DIAGNOSIS AND EVALUATION TECHNIQUE FOR SUPERCONDUCTING MAGNET AND GRAOUND COILS

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ABSTRACT: Since superconducting magnets (SCMs) and ground coils are key components of the JR-Maglev system, it is essential to verify those durability for their estimated life cycle in commercial use. Supplemental methods such as bench tests providing severe load condition to accelerate possible deterioration that could occur, are necessary to evaluate durability in short test terms. Unique bench tests respectively planned for SCM and ground coils, have been developed and conducted at Railway Technical Research Institute (RTRI).

1 INTRODUCTION

Superconducting magnetically levitated transport system (Maglev) is an innovative transportation system in which trains are levitated by electrodynamics forces and operated at a speed up to 550 km/h by linear motor technology. This Maglev system has been developed for forty-three years in Japan. As the final stage of the development, evaluation tests to prove the practicability of this system (JR-Maglev) as a commercial transport means have been conducted in combination with RTRI and Central Japan Railway Company (CJRC) since 1997 at the Yamanashi Maglev Test Line.

Examining all sorts of results obtained for the last eight years, the Maglev Technological Practicality Evaluation Committee under the Japanese Ministry of Land, Infrastructure and Transport acknowledged that the key technology for realizing a commercial use has been established.

Since further evaluation of its durability and cost reduction are essential, technical developments and running tests at the Yamanashi Maglev Test Line are continued.

At RTRI, we continue research and development for performance evaluation of SCMs and ground coils.

2 ROLL OF BENCH TESTS

Test operation at the Yamanashi Maglev Test Line has been continued for collecting running data for durability inspection of major devices. Accumulation of the operational results is effective means to demonstrate the durability of the whole system.

SCMs and ground coils, of which a linear motor consists, are the most important devices of the superconducting maglev system, thus requirements for durability in a commercial use are severe such as 15 years for SCM and more than 30 years for ground coils. In order to inspect the durability required for commercial use, it is important to take into consideration that peculiar load conditions should be included in the test condition not only the operation results obtained on the Yamanashi Maglev Test Line.

We believe it is indispensable to detect a possible defect in a short term that bench tests are essential on acceleration load conditions. Therefore the methods of durability tests are respectively devised for SCMs and ground coils.

3 DURABILITY EVALUATION FOR SCM [1]

SCMs are vibrated by electromagnetic force induced between the SCM and ground coils during a run. The dominant vibration continues at a specific frequency caused by ground coil configuration. However, the severest vibration for the SCM is its resonance vibration. It is efficient therefore that we concentrate on vibrating the SCM by resonance frequency at a stretch on a bench test. By means of the bench test method, we can complete the durability inspection at a short term otherwise it is impossible to have a SCM experience through the operation of the test line as same amount of load stress as in a commercial use.

The devised test method is that we simulate the vibration mode of outer vessel of SCM that occurs at the resonance frequency during a run, by using three mechanical vibrators.

3.1 Test Facilities

A SCM and mechanical vibrator units are arranged in a soundproof room in which a supply device of liquid nitrogen is equipped. Under the test condition of 60-degree pitch levitation coil, a SCM is vibrated out of phase at both upper ends and the center bottom of the outer vessel as shown in Fig.1 (1). Fig.2 (a) shows the obtained vibration mode of a vertical twist one that resembles to the real vibration mode observed during a run. Under the test condition of 120-degree pitch single-layer propulsion coil, a SCM is vibrated in a phase with three points at the center level of SC-coils as shown in Fig.1 (2), which resembles to a tertiary horizontal bending mode as shown in Fig.2 (b).

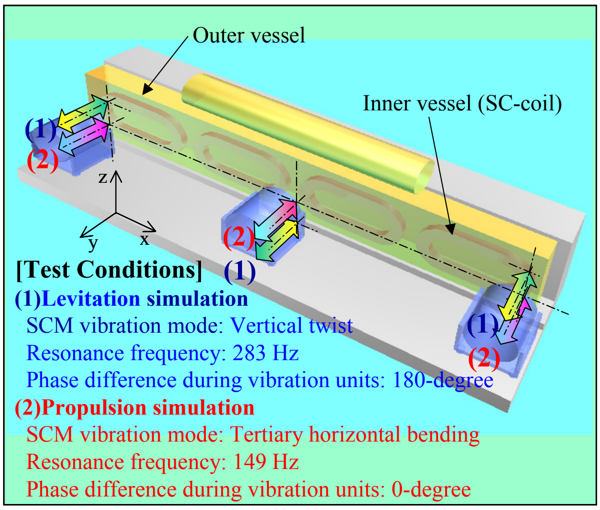


Fig.1: SCM and vibrator unit arrangement

Items to be measured are vibration acceleration, vacuum level, tank pressure, departmental temperatures, force and phase of vibrating points. Some of these have each threshold level, in case of exceeding the threshold; test operation is automatically stopped to maintain the safety.

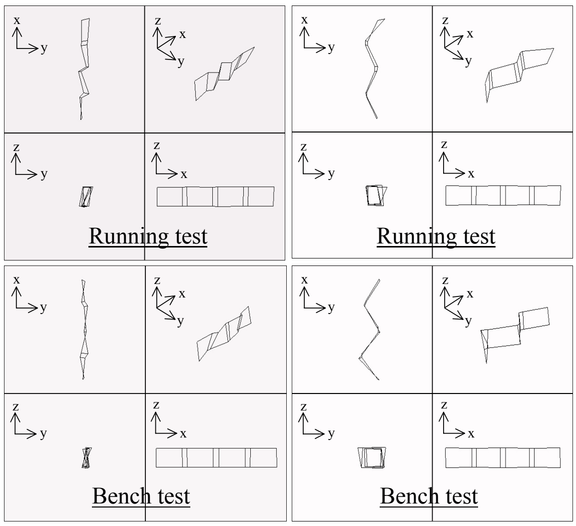
3.2 Temperature Requirements

In terms of material strength, fatigue strength increases at a low temperature than room temperature [2][3]. Therefore, the test condition at room temperature is severer than at the temperature under SCM is substantially applied. However, considering the effects of heat contractions, it is conceivable that the tests at the low temperature simulate a substantial condition. The effect of heat contraction between liquid helium temperature and liquid nitrogen temperature is comparatively very small than that of between liquid helium temperature and room temperature. Therefore we adopted liquid nitrogen temperature as the test temperature condition. By virtue of this choice, the test operation can be carried out much easily at liquid nitrogen temperature.

3.3 Test result

3.3.1 Test conditions

Vibratory conditions were selected so as to simulate that the vibration acceleration at each points are equivalent to the running tests as shown in Fig. 2, and the applied forces were selected considering the maximum payload of bogie specification and the maximum current of propulsion in commercial lines.



(a) Levitation simulation (b) Propulsion simulation
Fig.2: Vibration mode of outer vessel

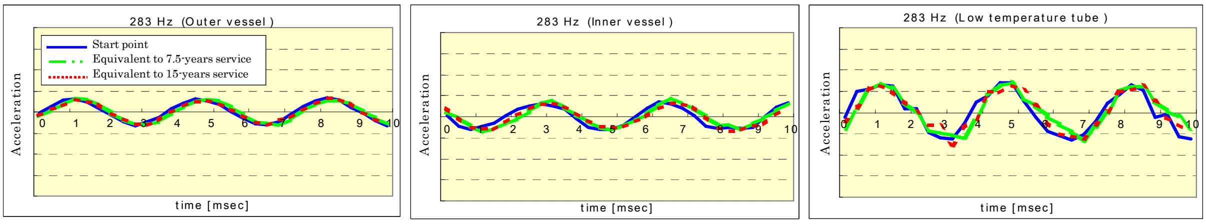


Fig.3: Vibration observed by progress of time on levitation simulation

3.3.2 Test results of durability evaluation

A series of test was carried out to evaluate the durability on a levitation simulation and a propulsion simulation, with each total time of 556 hours. Fig.3 shows the results of levitation simulation. There was no deteriorative change observed by progress of time in each graph, which means that the inner structure of SCM proved to maintain in sound state through the test. The results of propulsion simulation are the same as that. With this result we now concluded that the current SCM has sufficient durability performance against a commercial use.

4 DURABILITY EVALUATION FOR GROUND COILS

A huge number of ground coils will be required for outdoor use in a revenue service over an extended period of time. The verification of the durability of coils on the assumption of revenue service condition is really important in securing the total reliability of the Maglev system.

4.1 Basic configuration of Durability Verification

Fig.4 provides a block diagram showing the basic configuration of verification processes necessary for the durability assessment of ground coils [4].

The first process is a material performance test, the second is an examination of actually used coil and the third is a verification bench test using actual coils.

Considering these three test results, we intend to evaluate total performance for the durability of ground coils.

Since durability evaluation of ground coils is time consuming, we have devised bench test methods that enable to perform acceleration tests. Recently we have developed unique bench test apparatus for ground coils. An electromagnetic vibration apparatus is useful method in which, changing a ground coil current from an inverter, the ground coil conductor is directly affected by the electromagnetic force with magnetic field of SCM. By virtue of this method it became possible to simulate a real load condition applied at an actual ground coil. The detail of this method is introduced in “Development of Electromagnetic Vibration Apparatus for Ground Coils of Maglev” of this conference.

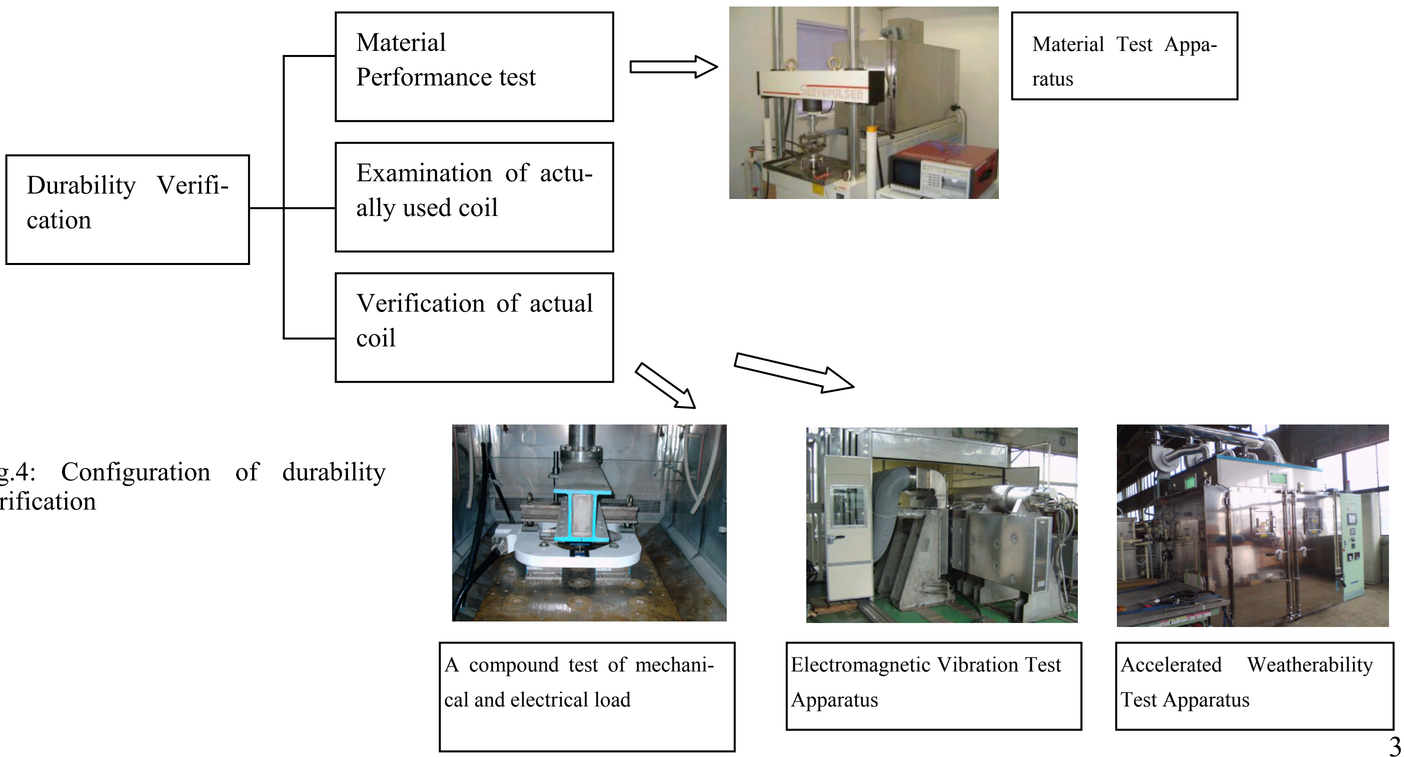


Fig.4: Configuration of durability verification

4.2 Fatigue properties of molding resin

Next, we introduce an example of a material performance test. An epoxy resin is used in manufacturing propulsion coils for insulation performance as well as structure material performance. However, epoxy resin has few uses demanded mechanical strength. To use resins as a structure material of coils, therefore, it is necessary to grasp their characteristics of strength and the degree of deviation.

Thus, in order to acquire the fatigue strength characteristics of epoxy resin, sample tests using test pieces were implemented and the distribution of fatigue strength was obtained, under the condition where mean stresses are applied.

Fig 5 shows the results of fatigue tests of epoxy resin summarized in the modified Goodman diagram. As predicted, the results indicates that the distribution of fatigue strength of epoxy resin dose not mach the straight line of the conventional Goodman diagram, in all range of the axis of mean stress, obtained distribution comes lower than that of the conventional Goodman formula.

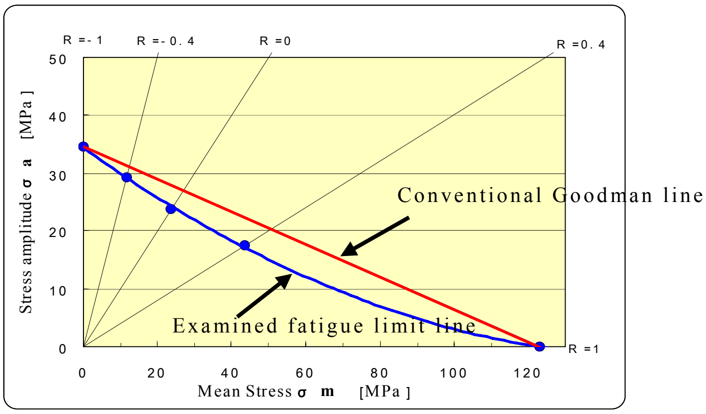


Fig.5: Fatigue limit diagram

5 CONCLUTION

SCMs and ground coils, of which a linear motor consists, are key devices of the superconducting maglev system, thus requirements of durability for a commercial use are very severe. It is indispensable to detect a possible defect in a short term that bench tests should be carried out on acceleration load conditions.

We devised new bench test methods for inspection of SCM and ground coils. Using the new test methods, we could evaluate the durability of SCM and ground coils effectively by simulating the vibration conditions that actually occur at SCM and ground coils during a run.

We are convinced that the newly developed test methods will be improved and be of a great helping for verifying the durability of SCM and ground coils in future as well.

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