Development and Running test of the ATO(Automatic Train Operation) Equipment for Korean standard EMU
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Abstract
The automatic/driverless operation, a very important technique for metro railways, is necessary for achieving higher safety, greater reliability, and bigger transport capacity. To achieve these things, we have to build up the system design and testing techniques for the railway system operation. These techniques are related to the onboard train control and communication systems which include TCMS(Train Control and Monitoring System), ATO(Automatic train Operation), ATC(Automatic train Control), and TWC(Train to wayside communication). These sub-systems should interface not only with each other but also between the sub-systems and the signal system on the ground. In this paper, we tested the train control system on the Seoul subway 7th line that has been developed on the basis of the standardized type of EMU for Korean railway systems.

1. INTRODUCTION
The automatic/driverless control of the urban transit has been necessary to achieve high safety and reliability and to minimize the errors of on-board control equipment recently. This technique is closely related not only to the on-board control but also to the communication method of the ground signal system. Therefore, the different systems are implemented according to several interfaces of both methods. These techniques are related to the onboard train control and communication systems which include TCMS(Train Control and Monitoring System), ATO(Automatic train Operation), ATC(Automatic train Control), and TWC(Train to wayside communication).
Especially, the ATO(automatic train control) system is an onboard automatic control equipment for the limited speed regulation and the precision station stop of train.
Because most of the train control systems were designed in some advanced countries, after the expected life span of an EMU(25 years), there are big problems such as increase of maintenance cost, difficulty of supporting the parts, etc.
To solve these problems, we started the Korean standard project with the support of government subsidies in 1995. This paper, one of research results from the project, shows the form of the optimal solution and how to minimize the energy consumption of the train driving control that can be included in Automatic Train Operation (ATO) systems.
For the support proof of reliability of the development products, we set up standardized requirements and conducted various efficiency tests, such as a component test, a combined test, a finished train test, and factory test run. In this paper, for the automatic train control, we made use of a fixed block based on track circuit. In order to minimize the energy consumption, we adopted the optimal control techniques based on coasting strategy using the speed band. We applied this system to the Korean standard EMU and performed running test in Seoul subway 7th Line. With the results of the test, we verified that the proposed algorithm could increase the energy consumption efficiency.

2. ON-BOARD TRAIN CONTROL
On-board train control of the urban transit carries out train movement control, accident prevention to ensure safety and increases the coefficient of line utilization.
The equipments related with safe train operation are TCMS(train control and monitoring system), ATS(automatic train stop), ATP(automatic train protection), ATC(automatic train control), and ATO(automatic train operation).

According to the train detection method and the train speed control method, on-board train control is separated into the speed step control, the single step brake control and the moving block control as following Figure 1.

![Figure 1: Classification of on-board train control](image)

Fig. 1 a classification of on-board train control

The speed step control used in most subway systems in Korea makes use of the fixed block of track circuit for detection of train and the target speed control for speed control. The single step brake control makes use of the fixed block like the speed step control and the distance-to-stop control for speed control of train. This technique, so called the quasi-moving block system, is adopted in the Busan subway 2nd Line and Inchion subway 1st Line.

The moving block control, used in the light railway system, makes use of radio communication for train detection. Also, the distance-to-stop control is used for speed control of train.

The speed profile of the train is generated by strategy with change point of powering, coasting, and braking mode according to ATC limit speed and track conditions.

In powering mode, inverter and traction motor consumed electrical energy. On the other hand, energy is regenerated in braking mode. In coasting mode, there is no energy consumption because of using inertia.

Therefore energy consumption occurs when the mode changes coating to powering.

In order to minimize the energy consumption, it is very important to use coasting mode and to decide the changing points while considering track conditions and train operation conditions. This technique also has to consider jerk limit, running time, running resistance, and traction/braking efforts.

Figure 2 represents a profile with optimal control for automatic train operation. In the figure, the train starts satisfying with jerk limit of 0.8km/h/s² and acceleration of 3.0km/h/s. After arriving target speed, the train is operated by the constant speed control that is under the optimal strategy with speed band.

With close arrival station, the train is under precision stop control with the distance-to-stop control. To increase the accuracy of train stop, on-board control system used precision stop maker on the ground. Also, on-board control system use the track database in which includes various information such as distance between station, station code, civil limit speed, gradient, curve etc.
3. RESULTS OF RUNNING TEST

The running test was conducted on partial sections (on 7th Line, (PORAMAE→CHONGDAM) of the Seoul subway 7th Line operated by SMRT. Table 1 shows the detail information of the Seoul 7th Line.

<table>
<thead>
<tr>
<th>Name of stations</th>
<th>Upt(West→East)</th>
<th>Down(East→West)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORAMAE ↔ SHINDAEBANG SAMGORI</td>
<td>784[1000] 3 793</td>
<td>6</td>
</tr>
<tr>
<td>SHINDAEBANG SAMGORI ↔</td>
<td>1,152[1000] 5</td>
<td>1,158[1000] 4</td>
</tr>
<tr>
<td>CHANGSUNGBAEGI ↔ SANGDO</td>
<td>941[1000] 3</td>
<td>938[1000] 3</td>
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<tr>
<td>SANGDO ↔ SOONGSIL UNIV.</td>
<td>908[1000] 5</td>
<td>906[1000] 4</td>
</tr>
<tr>
<td>SOONGSIL UNIV. ↔ NAMSONG</td>
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<td>1,976[1000] 5</td>
</tr>
<tr>
<td>NAMSONG ↔ ISU</td>
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<td>1,021[1000] 6</td>
</tr>
<tr>
<td>ISU ↔ NAEBANG</td>
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<td>1,030[1000] 5</td>
</tr>
<tr>
<td>NAEBANG ↔ EXPRESS BUS TERMINAL</td>
<td>2,204[1000] 8</td>
<td>2,206[1000] 7</td>
</tr>
<tr>
<td>EXPRESS BUS TERMINAL ↔ BANPO</td>
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<td>919[1000] 4</td>
</tr>
<tr>
<td>BANPO ↔ NONHYON</td>
<td>846[1000] 5</td>
<td>845[1000] 5</td>
</tr>
<tr>
<td>NONHYON ↔ HAKDONG</td>
<td>994[1000] 7</td>
<td>994[1000] 6</td>
</tr>
<tr>
<td>HAKDONG ↔ KANGNAMGU OFFICE</td>
<td>899[1000] 4</td>
<td>898[1000] 5</td>
</tr>
<tr>
<td>KANGNAMGU OFFICE ↔ CHONGDAM</td>
<td>1,108[1000] 5</td>
<td>1,105[1000] 6</td>
</tr>
</tbody>
</table>

Figure 3, 4, 5 show the results of the running test that include speed profiles operated with the automatic train operation control between NAMSONG and SOONGSIL UNIV., between SOONGSIL UNIV. and SANGDO, and between PORAMAE and SHINDAEBANG SAMGORI.

Figure 6 shows a view of the running test on the Seoul subway 7th Line with automatic train operation mode.
4. CONCLUSIONS

This paper introduced a development technique of the on-board train control that plays an important role in safety and the running performance of EMU. We implemented the automatic train operation with optimal control. We performed the running test in Seoul subway 7 Line and proved that this technique is available for urban transit system.

5. REFERENCES


