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## **Accident investigation of an automated guideway transit running in reverse at a terminal station**

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### **Abstract**

The Japan Transport Safety Board (JTSB) is a multi-modal investigation organization responsible for carrying out investigations into aircraft, railway and marine accidents. We contribute to preventing the occurrence of accidents and mitigating the damage caused by them, thus improving transport safety. As the recent representative example of our activities, we pick up the case of a collision accident of an automated guideway transit (AGT), in which the automatically operated train ran in reverse at a terminal station and collided with the buffer stop.

The purpose of this abstract is to set out the contents of the investigation reports on that accident made publicly available by the JTSB in 2020 and 2021. We show how the accident investigation was performed with the cooperation of the experts and the results of the investigation, such as the underlying cause of the accident and the measures to prevent the similar accidents.

It has been found that a wire which transmitted the command signal of the running direction was cut off with a ground fault to a stainless steel member of the carbody. The reason why the unmanned train ran in reverse against the right direction was the breaking of a wire which transmitted the command to the on-board motor controllers. It is very simple, but it is thought that there is the fundamental cause of this accident with the motor control system, that was designed following the former manned operation vehicles. Furthermore, we investigated the underlying causes of the accident, and pointed out that they were in the designing process of the vehicle made by the railway company, a vehicle maker and device manufacturers, which induced insufficiency of careful safety analysis.

The driverless automatic train operation system without a human error is believed to be more reliable than the conventional manned operation, but this accident reminds us of the importance of the hazard analysis in order to realize a fail-safe transport system. This accident should be a warning for the design and the safety evaluation of AGT systems used widely in the world today.

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) started the Council on Accident Prevention of Automated Guideway Transit with seven AGT companies with reference made to the JTSTB's report of safety information. The safety of the driverless automatic train operation system including the line where the reverse running accident happened has already been confirmed in the MLIT's Council.

**Keywords:** safety, accident investigation, automated guideway transit (AGT), automatic train operation (ATO).

## 1 Introduction

The Japan Transport Safety Board (JTSTB) is a multi-modal investigation organization responsible for carrying out investigations into aircraft, railway and marine accidents, established on October 1, 2008 [1]. As the representative example of our activities, we pick up the case of a collision accident of an automated guideway transit (AGT), in which the automatically operated train ran in reverse at a terminal station and collided with the buffer stop.

The purpose of this abstract is to set out the contents of the investigation reports on that accident made publicly available by the JTSTB [2-5]. We show how the accident investigation was performed with the cooperation of the experts and the results of the investigation, such as the underlying cause of the accident and the measures to prevent the similar accidents.

The driverless automatic train operation system without a human error is believed to be more reliable than the conventional manned operation, but this accident reminds us of the importance of the hazard analysis in order to realize a fail-safe transport system. This accident should be a warning for the design and the safety evaluation of AGT systems in operation widely in the world today.

The paper also describes the contents of Interim Report of Council on Accident Prevention of Automated Guideway Transit [6], which was started by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) with seven AGT companies in Japan with reference made to the JTSTB's report of safety information.

## 2 Methods

The accident occurred at Shin-Sugita station on the Seaside Line in Yokohama City (Japan) in June 2019. This line is an automated guideway transit (AGT), where the unmanned automatic train operation started in 1994 [7]. The 2009B train bound for Kanazawa-Hakkei Station, composed of 5 vehicles, started at Shin-Sugita terminal by turn. The train should have run in down direction according to the command from the wayside Automatic Train Operation (ATO) system, but it ran about 24 m in reverse, and crashed to the buffer stop at Shin-Sugita Station as shown in Figure 1.

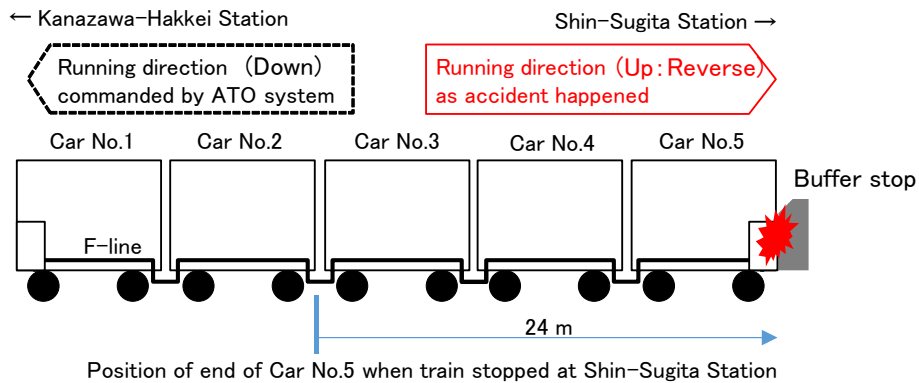


Figure 1: Situation of the reverse run accident.

The fact-finding investigation just after the accident collected evidence from vehicles to understand the sequence of events and identify the causes of the accident. The data of on-board recording device were also gathered and checked to confirm the driving situation and find defects of the train control system.

The on-board ATO system sets the running direction and it transmits to the on-board motor control systems by the voltage (DC100V) of a wire, F-line or R-line. The F-line is a wire to command the down direction and the R-line up direction. The following facts were confirmed in the journal record around the accidental time.

- (1) Before the departure, the on-board ATO system output the down direction at the Shin-Sugita station. This was a predetermined operation.
- (2) From the above mentioned action of the on-board ATO system, the F-line was supposed to apply the voltage, but both F-line and R-line were non-voltage.

Then we investigated the circuit of F-line and performed visual observation of the wire in Car No.1.

### 3 Results

Through the continuity inspection of the circuit, it is found that a wire (F-line); which commands the down direction from an on-board ATO system to the motor control system; was broken in the first car (Car No.1) of the accident train that crashed to the buffer stop at Shin-Sugita station. Though the F-line and the R-line thread through the whole train set, from the result of the visual inspection, we found that the F-line broke at the rear area of Car No.1 and the one end of the wire was welded to the carbody structure beam made of the stainless steel (Figure 2).

From the journal of the on-board recorder, it is confirmed that the voltage of the F-line turned to non-voltage during a previous running to the down direction of the accident. However, the next train could run to up direction because the R-line normally applied the voltage.

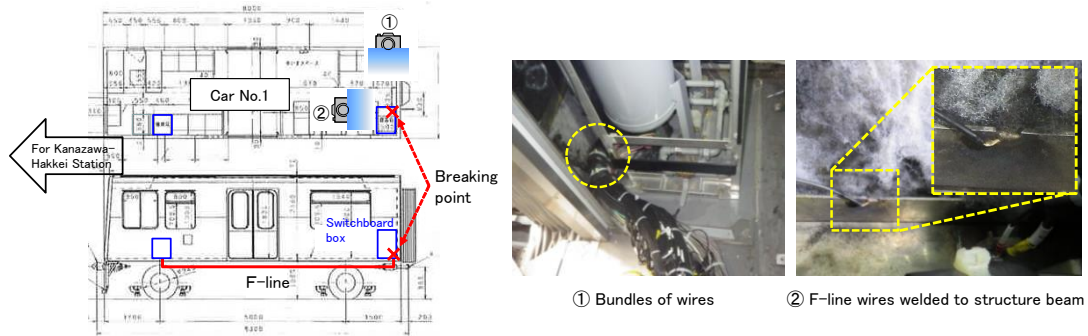


Figure 2: F-line wire cut off with ground fault to stainless steel member of carbody.

The specifications of the motor control system of this train is that the internal memory keeps the last running direction if the voltage of the both command lines is not applied as shown in Table 1. Although the on-board ATO system changed to the down direction at the Shin-Sugita station, the motor control system maintained the running direction to the previous up direction caused by the wire breaking of the F-line.

Voltage of F-line (V)	Voltage of R-line (V)	Running direction
0	0	<b>keep the last direction</b>
100	0	down direction (for Kanazawa-Hakkei Station)
0	100	up direction (for Shin-Sugita Station)
100	100	operation protection (stop)

Table 1: Relation between voltage of F, R-line and running direction.

The information that suggests any trouble related to the accident has not been found in other on-board and wayside control system. The cause of a ground fault of the wire has been investigated with the tests reproducing the contact condition of the wire to a stainless steel member, the vibration of the running vehicle and a voltage application. It is estimated that the insulating coating of the wire which was made of ethylene-tetrafluoroethylene was worn by the repeated application of the load of the cable bundle excited by the vehicle vibration to the contact point between the cable and the stainless member of the carbody.

#### 4 Conclusions and Contributions

The fact-finding investigation carried out by the JTSCB clarified the cause of the accident occurred on an automatic guideway transit. The reason why the unmanned train ran in reverse against the command and collided with the buffer stop at Shin-Sugita Terminal was the breaking of a wire (F-line) which transmitted the command signal of the running direction. It is very simple, but it is thought that there is the fundamental cause of this accident with the motor control system whose internal

memory keeps the last running direction if the voltage of the both F- and R- command lines is not applied, that was designed following the former manned operation vehicles [2-4]. The system has been used for the back-inching operation to adjust the train position when the train passed the right stop point a bit. Furthermore, we investigated the underlying causes of the accident, and pointed out that they were in the designing process of the vehicle made by the railway company, a vehicle maker and device manufacturers, which induced insufficiency of careful safety analysis. The motor control system with the memory of the running direction was unique to the device manufacturer who supplied the electric motor to the vehicle maker. In order to prevent the similar accidents, the JTSB recommended the MLIT that the MLIT should instruct them strictly to establish the design system realizing the accurate information exchange and the system integration among affiliates [5].

The driverless automatic train operation (ATO) system without a human error is believed to be more reliable than the conventional manned operation, but this accident vividly reminds us of the importance of the hazard analysis in order to realize a fail-safe transport system. This accident should be a warning for the design and the safety evaluation of AGT systems used widely in the world today.

With reference made to the JTSB's report 'Provision of Safety Information', the MLIT started the Council on Accident Prevention of Automated Guideway Transit with seven AGT operation companies in Japan. The council has been held three times so far, and determined to improve the software of the motor control system which caused the reverse running accident. The safety of the driverless ATO system including that operated by Yokohama Seaside Line has already been confirmed in the MLIT's Council [6]. The MLIT is now examining the improvement plan to solve the matters on the design system that were recommended by the JTSB.

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