The Simulation of Train Performance by Means of Digital Computer

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1. *Introduction*

This paper briefly describes the equations to be solved and the program to be formulated for the simulation of the train performance. In planning an operation of a new locomotive or a train operation on new lines, many decisions have to be so made concerning the tracks, locomotives, electric power-source stations, etc., as to best suit the requirements. Therefore, it is necessary to have a clear information about the running time, speed, electric power consumption and motor temperature rise of the train.

2. *Equations to Be Solved*

An adequate computer program predicts train performance directly from the physical data about trains and tracks. Given the basic factors such as characteristics of certain locomotive, train weight, grades and speed restrictions of a certain track, we can calculate the necessary information using the following formulas.

$$(1+\gamma)W\frac{dv}{ds}=\frac{T(v)-R(v)\pm G(s)-R}{v}, \tag{1}$$

$$\frac{dt}{ds}=\frac{1}{v}, \tag{2}$$

$$\frac{dp}{dt}=\frac{1}{\eta}\cdot T\cdot v, \tag{3}$$

$$\bar{I}^2=\frac{\int I^2dt}{\int dt}, \tag{4}$$

$$c\frac{d\theta}{dt}=Q-(\alpha+\beta v)(\theta-\theta_0), \tag{5}$$

where

γ: rollability factor,
W: train weight,
s: distance,
v: speed,
t: time,
B: braking force,
P: power consumption,
η: efficiency of the motor,
I: mean square current,
C: heat capacity,

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$T(v)$: tractive effort, Q: generated heat,
$R(v)$: rolling resistance, α, β: cooling coefficients,
$G(s)$: grade component, θ, θ_0: temperature.

Eqs. (1) and (2) determine the train movement. Eqs. (3), (4), and (5) determine the electric and heat characteristics of the train under the condition decided by Eqs. (1) and (2).

In addition to these equations there is another one to control the train operation; power running, coasting, or braking is selected depending on the requirements of a general speed limit, local speed limits or station stops.

$$J=\frac{1}{2}(v_l^2-v^2)+E_1+E_2, \tag{6}$$

where J: criterion factor,
v_l: next speed limit,
v: train speed,
E_1: potential energy difference between the point where the train is running and the point where the next speed limit exists,
E_2: energy dissipation between the two points.

A decision can be made according to whether J is negative or not.

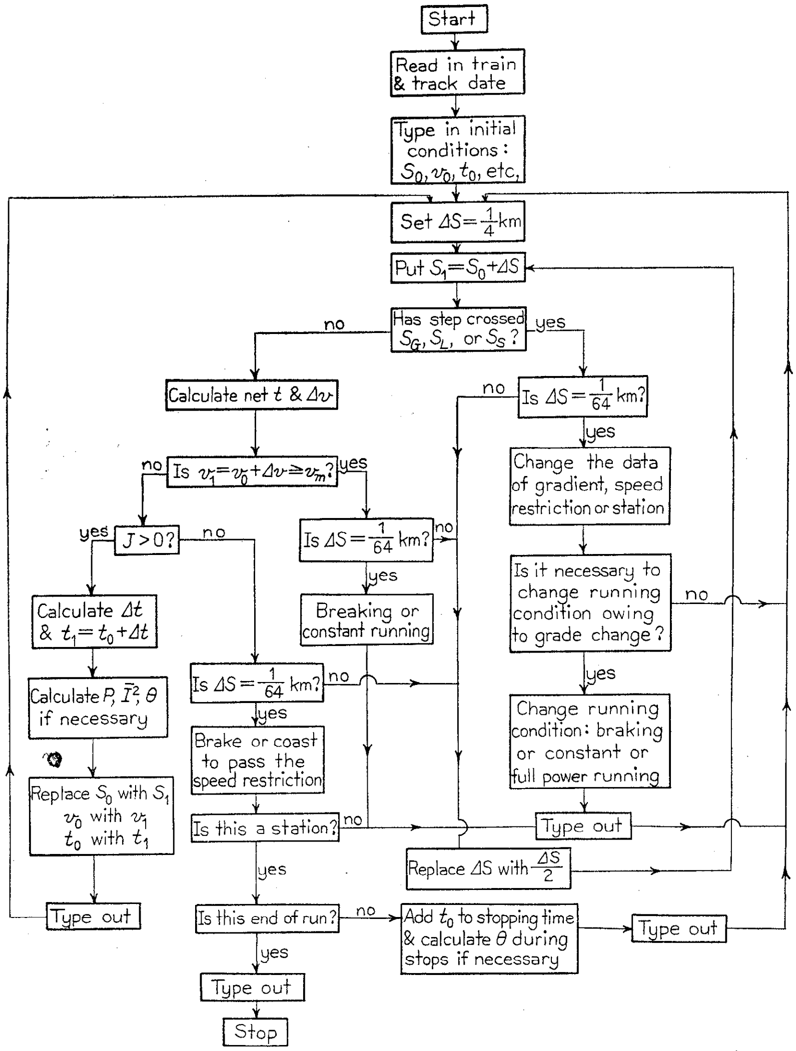
3. *Clock Diagram of the Main Program*

Fig. 1 shows the block scheme describing the procedure of simulation. For any given s_0 and v_0, unit increment Δs of independent variable s is added to s_0, from which corresponding increments Δv and Δt are computed. If necessary, power consumption and temperature rise of motors are computed, too. $s+\Delta s$ and $v+\Delta v$ thus obtained are fed back through the computing loop to give next starting values. This computing cycle is repeated until accumulated s successively covers the entire route ultimately.

Basic increment Δs of 1/4 km may be divided by two successively to 1/64 km in minimum, so that discontinuites of the function at the points, where grades or speed restriction changes, may not introduce the computation error.

Δv is calculated from Δs and the resultant $v+\Delta v$ for the next step is compared with v_m, where v_m is the speed limit in the section under consideration.

If $v+\Delta v \geqq v_m$, Δs is halved successively independently of track data, until the above condition is removed, to 1/64 km in minimum. "Decision of running condition change" owing to the grade change is used for A-C tractions. Other decisions in the schematic loop are self-explanatory except J, which is described in section 2.



S: distance
v: speed
t: time
θ: temperature of motor armature
I: motor current
T: tractive effort
ΔS: distance increment
Δv: speed increment
Δt: time increment
S_G: terminal point of gradient
S_L: initial point of next speed restriction
S_S: distance of station
J: criterion factor
v_m: speed limit

Fig. 1. Block scheme for train performance calculation

4. *Conclusion*

Japanese National Railways have been using this program in many developmental works as well as in routine works and the practical usefulness is verified. Its further extensions to solve new traffic problems are now in progress.