초전도 계자 권선형 동기전동기의 시험 설비 구축

Construction of Dynamo Test System for Synchronous Motor With Superconducting Field Winding

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Abstract — As a countermeasure against global warming, active research is being conducted around the world to replace internal combustion engines with electric motors for a reduction of greenhouse gases. Especially in the automobile field that electric motors are applied, the paradigm is rapidly changing. Accordingly, although many attempts have been made to increase the output power per unit weight of the electric motor, there has been a limit to increasing the output of the electric motor due to problems such as Joule heat in windings and demagnetization of permanent magnets that might induced from the large current density. On the other hand, the superconducting motor has essentially zero resistance, so large copper loss in conventional motors can be ignored. Accordingly, the current density can be greatly increased to increase the output power of the motor. Because the superconducting motor requires cryogenic environments, there are many limitations to its current practical application, but various studies are being conducted to overcome it. In this paper, as part of a preliminary study for the practical use of superconducting motors, a motor with superconducting field windings was developed and its feasibility was examined through experiments. A method of maintaining a cryogenic environment in chamber for superconducting rotor with liquid nitrogen is introduced, and the construction of a dynamo test facility for synchronous operation of the superconducting motor is described.

Introduction

Necessity of superconducting motors

- In response to the global warming problem, there are some active movement to electrify internal combustion engines.
- In particular, the demand for electric motors that can increase the output per unit weight in electric vehicles and electric aircraft is rapidly increasing.
- When the output is increased, the increase in loss due to the increase in current density and the limited improvement in output density due to heat generation can be overcome through superconducting motors.
- In this study, we plan to conduct a driving test by applying a non-insulated coil to a superconducting field winding type motor.

Concept of the proposed superconducting motor

- In a winding rotor synchronous motor, the copper field coils are replaced by the No-Insulation (NI) superconducting coils.
- Entire rotor is immersed in liquid nitrogen to maintain superconducting state.
- For this purpose, a liquid nitrogen chamber-integrated rotor was manufactured.

Design of Superconducting Synchronous Motor

Superconducting motor design

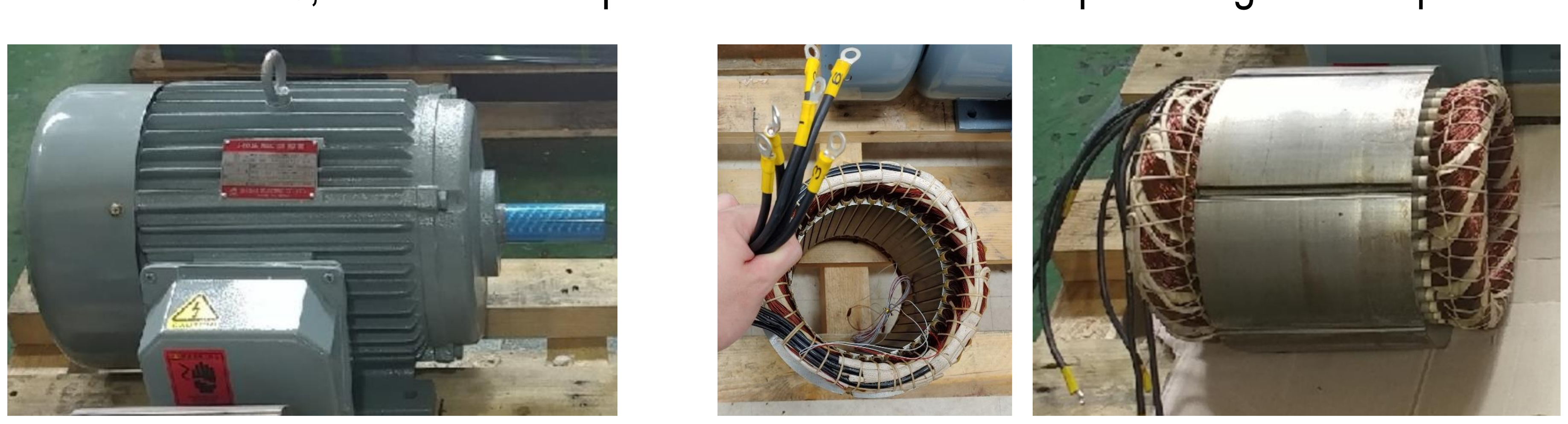
- High-speed operation is difficult due to the characteristics of the liquid nitrogen chamber-integrated rotor and vertical drive method. Therefore, the proper rotation speed was determined to be 300 rpm.
- Since it is driven by an inverter, it is a general-purpose sensorless inverter, so 4 poles that are easy to control are adopted.
- Based on the 3-phase 4-pole 15kW class induction motor, the existing rotor was removed and 4-pole superconducting field winding was designed and mounted.

Table I Design parameter of superconducting field winding synchronous motor

Number of Poles	4	Turns of field coils	80
Rated current [A]	66.9	HTS requirements [m]	183.6
Rated torque [Nm]	17.7	Field current [A]	66.9
Rated speed [r/min]	300	Critical current [A]	95.6
Output power [W]	556.8	Operating Temperature [K]	77

Fabrication concept of superconducting motor

- The stator of a 3-phase induction motor is used as it is.
- The rotor is manufactured by integrating the field winding and liquid nitrogen chamber.
- Vertical type is easy to drive liquid nitrogen chamber integral rotor.
- During the test, the problem of temperature rise of the superconducting coil due to vaporization of liquid nitrogen may occur.
- To overcome this, a hole in the top of the chamber allows liquid nitrogen to be poured.



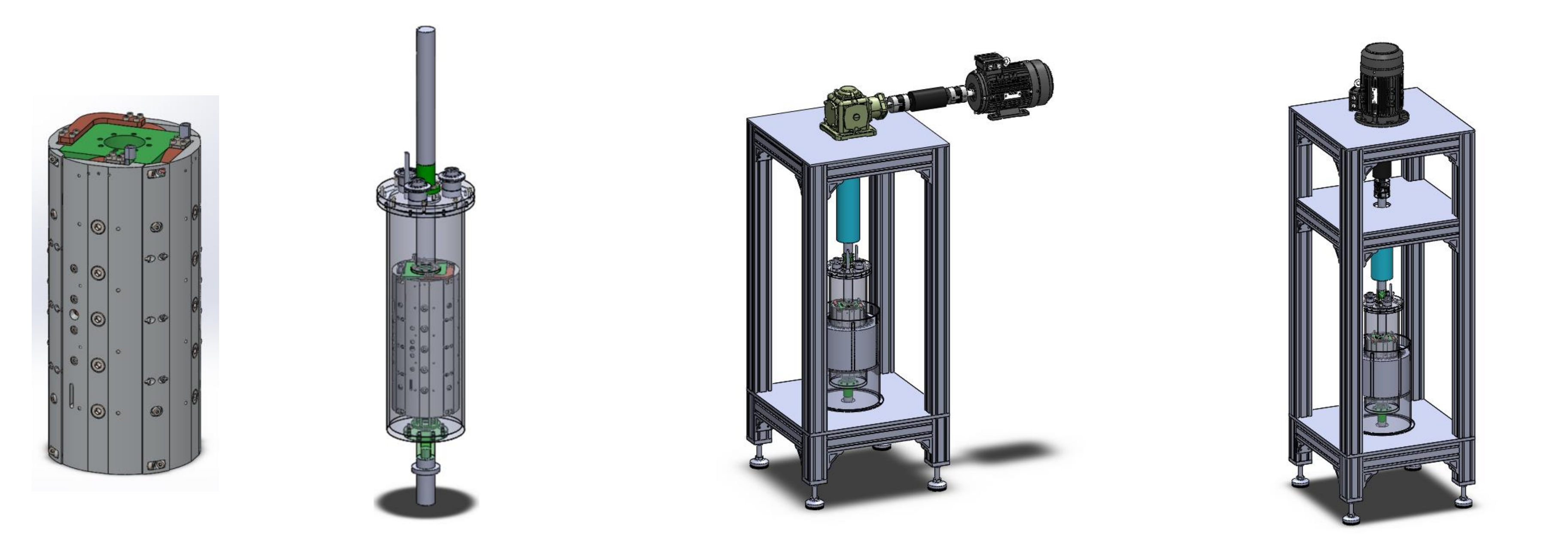
(a) Sample of 3-phase induction motor (b) Stator of 3-phase induction motor

Figure 1. Stator for fabrication of the propused superconducting motor

Construction of Dynamo Test System

Manufacturing of dynamo system for load test

- For the test of vertical motor, the type of dynamo motor is reviewed in two types; vertical type and horizontal type.
- In the case of vertical type, it is fastened directly through a coupling, and in case of horizontal type, it is fastened in a shaft orthogonal form using a bevel gear.
- The vertical type is decided in consideration of the error and vibration caused by the orthogonal axis.
- The stator is fixed to the test bed frame, bearings are installed on the bottom and ceiling of the frame, and the chamber-integrated rotor is inserted into the stator.
- Manufactured in the form shown in the figure.

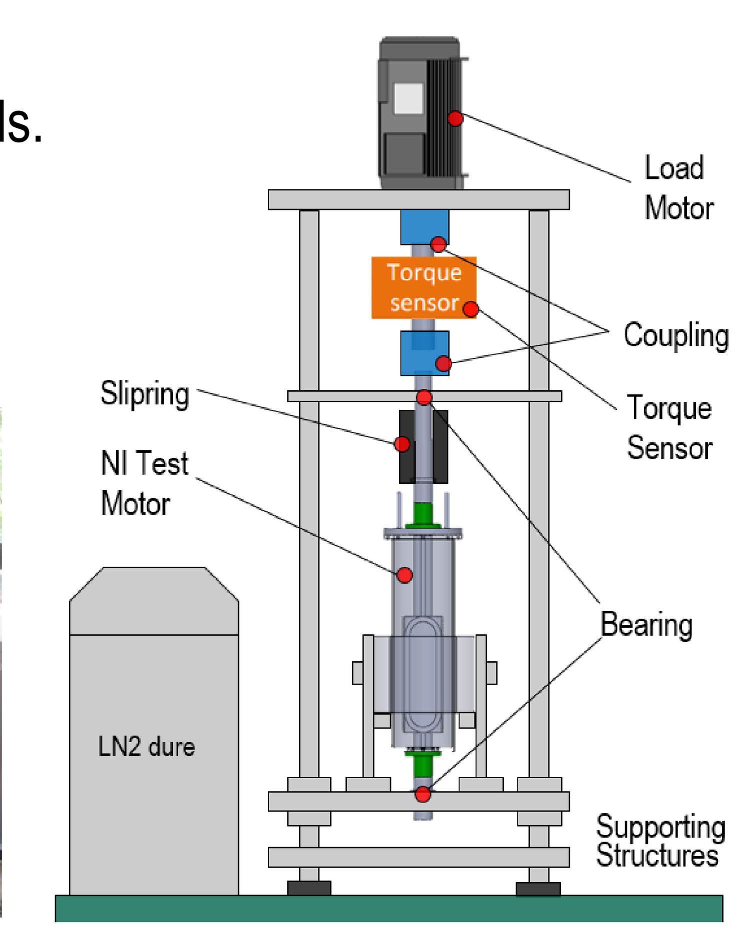


(a) Rotor and LN_2 Chamber (b) Horizontal type dynamo set (c) Vertical type dynamo set

Figure 2. Rotor chamber and test bed design

Test methods and procedures

- Inject liquid nitrogen into the rotor chamber
- Check a temperature of the superconducting field coils.
- Apply dc power to the field winding.
- Start motor using inverter.
- Measure motor performances



(a) Assembling the rotor and stator (b) Test bed (c) Schematic diagram of motor test

Figure 3. Dynamo test system for load test

Conclusion

The wound rotor synchronous motor with NI superconducting coil was developed. The chamber-integrated rotor structure was devised for liquid nitrogen injection, and the dynamo system for load test was fabricated. No-load test of the motor in a superconducting state was performed by injecting liquid nitrogen into the rotor chamber. We plan to conduct load tests of this NI superconducting motor.

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