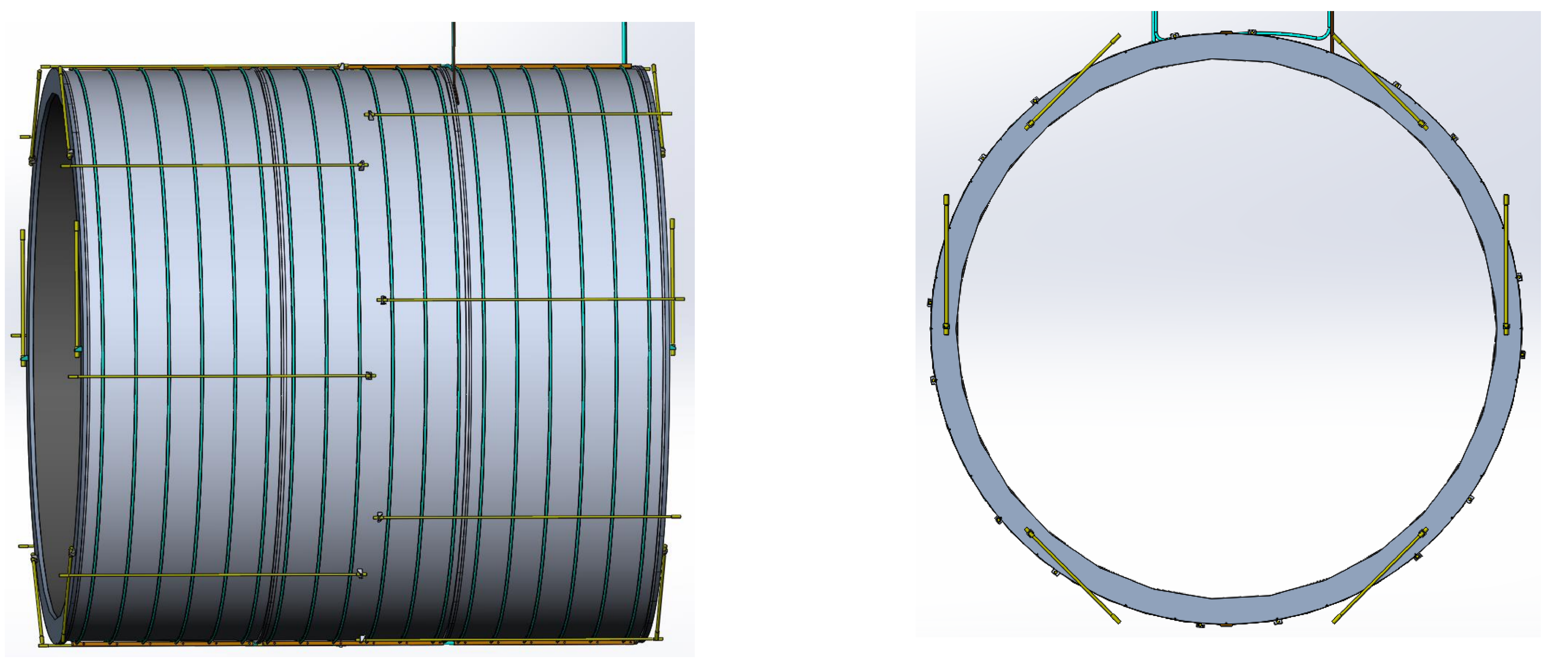


Fig. 3. Layout of the rods and the cold mass

Table 2. Parameters of the titanium alloy rods

Item	Diameter (mm)	Length (mm)	amount	Screw
Axial rods	30	3530	16	M36×3
Radial rods	40	1700	8	M48×4
Main pull rods	48	1650	4	M56×4

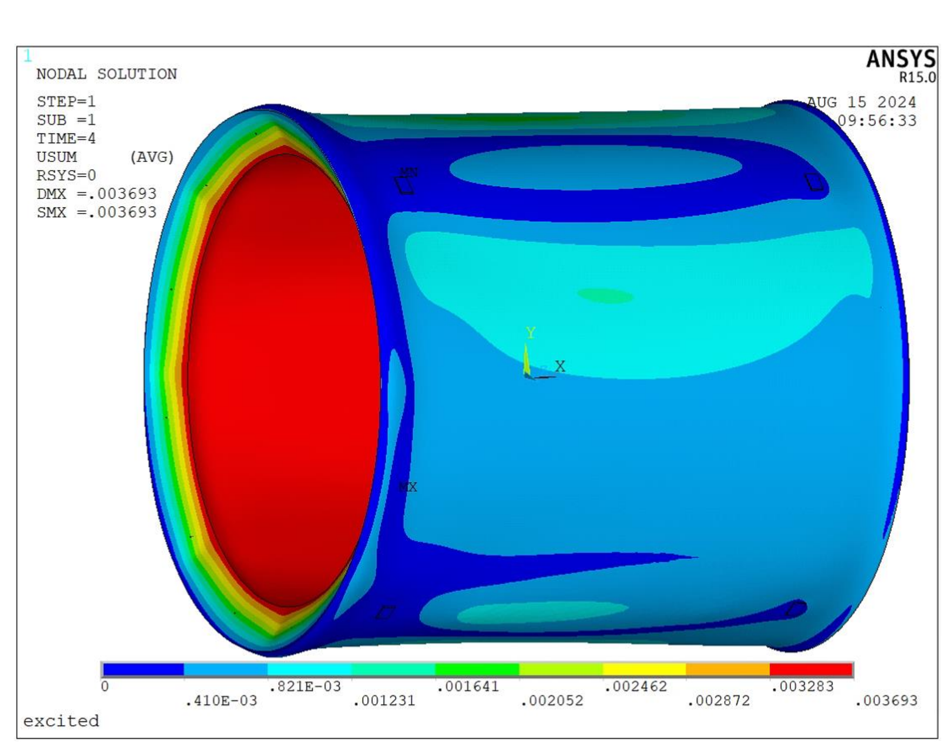
Vacuum tank Structure Analysis

The vacuum tank consists of two concentric cylindrical shells connected through structural welds by two end flanges. It must resist the huge electromagnetic force caused by cylindricity error and the decentering of misalignment of the solenoid when the magnet is excited, with respect to the return yoke, the pressure difference between inside and outside of the vacuum tank after vacuumed and the weight of the cold mass of the magnet. The calculation takes into account a 1.5 g acceleration in x and z direction(axial direction) and 2.5 g acceleration in y direction in the course of moving the magnet. Table 3. lists the electromagnetic force caused by misalignment.

According to the design guide of the cryogenic pressure vessel, the buckling stability and the mechanical strength is analyzed by using theoretical calculation and FEA. The thickness of the inner cylindrical shell is 15mm, the outer one is 25mm, and the end flanges is 60 mm. Figure 4. and figure 5. shows the deformation and stress distribution of the vacuum tank under maximum load and vacuum pressure.

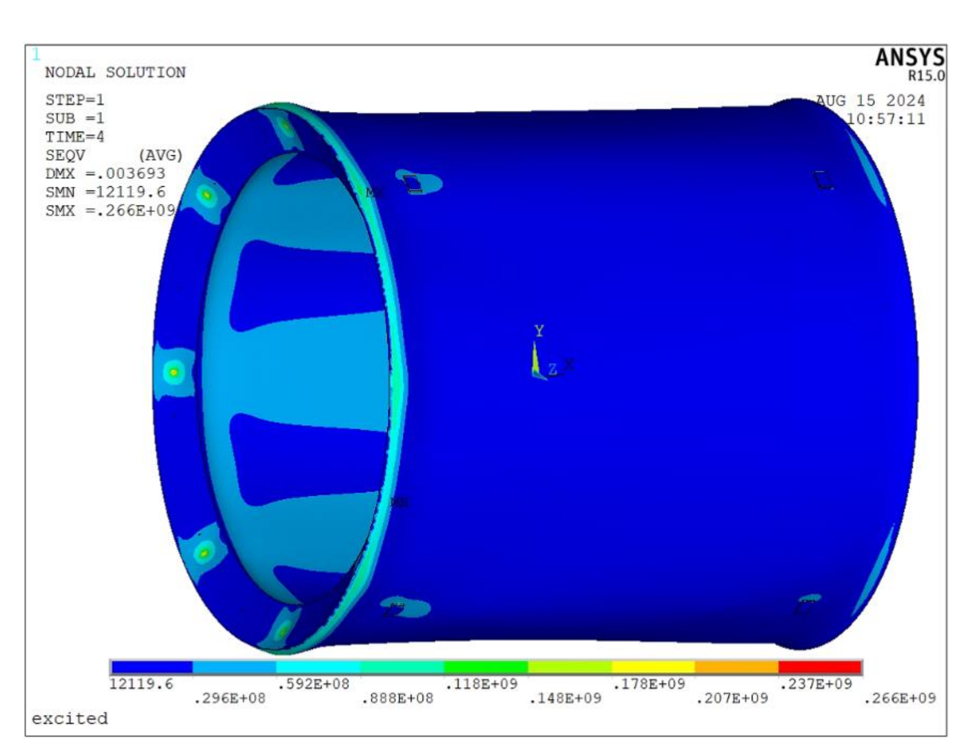
Table 3. Induced loads of misalignment of solenoid

Misalignment of solenoid	Z(X,Y) 1 cm Rotation 0.14 rad	Z(X,Y) 3 cm Rotation 0.42 rad	Z(X,Y) 10 cm Rotation 0.14 rad
Displacement in Z direction（kN）	484	1498	5034
Displacement in X(Y) direction（kN）	34.3	236	656
Rotation around X Torque（kN•m）	1965	6170	19935



Usum $_{max}$=3.69 mm

Fig.4. Deformation distribution of vacuum tank.



Seqv $_{max}$= 266 MPa

Fig.5. Stress distribution of vacuum tank.

Conclusions

The results of 3D structure analysis show that the maximum stress on the vacuum tank is 266 MPa, when the inner and outer cylindrical shells is 15 mm and 25 mm, respectively. The maximum stress is larger than the allowable stress of stainless steel. There are stress concentration points at the eight fixed positions. Nest step more fixed positions shall be added.