A Simplified Method to Calculate the Energy Consumed by Rolling Stock

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Making an effective energy saving plan requires the ability to calculate the reduction of energy consumption achieved by replacing rolling stock. Although energy consumption can be calculated by running train operation simulations, these programs require considerable input data such as gradients between stations, curves, turnouts and signals. This can amount to a large volume of data when the running distance is long. In the case of railway operators having various rolling stock and tracks in particular, there will be a number of combinations of these facilities. Therefore, simpler and quicker calculating methods are of value and we developed a simple method to calculate the energy consumed by rolling stock without implementing running simulations.

Figure 1 shows an example of the changes in the energy consumed by EMUs after starting from a station until stopping at the next station. In running simulations, the energy consumption is normally obtained by subtracting the volume of regenerated energy from that of the powering energy.

However, it is also possible to calculate the energy consumption by summing the separately calculated amounts of machine loss, running resistance loss and non-regenerative braking loss (see Fig. 1). We adopted this latter method, and developed the following calculation method. In the method, information equivalent to the train timetable is used as input data to represent the train operation, with the average distance (AD) and average running time (ART) being calculated for the section between stations. The following calculations are made while assuming a case where a train operates over the distance (AD) in the running time (ART) by following the pattern in Fig. 1.

For the purpose of the calculation, we follow the steps below.

1. Calculate the average speed (AS) from AD and ART.
2. Calculate the running resistance loss from AS using the formula of running resistance and the empirical formula obtained in advance through the analysis of actual running data.
3. Calculate the maximum speed attained (MS) and initial braking speed from AS using the empirical formula obtained in advance through the analysis of actual running data.
4. Calculate the machine loss at powering from the kinetic energy at MS, running resistance loss and the efficiency of rolling stock.
5. Calculate the machine loss and non-regenerative braking loss at braking from the kinetic energy at the initial braking speed, the efficiency of rolling stock and regenerative brake performance.

A summation of these losses gives an approximation to the energy consumption.

To verify the validity of this method, we repeated the above calculation process for multiple sets of EMUs and compared the calculated and measured values. The results indicate that these two sets of values are approximately in agreement with errors of 7% or less, as shown in Fig. 2. This is evidence that this method is an effective means to calculate the approximate energy consumption.

As this method calculates not only the energy consumption but also its breakdown, it is easily understood how energy saving can be attained. Although the above calculations were made for EMUs, this method is equally applicable to DMUs with satisfactory results expected.

We hope this method will be applied to energy saving plans by railway operators and contribute to further energy conservation in the railway industry.

Table 1 EMUs used for this study

	Traction control	Train category	Average distance between stations	Average speed
EMU 1	Inverter control	Local	2.28 km	58.2 km/h
EMU 2		Rapid	6.64 km	83.6 km/h
EMU 3	Armature chopper control	Local	2.12 km	52.6 km/h
EMU 4	Field added excitation control	Local	1.18 km	41.8 km/h
EMU 5	Rheostatic control	Local	1.23 km	41.2 km/h
EMU 6		Limited express	19.3 km	76.7 km/h

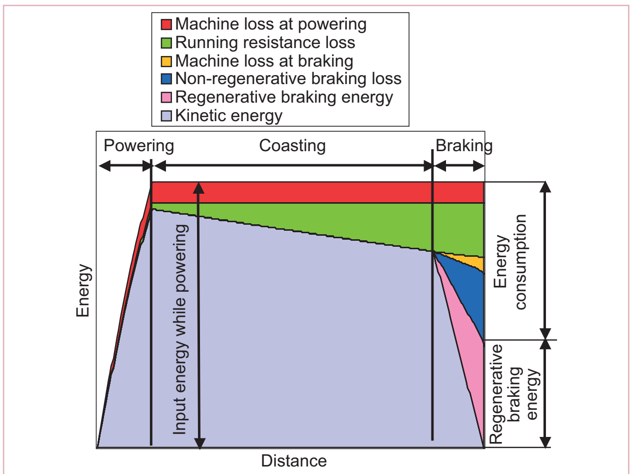

Fig. 1 Changes in energy during the operation of EMUs

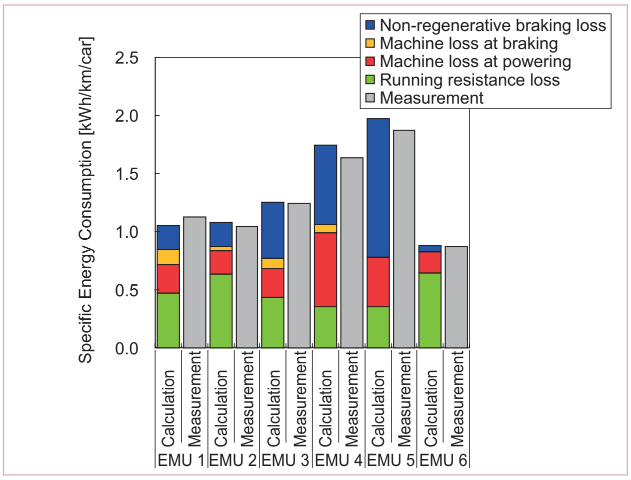

Fig. 2 Comparison between calculated and measured values