

# Test Results of Superconducting Magnet for Simplified Ground Coils

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**ABSTRACT:** For the superconducting Maglev system to be commercially viable, it is important to reduce costs. Simplifying the ground coil structure effectively would achieve this, but will increase the harmonic magnetic fields that intensify the vibration of on-board superconducting magnets (SCMs). Excessive vibration gives rise to greater heat loss. In this paper, we outlined the improvements and effects to the SCM for simplified ground coils, and described the results of emplacement tests and running test.

## 1 INSTRUCTIONS

The superconducting Maglev system has advanced successfully since the Maglev cars commenced running on the Yamanashi test line. As a result, the Maglev Practical Technology Evaluation Committee of the Ministry of Land, Infrastructure and Transport of Japan concluded in March 2005, "All the technologies of the Superconducting Maglev necessary for the future revenue service were established."

In the Maglev system, it is important to reduce the construction and maintenance costs of ground coils, since they are built into a guideway along the entire length of a line to propel, levitate and guide vehicles. Therefore, simplifying the ground coils will reduce costs.

On the other hand, the on-board superconducting magnets (SCMs) are subjected to electromagnetic disturbance by the harmonic magnetic field from the ground coils. Consequently, electromagnetical and mechanical heat loss will cause in the SCMs. Ground coil selection has a great influence on SCM reliability and durability as well as on the load capacity of the on-board refrigerator. Since the disturbance that the SCM is subjected to by the simplified coils becomes greater than that from existing ground coils, we proposed improving SCM performance.

Therefore, we developed an SCM that would provide sufficient performance to cope with the cost-saving, simplified ground coils built into the guideway, hereinafter referred to as the SCM for simplified ground coils.

In this paper, we outlined the improvements and effects to the SCM for simplified ground coils, and

described the results of emplacement tests and running test.

## 2 EXISTING SCM STRUCTURE

Figure 1 shows the existing SCM structure used on the Yamanashi Maglev test line. The SCM is composed of two sections, a tank section and a coil section. The tank section consists of tanks for liquid helium and liquid nitrogen tank as well as an on-board refrigerator. The on-board refrigerator liquefies helium and nitrogen gases evaporated in the coil section due to vibration disturbance. The coil section primarily consists of a superconducting coil, an inner vessel, a liquid nitrogen-cooled radiation shield and an outer vessel. The liquid helium in the inner vessel

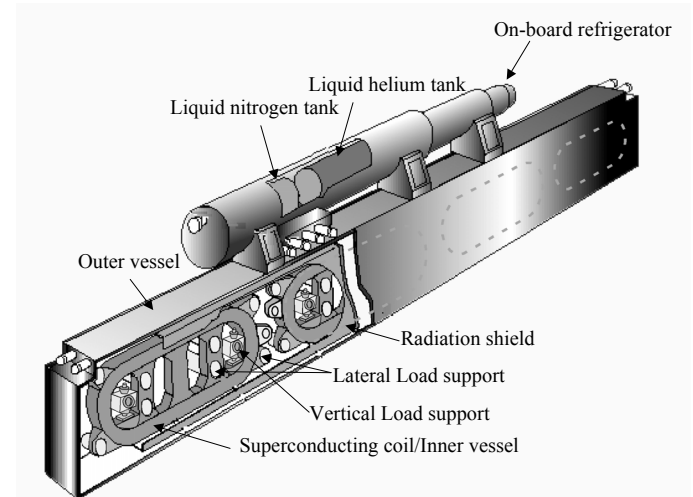


Figure 1: Outline of the superconducting magnet.

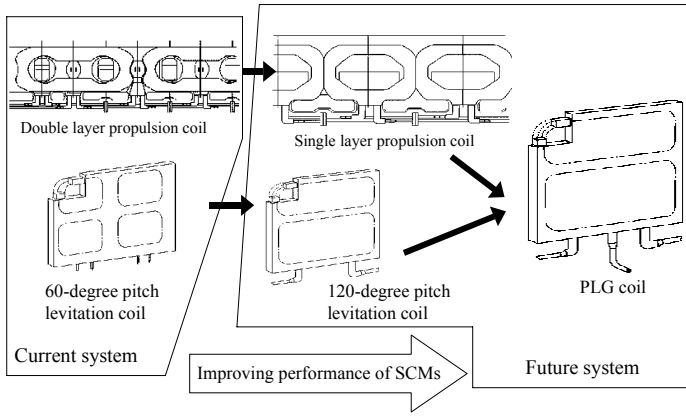


Figure 2: Structures of ground coils.

keeps the coil made of niobium-titanium alloy wire in the superconducting state. The outer vessel keeps these parts in a vacuum. The SCM energized by the exciting system at the train depot and operated in the persistent current mode during running tests.

### 3 SEVERAL IMPROVEMENTS AND EFFECTS

Figure 2 shows the Maglev system ground coil, composed of coils for propulsion, levitation and guidance. Propulsion coils or levitation coils also act as guidance coils.

Levitation coils of the Yamanashi test line are arranged at 60-degree pitches at present, although 120-degree pitch levitation coils could reduce the number of coils by half, and its propulsion coils are arranged to form a double layer. The simplified propulsion coils are designed as a single layer. We have developed a PLG coil that combines the propulsion,

levitation and guidance coils as reference in [1] considering essential aspects in a future system.

The improvements and effects to solve the problems of the SCM for simplified ground coils are indicated in Fig.3. The improvements are as follows.

[The improvements to SCM]

- Increasing of outer vessel thickness on the guideway side
- Improvement of vertical support stiffness
- Relaxation of the stress in the superconducting coil

[The improvements to ground coil]

- Adoption of asymmetrical levitation coil

Concretely, we improved the existing SCM in two ways, namely outer vessel thickness and improving vertical stiffness. Fig.3 represents the improved SCM. We confirmed whether vibration and the heat loss values fall in the range anticipated in the electromagnetic vibration tests and running tests.

### 4 EXPERIMENTAL METHOD

#### 4.1 Electromagnetic vibration tests

We implemented the vibration test in our simulator illustrated in Fig.4. The simulator can apply the vibration when the Maglev car was running to the SCM in the motionless state. Because we simulated the vibration, we provided the electromagnetic coils with the 3 phases alternating current at the frequency corresponding with the running velocity.

The simulator can survey from 100 km/h, at

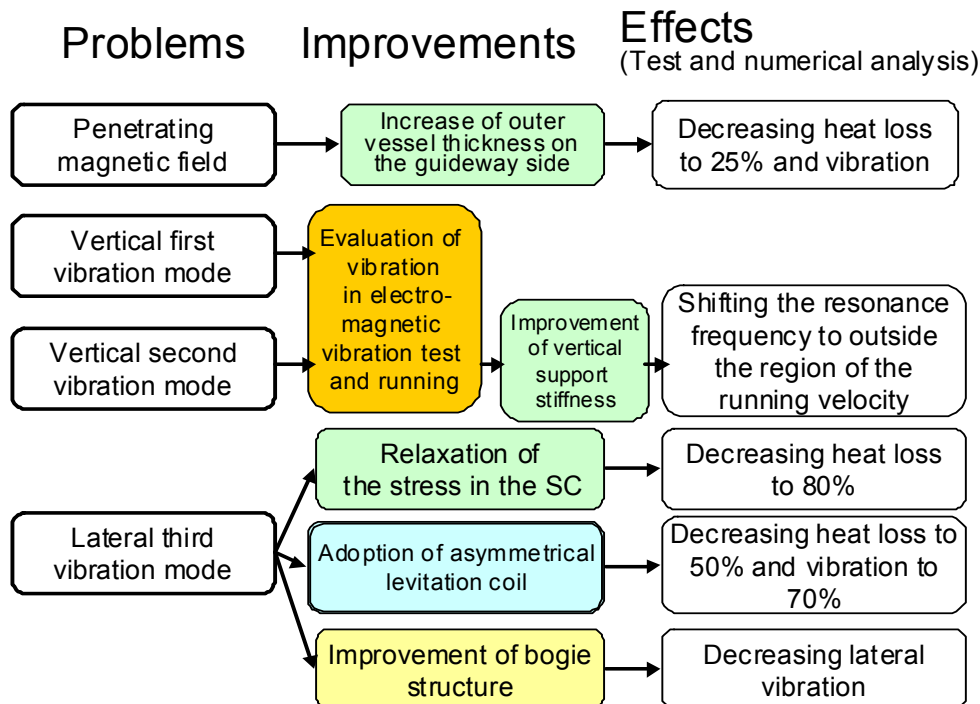


Figure 3: Several improvements and effects for superconducting magnets for simplified ground coils.

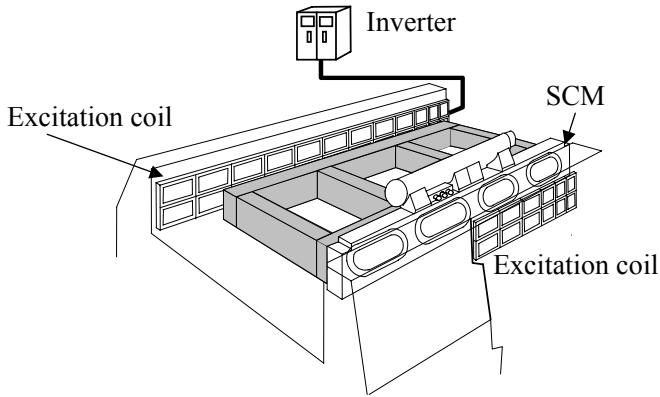


Figure 4: Electromagnetic vibration test apparatus.



Figure 5: 120-degree pitch levitation coils.

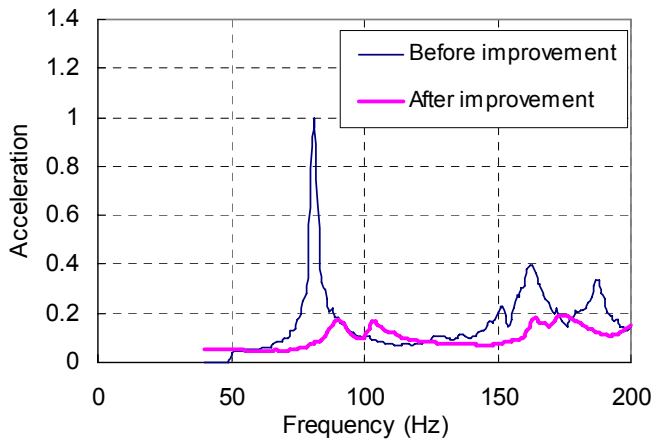


Figure 6: Vibration response in electromagnetic vibration test.

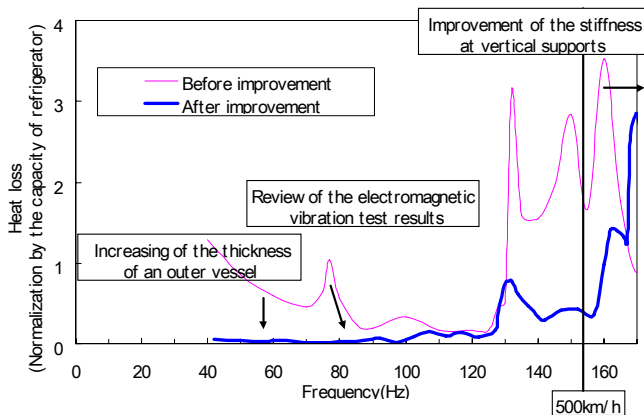


Figure 7: Heat loss of superconducting magnets for simplified ground coils.

which the Maglev car starts to levitate, to 550 km/h, which is the 10 % increase in the commercial maximum speed. We examined the performance of the improved SCM using this simulator in the 120-degree pitch levitation coil arrangement, and set the maximum vibration frequency to 200 Hz. The frequency of the harmonic magnetic fields at the 120-degree pitch is 154 Hz at 500 km/h.

Simulated levitation coils arranged in the simulator are of the symmetrical types.

#### 4.2 Running tests

We laid the 120-pitch levitation coils temporarily on the guideway of a given section of Yamanashi test line. We measured the vibration when the Maglev car was passing through the section at the velocity set for test conditions. In this test, we equipped some accelerators to note the vertical vibration at the bottom of the SCM additionally. We also equipped some accelerators at the opposite existing SCM to compare both of these vibrations. The temporal levitation coils arranged in the section were of the asymmetrical type shown in Fig.5. We expect that the asymmetrical 120-degree pitch levitation coil can reduce the lateral vibration to about 70 % and heat loss to about 50 % compared with the symmetrical levitation coil. We secured the necessary length of levitation coils laid temporarily to grasp the performance of the SCM vibration. The running velocity to examine was set to the maximum value of 500 km/h.

### 5 EXPERIMENTAL RESULTS

#### 5.1 Electromagnetic vibration tests result

We respected the performance of the vertical vibration because it was important to reduce the vertical vibration by the harmonic magnetic field from simplified ground coils, which becomes greater than that from existing ground coils.

Figure 6 shows the average vertical vibration response in the electromagnetic vibration test. The vibration amplitude was normalized to match the first vertical vibration mode amplitude in an existing SCM. The peaks of the first and second vertical vibration mode for the improved SCM shifted toward higher frequencies by about 10 Hz. Their amplitude also decreases by the same amount. The results of the improvement met our expectations.

Figure 7 shows the heat loss response in this test. The heat loss amplitude was normalized to match refrigerator capacity. The heat loss generated by the penetrated magnetic field in low speed running de-

creased so much by the increase in outer vessel thickness and no heat loss exceeding the capacity of the refrigerator generated at speeds up to 500 km/h.

## 6 CONCLUSION

In the development of an SCM for simplified ground coils, we could obtain prospective methods for reducing the assumed excessive heat loss successfully by a combination of the new vibration evaluation method and SCM improvements. We tested to verify that SCM performance was improved by increasing outer vessel thickness and improving the vertical support stiffness. We reached good conclusions by verifying results and the possibility of realizing the SCM for simplified ground coils has become clear.

We are going to carry out a fundamental analysis of several heat loss phenomena that occur as a result of the SCM vibration and study the bogie structures to reduce vibration.

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## 7 REFERENCES

IWAMATSU, M. 2004. Development of a superconducting magnet for simplified ground coils. *MAGLEV'2004 PROCEEDINGS*: 856-863.

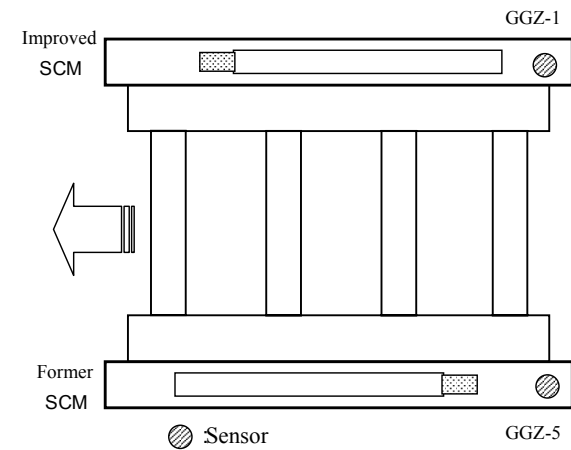


Figure 8: Measurement points.

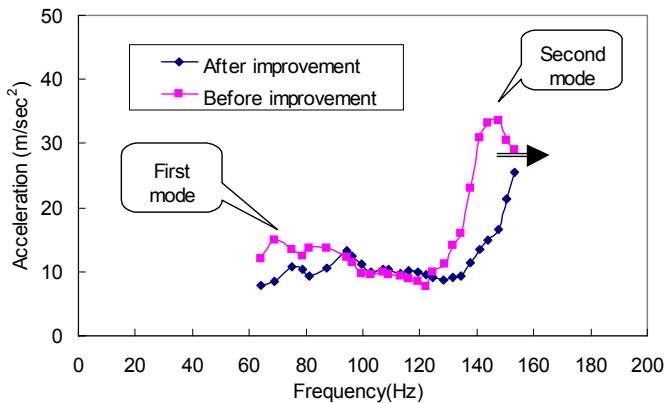


Figure 9: Vibration response in running test.

In this test, we used simulated levitation coils of symmetrical types and didn't improve the existing SCM in the relaxation of the stress in the superconducting coil. Therefore, we expected that the heat loss was reduced further if the entire SCM improvements as described in Fig.3 taken into account.

### 5.2 Running test result

Figure.9 explained the vertical vibration response at the bottom of the SCM illustrated in Fig.8. The direction of movement shows the arrow in Fig.8. Therefore, the measurement points are located on the backward of the direction of movement

Like the electromagnetic vibration tests result, Fig. 9 shows the peak of the second vertical vibration mode is shifted beyond the region of the maximum running speed of 500 km/h (154 Hz as vibrating frequency). The amplitude is less than 40 m/s<sup>2</sup>, the level not causing any specific problems.