§1. Optimization of the Control of the Subcooling System of the LHD

Okamura, T. (Tokyo Tech.),
Imagawa, S., Yanagi, N., Hamaguchi, S., Obana, T.

Modifications of the cooling system of the LHD were carried out in order to improve the cooling stability of the LHD helical coils. We established an operating scheme that 3.2 K subcooled helium is stably supplied to the helical coils at the mass flow rate of 50 g/s (designed value). The next step of this study is to establish a smooth transition process between a stand-by mode (@ 4 K cooling) and a subcooling mode (@ 3 K cooling), aiming at an automatic operation of the subcooling system. We have to control the helium mass flow rate within the range that the compressor works stably in the transition process. A heater in the saturated helium bath and a bypass valve are equipped in the present subcooling system for the helium flow controlling. The objective of this study is to find out the optimal control of the heater and the bypass valve.

Figure 1 shows a schematic diagram of the control equipments in the present subcooling system. The rotation speed of the cold compressor turbine is about 700 rps in the stand-by mode and it is about 1,500 rps in the subcooling mode. The opening degrees of the bypass valve are 70 % and 5 % at the stand-by and subcooling modes, respectively. We used an automatic control function for the helium flow with the heater in the saturated helium bath that was installed before the 11th experimental campaign of the LHD. We already know from the 2006's investigations that the range of the mass flow rate that keeps the cold compressor stably work is around 16-20 g/s. Therefore, we set the mass flow rate of 18 g/s as the set-up value. The helium level in the saturated helium bath was automatically controlled to be kept 70 % of the highest level with a valve at the inlet of the saturated helium bath. We planned that we clarify the helium flow controlling characteristics of the heater in the saturated helium bath and opening degree of the bypass valve at first and we establish an optimal arrangement of these controlling method for a smooth transition process.

After the confirmation that the controlling characteristics of the heater in the saturated helium bath are very good for both steady and transient processes, we changed the rotation speed of the cold compressor turbine and the opening degree of the bypass valve respectively under the automatic control of the helium flow rate in the cold compressors using the heater. The heater power changed linearly in correspondence with the rotation speed when we changed only the rotation speed. On the other hand for the case of changing the opening degree of the bypass valve, the heater power changed dramatically when the opening degree exceeded 50 %. The heater power reached 90 % of its maximum power.

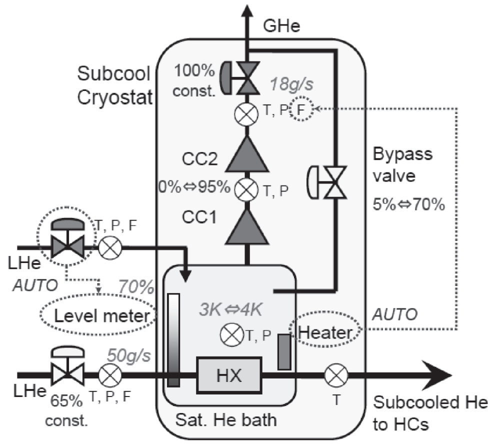

Fig. 1 Schematic diagram of the control equipments.

Based on the above mentioned results, we examined a smooth transition process. Figure 2 shows time traces of the rotation speed of the cold compressor turbine, the opening degree of the bypass valve, the heater power and the helium flow rate in the cold compressors in the period of the transition process. The helium flow rate was automatically controlled by the heater in the saturated helium bath in this process. It took 30 minutes to complete the transition process. The heater power in the saturated helium bath could be reduced less than 70 % of the maximum power because of a good opening/closing operation of the bypass valve. The helium flow rate was in the range from 17.2 g/s to 19.6 g/s. This means that a smooth transition process was achieved keeping a stable cold compressor operation.

We found from this experiment that this system has a margin in the heater power. This fact leads a possibility that the transition process time can be more

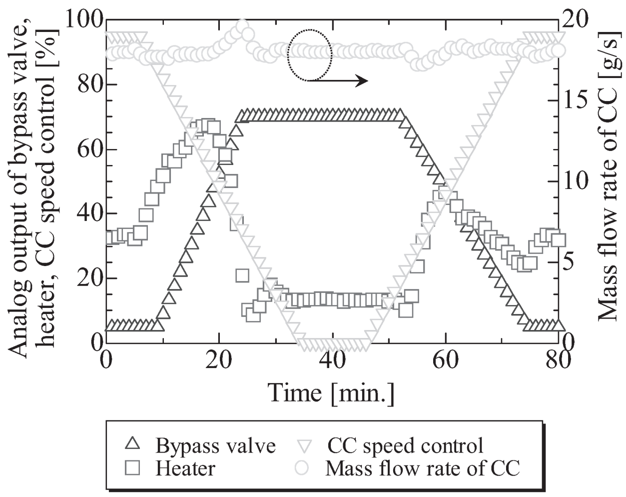

Fig. 2 Time traces of variable parameters in the period of the transition process.

reduced. For the next step of this study, we will investigate on an operation for a quick transition process, and we plan to establish a quick shut-down mode of the cold compressors for emergency cases.