# MLF Experimental Report	提出日 Date of Report 2011/02/07
課題番号 Project No. 2010A0050 実験課題名 Title of experiment Flux-pinning-induced stress and magnetostriction in bulk superconductors 実験責任者名 Name of principal investigator Masaru Tomita 所属 Affiliation Railway Technical Research Institute	装置責任者 Name of responsible person Kazuya Aizawa 装置名 Name of Instrument/（BL No.） Takumi (BL19) 実施日 Date of Experiment 2010/11/12（1st measurement）, 17,18 (2nd measurement)

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

High T_C bulk superconductor ($Y Ba_2 Cu_3 O_{7-\delta}$)
Φ45x10t（1st measurement）, Φ30x10t (2nd measurement)

2. 実験方法及び結果 （実験がうまくいかなかった場合、その理由を記述してください。）
Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

- Sample magnetization

Figure 1 and Figure 2 show the structure of the cryostat and a picture of cryostat, respectively. This cryostat mainly consists of a bulk superconductor (sample) and a cryo-cooler that can be able to cool down to a temperature below 40 K. The material of the bulk superconductor is Y123 ($YBa_2Cu_3O_y$) single grain compounds, which were processed by a melt-texture technique. The samples in this experiment were two YBCO bulks with dimensions Φ46 mm × 10 mm^t (Sample A) and Φ25 x 10 mm^t (Sample B). The standard Pt sensor was attached inside the top copper plate. The transverse Hall sensor was attached on the top surface of the bulk. For the each individual bulk, the characterization before strain measurement at TAKUMI was done by the trapped-field distribution at around 45 K. The trapped field means that the magnetic field in bulk superconductor is maintained by persistent currents inside therein bulk per conductor was activated using field-cooling magnetization using a hybrid superconducting magnet composed of NbTi and Nb_3Sn coils cooled by a cryo-cooler which can generate 10 T in a room temperature bore of 10 cm diameter. Then, we used an axial Hall probe to scan the entire upper surface of the cryostat.

. Figure 3 shows the trapped field distributions for Sample A and B at some gap from the bulk surface. The magnetic flux densities at the surface of the bulk reached 4.6 T and 2.2 T using the static applied magnetic fields of 5 T and 4 T, respectively. The trapped fields of the all samples were distributed as concentric circles, which mean they had no cracks, defects, or weak links. We confirmed these samples are suitable for magnetostriction measurement by neutron diffraction method.

• Moving

Figure 4 shows a picture of the bulk cooling system in the cargo space of the truck. We used the truck with air suspension as a means of transportation to prevent driving vibration as low as possible. It is a distance of 160 kilometers from RTRI (Railway Technical Research Institute) at Kokubunji-shi to J-PARC, JAEA (Japan Atomic Energy Agency) at Tokai village. The cryo-cooler consumes some electric power and needs AC 100V. Therefore, we prepared a generator for electric consumption and an UPS for a power failure.

Figure 5 shows that temperature profile of the bulk superconductor during moving by Sample A. It takes approximately four hours to move the bulk cooling system. The driving vibration causes the sample temperature to increase in approximately 4 K, however, has a little influence on the maximum of trapped field by less than 0.1 T. The sample B was successfully transported in the same way also.

• Strain measurement at the neutron diffractometer TAKUMI

Figure 6 shows a schematic diagram of neutron incident axis into sample. Figure 7 shows a picture of the sample setting. The neutron beam passes through the vacuum vessel made of Stainless 304. The thickness along the neutron beam is about 3 mm. Measurement parameters are as shown in Table at TAKUMI.

The procedure to measure is below in the case of Sample A. The first measurement was carried out on condition that the sample has the trapped field of 4.6 T at approximately 45K. Then, the cryo-cooler was turned off for de-magnetization. The sample temperature reached in 30 minutes to 110K above T_C (transition temperature, 90K). And the Y-system superconductor generates electric resistance, namely, super currents inside bulk sample disappear. We turned on the cryo-cooler for the next measurement condition that the sample has no trapped field at about 45K. The sample takes 3.5 hours to reach thermal equilibrium and start the second measurement. Neutron diffraction peaks from the typical lattice plane were measured at approximately 45K before and after de-magnetization. Plane spacing was calculated from the fitted peak angle by Bragg's law.

Finally, lattice strain was estimated as the difference of plane spacing with/without the trapped magnetic field in bulk superconductor. In this, we assumed the value of E to be 181.0 GPa at 50 K as reported by Reddy et al for Y-system bulk samples prepared by the MPMG method [1]. Poisson's ratio was expediently assumed to be 0.3.

The obtained diffraction profiles of sample A and B are shown in Figure 4. The measured lattice planes were the (220) (110) and (200) (020) of Y123 in sample A and B, respectively. This difference causes the different incident direction into each sample. The diffraction intensity through the wall of vacuum vessel is adequate in measurement time per point shown in Table 1. The strain distribution by electromagnetic force in sample A is shown in Figure 9. In this figure, positive and negative values correspond to tension and compression strain, respectively. The center values of strain indicated 100 με, corresponding to 18 MPa along x-axis in hoop direction. The tendencies that the strain values in hoop direction are larger than them in radial direction as a whole and the strain distributions have a peak in center are observed. These correspond to strain behavior theoretically predicted based on Bean model [2].

[1] Ravinder Reddy R, Murakami M, Tanaka S and Venugopal Reddy P 1996 Elastic behavior of a Y–Ba–Cu–O sample prepared by the MPMG method Physica C 257 137

[2] Ren Y, Weinstein R, Liu J, Sawh R P and Foster C 1995 Damage caused by magnetic pressure at high trapped field in quasi-permanent magnets composed of melt-textured Y-Ba–Cu–O superconductors Physica C 251 15

Table.1 Measurement parameters @ TAKUMI

Sample name	Sample dimension (mm)	Neutron beam dimension (mm x mm)	Measurement time per point (min)	The number of measurement point	Max trapped field (T)	Sample temp (K)
A	Φ46x10t	4 x 2	25	7 x 2 axis*	4.6	45
	Φ46x10t	4 x 2	25	7 x 2 axis*	0	45
B	Φ25x10t	4 x 2	60	11**	2.2	46
	Φ25x10t	4 x 2	60	11**	0	46

* 7 points were set from the outer edge to the opposite one though center in 2 axes.

** 11 points were set from the center to the outer edge.

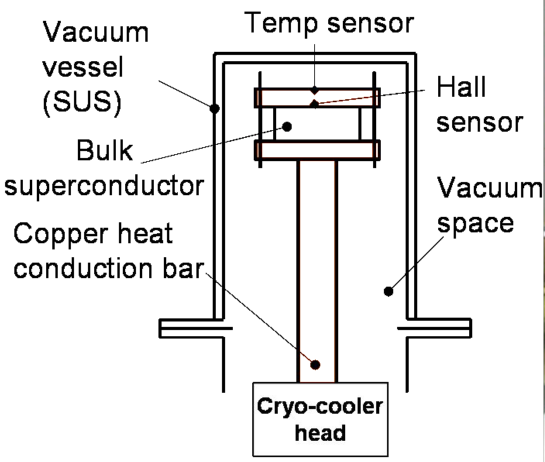


Fig.1 The structure of the cryostat

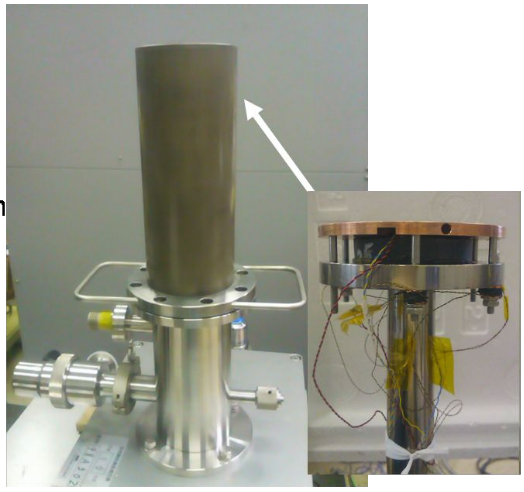


Fig.2 A picture of the cryostat

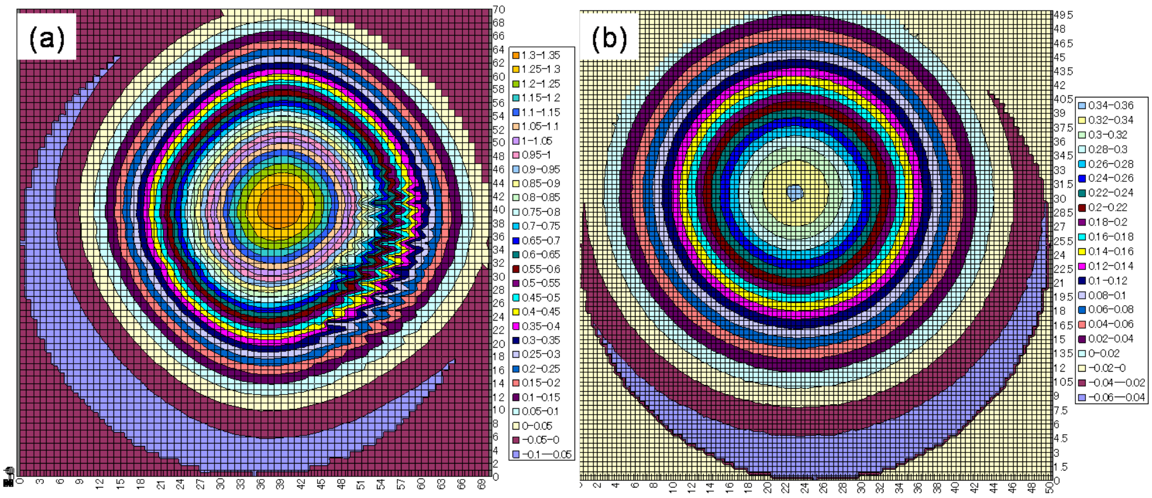
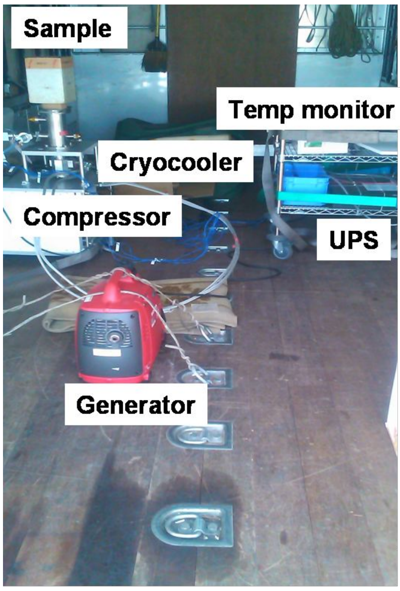


Fig.3 The trapped field distributions of YBCO bulk superconductor at the surface of the cryostat
(a) Φ46x10t, maximum 1.3T (b) Φ25x10t, maximum 0.24T



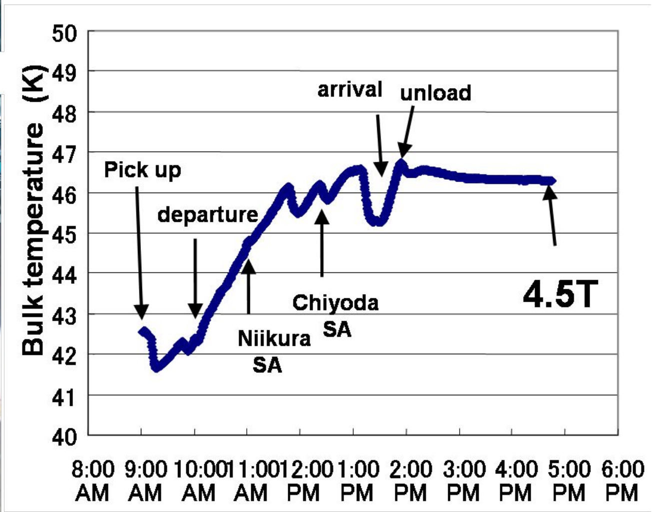


Fig.4 A picture of the bulk cooling system in truck

Fig.5 Temperature profile of the bulk superconductor during moving (2010/11/10)

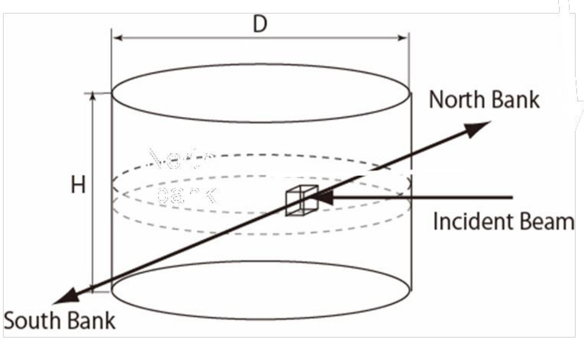


Fig.6 Schematic diagram of neutron incident axis into sample

Fig.7 A picture of the sample setting

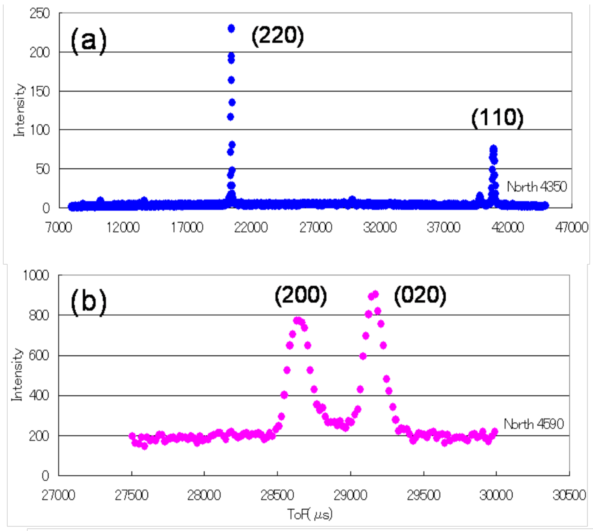


Fig.8 Neutron diffraction profile of Y123
(a) Φ46 x 10t (b) Φ30 x 10t

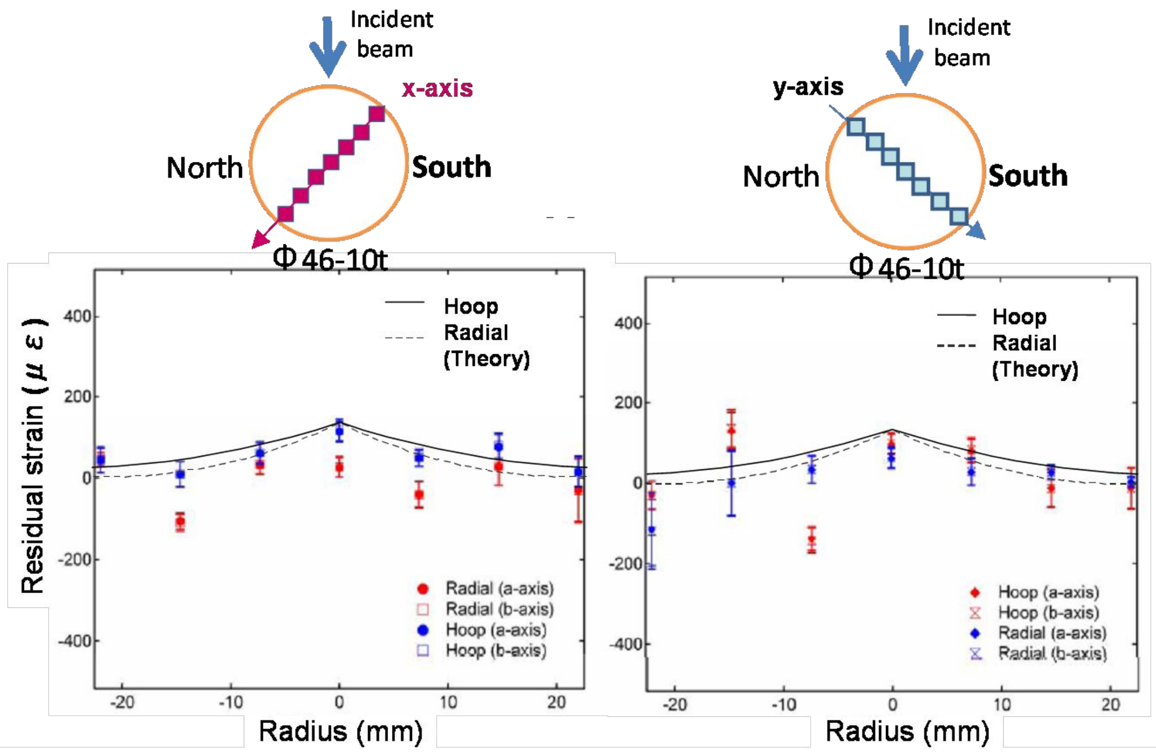


Fig.9 Measurement results of residual strain distribution in radial and hoop direction
(a) x-axis (b) y-axis