A Study on Necessity to Introduce Prognostic Maintenance of Rolling Stock

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Abstract

The easiest way to prevent the railway vehicle failure is to heavily invest money and labor into maintenance and advance the vehicle replacement and maintenance cycles. However, the actual operational maintenance resources (cost and time) are limited, making it difficult to predict when and where sudden failures would occur. Therefore, many studies have examined how to build an effective maintenance system that can minimize failures based on limited resource availability. In this paper, I will examine the necessity of predictive maintenance and research trends.

1. Introduction

Out of the many components constituting a railroad system, rolling stocks offer services that remain the closest to customers. Therefore, many efforts are made to improve rolling stock maintenance to prevent operational failures and improve customer services. The easiest way to prevent the railway vehicle failure is to heavily invest money and labor into maintenance and advance the vehicle replacement and maintenance cycles. However, the actual operational maintenance resources (cost and time) are limited, making it difficult to predict when and where sudden failures would occur. Therefore, many studies have examined how to build an effective maintenance system that can minimize failures based on limited resource availability.

There has been a shift of trend on rolling stock maintenance from general Preventive Maintenance (PM) - where the maintenance manager evaluates the current situation and decides on maintenance - towards Time Based Maintenance(TMB) based on a systematic maintenance standards taking into account failure frequency and importance of the devices and components. Today, the concept of Reliability Centered Maintenance(RCM), utilizing maintenance history and statistical theories, has been adopted to improve the weaknesses of the TBM. However, even the current RCM system develops maintenance plans based on failure history (failure frequency, importance, reliability, etc), making it extremely difficult to lower the failure rate including sudden failures below a certain level. As a solution to such obstacle, the equipment's sector adopted the Condition Based Maintenance(CBM). The CBM is the usual maintenance system used in today's industrial plant equipment sector, and Korea's technology in the field has reached a high level.

2. Main Issues

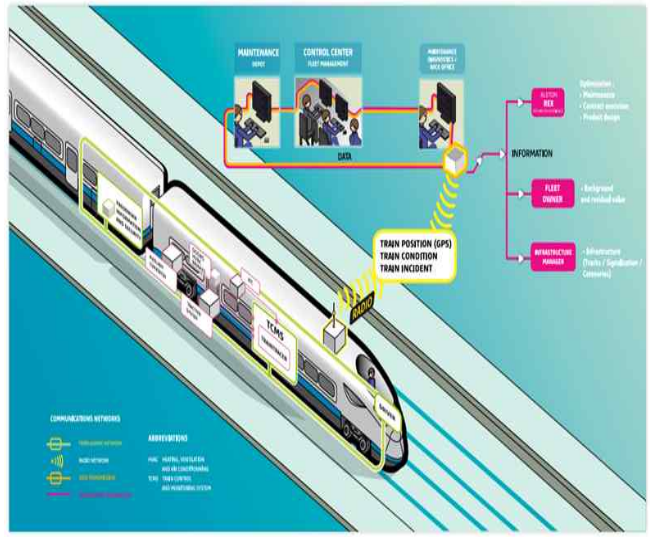
2.1. Condition Based Maintenance (CBM) and Rolling Stocks

Whereas many advanced studies have already focused on CBM applications in plant equipment, the CBM technology has not yet been applied to the railroad sector notably due to the following reasons:

First, the failure mechanism of major devices of rolling stocks is not very clear. Other than few devices whose failure can be easily identified with a simple measurement of physical quantity, it is in fact impossible to know how the measured physical quantity represents the condition of a device. Second, a railway vehicle is constantly on the move with changes of time, allowing its surrounding to change accordingly. And this makes it challenging to find the physical property values related with the failure. For example, vibration of a bogie is related with the conditions of the bogie itself, but also the conditions of the railway and the wheels, and is also impacted by changes in the weight of passengers, although to a slight degree. Third, initial investment costs are high because measurement sensors and failure analysis devices are needed in proportion to the number of vehicles, maintenance costs for measurement sensors, as well as risk management in relation to failures. All of these factors serve as obstacles in introducing the CBM in railway vehicles.

<Table 1. Comparison of Plant Equipment and Rolling Stock>

Plant Equipment	**Rolling Stock**
· Operating hours are constant	· Operating distance and time vary
· Limited environmental variables	· Many environment variables (climate, track condition, etc)
· Either on halt or running speed is low	· Running speed 80km/h ~ 300km/h
· Few interactive components	· No interactive components
· Relatively simple to create a testing environment (unit test is possible)	· Difficult to create a testing environment
· Short communications distance (limited to factory interior)	· Long communications distance (vehicle is constantly on the move)
· High level of component standardization and quality control	· Limited railroad market results in different quality levels of firms

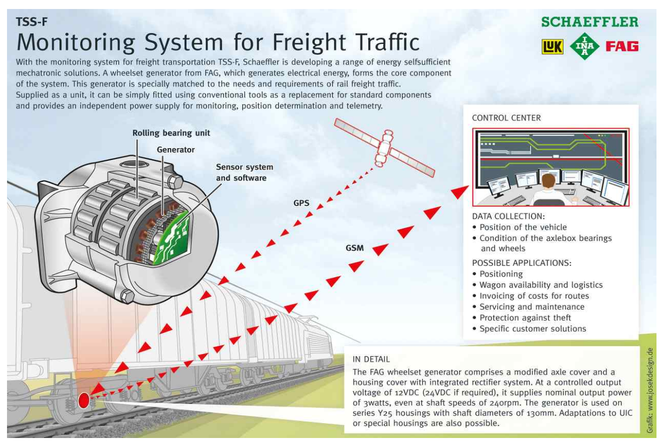


<Fig. 1 Alstom Train-Tracer Conceptual Image>

A bearing manufacturer SCHAEFFLER and SKF have engaged in the development and sales of a vibration and temperature measuring sensor-embedded axle bearing and axle box cover replaceable monitoring sensors. In particular, SCHAEFFLER's axle bearing sensor does not need cables or power for installation and in case of an axle bearing error, all abnormalities are immediately notified to the control center via telecommunications. Therefore, once the issues of installation costs and compatibility with the existing vehicles are addressed, this technology will be very effective in reducing the failure incidents of freight trains.

2.2. Korean and Overseas Examples of CBM Applications in Rolling Stocks

The most advanced CBM system application in the railroad sector is Train-Tracer developed by Alstom. Built on Alstom's vehicle-manufacturing technology, Train-Tracer monitors the conditions of key devices and wirelessly transfers relevant data to the maintenance manager allowing for a real-time monitoring of the vehicle, which is expected to reduce failures and increase maintenance efficiency. Ever since its pilot operation in 2010, it is operational in about 350 units of vehicles to date. Although its technical specifications are not yet fully known from the officially announced information, this technology is believed to have further developed the features of the conventional Train Control Management System (TCMS) of collecting failure information, combined with a wireless communications system tasked to send and receive the measured data. As of today, it is deemed that other advanced features supporting life diagnosis or PHM(prognostics and health management) (except for the real-time transfer of simple condition-related information) are yet to be developed.



<Fig. 2 Conceptual Map of SCHAFFLER's Bearing Sensor >

<Fig. 3 Application of Axle Bearing Sensor Developed by SKF>

The European Union has implemented various European railway standards for trans-boundary rail networks operations. Among them is the TSI(technical specification for interoperability), which in the EN2008/232/CE Official Journal, recommends monitoring the devices as listed in <Table 2> based on the monitoring and diagnostic concepts. The details of the specific monitoring vary according to devices, but doors, detection of driving instability, break system, fire detection, driving detection are items which are currently being monitored in KTXs as well. Since the TSI is mandatory technical specifications that need to be met for rolling stock operations within the EU, the new vehicles to operate in the future must accommodate TSI recommendations for manufacturing. Above all, the scope of devices to be monitored is likely to be expanded with the potential revision of TSI. Furthermore, as European standards are considered as global standards and are highly influential in the railway sector, not only Korea, but also China, Japan and other railroad leaders are highly likely to develop and implement technical specifications similar to those of the TSI recommendations.

Devices Subject to Monitoring
Door
Driving Instability Detection
Axle Box
Passenger Alarm
Break System
Derailment Detection
Fire Detection
Driver Detection
Control Information and Signal Device Information

<Table 2. TSI Monitoring Recommended Device>

2.3. R&D Trends in Prognostic Maintenance of Rolling Stock

There is a growing reliability and maximization of cost-effectiveness with regards to the maintenance of rolling stocks. Today, the maintenance of railway vehicles is generally TBO and RCM based, however, many issues arise thereof. The primary issue with the TBO is the increased maintenance costs due to the increase of train vehicles, and another secondary issue is the frequent failures taking place right after the TBO. The most optimum solution is to conduct maintenance on components with abnormalities while preserving the original state of vehicles as much as possible. To this end, reliability-based maintenance through RAMS management of rolling stocks is also being conducted, but statistics-based deduction entails limitations.

For the maintenance of railway vehicles, CBM must be adopted, and yet objective standards adding credibility to CBM must be presented. To this end, monitoring techniques capable of assessing the conditions of each vehicle are needed, and selectively accumulated monitoring data must be utilized to create reliable standardized condition-based data of vehicles.

For this purpose, a vehicle and surface early detection module is currently under development. Figure 8 represents a conceptual map of the early detection module under development. These models, as aforementioned, were conceptually designed to compare the normal state and abnormal state based on an algorithm applying PHM to technologies that offer monitoring and selectively accumulate data and identify failure of each device in advance. Once the development is finalized, it would allow for a more advanced monitoring technology compared to the current one merely offering incidence-based warning will be born, with the potential be exported to the global markets.

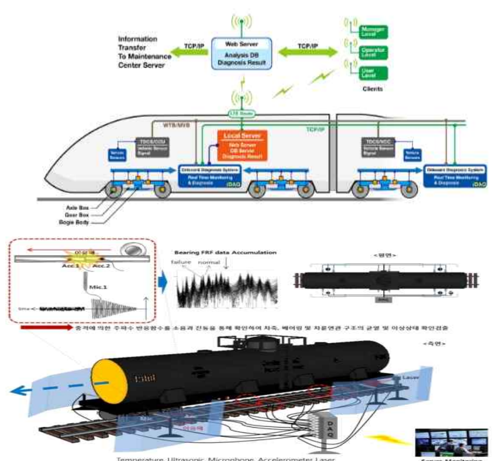


Fig. 4 High-speed Train Monitoring System at On-board(Left), Monitoring Detector Wheel and Bearing by Railway Side(Right)

3. Conclusion

The simplest way to prevent a failure is to let an expert conduct a 24/7 monitoring of all devices. However, given limited resources in maintenance, as well as the nature of railway vehicles constantly on the move, it is practically impossible for an expert to conduct a real-time monitoring of all vehicles. An alternative technology indirectly enabling this is the Condition Based Maintenance (CBM) system. With the recent IT developments it has become possible to go on-line through wireless internet anytime, anywhere, which enables furthermore the Internet of Things (IoT) on many different devices. What is more, physical quantity measurement sensors and high-performing data processing devices have become more affordable, smaller, and energy-efficient. In this regard, the technical foundation for remote-monitoring of vehicles and maintenance has been established. Today, information is gathered in a limited manner through axle bearing or TCMS from some devices and sent and received real-time but it is just a matter of time before the scope of CBM-covered devices will be expanded to include all major components of railroad rolling stocks.

Although the Korean railways may lack vehicle-manufacturing technology or financial resources compared to other railroad leaders like Europe, China or Japan, Korea as a nation excels in the world in terms of safety and punctuality as seen from its railroad accident rate or punctual arrival rate, etc. Were it not for its operational know-how of the railroad system accumulated over the years since its first operation in 1899 and also constant efforts made to improve technology, such achievements would not have been possible. Moving forward, for the purpose of ensuring the safety and speed of the Korean railway, preemptive investments and researches must be realized on the real-time CBM technologies for the Korean railway industry to keep up with the technological developments taking place in the global rail sector.

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Biographies

Juwon, Kim and graduated from Chungnam National University. also holds a master's degree in mechanical engineering from the same university. Currently, is a Ph.D. student and working at Korea Railroad Research Institute. His main areas of interest are railway vehicle technology, mechanical measurement, and reliability management (RAMS).