§24. Research and Development of Pre-Preg Material for LHD Winding

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It has been thought that the rigidity of LHD coils should be degraded at cryogenic temperatures because they can not be wound at high tension due to the complicated structure and hence the difference of thermal contraction between the magnet components could not be compensated. The degradation of rigidity could result in the wire motion during excitation and the loss of stability. It is, therefore, necessary to bind the windings together not to induce the wire motion and to increase the coil rigidity. The increase of the rigidity is important because not only to increase the stability but also to increase the accuracy of the magnetic fields. In this work research and development of the pre-preg or adhesive materials to increase the coil rigidity was studied.

The following properties were required for the pro-preg and adhesive materials considering the actual coil winding,
(1) curing temperature should be lower than 80 degree C ,
(2) pot life should be as long as 2 months and
(3) they could be inserted between the windings.

To answer the demands two types of materials were chosen that is pre-preg material with glass tape and room temperature curable epoxy . In the epoxy fillers were added to increase the cryogenic properties.

Pre-Preg Material

The latent curing agent was employed to realize the low curing temperature. The spacers made of GFRP were adhered with the pre-preg simulating the HLD winding and the shear tests were performed. The specimen was cured at 80 degree C for 8 hours. The shear strength was found to be 100kg/mm^2. The increase of Tg and shear strength with curing temperature was also found. The practical pre-preg material was thought to be developed and the practical application was tested.

The full curing could not be performed in the real sized HLD coil due to the low increase rate of temperature. The micro-capsule which involved the curing agent were aggregated and hence the fully mixture of epoxy with curing agent were not performed. Consequently the real application of the material was not decided.

Filled Epoxy

The amine curing agent was used for the epoxy and were filled with 50% silica by weight. The adhesive strength at room temperature is reported as 167 kg/cm^2. The epoxy was cured and the thermal contraction down to liquid helium temperature was measured. The fracture toughness was also measured at room and liquid nitrogen temperature. The obtained fracture toughness were 1.25 and 3.40 , respectively. The thermal contraction down to liquid helium temperature was also presented in Fig.1.

The thermal contraction was found to be 0.68 % down to liquid helium temperature. The fracture toughness at liquid nitrogen temperature was high considerably. The filled epoxy was decided to apply to LHD.

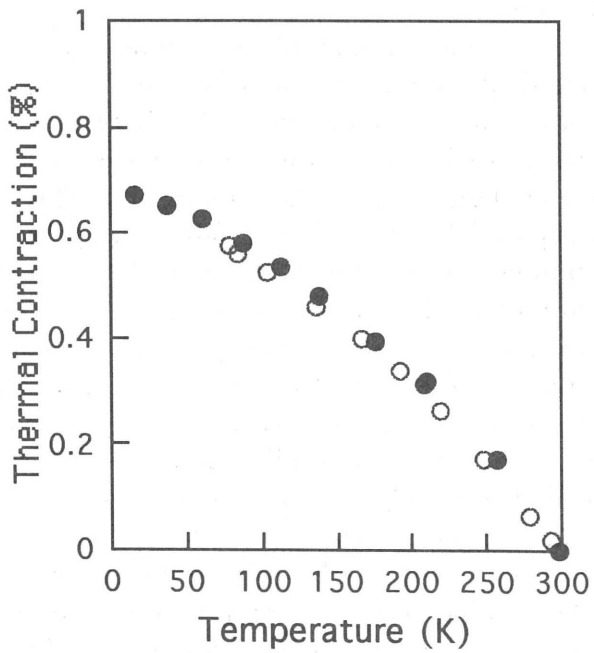

Fig.1 Thermal contraction of filled epoxy.