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論　文　内　容　要　旨

報告番号	甲　先　第　188　号	氏　名	鈴木　正夫
学位論文題目	Study on High Functionality, Durability Verification and Insulation Diagnostic Techniques for Superconducting Maglev Ground Coil （超電導磁気浮上式鉄道用地上コイルの高機能化および耐久性検証・絶縁診断技術に関する研究）		

内容要旨

The magnetically levitated railway (Maglev: Magnetically levitated transportation system) supports and guides its vehicles by electromagnetic (EM) force and is driven by a linear motor. A superconducting Maglev vehicle has no iron wheels or pantograph. The ultra-high-speed traveling is achieved by the state of complete non-contact with the ground. The electromagnets called "superconducting magnets" mounted on the vehicle and "the ground coil" laid on the guide-way make the ultra-high-speed traveling possible.

The limit design is required for optimizing the EM force characteristics against the superconducting magnet and reducing the cost of the huge number of ground coils. Furthermore, because mechanical, electrical and environmental complex loads are applied for a long period of time to the air-core molded ground coil, its operating condition will be extremely severe. It is an important issue how the reliability of the ground coil should be verified for practical commercial operation of the system. It is necessary to organize unique verifying procedures. In this study, high functionality and a systematized durability verification method for practical commercial operation were examined while considering the conflicting proposition of cost reduction against stable performance. Furthermore, the insulation diagnostic method for the propulsion coil using EM wave detection was studied and a new diagnostic technique to identify the insulation abnormality of laying coils from the ultra-high-speed running vehicle was examined.

The ground coils used as an EM guide-way are exposed to electrical, mechanical, and environmental complex load. Therefore, when designing the ground coil, it is necessary to scrutinize the operating and environmental conditions over a long time and to set appropriate specifications.

The cost reduction is an important proposition for a vast number of ground coils. In this study, we have made advanced research and development for the two systems, which is expected to reduce the cost. The manufacturing costs can be reduced by reviewing the material and process by applying the reaction injection molding (RIM) system. The overall cost can be reduced by half of the required number of coils by applying the propulsion, levitation and guidance (PLG) system.

For the practical application of the ground coil, when the cost reduction is considered, enhanced performance and reliability are important. The cable joined part or bolted part of the coil can easily become an operational weakness.

Superiority of the linear cable connecting part and the fiber reinforced plastics (FRP) bush aimed at improving the reliability under the electromagnetic vibrating environment were confirmed as representative research results. By applying a compression molding to the winding coils that tried to decrease the eddy current, the system running costs was decreased and the performance was stable. In addition, research and development concerning the ground coil ID information management method using RF tag and the ground coil self-diagnostic method for the purpose of preventing troubles were conducted to promote labor saving for the maintenance of the ground coils.

Durability verification of the ground coils which are operated in a severe environment, has become an important issue in ensuring the reliability of the Maglev entire system. Therefore, at the time of endurance verification, it is important to evaluate appropriately by understanding the characteristics of the materials and structures of the ground coils while considering appropriate verification measures equivalent to the actual on-site operation. In endurance verification of ground coils, unique verification procedures have been performed for the material property tests, actual operation study and the actual coil verification test as a basic configuration. It is important to carry out the investigations and experiments while reflecting on the obtained results each other.

The propulsion ground coil requires insulation stability as special high-voltage equipment. As there is no means for applying a high voltage to the propulsion coil from the substation while the vehicle is stopped in the current Maglev system, development of effective on-site insulation diagnostic procedures is required. The fundamental verification concerning the PD characteristics of a defect-simulated specimen and a non-destructive inspection of the defective part targeting the propulsion ground coil was performed. In addition, PD occurring in the internal defect of the ground coil was located by the radio interferometer system using multiple dipole antennas. Furthermore, by applying this method, a basic experiment to identify the abnormal coil as installed condition was performed by the on-vehicle antenna traveling in the Miyazaki Test Line. As a result, the defective coil was identified from the traveling vehicle. For establishing an effective insulation diagnostic technique in the future, the possibility of a practical application greatly increased. Furthermore, assuming future actual commercial operations, the insulation diagnostic technique for detecting abnormal coils from the high-speed traveling vehicle was investigated. Because the Maglev system employs a linear synchronous motor for the primary ground coils, the current phase of the propulsion coils and moving vehicle are synchronized. Therefore, if the antennas of EM wave detection are installed in the vehicle, it is possible to adjust the voltage phase of the ground coils so that the voltage phase that generates PD can be easily detected. In addition, it was confirmed that application of the EM wave shielding material to the back and sides of the antenna and the digital signal processing for the sampling data were effective measures for removing noise in insulation diagnosis.

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論文審査の結果の要旨

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学位論文題目

Study on High Functionality, Durability Verification and Insulation Diagnostic Techniques for Superconducting Maglev Ground Coil
超電導磁気浮上式鉄道用地上コイルの高機能化および耐久性検証・絶縁診断技術に関する研究

審査結果の要旨

超電導磁気浮上式鉄道は，従来の鉄道とは異なり，車両を電磁力により地上から浮上させ，かつ，推進させるというものである。超電導磁気浮上式鉄道では車両側に超電導磁石を搭載し，地上側に推進，浮上案内用のコイル（以下，地上コイル）を設置し，この地上コイルに電力を供給することで上記の電磁力を得る仕組みとなっている。実運用では，膨大な数の地上コイルを設置する必要があり，さらに長期間屋外で使用されることから，安価でかつ高い耐久性，信頼性が要求されている。

本研究では，地上コイルの経費削減法として新たな地上コイル製造法を提案するとともに，新しい推進・浮上案内一体型コイルを提案している。また，地上コイルの高機能化としてケーブル接続部の小型化や地上コイル固定具，IC(Identification)タグを利用した保守管理装置，新たなモールド樹脂の開発を実施している。さらに，実運用環境を考慮した地上コイルの耐久性検証実験，電磁波を利用した非接触型の絶縁診断技術の開発を実施している。

本論文の構成は，１章では本研究の背景，目的，２章では地上コイルの使用環境，３章では地上コイルの経費削減のための製造法(RIM法 : Reaction Injection Molding Method, 反応射出成形法)，及び，地上コイル設置数を削減することを目的としたPLGコイル（Propulsion, Levitation and Guidance : 推進，浮上，案内一体型コイル）の仕様説明，４章では地上コイルの高機能化，５章では地上コイルの耐久性検証，６章では地上コイルの絶縁診断技術，７章は全体のまとめとなっている。

以上本研究では，超電導磁気浮上式鉄道用の地上コイルの高機能化，耐久性検証，絶縁診断技術において有効な手法の提案，結果を得ており，本論文は博士（工学）の学位授与に値するものと判定する。