Design and manufacture of Solenoid center deviation measurement device

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Background

China Spallation Neutron Source (CSNS) is the first large scientific facility in southern part of China. The project construction started in 2011 and will be completed in March 2018. The Hall Probe measurement system in CSNS have finished the measurement task. We modified the system to measure the center deviation of the solenoid. The deviation between magnetic center and mechanical center of solenoid is an important parameter and has to be measured accurately. This work was supported by the Jia-Lin Xie Foundation (Y6546220U2).

Objectives

- The device can measure the angular deviation of solenoid is 0.015°
- The device can measure the center displacement deviation of solenoid is 0.1mm

Conclusion

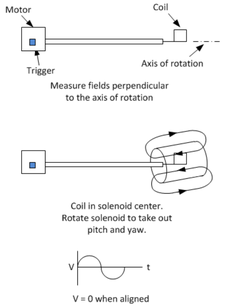
- A device is designed to measure the center deviation of the solenoid, which can be both used in conventional solenoid and superconducting solenoid.
- A new rotating coil built base on hall measurement system had successfully been developed.
- The precision of the device is good enough to meet the measurement requirements.
- Some key issues were solved in the process.

Principle

Induced voltage

In the center of the solenoid we get a transverse field from pitch and yaw of the solenoid. We can use this to take out pitch and yaw by moving the measurement device until the coil voltage goes to zero.

At the ends of the solenoid, we get a transverse field locally if the coil is not on the magnetic axis. We can move the coil to the magnetic axis by watching the coil voltage go to zero as we move the coil.



Numerical calculation

We calculated the magnetic axis deviation in three cases:

1. When the angle of solenoid axial deviation in the case of 0.015 ° :

$$\Phi = BS = \sin 0.015^\circ * Bc * S \quad (1)$$

$$\Phi = 2.618e\text{-}4 * 4000 * 10e\text{-}4 * 0.1 * 0.1 = 1.0472e\text{-}6 \quad (2)$$

$$V = Nc d\Phi/dt = (200 * 1.0472e\text{-}6)/0.25 = 0.83mV \quad (3)$$

When the Φ is magnetic flux, B is the max magnetic field, S is the area, V is the induced voltage. And we set the rotate speed is 1 circle per second. The calculated results showed that the induced voltage is 0.83mV.

2. When the displacement deviation between mechanical centre and magnetic center in the case of 0.1mm:

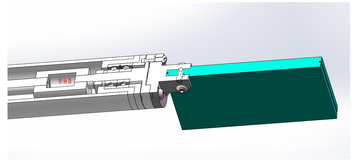
$$V = Nc d\Phi/dt = (200 * 0.9063e\text{-}6)/0.25 = 0.72mV \quad (4)$$

When the Nc is the number of turns of the measurement coils. The calculated results showed that the induced voltage was 0.72mV.

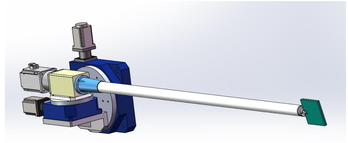
Manufacture

Coil framework

The induction coil framework is made of G10, and the wire is winding on the groove of the framework. The size of the groove is 100mm*100mm.



Final manufacture of the rotation lever

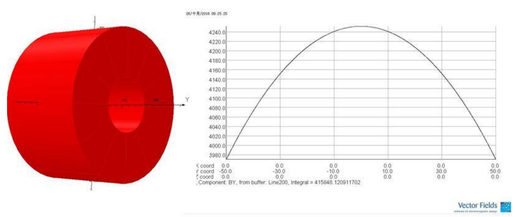


The lever has six degree of freedom: three rotating degree of freedom and three translation degree of freedom. The accuracy of the rotation lever is 0.02mm.

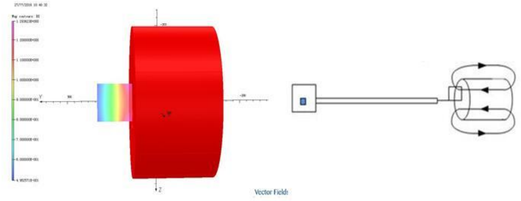
Test the fluctuation of the groove

Analysis Results

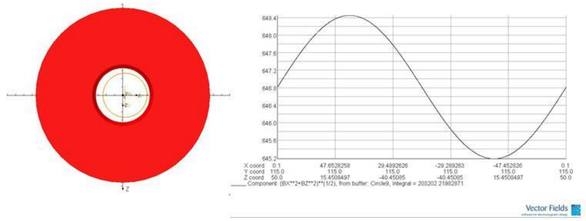
FE model of the solenoid



The distribution of center magnetic fields of the solenoid. The maximal magnetic field of the model is about 4240Gs. The right curve shows the distribution of magnetic fields along longitudinal direction of the solenoid about 100mm.



The distribution of magnetic fields on the edge when the displacement deviation between mechanical center and magnetic center in the case of 0.1mm. We can use hall sensor to measure the difference of magnetic field on the edge to measure the deviation.



The distribution of magnetic fields in radial direction. And the center is 0.1mm off. The magnetic field is 645.2Gs and in the other side is 648.4Gs.

Accuracy of the device

Item	X-rotation	Y-rotation	Z-rotation
Rotation angle (°)	5	5	360
Velocity (360°/s)	0.1~5	0.1~5	0.1~5
Rotation Positional Accuracy (°)	0.005	0.005	0.005
Rotation angle resolution (°)	0.001	0.001	0.001

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