



Manufacturing of a REBCO racetrack coil using thermoplastic resin aiming at Maglev application



Katsutoshi Mizuno*, Masafumi Ogata, Hitoshi Hasegawa

Railway Technical Research Institute, 2-8-38, Hikari-cho, Kokubunji-shi, Tokyo 185-8540, Japan

ARTICLE INFO

Article history:

Received 2 February 2015

Received in revised form 23 June 2015

Accepted 26 June 2015

Available online 2 July 2015

Keywords:

REBCO coated conductor

Racetrack coil

Maglev

Thermoplastic resin

ABSTRACT

The REBCO coated conductor is a promising technology for the Maglev application in terms of its high critical temperature. The operating temperature of the on-board magnets can be around 40–50 K with the coated conductor. The REBCO coils are cooled by cryocoolers directly, and hence the thermal design of the REBCO coils significantly changes from that of LTS coils. We have developed a novel REBCO coil structure using thermoplastic resin. The coil is not impregnated and the thermoplastic resin is used to bond the coil winding and the heat transfer members, e.g. copper and aluminum plates. The viscosity of the thermoplastic resin is high enough for the thermoplastic resin not to permeate between the turns in the coil. Therefore, the thermal stress does not occur and the risk of degradation is removed. This paper contains the following three topics. First, the thermal resistance of the thermoplastic resin was measured at cryogenic temperature. Then, a small round REBCO coil was experimentally produced. It has been confirmed that the thermoplastic resin does not cause the degradation and, the adhesion between the coil winding and copper plates withstands the thermal stress. Finally, we successfully produced a full-scale racetrack REBCO coil applying the coil structure with the thermoplastic resin.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

The existing on-board magnets of the Maglev employ LTS coils and they are cooled by liquid nitrogen and helium. They also have cryocoolers for condensation of these cryogenes. The application of the REBCO coated conductor to the Maglev has several advantages. For example, conduction cooling of the coils is possible and cryogenes are no longer necessary. Therefore, the operation cost of the magnets is reduced and the magnet structure is simplified. Our previous study revealed that the optimum operating temperature is in the region of 40–50 K [1]. In this temperature region, the total weight of the coil and the cryocooler is minimized. Higher operating temperature means lower energy consumption. Downsizing of the on-board power source is another advantage since the Maglev vehicle is required to be light weight.

For the realization of the on-board REBCO magnet, it is essential to develop a novel coil structure instead of the conventional epoxy impregnation. Basically, the epoxy impregnation is suitable for a conduction-cooled coil. The epoxy resin works as the heat transfer path and moreover enhance the stiffness of the coil. However, the epoxy impregnation causes serious performance degradation of

the REBCO coil [2]. Even though several methods of avoiding the degradation have been reported already [3–5], the REBCO coil structure specialized for the Maglev application has not been studied yet. Considering the vehicle vibration, the coil should have a reliable heat transfer path and be mechanically strong.

We have developed two types of novel coil structure which prevents the degradation and it also has excellent heat transfer property. One has been reported already and it employs PTFE (polytetrafluoroethylene) tape to avoid the degradation due to the epoxy impregnation [6]. In this paper, we describe the other coil structure using thermoplastic resin. The thermoplastic resin is used for bonding of the coil winding and heat transfer members, e.g. copper and aluminum plates. The fabrication process is totally different from that of epoxy-impregnated coils.

2. Concept of the REBCO coil structure specialized for conduction cooling

The coated conductors exhibit poor strength in the direction in which the lamination proceeds [7]. However, there are variations in the reported stress which causes the delamination of the conductor [2,7–11]. It is, therefore, considered that minimizing the thermal stress between the turns in the REBCO coil is the most reliable method of avoiding the degradation. If an impregnation

* Corresponding author. Tel.: +81 42 573 7301; fax: +81 42 573 7300.

E-mail address: mizuno.katsutoshi.14@rtri.or.jp (K. Mizuno).

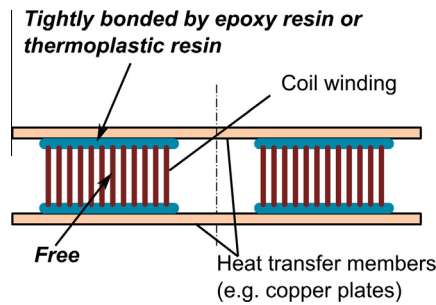


Fig. 1. Schematic drawing of a pancake REBCO coil (cross sectional view). Only the side surfaces of the coil winding are bonded to heat transfer members by epoxy resin or thermoplastic resin.

material has low adhesiveness, detachment would occur between the impregnation material and the conductor instead of the delamination of the conductor. On the other hand, for conduction cooling, a REBCO coil and heat transfer members such as copper plates should be bonded strongly enough to endure the thermal stress or any other stress during the magnet operation.

One of the solutions for achieving these conflicting characteristics is controlling the adhesion area in the REBCO coil. In the case of the pancake coil, only the top and bottom side surfaces are bonded to heat transfer members. Moreover, the winding is separated between the turns as shown in Fig. 1. Based on this concept, we have developed and reported epoxy-impregnated REBCO coils with a PTFE tape for turn-to-turn insulation [6]. The other coil structure, which is introduced in this paper, employs thermoplastic resin. The thermoplastic resin is used to bond a coil winding and heat transfer members. Generally, thermoplastic resins have higher viscosity than that of thermoset resins like epoxy resin. Because of this high viscosity, the thermoplastic resin does not permeate between the turns. The configurations of the coil structure which we propose are summarized in Table 1.

3. Thermal resistance measurement of the thermoplastic resin film

Metals such as OFHC or high purity aluminum are suitable for heat transfer members because of their high thermal conductivity. Of course, they must be electrically insulated from coils. Hence, we have selected a three-layer thermoplastic resin film which consists of a polyimide film and Nucrel® layers (see Fig. 2(a)). Nucrel® is an ethylene acrylic acid and methacrylic acid copolymer. Its melting point is approximately 370 K [12]. By use of this thermoplastic resin film, adhesion and electrical insulation are possible at the same time.

Before producing REBCO coils, the thermal resistance of the thermoplastic resin film was measured. The configuration of the test specimen is shown in Fig. 2(b). The resin film was sandwiched between copper plates and the specimen was heated at 393 K for fusion bonding. The thickness of the resin film is 0.185 mm (0.025 mm thick polyimide and 0.08 mm thick Nucrel® layers). One of the copper plates was connected with the cold head of the cryocooler. A film heater was attached to the other copper plate

to make a temperature difference. The measurement was carried out at approximately 290 K first. Then, the specimen was cooled down and the thermal resistance was measured at 10 K, 20 K, 30 K, 40 K, 50 K, 77 K and finally 290 K again. If the bonding strength of the resin film is not high enough, the adhesive layer will separate because of thermal stress and the resistance will increase. All the measurement was carried out in a vacuum chamber to eliminate the gas conduction. Fig. 3(a) plots the experimentally obtained thermal resistance of the thermoplastic resin film. The thermal resistance increased continuously from 290 K to 10 K. In addition, after the experience of cooling down, the thermal resistance at 290 K still maintained the original level. These results indicate that the adhesion is retained between the thermoplastic resin film and the copper plates. The thermal resistance is mainly due to the thermal conductivity of the resin film itself. In the case of paraffin wax, the thermal resistance increased drastically (see Fig. 3(b)) [6]. The bonding strength of the paraffin wax is not strong enough to withstand the thermal stress when it is cooled down. The thermoplastic resin film does not lose adhesion properties at cryogenic temperature as well as the epoxy resin [6].

4. I–V Characteristics and thermal resistance measurement of a round REBCO coil

A round REBCO coil was produced to demonstrate that the thermoplastic resin bonds the coil winding and heat transfer members without the degradation. The coil was wound with a commercial coated conductor around a GFRP former. The winding tension of the coated conductor was approximately 45 N. The number of turns is 40. Ring-shaped copper plates with the resin film were attached to both top and bottom sides of the coil winding as shown in Fig. 4. The basic shape of the coil is the same as the coils for the comparison experiments in our previous study [6]. The dimensions and other specifications of the coil are summarized in Table 2.

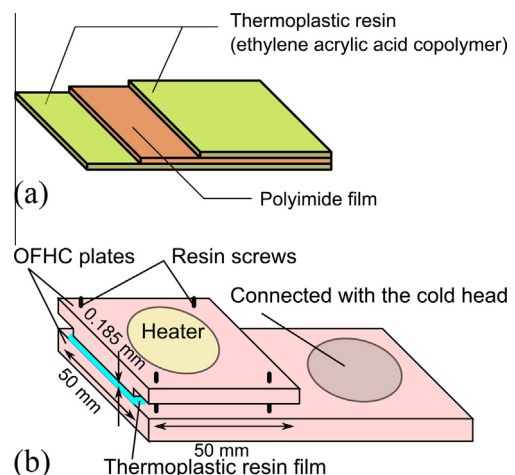


Fig. 2. (a) Schematic drawing of the three-layer thermoplastic resin film; (b) Schematic drawing of the test specimen for the thermal resistance measurement.

Table 1

Configurations of the novel coil structure which prevents the degradation and is excellent at heat transfer properties.

	Epoxy type	Thermoplastic type
Turn insulation	PTFE tape	Polyimide tape
Impregnation	Epoxy resin	N/A
Method for bonding to heat transfer members	Epoxy resin (at the same time of the impregnation)	Thermoplastic resin

Download English Version:

<https://daneshyari.com/en/article/1817508>

Download Persian Version:

<https://daneshyari.com/article/1817508>

[Daneshyari.com](https://daneshyari.com)