§103. Neutron Irradiation Effect on Superconducting Magnet Materials for Fusion

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The new evaluation test facility on superconducting property for irradiated wires consisting of 15.5 T superconducting magnet, a variable temperature insert (VTI) and control/data acquisition system has been installed at Oarai center in Tohoku University. The sample current was able to be put into the sample wire stably up to 500 A. However some temperature rise was observed during the current test in 2013. Therefore, the systematic tests were planned in 2014 to investigate the reason of the temperature rise and the conceptual design of the connection part between the pure aluminum rod and the second stage plate of refrigerator was carried out.

The full current test up to 500 A was carried out at 0 T, 2.5 T, 5.0 T and 7.5 T. The results are shown in Fig. 1. The temperatures of +/- electrodes rose quickly after the current input started, but it was recovered in a short time under 0 T, 2.5 T and 5.0 T. However, in case of 7.5 T, the temperature did not come back to the original and very high temperature was recorded after the full current test.

Regarding the temperature rises, they become larger in the higher magnetic field. When the current runs into the bas bars and the sample wire, the joule heating of I x I x R (I is current and R is electric resistance.) generated in the copper bas bars. The electric resistance of the copper increases under the high magnetic field, it results in increase of the heat generation and the larger temperature rise.

In case of the current test at 7.5 T, the temperature did not come back to the original temperature. The other test results are summarized in Table 1. The mechanism of this phenomenon was considered as follows:

A schematic illustration of the main rod of VTI is shown in Fig. 2. The high purity aluminum rod was attached to the second stage plate connecting with the refrigerator and the sample holder was arranged at the top of the high purity aluminum rod. The sample holder was connected by the copper bas bars to put the current in the sample wire. The heat load was transferred to the refrigerator through the high purity aluminum rod. When the current was put in the sample under the high magnetic field, the electro-magnetic force ($I \times B$, where I and B are current and magnetic field, respectively) is generated and acts on the sample. This electro-magnetic force will bend the main rod of the VTI.

The high purity aluminum rod was fixed to the second stage plate with four screws to transfer the heat. Since the pure aluminum is very soft, the plastic deformation occurs easily by electro-magnetic force and a small gap was considered to be formed during the full current test at 7.5 T. This change on the interface between the high purity aluminum rod and the second stage plate would cause the change in the heat transfer condition on the interface. When some gap is generated on the interface, the heat transfer would be degraded and the temperature of the sample holder would not come back to the original temperature.

Some analyses were carried out to investigate the stress and the deformation on the interface. The results suggest the improvement of the heat transfer on the interface by adding additional fixtures of copper and stainless steel supports. By introducing such supports, the stress at the corner of the fix position of the high purity aluminum rod would be reduced to about 17 MPa from about 40 MPa and the deformation on the interface would be kept within 0.001 mm, which means almost no gap occurs.

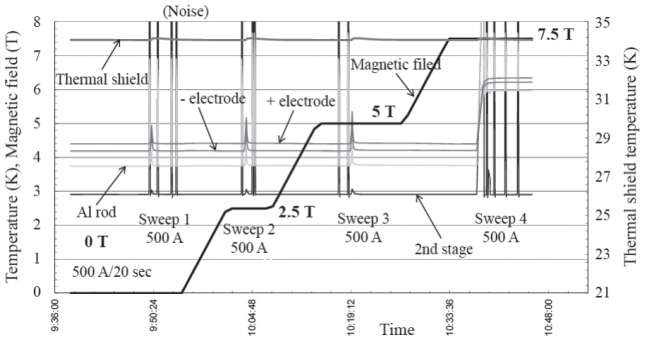

Fig. 1 Test results of full current tests.

Table 1 Change in temperature of 2nd stage and AL rod tip

Magnetic field, current and time	2nd stage (K)		AL rod tip (K)	
	Before	After	Before	After
15.5T 50A 30s	2.90	2.90	3.53	3.54
15.5T 100A 30s (1st run)	2.90	2.90	3.54	3.66
15.5T 100A 30s (2nd run)	2.90	2.90	3.65	3.66
15.5T 100A 45s (1st run)	2.90	2.90	3.65	3.96
15.5T 100A 45s (2nd run)	2.89	2.90	3.96	3.99
0T 500A 30s (1st run)	2.89	2.89	3.99	3.99
0T 500A 45s (2nd run)	2.89	2.89	3.99	3.99

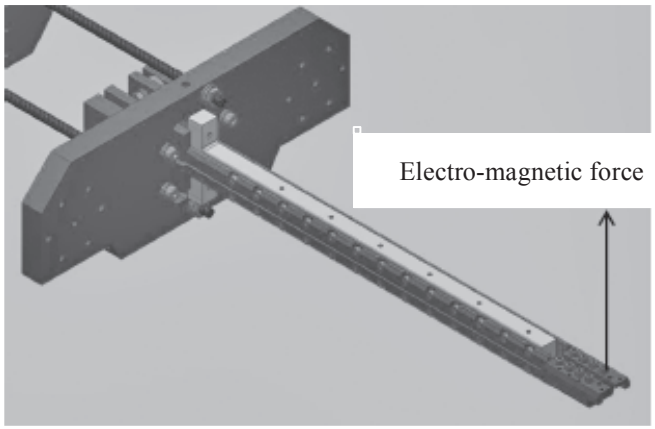

Fig. 2 Schematic illustration of main rod with sample holder.