A Study on the Design, Manufacture and Performance Evaluation of a 300kW-class Superconducting Induction Heater using the HTS Magnets

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論 文 名　：A Study on the Design, Manufacture and Performance Evaluation of a 300 kW-class Superconducting Induction Heater using the HTS Magnets
（高温超伝導マグネットを用いた 300kW 級超伝導誘導加熱装置の設計、製作、特性評価に関する研究）

区　　分　：甲

論　文　内　容　の　要　旨

In industries, there are many issues against the implementation of conventional hearting furnaces. Firstly, the current metal-hearting-furnaces with large capacity adopt an old-fashioned heating method, which is very inefficient against input power. These heating furnaces are large in size, which require a large work space. The furnaces have low-safety because ingots are loaded and discharged manually. In addition, engineers with various skills are required to operate the furnaces. In Korea, in recent years, the government executed an environmental protection policy in order to improve energy efficiency and reduce CO_2 emissions. Therefore, improvement in the efficiency of the metal heating furnaces is an urgent task.

Conventional metal hearting methods are: (1) directly heating an ingot by a heater, (2) inducing an eddy current by apply an alternating magnetic field to an ingot and hearting by the Joule heart. In the case of (1), heating efficiency for input power is 20-30%. In the case of (2), heating efficiency is 50-60% due to the restriction of penetration length. In this study, we developed new type of induction heater furnace as below and succeeded in greatly improving the efficiency. A DC magnetic field is applied to a metal ingot and the metal ingot is mechanically rotated to generate an eddy current. In this new method, container, heater, AC coil are omitted and only the metal ingot is heated. In the result, efficiency improves to 90%. However, the realization challenge was how to keep the superconducting magnet at low temperature and operate stably from the radiation ingress of the metal ingot reaching 1000℃.

The heating device has a C-shaped iron core which is excited with a high-temperature superconducting magnet. The metal ingot is loaded in the gap portion of the iron core and mechanically rotated by a motor. Loading and discharging of ingots is also done automatically. The superconducting magnet using a high-temperature superconducting wire is adopted for generating a DC magnetic field. By improving the critical temperature and operating temperature, the thermal stability of the superconducting magnet was secured and further efficiency improvement was attempted. By making the superconducting wire with no-insulation and co-winding a high resistance stainless steel tape wire, the current path at the time of magnet excitation is promptly converged to the correct current path along the superconducting wire. This method suppresses the temperature rise at the quenching part by performing the current diversion to the other turns at the early stage during quench.

This the doctoral dissertation is a series of development studies of 300 kW-class DC induction heating equipment using high-temperature superconducting magnets and consists of

6 chapters. In chapter 1, the background, purpose and the outline of this paper were explained. In chapter 2, the numerical analysis method for DC induction heating by the finite element method is described in detail. In chapter 3, the design of 300 kW-class DC induction heater device is described. The magnetic field generated by the high-temperature superconducting magnet with iron core was set so as to give a heat quantity of 300 kW to the aluminum billet. The specifications of the supporting stand, the loading/unloading system, and the motor spindle are described. Numerical analysis examples of temperature rise, temperature distribution, etc. by the finite element method when heating various metal billet using this equipment are also explained. In chapter 4, parts of the high-temperature superconductive induction heating device and its manufacturing process and the actual heating process are introduced. In chapter 5, performance evaluation results by heating test of aluminum and stainless steel billet by prototype machine are shown. In addition, numerical analysis is carried out in more detail, and proposals for improvement of heating method are also being made. In chapter 6, the results obtained in this paper are summarized and discuss future issues.