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Practical deisgn of a 3 T superconducting magnet for a 300 kW-class DC induction heating using various types of MgB_2 wires

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Abstract. This paper presented a practical design of a 3 T superconducting magnet using MgB2 sandwich-type and round wires for a 300 kW class DC induction heater. First, the specifications of two types of the MgB2 wires were investigated. Then, the magnet was designed so that the maximum magnetic flux density of the magnet was 3 T. A racetrack-shaped double pancake coil (DPC) was applied to all the magnets, and two DPCs with two iron cores were placed on both sides of the billet. The magnetic field distributions were analyzed using a 3D finite element method program. Finally, magnet designs were compared in terms of size, magnetic flux density, operating current, operating temperature, winding method, required length and cost of the wires. This study will be effectively applied to the development of a commercial 300 kW class superconducting DC induction heater.

Keywords; electromagnetic analysis; DC induction heater; MgB2 wire; superconducting magnet

1. Introduction

Nowadays, several superconductors such as the second generation high-temperature superconducting (2G HTS) and low-temperature superconducting MgB_2 wires are used in DC induction heater [1]- [4]. The 2G HTS wire has superior

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performance, but complexity and high cost currently delay their positive effects. On the other hand, MgB_2 wire has a much lower cost advantage [5], [6]. Considering economic efficiency, the DC induction heater using MgB_2 wire is more attractive than those using 2G HTS wire. This paper deals with a practical design of a 3 T superconducting magnet using two types of MgB_2 wires for the 300 kW-class DC induction heater. The detailed features of MgB_2 wires were investigated. Then, a MgB_2 magnet was designed considering the shape, size, magnetic flux density, operating current, operating temperature, winding method, total length and cost of the wire. The target maximum magnetic flux density of the magnet was 3 T. A 3D finite element method (FEM) model was built for analyzing the magnetic distribution of the DC induction heater. Finally, the magnet designs using two types of MgB_2 wires were compared in terms of size, magnetic flux density, operating current, operating temperature, winding method, required length of the wires.

2. Methods

In 2017, Changwon National University and Supercoil Co., Ltd. completed the project on the development of a 300 kW-class DC induction heater using 2G HTS YBCO wires and achieved over 90% system efficiency [7]. The YBCO wire used in the magnet design has high performance but is complex and very expensive. Thus, the authors proposed a 300 kW-class superconducting DC induction heater using MgB_2 wire that has more economic efficiency. Fig. 1 describes the configuration of the 300 kW-class DC induction heater using the MgB_2 magnet.

To design the magnet system for a 300 kW-class DC induction heater, we considered two kinds of MgB_2 wires: circular wire and sandwich-type tape which are manufactured by Hyper Tech Research, Inc. and Columbus Superconductors, respectively. Detailed design process of the 3 T superconducting magnet for the 300 kW-class DC induction heater is shown in Fig. 2

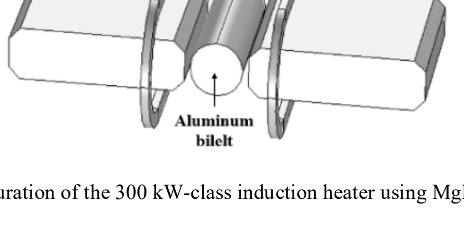


Fig. 1. Configuration of the 300 kW-class induction heater using MgB_2 magnet

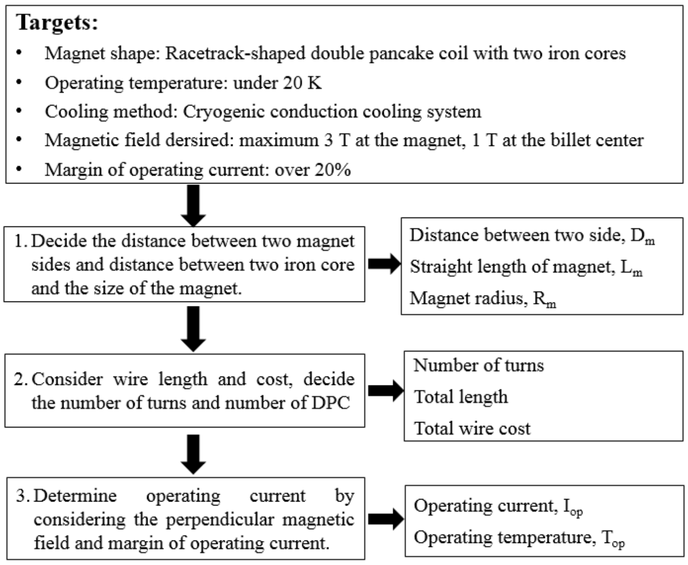
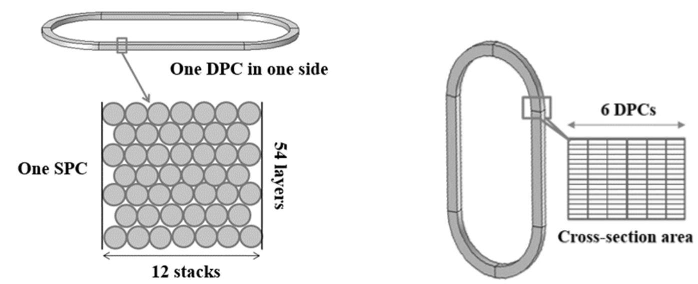


Fig. 2. Design flow chart for the 3 T superconducting magnet

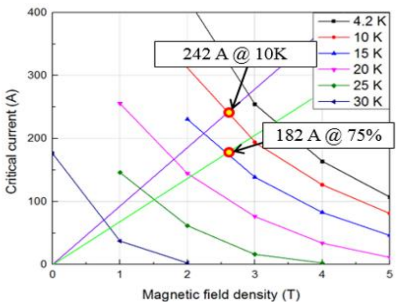
3. Results

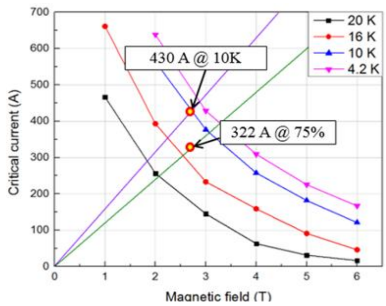
Fig. 3 shows the structure design of the 3 T magnet with two types of MgB_2 wires. The load lines of the 3 T magnets are described in Fig. 4. The operating current of each magnet was estimated, and the magnetic flux density in the MgB_2 magnet and billet are shown in Fig. 5.



(a) (b)

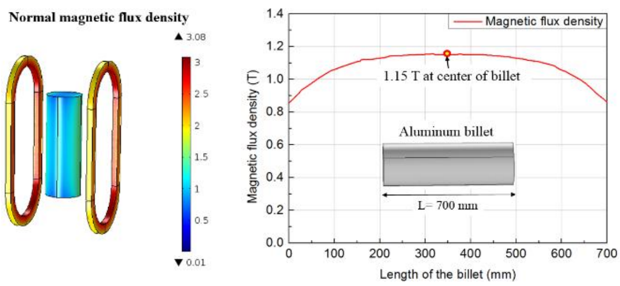
Fig. 3. Structure design of 3 T MgB_2 magnet using: a) MgB_2 circular wire and b) MgB_2 sandwich tape



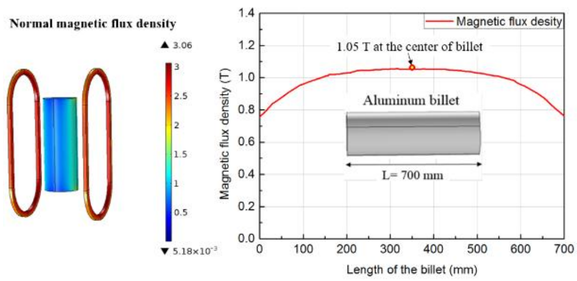


(a) (b)

Fig. 4. Load line of the 3 T magnet using: a) MgB_2 circular wire and b) MgB_2 sandwich tape



(a)



(b)

Fig. 5. Magnetic flux density at the 3 T magnets and aluminum billet in two cases: a) MgB_2 circular wire and b) MgB_2 sandwich tape

With the same shape, straight length, magnet radius and design targets, the 3 T magnet using MgB_2 sandwich-type tape had higher critical current and lower wire cost than those of MgB_2 circular wire. However, the magnet using MgB_2 circular wire was lighter in weight, smaller in size and easier in winding.

4. Conclusion

The authors have designed a 3 T magnet using two types of MgB2 wires for the 300 kW-class DC induction heater. The magnet system consisted of two magnet sides with two iron cores placed on both sides of the billet. The maximum magnetic flux density at the edge of the magnet in the case of using MgB2 sandwich-type tape and MgB2 circular wires were 3.08 T and 3.06 T, respectively. The operating temperature in both cases was 10 K. Next step is winding and testing a full-scale 3 T magnet using MgB2 wires, which is expected to be more economical for 300 kW DC induction heater fabrication.

Acknowledgment

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