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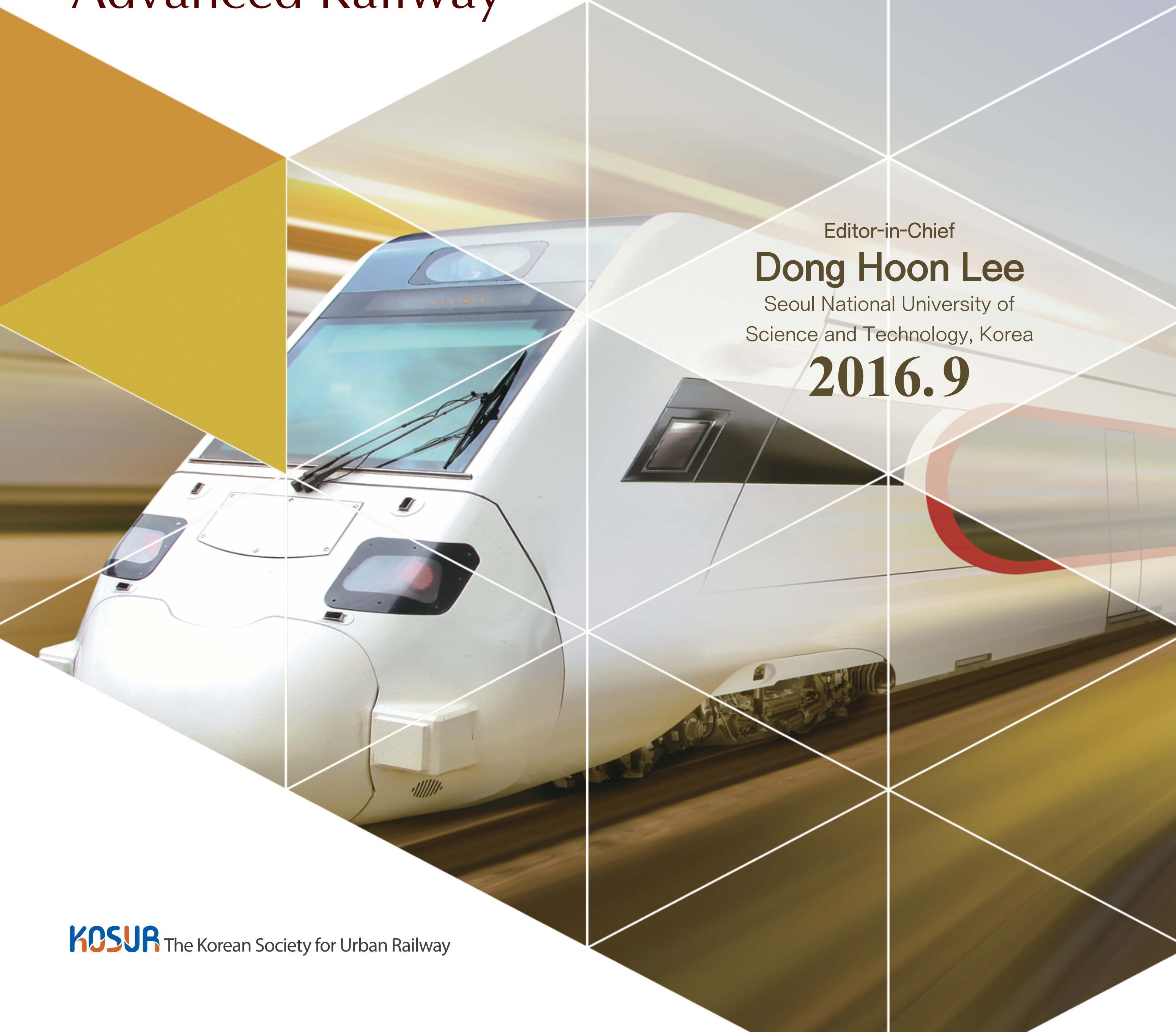

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Correlation study modules standardization between and the Wheel-Loading deviation of electric vehicles

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Key words : Wheel-Loading, Modules Standardization

1. Introduction

Weight distribution control is the most important in designing railroad cars because it is associated with derailment. In general, it may consist only of simulations by calculation and on-track tests by actual measurement. However, adjusting axial height and airbag of complete trains and then reflecting them in actual trains potentially mean the failure of weight control.

Therefore, in order to control these problems in advance, it is possible to mean the essence of weight control by managing design DB in the design phase based on modularized definition and controlling risk factors in advance.

2. Body

If other methods except for simulations by calculation and measurement sites of manufacturers are used when measuring the wheel load, errors occur in the results.

<Fig. 1 Measurement on track in station yard (car storage track of Siheung car)>

<Fig. 2 Utilization of manufacturer' s measurement site>

Generally, the following three methods are used to measure wheel load: The first is to use measurement sites of manufacturers. This method is the most reliable and accurate because tracks are produced for testing and continuous maintenance is performed with track irregularity corrected. The second is to use scales. This method is to measure weight by putting a scale under the wheel after lifting a railroad car to a certain height using a hydraulic jack or heavy machinery such as a crane. Although it is estimated that this method is as reliable as that using measurement sites, it is considered difficult to obtain accurate values when tracks are not properly managed. The third is to use strain gauges. This method is to calculate corrected values at a fixed ration by measuring the shear stress of tracks. Although it seems that this method is less reliable than the above two methods because two-phased corrections are performed, it is considered possible to measure actual wheel load as the most reasonable and accessible method.

Division	Reliability	Measure ment time	Measurement principle
Use of measure ment site	Very accurate	Short	Use of track load cells
Use of scale	Relatively accurate	Long	Use of scales
Use of strain gauge	Accurate	Short	Measurement of shear stress

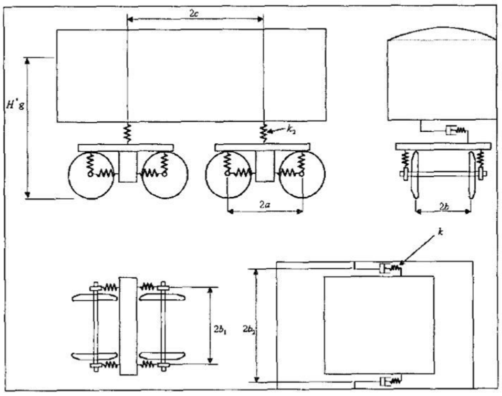
<Table 1 Comparison of weight measurement methods>

Although it costs to use measurement sites of manufacturers, it is not easy to receive their cooperation for measurement because the process state is very important for manufacturers. Each measurement method has advantages and disadvantages because various matters are not good in the method using a scale.

Division		Design weight	Allowable value (tons)
Weight by railroad car	Tc1	38.308 tons	38.39 ~ 40.22
	M	38.231 tons	36.2 ~ 40.14
	M'	43.906 tons	41.71 ~ 46.10
	T	30.460 tons	28.94 ~ 31.98
	Tc2	38.295 ton	36.38 ~ 40.21

<Table 2 Comparison of design values for actual railroad cars>

Based on the above table, the design load and allowable value are 5%. However, it is considered that there values will increase more in consideration of the state of railroad cars (profile position of wheels, state of rail head, track irregularity).



<Fig. 3 Comparison of design values for actual railroad cars>

As shown in the figure, many elements are related to wheel load. Design values can be obtained by approximately 18 variables. If design weight values are standardized by modularizing these values more compact and then dividing them into truck, body, and overall length, many more standardized railroad cars will be manufactured.

3. Conclusion

In order to operate railroad cars, mass production should be performed using perfectly designed ones. When the manufacture is wrongly started, there is no use maintaining based on the principles. In general, maintenance is performed to keep the status quo, and wheel load is measured based on the initially measured values. It means that maintaining railroad cars to keep them within the lifetime according to the theoretical original state in the manual. Currently, there is a need to accurately analyze whether standards for track irregularity are very strict as shown in the above mentioned measurement methods. Follow-up studies will be conducted on this issue. It is considered that standardized and modularized weight control is greatly needed because everything is determined in designing railroad cars.

Postscript

This study describes only related facts because it is being conducted and proper result values have yet to be descried.

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Study on the Performance Improvement of Propulsion Control System of Chopper subway train by Utilizing Digital Calculation Methods

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Seoul National University of Science & Technology

Key words : Propulsion Control System, Electronic Control Unit(EC BOX), Chopper System of Line 2

1. Introduction

GEC chopper trains were introduced in 1989 and have been operated in the Seoul Metropolitan Subway Lines 2 and 3 for 25 years to the present. The propulsion control apparatus to control the powering and braking of these chopper trains as a main controller frequently has broken down due to the deterioration by long-term use. Accordingly, it has cost a lot to maintain the failure, and this has considerably interfered with train operation schedules. In addition, it is a fact that there is difficulty in maintenance because the reason for the failure cannot be identified when the failure automatically disappears during main line services. Therefore, in order to improve these problems, this study examined the new controller analyzing failure information and preventing analog computing methods by storing failure information in case of failure and applying the design with digital computing. Based on the study results, this study aims to contribute to reducing the budget and safe train operation.

2. Body

2. 1 Outline of propulsion control apparatus (EC BOX)

The propulsion control apparatus (existing product) for chopper trains has been operated in the Seoul Metro Lines 2 and 3 and consists of M1-car (power car) and M2-car (power car) per unit. Based on request signals input by a railroad engineer and main signals input from general control circuits, the propulsion control apparatus executes chopper control related to powering and braking. Moreover, it prohibits powering or braking by providing the card with the signals input from various detection devices in the event of failure and displays the type of failure related to the failure card. In the normal state, it controls electrical energy supplied to an electric motor by finally outputting a turn-on signal to the chopper thyristor. This controls the motor output by adding and subtracting the turn-on conduction ratio of the thyristor.

Based on request signals input from railroad engineers such as Notch signal and motion identification signals for each apparatus by control circuit, the current amount of the main circuit is controlled by computing the current amount of the main circuit, idling, or axle slip in the current state of Notch input, passenger load, train speed, and trolley voltage. It consists of a total of 38 modules and is equipped with 10 externally connected cannons and 1 idle conversion module used for inputting, outputting, and monitoring signals. The main functions are as follows:

Items	Major motions
Powering	Chopper interlacing, motor drive, field-weakening control, motor re-drive
Braking	Electric braking, air braking, combined braking
Wheel slip	Detection and control of wheel slip
Failure detection	Overload, idling, overheating

2. 2 Operation and problem of the existing propulsion control apparatus

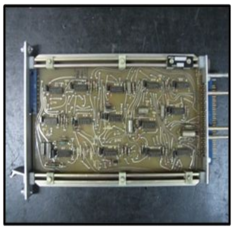
Failures frequently occur because 38 modules are used in the existing propulsion control apparatus and connected to each other by jump wires. Thus, supplies of additional modules and parts for maintenance are costly and time-consuming. Due to the limited failure information, it is impossible to analyze failure causes or takes long to do it. The reason for the failure cannot be identified when the failure automatically disappears during main line services. Additionally, only the light for the failure turns on without being able to obtain any data related to the failure in the event of failure. Failures frequently occur due to errors in passive elements and automatically disappear by long-term use because all control and computation such as train powering and braking were analyzed by analog circuits. Bending of the body occurs due to the load of many modules.

2. 3 Introduction of new electronic control method

In order to solve the problems of the existing propulsion control apparatus, the control section with analog computation was digitalized by numerical analysis, and failure occurrence points decreased by reducing the number of modules from 38 to 11. Moreover, as for the parts used in the module, this study selected accessible and appropriate parts for railroad cars. The operation records and import data for each point were stored to analyze the cause in the event of failure so that it was possible to examine the operating state at the time of the failure. A new analysis tool was developed so that users could easily analyze the data. The existing relays and thyristors are used to achieve the best effect at a minimum cost in remodeling trains. Thus, it was necessary to maintain the compatibility of input and output so that it was possible for maintenance personnel to perform maintenance without difficulty in treating the new controller. Moreover, because the external electromagnetic environment has worsened than thirty years ago, this study applied the module design responding to this. This study also applied a structural design method to support bending of the body due to the load of many modules. In consideration of convenience in maintenance, this study enabled to perceive the motion state of the control apparatus through LED lamps on the front without connecting to the external tester and substantially improved the convenience in maintenance by ensuring the testing point on the front of the control apparatus for easy inspection.

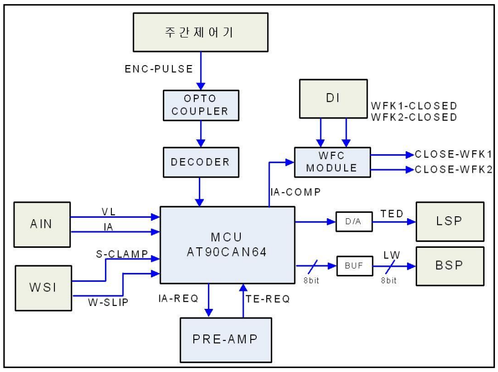
2. 4 Design/manufacture of new propulsion control apparatus

2. 4. 1 Application of digital computation method



(a) PCB of the existing control

(b) PCB of a new control apparatus

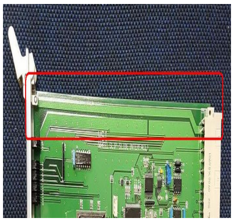


(c) Block diagram of powering section (analog + processor design)

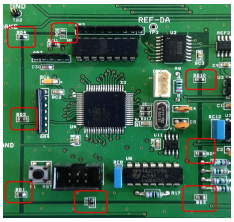
Fig. 1 Block diagram of the existing electronic control apparatus and new electronic control apparatus with improved performance

The new control apparatus with improved performance was designed by simplifying the signal flow of powering, braking, wheel slip, and wheel slide using microprocessors. The functions were expanded by changing the existing analog control method to the control form with the combination of processors and analog signal computation, and the number of modules was remarkably simplified.

2. 4. 3 Application of measures against electromagnetic wave



(a) Connection of chassis ground wire by PCB



(b) Separation of digital section and analog ground

Fig. 2 Design against electromagnetic waves to block external noise

The chassis ground wire was connected to prevent noise from entering and rapidly remove the noise in designing PCB module, and filters were located closest to the power input section by PCB. Bypass capacitors were inserted at less than 5 cm intervals at least, and digital and analog grounds were separated to swiftly remove the noise generated in the circuit. The next is the LOW-PASS filter applied to the analog input module.

R = 12 Kohm and C = 10 nF. Thus, the frequency of -3 dB is as follows:

$$W_c = 0.707 / (R \times C) = 0.707 / (12K \times 10n) = 5891, \quad W_c = 2\pi f.$$

Thus, Fc = 5891 / 6.28 = 938[Hz]

In other words, the frequency decreasing by 0.707 time compared to the input frequency is 938 [Hz]. In addition, electromagnetic wave was tested as follows:

① Radiation test (electromagnetic interference (EMI))

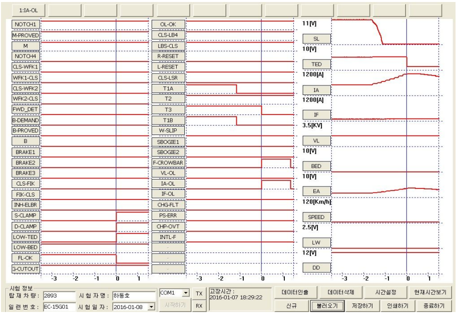
KS C CISPR 11 was applied.

② Immunity test (electromagnetic suspension (EMS))

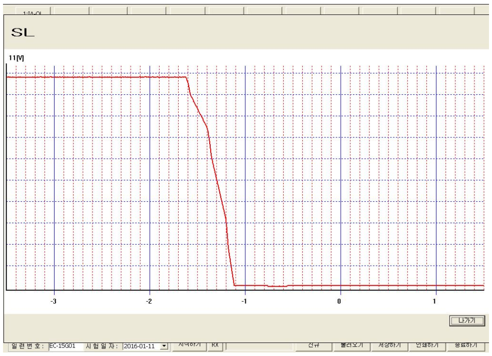
KS C IEC 61000-4-2, KS C IEC 61000-4-3, KS C IEC 61000-4-4, KS C IEC 61000-4-5, KS C IEC 61000-4-6, EN 50155

2. 4. 4 Development of analysis software

The controller of the new control apparatus made it possible to store data by important point in real-time and to use them for analysis of the data at the time of failure. It stores motion data in SRAM at 5 ms during the operation and stores the data from -3.5 seconds to +1.5 seconds based on the time of failure when failure occurs. A total 10 failure records are stored, and operations record is stored for seven days.



(a) Analysis program for failure data

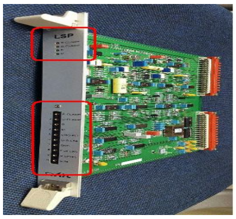


(b) Analysis of failure data

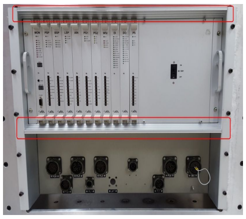
Fig. 3 Analysis software

2. 4. 5 Improvement of visibility of housing and module

In order to prevent the frame from bending, an anti-bending support was attached together. The new control rack was lightened to prevent the frame from bending and is characterized by much stronger using 7000 series aluminum than the existing product. Additionally, four supports (two on the front, two on the back) were attached to support the frame load. In consideration of convenience of maintenance, the test point was installed on the front for better visibility and easier maintenance.



(a) Improvement of housing load



(b) Improvement of visibility and maintenability

Fig. 4 Appearance of new electronic control apparatus

2. 4. 5 Improvement of performance for new controller

The following table shows the comparison of the existing and new control apparatus. Many improvements such as application of digital computation, simplification of the number of modules, storage and analysis of failure records, and improvement of maintenability were performed and applied to the new control apparatus.

Table 2 Comparison of existing and new electronic control apparatus

Items	Existing electronic control apparatus	New electronic control apparatus
Control method	Analog computing method	Analog computation + microprocessor control
Number of modules/appearance	Use of 38 modules, non-standard rack, relatively large size	Use of 11 modules, standard rack, small size
Monitoring function	None	Storage of failure records
Analysis S/W	None	Management of output data
Testing method	Injection/monitor Use of testing module	Use of injection modules, Additional monitoring test
Maintenance	Long-term required (excessive number of modules), Discontinuance of parts or long-term required for supply	Ease of maintenance (storage of failure information, analysis use), ease of part supplies
Technical support	No support from manufacturer	Ease of technical support from manufacturer, standardization of testing methods by use

3. Conclusion

This study applied digital computing technology to improve the performance of the propulsion control apparatus for chopper trains in Seoul Metro Lines 2 and 3 produced by analog technology in the 1980s and developed a new propulsion control apparatus capable of simplifying the number of control modules and storing and analyzing failure data. In addition, this study applied all the requests of the demand such as taking measures against electromagnetic to apply them to the circuit, reducing the weight in consideration of the convenience of maintenance, structurally supporting the housing bending, applying the design for separated structure of sub rack, and improving the visibility of the apparatus. The new control apparatus passed the KORAS reliability testing (temperature, vibration, electromagnetic wave, and others) and proved the reliability and stability of the product without any failure during train services for more than 12 months including the test operation of the main line in Seoul Metro Line 2.

Postscript

This paper aimed to improve the performance of the deteriorated propulsion control apparatus. Moreover, this paper is the outcome of "Improvement of Performance for Electronic Control Apparatus of Train (British Chopper Control)" performed for 24 months between December 2013 and December 2015 as a part of the Option to Purchase Support Project by the Small and Medium Business Administration. The performance was verified by business negotiations with the demand more than 30 times, test operation in the yard for two

months, and test and regular operation in the main line. Satisfactory results were obtained by reflecting all the requests from the demand.

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Research on Establish of the efficient the track switching to the turning point and operation for scheduling.

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Busan-Gimhae Light Rail Transit Operation Co., Ltd.

Key words : ATS(Automation train supervision), PMA(Primitive Movement Authority)

1. Introduction

The Busan-Gimhae Light Rail Transit dealt with in this paper is operated by the steel-wheeled radio-based train control system called Communication-based Train Control (CBTC) originally introduced to Korea.[1][6][8]

Currently, the railroad switches in the main line' s turnaround section operated in the Busan-Gimhae Light Rail Transit consist of two pairs of railroad switches at the starting (Kaya University Station and terminal (Sasang Station stations, respectively. The reason why two pairs of railroad switches are used to maintain train operation without interruption using a pair of the railroad switches in the event of failure of the remaining railroad switches during train operation.

In the early stage, train services were provided by applying the schedule (LINE 1) with the use of a railroad switch at starting and terminal stations. This frequently caused significant problems in train services due to the failure of the railroad switches by putting a heavy burden on the railroad switches.

Presently, several train operation schedules such as LINE 1 and LINE 3 in the morning, afternoon, and night are used in combination with each other in order to overcome this weakness. This reduced significant problems in train services due to the failure of the railroad switches by reducing the burden on each railroad switch.

This paper introduces this simple improvement. In addition, this paper aims to introduce problems of turnaround section in the failure of railroad switches based on the basic block design.

Other institutions need that the block will be designed by considering this point. This paper aims to present this in a collection of papers in the future due to space limitations.

This paper aims to help other institutions establish a more effective and safe train operation system by considering and applying the method proposed in this paper and establishing an effective system.

2. Body

2. 1 System configuration of automatic train supervision (ATS)

Communication-based Train Control (CBTC) operated in the Busan-Gimhae Light Rail Transit consist of the following systems for train operation:[1][6][8]

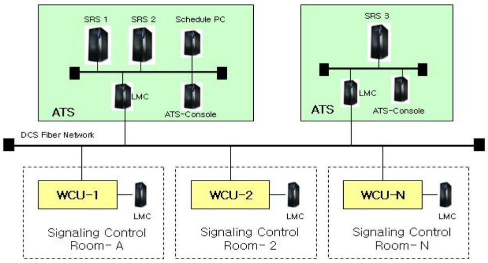

Fig.1 The ATS Network Configuration.

Train schedules are needed to regularly operate the Busan-Gimhae Light Rail Transit in automatic mode. Schedules are created in the schedule server first and then sent to Schedule Regulation Sever 1 (SRS 1) and SRS 2 in the central control room in the central control room to operate trains based on these schedules. In addition, in the event of failure of SRS 1 and 2, backup controllers are dispatched to the backup control room to continue train operation by sending the schedules to SRS 3 in the backup control room.[1][3][7]

As shown in Fig. 1, it consists of triple ATS system in order to increase the stability of the important ATS system in train operation control.[2]

2. 2 Timetable equipment

Timetable Compiler System (TCS) is operated to generate train operation schedules in the ATS of the Busan-Gimhae Light Rail Transit.[1]

In general, The Busan-Gimhae Light Rail Transit is operated by several schedules such as daily schedule, emergency schedule in the event of failure of railroad switches at starting and terminal stations, and extended operation schedule with events such as fireworks festival.

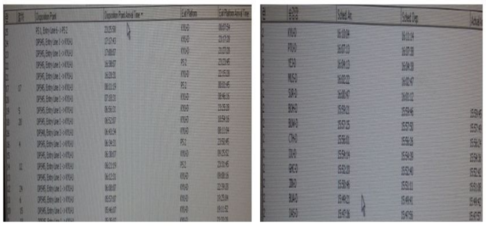

Fig.2 Sample of schedule in SRS server

As shown in Fig. 2, the schedules generated by the TCS Server are transmitted to SRS 1 and SRS 2 to operate trains. The schedule list for train entry and exit is shown on the left of the figure, and the detailed schedules related to regular services are shown on the right of the figure. All the planned and actual train operations are represented by the detailed schedules.

In fact, trains are operated according to detailed timetable. Controllers select and execute a schedule from schedule list of the ATS and then allocate schedules for each train in the spur line of the rail yard.

2. 3 Line allocation operation

Train operation routes are set by line allocation. Although lines are defined by points, most of them are realized in the form of a closed loop next to the railroad tracks. When an operator of the control room allocates lines, line schedules are automatically allocated to trains by the ATS system.

2. 4 Schedule allocation for effective train operation and disadvantages of railroad switches based on basic block structure

2. 4. 1 Disadvantages of single line operation

In the Busan-Gimhae Light Rail Transit, single line (LINE 1) was allocated to trains intensively using one railroad switch for several years in the early stage.

Additionally, the electric power supply section is installed in two-frame railroad switches at the starting station. Thus, when cutting off electricity to treat troubles due to the failure of one railroad switch, two-frame railroad switch cannot be used. This causes significant problems in train services of the whole main line.

This method intensively using single railroad switch causes failure, and it takes a long time to return to normal train operation due to this severe problem.

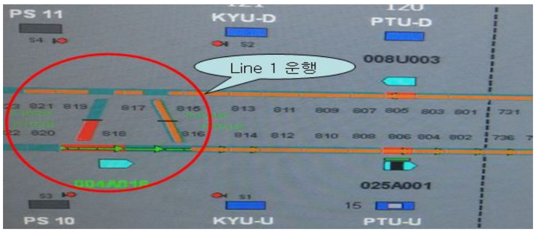

Fig.3 Line 1+ Schedule Train Operation

As shown in Fig. 3, the railroad switch on the right is used out of the two railroad switches (LINE 1 + Scheduling).

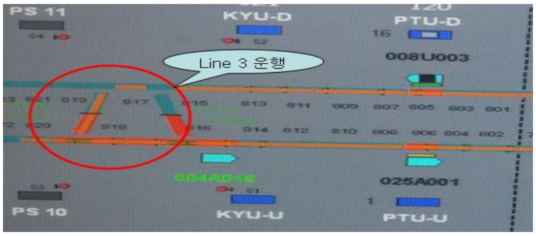

Fig.4 Line 3 + Schedule operation

Fig. 4 shows a method of using the railroad switch on the right (Line 3 + Schedule).

The intensive use of one railroad switch caused significant problems in train operation.

This paper aimed to propose a method for solving this problem and using schedules effectively. Moreover, this paper shows the problems of train turnaround with the ineffective basic block structures in the turnaround section.

2. 4. 2 Improvement of defect in single line operation

The failure of railroad switches decreased by reducing the load due the intensive used of single railroad switch by operating trains with (Line 1, Line 3) + schedule as a means of reducing the failure of railroad switches.

Fig. 5 Train operation mixed by Line 1 and Line 3

Fig. 5 shows the current operating method. The railroad switch on the right was applied using (Line 1 + Schedule in the morning, that on the left was applied using (Line 3 + Schedule) in the afternoon, and the method returned to (Line 1 + Schedule) in the late afternoon. The failure of the railroad switches was reduced by lowering the utilization rate of single railroad switch. This requires controllers to pay attention to train exchange.

Fig. 5 Line1 and line3 are using same switching at end line

The railroad switch at the terminal point cannot be used in turn due to changes in arrival and departure. Fortunately, however, because the power section is separated by two-frame railroad switch, it is possible to operate the main line normally by changing arrival and departure while one railroad switch is being repaired even if it breaks.

2. 4. 3 List of train schedules

However, there has been a large difference in the number of passengers between weekdays and holidays thus far. Although the demand of passengers may vary from operating agencies, it is more effective to operate trains by dividing trains schedules into weekdays and holidays.

It is possible to operate many more train schedules, but regular services are absolutely required for unmanned operation. In addition, passengers are informed of timetable of regular services by posting it on stations. If trains are operated based on weekend and holiday schedules, it will be more cost-effective because many schedules can cause inconvenience to passengers.

2. 4. 4. Problems related to discrepancy between railroad switches by ineffective block structure

As shown in Fig. 6, there is no way of operating trains in automatic mode using SAS-D when discrepancies occur in P 101 railroad switch. Therefore, there is a need to operate trains in manual mode by boarding safety staff.

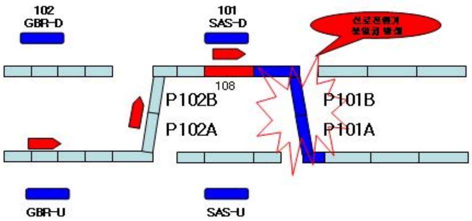

Fig.6 Train moving according to PMA status by WCU control.

As shown in Fig. 6, if there is a failure in the railroad switches of P101A and P101B, Train GBR-U cannot be operated in automatic mode by SAS-D. Trains cannot enter Block 108 due to the route locking of Railroad Switch P101.

This is because WCU does not allow PMA to operate trains from the closed block to SAD-D to ensure safety. Therefore, engineers change train operation mode in manual mode to operate trains by changing the arrival and departure at SAS-D.

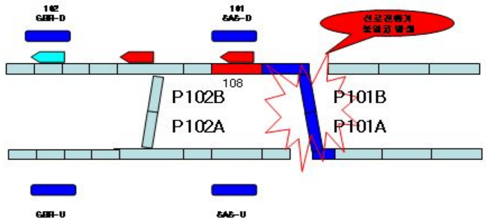

Fig.6 Train moving according to PMA status from WCU control.

When a train carries passengers at SAS-D, an engineer operates a train to GBR-D by converting Railroad Switch P102 to the original position and then changed train operation mode to automatic mode. This train operation is repeatedly performed until P101 is completely repaired.

At least three safety personnel (engineers) are required to deal with this failure as follows: an engineer to operate a train from GBR-U to SAS-D, one engineer to change the operation mode at GBR-D, and one engineer to change the train operation mode at SAS-U. It is expected to propose a plan for realizing the basic block to create effective railroad switches in the next paper.

3. Conclusion

In the early stage, train services were provided by automatic train operation method based on single schedule intensively using signal railroad switch at starting and terminal stations. This train operation method caused the failure of railroad switches by increasing the level of fatigue of one railroad switch, and this failure caused significant problems in train services.

In order to reduce these problems, significant failure decreased by reducing the level of fatigue of one railroad switch using Line 1, Line 3, and Schedule in combination with each other.

Moreover, this paper showed that weekend and holiday train operation schedules were effective by describing the currently used train operation schedule list.

It is expected to propose a design for the basic block to design effective railroad switches in the next paper.

It is difficult to discontinue train services once the system is realized. Thus, it is considered necessary to realize an effective system after careful considerations.

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Considerations on the Cabin Noise Measurement in Seoul Metro Subway

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1. Introduction

Subway is a useful means of transportation to solve traffic congestion and smoke pollution that occur in downtown areas that are densely populated and has advantages of accuracy, speedy, and safety compared to other means of transportation. However, in nature of operation environment, i.e. tunnel where most trains pass through, the reflective sound field with high sound energy density is formed inside of the tunnel. Due to this, passengers who are in cabins when the subway train passes through the tunnel sections are exposed to poor noise environment. If they are exposed to such noises for long time, the passengers who are in cabins may be fatigued and the exposure may cause hearing loss, and thus noise is an important problem to solve because it is an environmental pollution when the subway train passes through the tunnel sections.[1~4]

Subway train tunnel noise occurs in the entire frequency band, but the characteristics of frequency that may cause noise to occur depend on abrasion of rail, type of tunnel, driving speed of rail motor, shape of railroad, and type of roadbed. To reduce such noise, it is important to identify the characteristics of frequency in sections where noise occurs. In this study, the cabin noses were measured in subway line 3 among the Seoul Metro subway lines 1, 2, 3, and 4. In Seoul subway line 3, it is possible to identify the subway noise with various characteristics because it consists of various types of operation environment such as radius of curvature in railroad, type of roadbed, and type of tunnel although its speed is not so fast.

Therefore, this study measured and analyzed the cabin noises of the subway line 3 as basic data for reducing the subway train noise.

2. Noise Measurement Method

This study measured the cabin noises in the subway line 3 by using the cabin noise frequency analyzer and obtaining the 1/3 octave band center frequency range (A-weighting),

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in order to identify the characteristics of cabin noise of subway train when subway train passes through the tunnel.

The cabin noise measurement was conducted for the operation hour 06:00~08:00 a.m., the first train operation hour on the weekend, the least populated day of the week to minimize the background nose.

The noise measurement equipment is shown in Table 1 and the distribution of microphone is like in Fig. 1.

Table 1. Cabin noise measurement equipment in subway train

Model	Type No.	Description
Module (B&K)	Type 3560B	Acquisition Front-end
Sensor (PCB)	Type	Micro Phone
Calibrator (B&K)	Type 4231	Sound Pressure Calibrator
Multi-nalyzer	Type 7700	Noise & Vibration Analysis

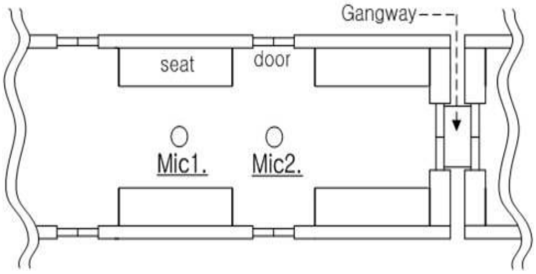


Fig. 1. Location of microphone mounted in cabin of subway train

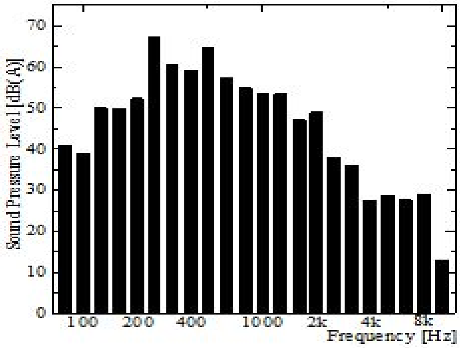
As for the cabin noise analysis section, this study analyzed single-track operation as vehicle operation method, box type tunnel as tunnel model, and ballast bed as roadbed to analyze the noise characteristics depending on the radius of curvature. Table 2 represents the cabin noise measurement section depending on the radius of curvature.

Table 2 Cabin noise measured section with the radius of curvature

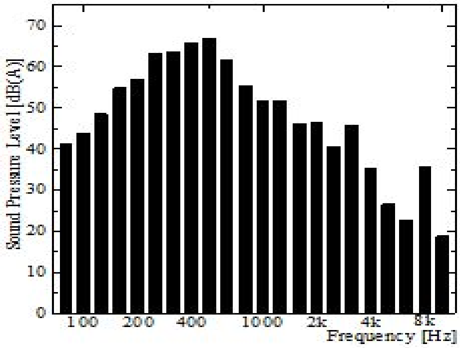
	Start Station	Arrival Station	Radius of Curvature
Case 1	Nambu Bus Terminal	Yangjae	R 256
Case 3	Bulgwang	Nokbeon	R 401
Case 3	Hongje	Muakjae	R 501
Case 4	Sinsa	Jamwon	Straight

3. Results and Considerations

Fig. 2 compares the noise measurement results depending on the location in the cabin. As a result, it was found that the highest noise level was entrance, i.e. location where microphone 2 was installed compared to the center seats. This is because airtightness is not obtained at the entrance.



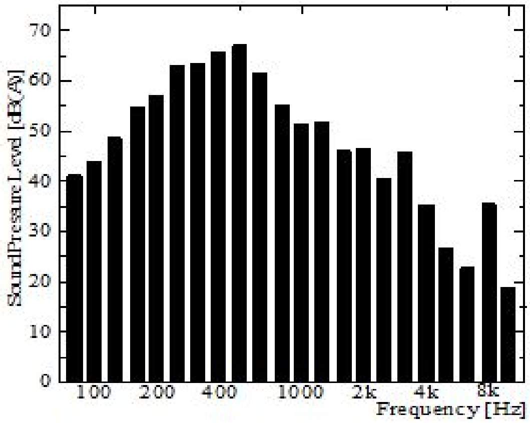
(a) Mic 1



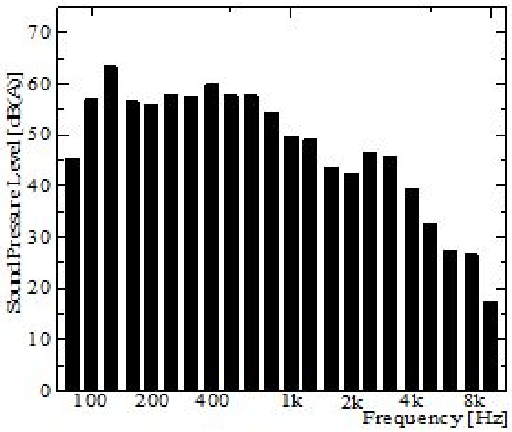
(b) Mic 2

Fig. 5 Results from Cabin Noise Measurement depending on Location of Microphone

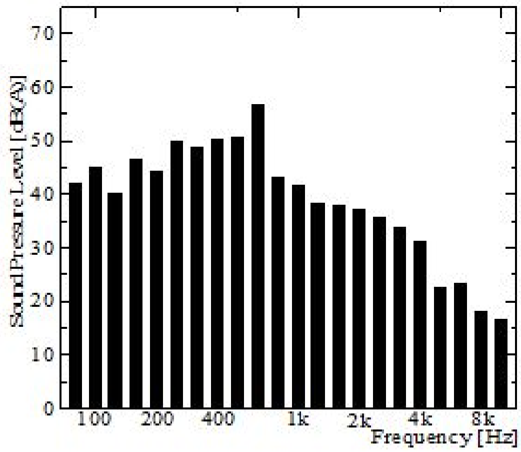
Fig. 3 represents the results of cabin noise measurement depending on the radius of curvature, cause of squeal noise. It was found that the frequency representing the peak level depending on the radius of curvature was different. It was also found that the smaller the radius of curvature, the higher the noise level. This is because the smaller the radius of curvature, the larger the friction between rail and wheel. Furthermore, when the overall frequency range was examined, the noise level of the mid-frequency range was relatively prevalent.



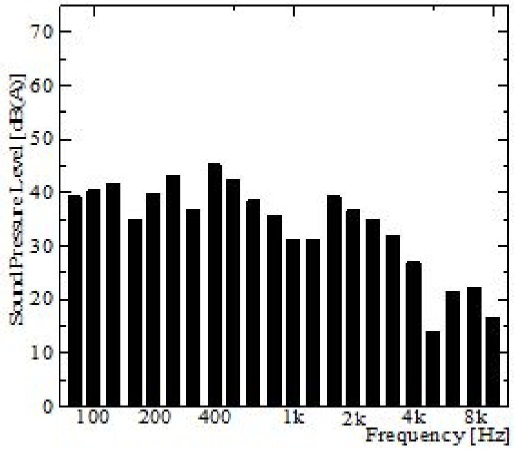
(a) R256



(b) R401



(c) R501



(d) straight

Fig. 3 Measured results of cabin noise in squeal noise section

Fig. 4 represents the results of drawing Fig. 3 into NC curve, indoor noise scale. As shown in the results, the section where the radius of curvature was small exceeded NC-65, where the cabin noise level was the loudest.

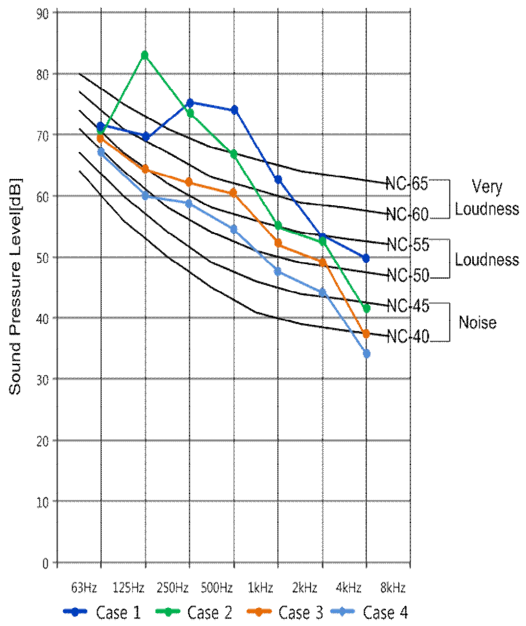
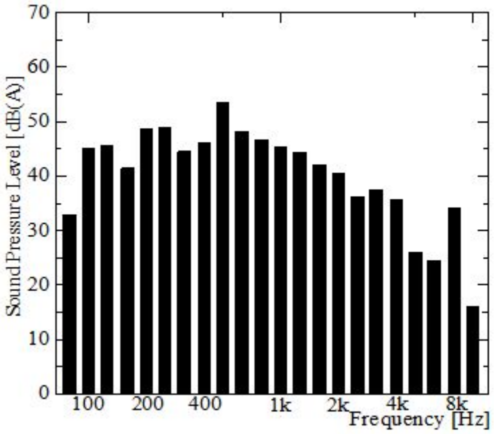
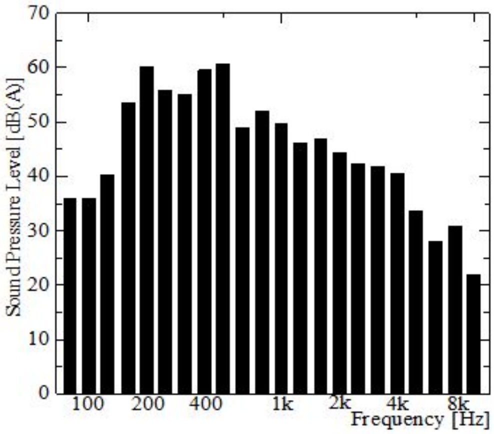


Fig. 4 NC value of measured cabin noise in squeal noise section

Fig. 5 represents the results of cabin noise measurement depending on the condition of roadbed. To look at the overall noise level, it was found that the noise level appeared higher when the train ran on the concrete roadbed than in ballast bed. This is because the concrete roadbed can reflect better sound than the ballast bed and the noise characteristics of concrete track includes higher noise level in medium-low frequency range.



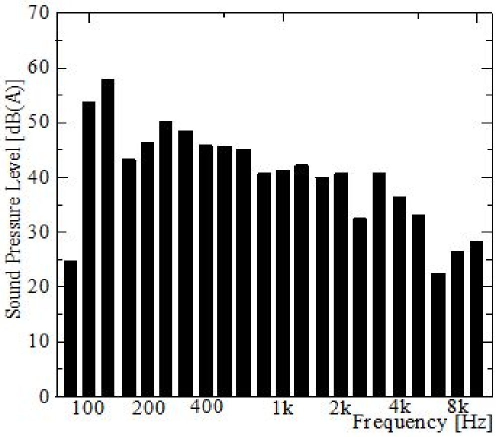
(a) ballst track



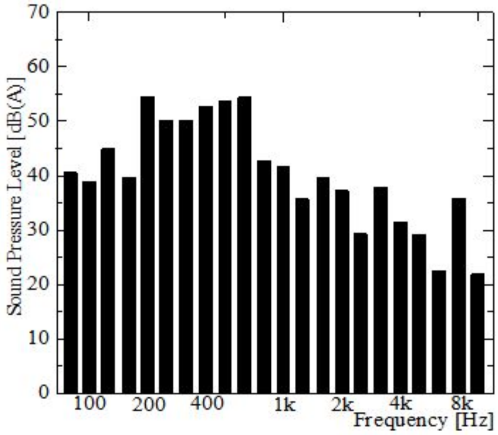
(b) concrete track

Fig. 5 Results from Subway Train Cabin Noise Level depending on Type of Ballast

Fig. 6 represents the results of noise level measurement depending on box type tunnel and horseshoe tunnel to identify the noise characteristics of tunnel type. It was found that the noise characteristics depending on the tunnel type did not show a certain tendency.



(a) box type tunnel



(b) horseshoe tunnel

Fig. 6 Results from Subway Train Cabin Noise Measurement depending on Tunnel Type

5. Conclusion

This study measured and considered the noise status in subway trains operating in Seoul and the results can be summarized as follows:

1. As a result of measuring the subway train cabin noise depending on the radius of curvature to identify the squeal noise of subway train, it was found that the higher the radius of curvature, the higher the noise level. This is attributable to the fact that as the horizontal friction between rail and wheel becomes larger, the cabin noise level also becomes higher.

2. It was found that the noise level was higher when the subway train ran on the concrete roadbed than when it ran on the ballast bed. This is attributable to the fact that the concrete roadbed reflects sound better than the ballast bed.

Acknowledgement

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