Design of the Local Instrument for KSTAR Gravity Support

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1. Introduction

The gravity support installed between the lower toroidal field (TF) coil cooled by 4.5 K supercritical helium and the cryostat base is the main support structure for the Korea Superconducting Tokamak Advanced Research (KSTAR) superconducting magnet system. This structure should be flexible to absorb thermal shrink of the magnet and also should be rigid to support the magnet weight and the plasma disruptions loads. The gravity support was designed with stainless steel 316LN and Carbon fiber Reinforced Plastics (CFRP) that has low thermal conductivity and high structural strength at low temperature. The fabrication of the support has been completed after engineering design.

The gravity support is composed of one toroidal ring and eight supporting posts as shown in Figure 1 [1]. The toroidal ring and post are cooled by 4.5 K supercritical helium and 77 K gaseous helium, respectively. The overall dimension of the post is 1 m height and 0.8 m width and depth, respectively. The post is composed of upper block, inner CFRP plate, lower block, flexible plate, thermal anchor block, outer CFRP plate, base block, and strengthen plate. Inner CFRP plate is connected to the upper and lower block using the pin. And the outer CFRP plate is connected to the thermal anchor block and the base block. Inner and outer CFRP plates consist of four and two 20 mm thin plates, respectively. Flexible plates consist of four 8 mm thin stainless steel plates to absorb the magnet shrinkage. These plates are assembled into the thermal anchor block and lower block. The fabrication of the gravity support initiated October 2002 has been completed in October 2003. The supporting post and toroidal ring were fabricated at shop individually and assembled at site.

Various of static and dynamic loads will increase the stress level of the structure during the cool-down and plasma operation. After fabrication of the structure, we designed an instrumentation system to monitoring the structural safety. This system should be operated without malfunction in the environment of cryogenic temperature up to 4.5 K and high magnetic field up to 2T(Tesla). In this study, the design of local instrumentation system for gravity support and its prototype testing results are summarized.

2. Local instrument design

Local instrumentation system of the gravity support consists of sensors and data acquisition system. Three types of sensor for strain, temperature, and displacement were considered as shown in Table 1.

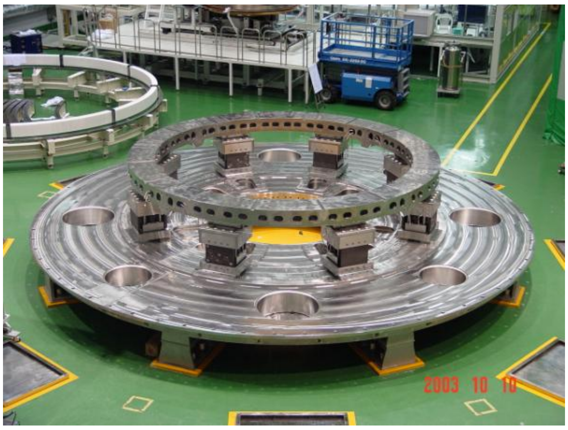

Figure 1. Fabricated gravity support

Supporting posts are main supports of magnet system. They consist of CFRP and flexible plates for heat isolation between cold parts of support from cryostat base plate. Strain gages are proposed to place on the outer peripheral packets of these plates [2]. These plates are loaded by membrane vertical stress and bending in-plane and out-of-plane stresses. To know all these components of stress 4 strain sensors are placed at the corners of the outer and inner plates of the packet. Active–active bonded strain sensors are used on these plates. Total number of strain sensors on the plates of gravity support is 136.

Measurements by strain gages in high magnetic fields and at cryogenic temperatures are connected with the appearance of non-informative signals. And resistance of a single strain gage changes with temperature ($\Delta R/R(T)$) and magnet field ($\Delta R/R(B)$).

$$\Delta R_{\Sigma}/R = \Delta R(T)/R + \Delta R(B)/R + \Delta R(\varepsilon)/R;$$

$\Delta R_{\Sigma}/R$: measured signal.

$\Delta R(\varepsilon)/R = k(T)\,\varepsilon$: useful signal,

where $k(T)$: gage factor at measuring temperature,

ε : object strain.

Active and compensating strain gages are attached to the object as two-component rosette, at an angle of 90 degrees to one another strain gage. Strain gages are connected in half bridge configuration. In this model compensating strain gage reacts on the object deformation and its useful signal will be equal to

$$(\Delta R(\varepsilon)/R)_c = -\nu\, k(T)\, (\varepsilon)_a ,$$

$(\varepsilon)_a$: strain of the object in the direction of active strain gage.

ν : Poisons ratio of material.

Signal from compensating strain gage is subtracted from the signal of active strain gage. The strain gages were already bonded on the plate of the supporting post as shown in Figure 2.

Table 1 Sensors for gravity support

Sensors		Quantity	Remark
Strain	WK-00-250WT-350	78	CFRP of Post
	WK-09-250WT-350	48	STS of Post
Temperature	PT-100	24	77K on Post
	Cernox	4	Toroidal Ring
Displacement	Displacement Transducer (Horizontal)	4	Toroidal Ring
	Displacement Transducer (Vertical)	4	Toroidal Ring

Radial displacements of the toroidal ring are measured at the same mutually perpendicular diameters (SP02, SP04, SP06, SP08) to obtain displacement of the ring as a rigid body in its plane. Four displacement transducers located at 4 supporting posts (SP02, SP04, SP06, SP08) measure vertical displacement of the ring. The type of displacement transducer is not decided yet.

Temperature monitoring system of the gravity support serves similar functions with the stress and displacement monitoring system. It provides information on the temperature status during normal operation, cool-down and warm-up. Four Cernox sensors which has high reliability at the environment of cryogenic temperature up to 4.5 K and high magnetic field will be attached on the bottom plate of toroidal ring. And three PT-100 sensors attached on the base block, upper anchor block, and lower block will give temperature distribution of the each post.

3. Prototype test

A prototype of data acquisition system for the gravity support was fabricated to verify the reliability of the instruments. It consists of sensors, PXI and SCXI H/W, and Lab View S/W [3]. The test of strain gages and temperature sensors were carried out using PPMS (Physical Property Measurement System) which gives special environments of cryogenic temperature and high magnetic field as shown in Figure 3. The test range of temperature and magnetic field were RT to 4.5 K and 0 to 2 T, respectively. The fluctuations of the strain rate for two types of strain gages, WK-00-250WT-350 and WK-09-250WT-350, were small at the test conditions. PT-111 was reliable at RT to 50 K, and magnetic field affect its signal at 4.5 K. Cernox was reliable at RT to 4.5 K and high magnetic field condition.

Figure 2. Strain gages bonded on the post.

Figure 3. Local instrument prototype with PPMS

4. Conclusion

Design and prototype of the local instrument for gravity support were performed. The environmental conditions of cryogenic temperature and high magnetic field were considered in this work. Three types of sensors, strain gage, temperature sensor, and displacement transducer, were decided after instrument prototype testing.

Acknowledgment

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