§29. Evaluation of Fiber Reinforced Plastics (FRP) for a Former of Superconducting Magnets

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Formers made of FRPs have been researched in order to utilize their high specific strengths and non-magnetic characteristics. However, there are some problems in actual application. Conventional laminated FRP has larger thermal contraction in its thickness direction than that of superconducting wire. Moreover, a former consists of three pieces of FRPs, that is, a filament-winding(FW) pipe as a barrel and two sheets as flanges, which usually induce the deformation of the former itself because of the anisotropic thermal contraction of FRPs. If superconducting wires become easy to move by the unfitness towards the former as cooling down, there is a strong suspicion that it affects on the stability of superconducting magnet.

In this study, the former was fabricated employing high glass content glass fiber reinforced plastics(GFRPs) as flanges, which has almost the same thermal contraction with metallic materials from room temperature(RT) to liquid helium temperature(LHeT), [1] and the shrink behavior of the former made by GFRP at cryogenic temperatures has examined.
The deformations of 19 parts of the former were measured by strain gauges to which 0.5 V is applied, with dynamic strain measurement system from RT to LHeT and from RT to liquid nitrogen temperature(LNT). The strain of two pieces of the FW pipe and the GFRP, whose sizes are 40 × 20 × 20 mm, and they are cut out from the former, were also measured as unit pieces.

Figure 1 shows the measurement results of thermal contractions from RT to LHeT, shown in circles, and from RT to LNT, shown in squares. Figure 2 shows the schematic drawing of the GFRP former and its shrink behavior from RT to LHeT, which the operating condition is demonstrated. The numbers are correlated to those of Fig. 1 and the values written in this figure shows the thermal strain from RT to LHeT.

In Fig. 1, few thermal shrinkage occurred in cooling down from LNT to LHeT, except the thickness direction of FW pipe(no.19, 0.2%). On the other hand, large thermal strains were observed in cooling from RT to LNT, except in the circumferential direction of FW unit piece(no.13). Compared with the strain in the circumferential direction of FW unit piece(no.13), those of barrel both at the center(no.17) and the edge(no.15) are more than 6 times larger. The effect of being cut out from formers is assumed to be the release of internal stress in the material and hence it means the less initial thermal stress compared with the former itself.

The orientation dependency of woven fibers concerning with the thermal strain of high glass content GFRP is not obvious for its high rigidity.

Fig. 2 indicates that the strain in radius direction of inner flange (no.5,6,12) is relatively large compared with those of outer flange (no.9,10) and those of unit pieces(no.1,2), following the large strain in thickness direction of FW pipe(no.19). And obtained smaller strain in the circumferential direction of GFRP(no.3,4,11) is caused by that of FW pipe(no.15). These results suggest that the combination of flange and barrel FRP is important for the former not to deform by thermal stress.

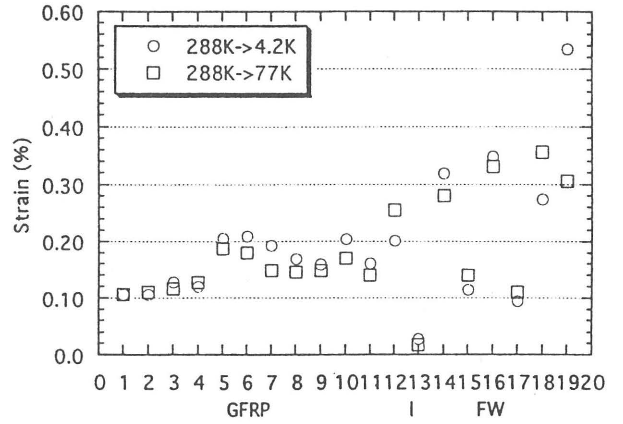

Fig. 1. Thermal strain from RT to LHeT, shown in circles, and from RT to LNT, shown in squares.

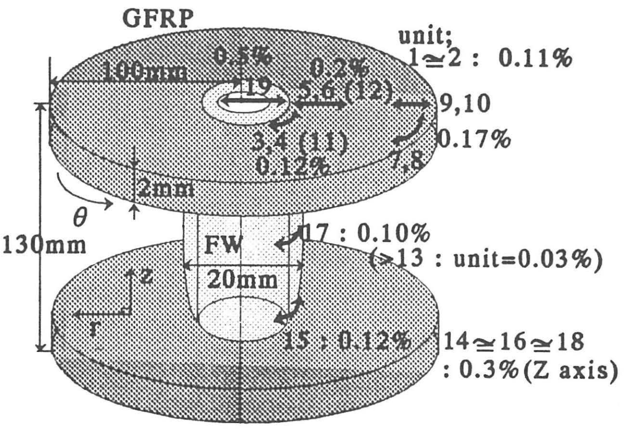

Fig. 2. The schematic drawing of the GFRP former and its shrink behavior from RT to LHeT.

References

1) Nishijima, S., Nojima, K., Asano, K., Nakahira, A., Okada, T. and Niihara, K., Adv. Cryog. Eng. 40 (1994) 1051.