

Automatic train operation system for the high speed Shinkansen train

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Abstract

In train operation over 300 km/h, drivers are supposed to operate the handle for acceleration or deceleration quite often due to speed restriction at the curve. To ensure on-schedule operation and lighten the burden imposed on drivers under high speed operation, we developed the automatic train operation system for the Shinkansen train. This system automatically controls the speed to follow the target speed of operation as well as obey Automatic Train Control (ATC). The target speed is set by taking account of the ATC restriction, on-schedule running, and energy-efficient operation. The system was applied to running tests using a series E2 Shinkansen train from Morioka to Hachinohe, about 100 km, on Tohoku Shinkansen line. The test results tell that the accuracy of on-schedule operation is 4 s longer than the simulated running time, and the accuracy of following the target speed is within 2 km/h at the maximum speed of 320 km/h. We conclude that the system performance is satisfactory for the secure speed control and on-schedule operation.

Keywords: automatic train operation, automatic train control.

1 Introduction

East Japan Railway Company is developing the Shinkansen train with the concepts of high speed, safety, stability, environmental compatibility, and comfortableness. As for high speed, it plans to operate the train at the maximum speed of 360 km/h. To ensure on-schedule operation and lighten the burden imposed on drivers under the high speed operation, we developed the automatic train operation system for the Shinkansen train and carried out the running test on Tohoku Shinkansen line.



2 System outline

Automatic Train Control system (ATC) helps to keep train intervals fixed by braking the train, but in the high speed Shinkansen it is necessary to control the train in the shortest running time by powering and braking. This system automatically controls the speed by powering and braking to follow the target speed of operation as well as obey the ATC. The target speed is set by taking account of the ATC restriction, on-schedule running, and energy-efficient operation. The basic action of the system is as follows. Firstly, it accelerates up to the speed just below the ATC restriction. Secondly, it keeps the train at the maximum permissible speed with extreme accuracy. Thirdly, it stops accelerating at the point allowing on-schedule operation to the destination as it runs. The accurate operation at the maximum permissible speed reduces the loss of running time and produces the marginal time to the scheduled running time. According to the marginal time, it stops accelerating to save energy consumption, fig. 1.

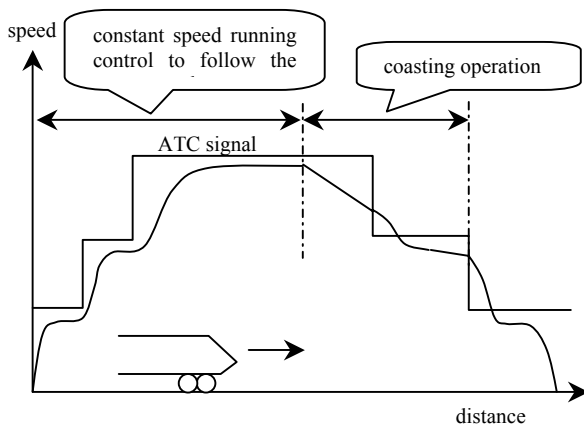


Figure 1: Running pattern image.

3 System constitution

This system consists of a switch in the drivers cab and the operation system connected to some devices, fig. 2. The switch in the drivers cab is pushed to start the automatic train operation. The operation system is connected to monitoring equipment in order to get information of kilometre and ATC signal aspect by way of ATC equipment, so it recognizes the train location and the restriction speed. It is also connected to a tachometer generator to get information of the train speed, so it controls notch for powering and braking to follow the target speed. The notch means steps for powering and braking.

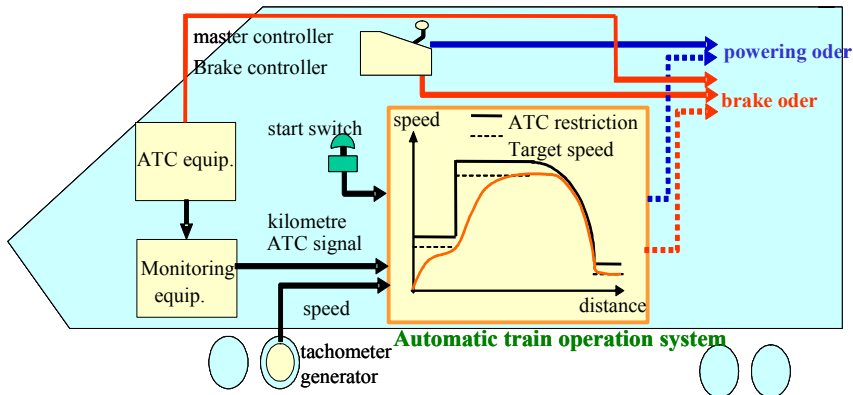


Figure 2: Constitution of automatic train operation system.

4 Function

4.1 Target speed

The system receives the ATC signal aspect from the monitoring equipment and sets the target speed of operation as the speed below the ATC signal aspect by 3km/h. Using information of kilometre, it can set the target speed according to the train location.

4.2 Constant speed running control to follow the target speed

The system controls to keep the speed constant to follow the target speed of operation until the target speed changes. The accuracy of constant speed control is set by within 2 km/h over or below the target speed. Concretely, it orders notch control to absorb changes of the train acceleration or deceleration by gradient resistance and running resistance, and keep riding comfort as it is. For this control, it has data of notch choice set by the train location and running speed zone and calculates relevant notch forward and back according to the changes of train acceleration or deceleration.

4.3 On-schedule operation

The system counts the time passed from leaving a station and calculates the difference between running time left and the target running time. When the difference is plus, it stops accelerating to shift to coasting operation for punctuality and energy saving. The accuracy of on-schedule operation is set within 10 seconds more or less than the target running time. The basic control routine for coasting and efficient operation is as follows, fig. 3:

- (1) In the fastest operation pattern, the time to arrive at a next station by coasting from a point is defined as T_{ex} . The system has T_{ex} data by simulation in advance.

- (2) The system calculates the time passed from leaving a station, T_{sx} . It compares a sum of T_{sx} and T_{ex} with scheduled time, T_t . At a point where the sum of T_{sx} and T_{ex} is equal to T_t , it starts coasting operation.
- (3) In case of driver's manual control, it cancels the operation once and start again coasting operation when the condition is satisfied.

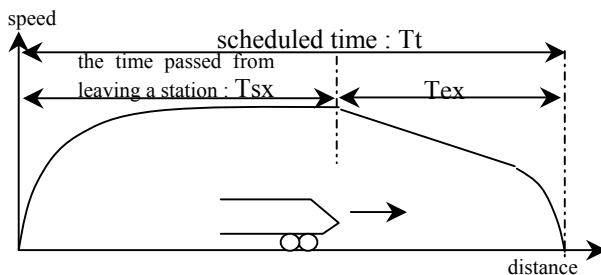


Figure 3: On-schedule operation image.

5 Test result

The system was applied to running tests using series E2 Shinkansen train from Morioka to Hachinohe, about 100km, on Tohoku Shinkansen line.

5.1 Constant speed running control to follow the target speed

The accuracy to follow the target speed was within 2 km/h in almost all section of running tests. There were two points where the accuracy was 2.2 km/h over or below the target speed. It is because of gradient fluctuation such as from plus 9 to minus 8, so it is improved by adjustment of control parameters of notch choice data.

5.2 On-schedule operation

Firstly, the fastest operation under the ATC restriction was tested. Secondly, we set the marginal time as 30 s. On-schedule operation was tested with the target running time as a sum of the running time of the fastest operation and 30 s. As table 1 shows, the running time of the fastest operation was 1591 s. The target running time was set as 1621 s. The running time of 30 s marginal time operation was 1625 s, so the difference between the target and result was 4 s accuracy. Figure 4 shows the result of running test with marginal time of 30 s.

6 Evaluation

6.1 Constant speed running control to follow the target speed

It is a satisfactory result that the accuracy of constant speed running control was within 2 km/h over or below the target speed in all section except for abrupt gradient fluctuation. The system performed stable control to absorb gradient resistance and running resistance from lower to higher speed zone, so it helps to

lighten operating load of drivers, who are supposed to operate the handle for acceleration or deceleration quite often, and realize constant patterned operation in all time.

Table 1: The accuracy of on-schedule operation and energy consumption (running section: Morioka to Hachinohe).

	The fastest operation	Marginal time 30 sec.
Target running time (second)	-	1621
Running time (second)	1591	1625
Powering energy (kWh)	2443	2173
Regenerative braking energy (kWh)	353	230
Consumption energy (kWh)	2090	1943

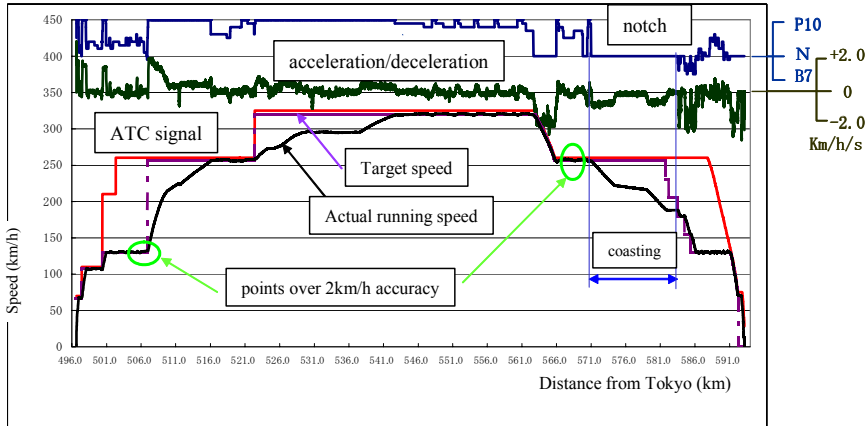


Figure 4: The result of running test from Morioka to Hachinohe.

6.2 On-schedule operation

On-schedule operation was realized by shifting accelerating to coasting according to marginal time of running. The accuracy of punctuality was 4 s, which means that the simulation data about target running time was highly accurate. It satisfies what we set at a target, and we regard the on-schedule operation as possible in the high speed Shinkansen.

7 Conclusion

It is concluded that the system performance is satisfactory for secure speed control, constant speed running control, and on-schedule operation. The system also realizes energy saving operation. For the practical use, we will accumulate

the data of various running patterns in the high speed Shinkansen test train aiming at 400 km/h running.

References

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