Development of Algorithm to Calculate Energy Saving Train Performance Curve

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BACKGROUND AND PURPOSE

The power consumption by seven Japan Railway companies amounts to about 13 billion kW or about 125 trillion Japanese yen (Fig. 1). It is desired, therefore, to cut the power consumption and its cost in train operation, which requires a train operation pattern to minimize energy consumption by using the existing rolling stock with the operation time between stations kept unchanged. What is the purpose of this study is to develop an algorithm to design the train operation pattern (energy-saving train performance curve) at the minimum power consumption.

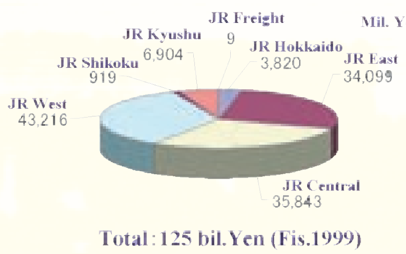

Figure 1. Expenditure on Electricity Consumption of JR Companies.

ESTIMATION AND EVALUATION OF POWER CONSUMPTION

To develop the algorithm to calculate an energy-saving train performance curve, the technique to estimate the power consumption in train operation is required. Although the method to approximately calculate power consumption dependent on the train-performance curve has been known, there have been few studies to evaluate the precision of the curve estimated by cross-checking it with field test results. In this study, the author developed a power-consumption calculating method by applying a loss coefficient, the power consumption by auxiliary machines, and the know-how to the calculating formula introduced based on the rolling stock control theory, and then compared the energy consumption obtained through the method with measurements in field tests. As a result, it was found that the method was capable of estimating power consumption at high precision with small errors of about 2%.

ALGORITHM TO CALCULATE THE ENERGY SAVING TRAIN PERFORMANCE CURVE

The author developed an algorithm to create the train operation pattern (train performance curve) at the minimum energy consumption based on the information given on operation times between stations, rolling stock performance, and track condition.

Conventional studies in this field were mostly to acquire knowledge on the theoretical features of the energy-saving train performance curve under ideal conditions or on the algorithm to determine one that is applicable to actual train operation. There has been no algorithm that is capable of creating an energy-saving train performance curve on a real time basis for sections where complicated and frequently-changing speed limits are set. The newly developed algorithm enables highly speedy data-processing to meet this requirement by using onboard devices.

EVALUATION RESULTS

The author analyzed the operation of a revenue service train running on a line in a coastal area studded with a number of speed limits for curves, calculated the corresponding operation pattern for the train by using the algorithm, and then compared the measured and calculated train operation patterns to find the following.

(1) The train operation pattern significantly differs from driver to driver, which causes remarkable differences in the power consumption (Fig. 2).

(2) Figures 3 shows the train operation patterns 1 and 2 that consume the maximum and minimum amounts of power, respectively, among those observed in actual train operation and the energy-saving train operation patterns obtained by the algorithm. The latter suppresses the maximum speed and tactfully performs coasting, to cut energy consumption about 20% and 7% from that in the patterns 1 and 2, respectively, (Fig. 4).

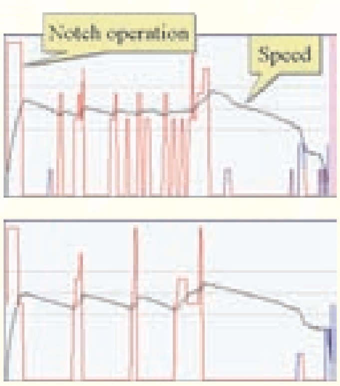

Figure 2. Difference of Driving Patterns among drivers.

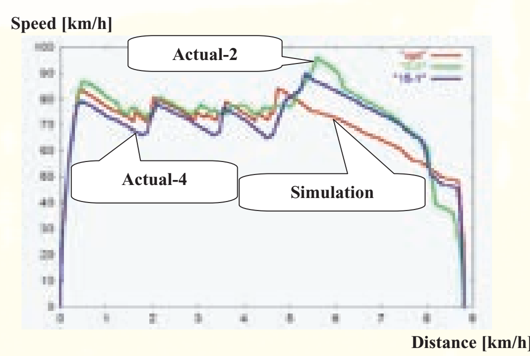

Figure 3. Comparison of Actual Train Driving Patterns and Simulation Results.

Table 1. Improvement Ratios of the Algorithm[a]

	Actual-1	Actual-2	Actual-3	Actual-4	Simulation
Running time (actual) / s	480	477	482	479	480
Energy consumption / kWh	28.2	30.5	28.0	26.1	24.2
Improvement ratio, %	14	21	14	7	---

[a] Distance, 8.8 km; car type, 731 Series; running time (specified), 480 s.