

Development of ground coils for the Superconducting Maglev

Hiromori Ishihara
Keizo Yoshikawa
Tsuyoshi Fujimoto
Hiroaki Ota

Central Japan Railway Company, 2-1-85, Konan, Minato-ku, Tokyo, Japan

ABSTRACT: Test runs of the superconducting magnetically levitated linear motor cars (the Superconducting Maglev) have been carried out on the Yamanashi Maglev Test Line. It has been certified that ground coils introduced to side walls of the guide-way prior to the start of the test runs meet the basic specifications for the Test Line. The ground coils are key components of the Superconducting Maglev System, and reduction in production cost is one of the major issues to enable mass production for future revenue services. Hence, two new types of ground coils have been developed. One is the “Integrated-type Coil”, a paired coil for propulsion and levitation in a single mold, and the other is the new-type propulsion coil, or the “Cable-type Coil”, which is made by winding an electric power cable. With the new-type coils, the number of bolts to connect the sidewall could be reduced. Furthermore, eddy current loss and operational electric power could also be reduced. A speed of 575km/h was achieved while the test vehicles were passing through the new-type coils. The superior performance of the new-type coils has been certified.

1 INTRODUCTION

The Superconducting Maglev system has adopted two types of ground coils. One is for propulsion and the other is for levitation and guidance. As the ground coils are installed throughout the guide-way, the production cost of the ground coils significantly affects total construction cost. Hence, the new type ground coils have been developed with the aim of reducing the construction cost by half for commercial operations in the future.

2 CONCEPT OF DEVELOPMENT

2.1 Conventional ground coils

At the initial stage of test runs, double-layered propulsion coils were introduced in order to reduce high harmonic magnetic fields. (Fig. 1) High harmonic magnetic fields unfavorably affect the performance of the superconducting magnet (SCM) while running. Also, their complex structure cost a great deal.



Fig. 1: Double-layered type

2.2 New arrangement of propulsion coils

In recent years, as the performance of the SCM has been improved, single-layered propulsion coils have been made applicable (Fig. 2)

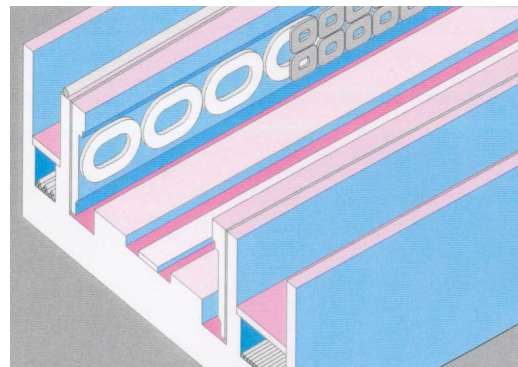


Fig. 2: Single-layered type

However, applying the single-layered coils to the guide-way is not enough to meet the target cost, mentioned in *introduction*, and more improvements or changes in specifications have been examined.

2.3 Specifications for revenue service systems

The ground coils, which were designed to carry out test runs for several years only, are not applicable to the revenue services in the future.

Thus, specifications for future revenue services were newly determined. Propulsion coils must bear high voltage of linear motors and reaction forces equivalent to propulsion forces. On the contrary, levitation coils are not high voltage equipments,

while they must bear reaction forces equivalent to levitation and guidance forces.

The main subjects are to improve endurance of the propulsion coil for high voltage due to high-frequency operations by longer trainsets, to improve reliability over 30 years, and to reduce eddy current loss. (Table 1)

Table 1: Specifications for main development subjects

| | Revenue service system | Yamanashi Test Line (1997-2006) |
|-----------------------------|------------------------|---------------------------------|
| Speed | 500 km/h | 581 km/h |
| Trainset | 16 cars | 3-5 cars |
| Operation years | 35 years | 10 years |
| Propulsion coil arrangement | Single-layer | Double-layer |
| Nominal voltage | 33 kV | 22 kV |
| Eddy current drag reduction | Considered | Not considered |

2.4 New-type ground coils

Two new-type ground coils have been developed. One is the “Integrated-type Coil”, a paired coil for propulsion and levitation in a single mold. (Fig. 3)



Fig. 3: Integrated-type Coil

The other is the new-type propulsion coil, which is made by winding an electric power cable. (Fig. 4) The number of bolts to connect the sidewall was decreased. Furthermore, eddy current loss and operational electric power could also be reduced.

3 INTEGRATED-TYPE COIL

3.1 Concepts

An Integrated-type Coil consists of a propulsion coil and a levitation coil in a single mold. (Fig. 5)

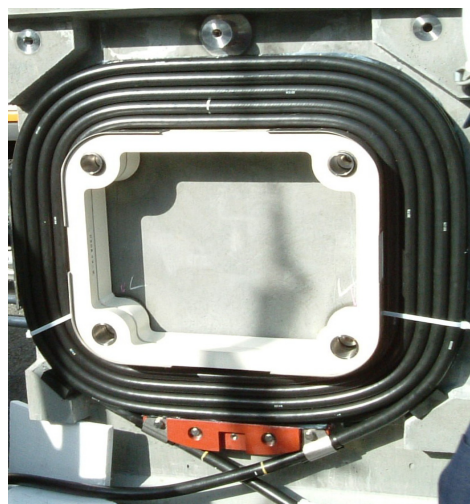


Fig. 4: Cable-type Coil

In 2002, as a prototype for commercial operations, the Integrated-type Coils were set up in some high-speed sections of the Test Line.

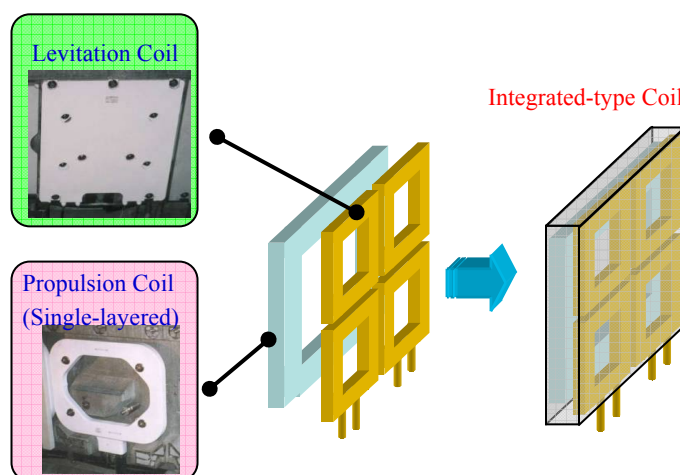


Fig. 5: Image of the Integrated-type Coil

3.2 Advantage of the Integrated-type Coil

A main subject of ground coils was to unify resin materials. The conventional propulsion coils are made of electrical insulation resin (epoxy resin) that endures high voltage, and the conventional levitation coils are made of fiber-reinforced plastic (unsaturated polyester resin) to endure reaction forces equivalent to vehicle’s weight. Briefly, electrical insulation is a top priority in designing propulsion coils and mechanical strength is for levitation and guidance coils.

Due to successful structural design, the resin materials for propulsion coils have been made applicable to the Integrated-type Coil.

3.3 Other properties

The grounded layer is inserted between a propulsion coil and a levitation coil in a single mold so that the high voltage of the propulsion coil cannot affect the levitation coil.

Moreover, as the coil shape was simplified, the surface of a side wall was made flat. This enables reduction in the construction cost. In addition, the number of bolts to connect the side walls was reduced from 12 to 4. (Fig. 6)



Fig. 6: Side-wall shape of Integrated-type Coils

uled to be installed on the Test Line within several years.

4.2 Advantages of the Cable-type Coil

The conventional propulsion coils are produced by placing the conductor in a metallic mold and stiffening resin materials. This method needs a lot of time and costs a great deal. Moreover, they are connected with each other by high-voltage electric power cables with connectors, which is another factor of higher costs.

4.3 Difficulty in producing the Cable-type Coil

Although the electric power cables endure high voltage, they are not strong enough to bear stress derived from winding or reaction forces equivalent to propulsion forces. Iron cores should not be used as the SCM attracts iron magnetically, and the cable's conductor must bear electromagnetic forces. Considering that the mechanical fatigue properties are essential, mechanical strength tests were performed.

4.4 Other properties

The "continuous winding device" was developed to produce the Cable-type Coils. Winding two or more coils continuously makes the conventional electric power cables with connectors useless. (Fig. 7) This device makes it possible to wind the maximum five coils at a time. (Fig. 8)



Fig. 7: Image of Cable-type Coils

4 CABLE-TYPE COIL

4.1 Concept

The Cable-type Coils were designed to reduce production costs by using electric power cables whose production technology had been established.

The coils were installed in some high-speed sections of the Test Line in 2004. The specifications such as anti-high voltage properties and the size of the conductor's cross section were determined for the Test Line.

Development of the Cable-type Coils for revenue services has also been started. The Coils are sched-

In addition to developing the Cable-type Coils, we have been making efforts to develop low-cost levitation coils.



Fig. 8: Cable-type Coils

5 TEST RESULTS

5.1 Bench tests

Various bench tests have been performed at the final stage of developing the new-type ground coils, prior to their installation on the Test Line.

- mechanical strength tests
- electrical insulation tests
- heat shock tests
- long-term electric current application tests
- temperature rising tests
- etc.

5.2 Test Runs

The new ground coils had been set up in some high-speed sections of the Test Line from 2002 through 2004. A maximum speed of 575 km/h was achieved while the test vehicles were passing through the sections, and the superior performance of the coils was certified.

Moreover, in order to reduce operational electric power, the reduction in eddy current loss was also measured. The total running resistance could be reduced to 60 %, suggesting that the practical use level was reached. (Fig. 9)

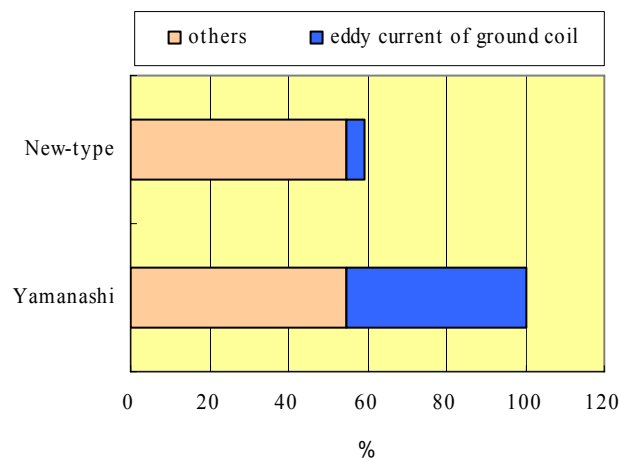


Fig. 9: Running resistance (3 cars, 500km/h)

6 REFERENCES

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