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C1Po2A-01: Development of a cryogenic stepping motor using high-purity copper wire

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We developed a stepping motor working in a cryogenic environment with small heat dissipation from it. While a cryogenic motor is commercially available, a user must prepare a cryogenic environment that can tolerate a large heat dump during the operation.
We modified a commercial stepping motor (TAMAGAWA SEIKI CO., LTD) for room temperature usage. The components of the motor were replaced from a conventional electromagnetic wire to 6N high-purity copper and from aluminum chassis to a glass-fiber resign epoxy chassis. The former reduces the Joule heat, and the latter reduces the eddy current. In addition, the bearings have been replaced with ones with a dry lubricant. An iron yoke, a stack of iron core plates, is already introduced in the commercial motor to reduce an eddy current loss, and this was kept from the commercial design.
The preliminary experiment was conducted at teh temperature of 15 K using a GM cryocooler to estimate the heat dissipation on the motor. The results show that the electrical resistance of the high-purity copper wire at 15 K is 1950 times lower than at room temperature. We measured the total heat dissipation of the motor with the high-purity copper coils and compared it to the conventional one. The measured heat dissipation was reduced by about 40% when the motor rotation speed was 2.25 rpm. The Joule loss of the motor with a high-purity copper wire was about 1/20 smaller than the conventional motor due to the reduction of the wire resistance. We also identify that the remaining heat dissipation is dominated by the component proportional to the rotational frequency, i.e. hysteresis or static friction from the bearing.
This development was motivated by using a cryogenic stepping motor in a cryogenics space mission with limited active and passive cooling power.

Author: Dr IIDA, Teruhito (task, inc.)

Co-authors: Mr NAKAGAWA, Jun (Mitsubishi Electric Corporation); Prof. KATAYAMA, Nobuhiko (Kavli IPMU The Univ. of Tokyo); Dr TAKAKU, Ryota (The Univ. of Tokyo); Dr HASEBE, Takashi (Kavli IPMU The Univ. of Tokyo); Dr DUC HOANG, Thuong (Kavli IPMU The Univ. of Tokyo); Dr GHIGNA, Tommaso (KEK/QUP); Prof. MATSUMURA, Tomotake (Kavli IPMU The Univ. of Tokyo); Prof. SAKURAI, Yuki (Okayama University)

Presenter: Dr IIDA, Teruhito (task, inc.)

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