§6. Research and Development of High Temperature Superconducting Induction/ Synchronous Machine for Liquid Cryogen Circulation Pump

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We have fabricated a 5 kW class prototype of High Temperature Superconducting Induction/Synchronous Motor (HTS-ISM), based on the design result carried out last year. 7 pieces of GdBCO superconducting tape (critical current: 85 A@77 K) are stacked together, and then attached to a copper bar (2x3 mm^2) as a rotor bar. We assume that the reduction rate of the rotor bar's critical current due to the self-field is 0.7, and then the overall critical current is about 85 A×7 ×0.7≒ 417 A. 44 pieces of such rotor bars are fabricated, and then installed in the slots of the rotor core. We use the commercial Cu stator (3-phase and 4-pole), and combine such stator and the fabricated HTS rotor. Fig. 1 shows a photograph of the fabricated motor. It should be noted that the whole body of the motor is cooled at cryogenic temperature, and then the lubrication oil of the bearings must be removed.

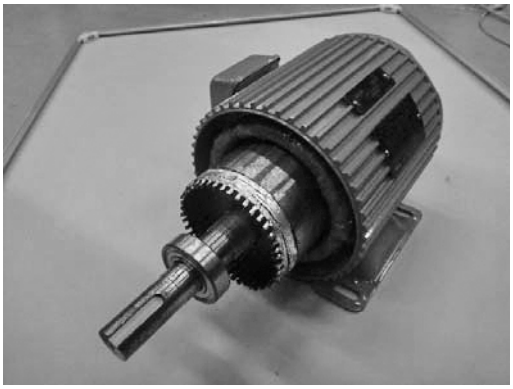

Fig. 1. Photograph of a fabricated HTS rotor

Fig. 2 shows a photograph of a cryostat, in which the fabricated HTS motor is installed and immersed in liquid nitrogen. That is, the motor has been tested in atmospheric liquid nitrogen (77 K). Fig. 3 illustrates a schematic diagram of the test bench. As this figure shows, pressurized nitrogen gas is flowed through the SUS pipe, at which the rotor shaft is installed, in order to prevent the leak of liquid nitrogen. Mechanical load is applied by the use of the DC motor.

Fig. 3 shows the typical experimental results, of which the motor is excited at 200 V and 60 Hz[1]. It should be noted that the motor successfully rotate at synchronous speed (1800 rpm), and the maximum torque reaches for more than 13 Nm. Strictly speaking, the motor is slightly in a slip mode when the load torque is more than 10 Nm, and this could be due to the solder resistance in between the HTS rotor bars and the HTS end rings. The reduction of such resistance will be our next important work. We are also planning to examine the temperature dependency of the motor's performance. As is well known, the current transport property of the superconducting materials will be increased by decreasing the operation temperature, and then the relationship between such superconducting property and the motor's characteristics is really important for the optimum drive.

Fig. 2. Photograph of a cryostat

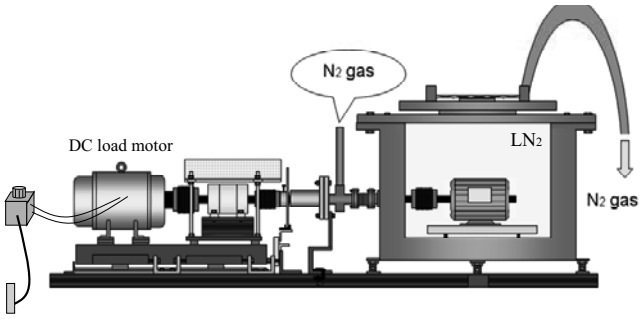

Fig. 3. Schematic diagram of a test bed

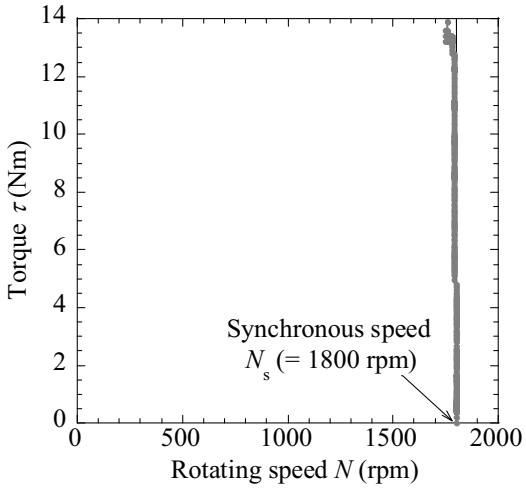

Fig. 4 Experimental result of load characteristic (77 K, 60 Hz) [1)]

1) T. Nakamura and S. Imagawa: Abstracts of CSSJ Conference, vol. 92, 3A-a11 (2015).