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(54) **Optimal running-pattern calculating apparatus and system of the same.**

(57) An optimal running-pattern calculating apparatus is disclosed, which comprises input means (1) for inputting line data and car data, running simulation means (3) for simulating the running of a train by using various data received from input means (4), backward curves received from backward curve calculating means (4), notch switching parameters received from parameter initializing means (10), and an upper limit speed and for calculating a running-pattern for the train to run within a restricted speed in a predetermined running distance, and time fitting means (5) for causing upper limit speed adjusting means (6) to adjust the upper limit speed and causing the running simulation means (3) to recalculate the running-pattern when the running time calculated by the running simulation means (3) deviates from a predetermined running time.

Thus, a running-pattern for a train to run with small energy consumption and riding comfort while satisfying a predetermined running distance, a predetermined running time, and a restricted speed can be easily and quickly created.

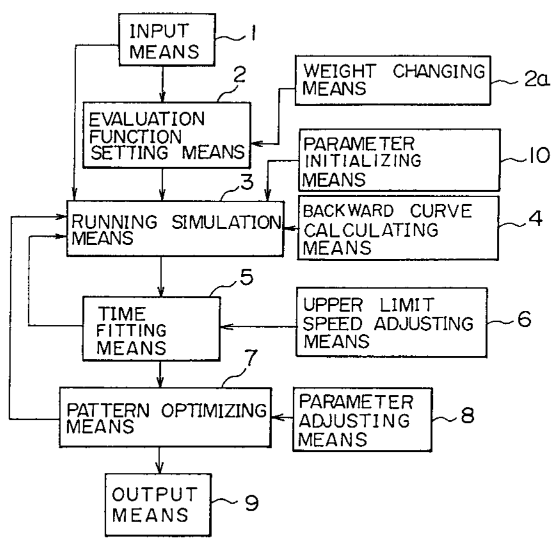

FIG. 1

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BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an optimal running – pattern calculating apparatus and the system of the same for calculating an optimal running – pattern for a train to run with small energy consumption and riding comfort while satisfying conditions such as a running distance, a running time, and a restricted speed.

2. Description of the Related Art

Thus far, a standard running – pattern for a train to run with small energy consumption and riding comfort while satisfying conditions such as a running distance, a running time, and a restricted speed has been created manually by connecting curves on paper in accordance with a running technique obtained through the experiences of motormen. When a train deviates from a running schedule, a schedule restoration running operation is performed. In this event, since there is no reference pattern, the motorman should perform a schedule restoration running operation through his perception and experience. It is very difficult to optimize the running – pattern of a train mathematically due to its strong non – linearity and discontinuity. So far, studies with respect to the optimal running techniques of trains as disclosed in the following papers have been conducted.

[1] "A Predictive Fuzzy Control for Automatic Train Operation", by Yasunobu et. al., published on "ISCIE Systems and Control" of Japanese magazine, pp 605 – 613, No. 10, Vol 28, 1984.

[2] "Laboratory Development of New Train Control System by Radio", by Inage et. al., published on "RTRI Report", pp. 48 – 55, No. 1, Vol. 5, January 1991.

[3] "A Method for Calculating the Energy Consumed in Train Operation and Its Application for a Study on Energy Saving in the Shinkansen Accommodation Train Service", by Yasukawa, published on "Trans. of IEEE of Japan", pp 769 – 776, No. 9, Vol. 106 – B, September 1986.

In these studies, however, a running technique which deals with all of riding comfort, energy consumption, and running time adjustment has not been disclosed.

It is not known whether or not the running technique which is obtained through the experience of a motorman is optimal from the standpoints of riding comfort and energy consumption. In addition, manual creation of a standard running – pattern takes a long time and is very troublesome. Moreover, the running schedule of trains becomes tight year by year. The number of applicants for motormen decreases, and so does the number of skilled motormen. Thus, in the schedule restoration running operation based on the skill of a motorman, it is not assured whether or not the motorman can stop the train at a predetermined position and run the train within a restricted speed. Furthermore, the schedule restoration ratio is not constant.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an optimal running – pattern calculating apparatus and a system of the same for easily, quickly, and securely obtaining an optimal running – pattern of a train which can run with riding comfort and small energy consumption in conformity with a restricted speed, predetermined stop positions and a running schedule.

An aspect of the present invention is an optimal running – pattern calculating apparatus, comprising input means for inputting line data and car data, backward curve calculating means for outputting backward curves, parameter initializing means for outputting notch switching parameters and an upper limit speed, running simulation means for simulating the running of a train by using the data received from the input means, backward curves received from backward curve calculating means, and the notch switching parameters and an upper limit speed received from the parameter initializing means, and for calculating a running – pattern for the train to run within a restricted speed in a predetermined running distance, and time fitting means for causing upper limit speed adjusting means to adjust the upper limit speed and causing the running simulation means to recalculate the running – pattern when the running time calculated by the running simulation means is different from a predetermined running time.

Another aspect of the present invention is an optimal running – pattern calculating system, comprising a database for storing line data, car data, and operation condition data, a running – pattern calculating unit for calculating a running – pattern for a train to run in a predetermined section in a predetermined running time with riding comfort and small energy consumption in accordance with the line data, the car data, and the operation condition data received from the database, and an interface for outputting a running – pattern calculating command to the running – pattern calculating means and for displaying the running – pattern obtained.

A further aspect of the present invention is an optimal running – pattern calculating system, comprising a database or a storage medium for storing line data, car data, and operation condition data, a running – pattern calculating unit for calculating a running-pattern for a train to run in a predetermined section in a predetermined running time with riding comfort and small energy consumption in accordance with the line data, the car data, and the operation condition data received from the database or the storage medium, an interface for outputting a running-pattern calculating command to the running-pattern calculating means and for displaying the running-pattern being obtained, and a communication system for outputting data of the position and speed of a preceding train and operation management data to the running-pattern calculating unit, wherein the database, the running-pattern calculating unit, and the interface are mounted on the train.

Thus, a running-pattern for a train to run with small energy consumption and riding comfort while satisfying a predetermined running distance, a predetermined running time, and a restricted speed can be easily and quickly created.

In addition, automatic train operation tracking a target running-pattern can be realized. Thus, the train can run in a predetermined running time with riding comfort.

These and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of best mode embodiments thereof, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a block diagram showing an optimal running-pattern calculating apparatus of a first embodiment in accordance with the present invention.

Fig. 2 is a graph showing a running-pattern obtained by a running simulation means;

Fig. 3 is a graph showing a running-pattern obtained by a time fitting means;

Fig. 4 is a graph showing a running-pattern obtained by a pattern optimizing means;

Fig. 5 is a graph showing a running-pattern obtained by a running simulation means of an second embodiment in accordance with the present invention;

Fig. 6 is a graph showing a running-pattern obtained by a time fitting means of the second embodiment;

Fig. 7 is a graph showing a running-pattern obtained by a pattern optimizing means of the second embodiment;

Fig. 8 is a graph showing a running-pattern obtained by using notch switching parameters in the case where line resistances is not considered;

Figs. 9 (a) to (d) are graphs showing running conditions in accordance with the notch switching parameters;

Fig. 10 is a block diagram showing an optimal running-pattern calculating system of a third embodiment in accordance with the present invention;

Fig. 11 is a schematic diagram showing an operation screen of an interface;

Fig. 12 is a schematic diagram showing a running-pattern condition inputting sub-window of the interface;

Fig. 13 is a schematic diagram showing a running-pattern reading sub-window of the interface; and

Fig. 14 is a block diagram showing another example of the optimal running-pattern calculating system.

DESCRIPTION OF PREFERRED EMBODIMENTS

First embodiment

Now, with reference to the accompanying drawings, a first embodiment in accordance with the present invention will be described. Figs. 1 to 4 show the first embodiment in accordance with the present invention. Fig. 1 is a block diagram showing an optimal running-pattern calculating apparatus of the first embodiment in accordance with the present invention.

In Fig. 1, the optimal running-pattern calculating apparatus comprises an input means 1 which inputs line data, car data, and so forth, an evaluation function setting means 2 which sets evaluation functions with respect to energy consumption and riding comfort in accordance with data being input form the input means 1, a running simulation means 3 which simulates the running of a train and which calculates a running-pattern for the train to run in a predetermined running distance in a restricted speed, a time fitting means 5 which adjusts a running time of the running-pattern calculated by the running simulation means 3, and a pattern optimizing means 7 which adjusts notch switching parameters so that the evaluation functions of the running-pattern adjusted by the time adjusting means 5 become minimal.

The running simulation means 3 is connected to a parameter initializing means 10 and a backward curve calculating means 4. The time fitting means 5 is connected to an upper limit speed adjusting means 6. The pattern optimizing means 7 is connected to a parameter adjusting means 8. The pattern optimizing means 7 is also connected to an output means 9 which outputs a running-pattern obtained by the pattern optimizing means 7.

Next, the operation of this embodiment will be described.

On the input means 1, using an electronic pen, a touch sensor, or the like, the user inputs line data and car data. The line data includes for example a running distance between each station, a predetermined running time thereof, a restricted speed thereof, and line conditions (curves and grades). The car data includes for example a train composition, car weight, passenger capacity, and traction characteristics. The evaluation function setting means 2 obtains a formula for calculating energy consumption of the train in accelerating phase in accordance with the car data such as car weight. In addition, the evaluation function setting means 2 obtains as an index of riding disconfort a formula with respect to the number of notch switching times. The evaluation function setting means 2 uses these formulas as evaluation functions. When necessary, a weight changing means 2a changes the weights of the evaluation functions obtained by the evaluation function setting means 2. There are some notches corresponding to discrete tractions in each of accelerating phase and decelerating phase. One of the notches of each phase is used for calculating a running pattern. So the number of notch switching times represents the number of times of the notch switching between power-on state (accelerating phase), neutral state (inertial running phase), and brake-on state (decelerating phase). As the number of notch switching times increases, the riding comfort degrades. In addition, when a notch is switched, the more the traction varies, the more the riding comfort degrades.

Next, the operation of the running simulation means 3 will be described. The running simulation means 3 simulates the running of a train in accordance with the line data and the car data obtained by the input means 1, the backward curves obtained by the backward curve calculating means 4, the initial values and the upper limit speeds of the notch switching parameters which are set by the parameter initializing means 10. The backward curves obtained by the backward curve calculating means consist of backward brake curves and backward power curves. As shown in Fig. 2, backward brake curves 12 are obtained as running curves of a train in brake-on state calculated backward from a point where an upper limit speed 14 decreases and from an end point b. On the other hand, a backward power curve 13 is obtained as a running curve of a train in power-on state calculated from a point c where an upper limit speed increases.

The notch switching parameters are defined based on notch switching between power-on, neutral, and brake-on states. The notch switching parameters consist of brake-on parameter, power-off parameter, brake-off parameter, and power-on parameter in the ordinary order of value. Each of the notch switching parameters has an individual value for example 100 %, 90 %, 80 %, or 70 % to an upper limit speed.

As shown in Fig. 9, in the condition where the brake-on parameter is set to 100 %, the power-off parameter to 90 %, the brake-off parameter to 80 %, and the power-on parameter to 70 %, when the speed of the train increases to 100 % of the upper limit speed in neutral state (N), the brake is turned on (see Fig. 9 (a)). When the speed of the train increases to 90 % of the upper limit speed in power-on state (P), the power is turned off (see Fig. 9 (b)). In this case, when the line resistance is positive, the train is decelerated in the neutral state (N). On the other hand, when the line resistance is negative, the train is accelerated in the neutral state (N). When the speed of the train decreases to 80 % of the upper limit speed in the brake-on state (B), the brake is turned off (see Fig. 9 (c)). In this case, when the line resistance is positive, the train is decelerated in the neutral state (N). On the other hand, when the line resistance is negative, the train is accelerated in the neutral state (N). When the speed decreases to 70 % of the upper limit speed in the neutral state (N), the power is turned on (see Fig. 9 (d)).

The parameter initializing means 10 sets the initial values of the notch switching parameters. In other words, the parameter initializing means 10 sets individual values of the notch switching parameters. These individual values are represented with percentage to an upper limit speed of the train.

As an initial values of an upper limit speed which is input to the running simulation means 3, a restricted speed is used. The restricted speed is an absolutely restricted speed predetermined for each portion in accordance with the line condition and so forth. Thus, the restricted speed is a restricted value of the running speed of the train. On the other hand, an upper limit speed is an expedient upper limit speed for use in obtaining an optimal running-pattern. The restricted speed is the maximum value of the upper limit speed.

The running simulation means 3 simulates the running of the train so that it can run at speeds which do not exceed a predetermined upper limit speed for a predetermined running distance. In simulating the running of a train, when a running curve intersects with a backward brake curve 12 or a backward power curve 13 as shown in Fig. 2, the resultant running curve is drawn therealong. Thus, when the upper limit speed increases in a forward position, by turning on the power early, the train can be effectively accelerated. On the other hand, when the upper limit speed decreases in a forward position, the train can run at a speed which does not exceed the restricted speed and securely stops a predetermined position.

In the running simulation, when the running speed of the train increases to the brake-on speed, the brake is turned on. When the running speed of the train increases to the power-off speed, the power is turned off. When the running speed of the train decreases to the brake-off speed, the brake is turned off. When the running speed of the train decreases to the power-on speed, the power is turned on. Thus, the train can run at a speed in conformity with the restricted speed. In addition, the train can be prevented from stopping before reaching a predetermined stop position. In this manner, a running-pattern 11 as shown in Fig. 2 can be obtained. In Fig. 2, the energy consumption is 6.3; the number of notch switching times is 6; and the time error is -17.5 sec.

When the running time of the running-pattern obtained by the running simulation means 3 has a margin, the time fitting means 5 adjusts the running time.

In other words, when the running time of the running-pattern obtained by the running simulation means 3 has a margin (17.5 sec.) (see Fig. 2), the upper limit speed adjusting means 6 adjusts the upper limit speed of the train in accordance with the running time error. A signal of the time adjusting means 5 is input to the running simulation means 3. The running simulation means 3 repeats the running simulation. The running simulation is performed in such a way that the train can run at as close to the upper limit speed as possible. Thus, when the upper limit speed is decreased, the maximum running speed decreases and the running time is prolonged. The upper speed adjusting means 6 adjusts the upper limit speed by decreasing the upper limit speed of the convex portion as shown in Fig. 2. Adjusting of the upper limit speed and the running simulation are repeated until the running time error comes in the allowable range. In this manner, a running-pattern 21 as shown in Fig. 3 is obtained. In Fig. 3, reference numeral 22 is a backward brake curve. Reference numerals 24 and 25 are an upper limit speed which has not been adjusted and an upper limit speed which has been adjusted, respectively. In Fig. 3, the energy consumption is 3.5; the number of notch switching times is 8; and the time error is 0.1 sec.

When the four notch switching parameters are set to individual values such as 100 %, 90 %, 80 %, and 70 %, after the running time has been adjusted a running-pattern is uniquely fixed, as shown in Fig. 3. Thus, the pattern optimizing means 7 selects the notch switching parameters as parameters to optimize the running-pattern. Then, the notch switching parameters are adjusted. A signal of the pattern optimizing means 7 is input to the running simulation means 3. The running simulation means 3 repeats the running simulation and the time fitting means 5 repeatedly adjusts the running time. In this manner, the individual values of the notch switching parameters where the values of the evaluation functions are minimized are obtained.

The parameter adjusting means 8 adjusts the notch switching parameters in accordance with a rule based on situations of the notch switching and evaluation functions varying or by using an AI (Artificial Intelligence) system. In addition, while observing the running pattern and the values of evaluation functions displayed on a display of the pattern optimizing means 7, the user can manually adjust the notch switching parameters. As the number of switching times of notches caused by notch switching criteria speeds which are products of the upper limit speed and the notch switching parameters, other than backward curves decreases, the riding comfort is improved. In addition, since the wasteful accelerating is decreased, a running-pattern 31 of the train which decreases energy consumption is obtained (see Fig. 4). The resultant running-pattern is displayed on a running-pattern display unit.

In Fig. 4, reference numeral 32 is a backward curve. Reference numerals 34 and 35 are an upper limit speed which has not been adjusted and an upper limit speed which has been adjusted, respectively. In Fig. 4, the energy consumption is 2.5; the number of notch switching times is 2; and the time error is 0.1 sec.

Thus, a running-pattern for a train to run with small energy consumption and riding comfort in conformity with a predetermined running distance, a predetermined running time, and a restricted speed can be easily, quickly, and securely obtained. When a shorter running time is specified, a running-pattern for a schedule restoration running operation can be obtained. In addition, since a shortest running time can be obtained, the apparatus in accordance with the present invention can be used when a train schedule is revised or when a new line schedule is created. Moreover, provided that a optimal running-pattern has been input to an automatic train operation system as a target running-pattern, when a train is controlled to track this pattern, it can run with small energy consumption and riding comfort in conformity with the designated running distance, the designated running time, and the designated restricted speed.

Second Embodiment

Next, with reference to Figs. 5 to 8, a second embodiment in accordance with the present invention will be described.

The second embodiment shown in Figs. 5 to 8 is the same as the first embodiment shown in Figs. 1 to 4 except for the notch switching parameters which are input to the running simulation means.

On the input means 1, using an electronic pen, a touch sensor, or the like, the user inputs line data and car data. The line data includes for example a running distance between each station, a predetermined running time thereof, a restricted speed thereof, and line conditions (curves and grades). The car data includes for example a train composition, car weight, passenger capacity, and traction characteristics. The evaluation function setting means 2 obtains a formula for calculating energy consumption of the train in accelerating phase in accordance with the car data such as car weight. In addition, the evaluation function setting means 2 obtains as an index of riding discomfort a formula with respect to the number of notch switching times. The evaluation function setting means 2 uses these formulas as evaluation functions. When necessary, a weight changing means 2a changes the weight of the evaluation functions obtained by the evaluation function setting means 2. The number of notch switching times represents the number of times of the notch switching between power-on state, neutral state, and brake-on state. As the number of notch switching times increases, the riding comfort degrades. In addition, when a notch is switched, the more the traction varies, the more the riding comfort degrades.

The running simulation means 3 simulates the running of a train in accordance with the line data and the car data obtained by the input means 1, the backward curves obtained by the backward curve calculating means 4, the initial values and the upper limit speeds of the notch switching parameters which are set by the parameter initializing means 10. The backward curves obtained by the backward curve calculating means 4 consist of backward brake curves and backward power curves. As shown in Fig. 5, backward brake curves 102 are obtained as running curves of a train in brake-on state calculated backward from a point where an upper limit speed 104 decreases and from an end point b. On the other hand, a backward power curve 103 is obtained as a running curve of a train in power-on state calculated backward from a point c where an upper limit speed increases.

The parameter initializing means 10 sets the initial values of the notch switching parameters. The notch switching parameters are set as criteria of whether the brake and/or power are turned on and/or off. Thus, the notch switching parameters consist of brake-on parameter, power-off parameter, brake-off parameter, and power-on parameter. Each parameter has an individual value constant between a station and the next station. The individual value is represented with percentage (%) to an upper limit speed. The value of the brake-on parameter is larger than the value of the power-on parameter. The values of the power-off parameter and the brake-off parameter are larger than the value of the power-on parameter and smaller than the value of the brake-on parameter.

In this embodiment, the power-off parameter and the brake-off parameter have two individual values in accordance with the cases whether the line resistance is positive or negative. The value of line resistance varies from point to point depending on the resistance of grade, the resistance of curve, and the resistance of running. With respect to the power-off parameter and the brake-off parameter, one of the two values is selected for each parameter depending on the value of the line resistance at the point the train is running.

The restricted speed is an absolutely restricted speed predetermined for each portion in accordance with the line condition and so forth. Thus, the restricted speed is a restricted value of the running speed of the train. On the other hand, an upper limit speed is an expedient upper limit speed for use in obtaining an optimal running-pattern. The restricted speed is the maximum value of the upper limit speed.

The running simulation means 3 simulates the running of the train so that it can run at speeds which do not exceed a predetermined upper limit speed for a predetermined running distance. In simulating the running of a train, when a running curve intersects with a backward brake curve 102 or a backward power curve 103 as shown in Fig. 5, the resultant running curve is drawn therealong. Thus, when the upper limit speed increases in a forward position, by turning on the power early, the train can be effectively accelerated. On the other hand, when the upper limit speed decreases in a forward position, the train can run at a speed which does not exceed the restricted speed and securely stop in a predetermined position. In addition, during simulation of the running-pattern, the individual value of each notch switching parameter is multiplied by the upper limit speed of the section in which the train is running. Thus, the brake-on speed, the power-off speed, the brake-off speed, and the power-on speed which are notch switching criteria speeds for switching notches are obtained in advance.

With respect to the power-off speed and the brake-off speed, two individual values for each speed in accordance with the cases whether the line resistance is positive or negative are obtained in advance. When the running speed of the train increases to the brake-on speed, the brake is turned on. When the running speed of the train decreases to the power-on speed, the power is turned on. At a point where the line resistance is positive (namely, the speed of the train in the neutral state decreases), the power-off speed or the brake-off speed in accordance with the individual value for the positive line resistance is selected. At a point where the line resistance is negative (namely, the speed of the train in the neutral state increases), the power-off speed or the brake-off speed in accordance with the individual value for the negative line resistance is selected. When the speed of the train increases to the power-off speed, the power is burned off. When the speed of the train decreases to the brake-off speed, the brake is turned off. Thus, the train can run in conformity with the restricted speed. In addition, the train can be prevented from stopping before reaching a predetermined stop position.

In this manner, a running-pattern 101 as shown in Fig. 5 can be obtained. In the figure, the value of the brake-on parameter is set to 100 %. The value of the power-on parameter is set to 45 %. Both the values in accordance with the positive and negative line resistances of the power-off parameter and the brake-off parameter are set to 99 %. All these values are initial values. In the figure, the energy consumption is 1156; the number of notch switching times is 15; and the running time error is -5.616 sec.

When the running time of the running-pattern obtained by the running simulation means 3 has a margin (5.616 sec. in Fig. 5), the time fitting means 5 adjusts the running time.

The time fitting means 5 determines the running time error of the running-pattern obtained by the running simulation means 3. The upper limit speed adjusting means 6 adjusts the upper limit speed in accordance with the error and outputs a new upper limit speed to the running simulation means 3. The running simulation means 3 repeatedly simulates the running simulation. Adjusting of the upper limit speed and the running simulation are repeated until the running time error comes in the allowable range.

The upper limit speed adjusting means 6 increases or decreases the upper limit speed at the convex portion shown in Fig. 5 in the range below the restricted speed in accordance with the running time error which is positive or negative, respectively. Thus, the upper limit speed adjusting means 6 obtains a new upper limit speed. Since the individual values of the notch switching parameters have been fixed, when the upper limit speed is decreased, the maximum running speed is decreased and thereby the running time is prolonged. On the other hand, when the upper limit speed is increased, the maximum running speed is increased and thereby the running time is shortened.

In this manner, a running-pattern 121 as shown in Fig. 6 can be obtained. In the figure, reference numeral 122 is a backward brake curve. Reference numeral 123 is a backward power curve. Reference numeral 124 is an upper limit speed which has not been adjusted (this speed is equal to the restricted speed). Reference numeral 125 is an upper limit speed which has been adjusted. In this figure, the energy consumption is 705; the number of notch switching times is 15; and the running time error is -0.099 sec.

When an individual value of each notch switching parameter is set, a running-pattern obtained by the time fitting means 5 is uniquely fixed. Thus, the pattern optimizing means 7 adjusts the notch switching parameters so as to optimize the running-pattern.

The pattern optimizing means 7 determines situations of the notch switching and the evaluation functions varying of the running-pattern adjusted by the time adjusting means 5. Thus, the parameter adjusting means 8 adjusts the notch switching parameters so that the values of the evaluation functions are decreased. New notch switching parameters are sent to the running simulation means 3. The running simulation means 3 repeatedly simulates the running simulation. The adjusting of the notch switching parameters, the running simulation, and, when necessary, the adjusting of the upper limit speed are repeated until the values of the evaluation functions become minimal.

The parameter adjusting means 8 adjusts the notch switching parameters in accordance with a rule based on situations of the notch switching and evaluation functions varying or by using an AI (Artificial Intelligence) system so as to the values of the evaluation functions decrease. In addition, while observing the running-pattern and the values of the evaluation functions obtained, the user can manually adjust the notch switching parameters. As the number of switching times of notches caused by notch switching criteria speeds other than backward curves decreases, the riding comfort is improved. In addition, since the wasteful accelerating is decreased, energy consumption is also decreased.

Some of the notch switching parameters are selected to be adjusted at the same time. With respect to the power-off parameter and the brake-off parameter, two individual values in accordance with the cases where the line resistance is positive or negative are independently adjusted. Thus, in the case where the brake or power is turned off in a particular point between two stations where the line resistance is positive and in another point where the line resistance is negative, an optimal running-pattern 131 suitable to the condition of the line resistance can be obtained as shown in Fig. 7. In the figure, reference numeral 132 is a backward brake curve. Reference numeral 133 is a backward power curve. Reference numerals 134 and 135 are an upper limit speed which has not been adjusted and an upper limit speed which has been adjusted, respectively. The individual value of the brake-on parameter is 100 %. The individual value of the power-on parameter is 45 %. The individual value of the power-off parameter in the case where the line resistance is positive is 98 %. The individual value of the power-off parameter in the case where line resistance is negative is 91 %. The individual value of the brake-off parameter is 99 % regardless of whether the line resistance is positive or negative. In this figure, the energy consumption is 896; the number of notch switching times is 5; and the running time error is 0.138 sec.

As opposed to the case shown in Fig. 7, when each of the power-off parameter and the brake-off parameter has one value, the parameters cannot be optimized enough and thereby a running-pattern 141 as shown in Fig. 8 is obtained. In Fig. 8, reference numeral 142 is a backward brake curve. Reference numeral 143 is a backward power curve. Reference numerals 144 and 145 are an upper limit speed which has not been adjusted and an upper limit speed which has been adjusted, respectively. The individual value of the brake-on parameter is 100 %. The individual value of the power-on parameter is 45 %. The individual value of the power-off parameter is 93 %. The individual value of the brake-off parameter is 99 %. In this figure, the energy consumption is 905; the number of notch switching times is 7; and the running time error is -0.057 sec. As a result when the line condition is considered in the notch switching parameters (as shown in Fig. 7), the number of times where an unnecessary brake operation is used is reduced in comparison with the case where the line condition is not considered (as shown in Fig. 8), and the energy consumption is reduced by 1 %.

Thus, a running-pattern for a train to run with small energy consumption and riding comfort in conformity with a predetermined running distance, a predetermined running time, and a restricted speed can be easily, quickly, and securely obtained. When a shorter running time is specified, a running-pattern for a schedule restoration running operation can be obtained. In addition, since a shortest running time can be obtained, the apparatus in accordance with the present invention can be used when a train schedule is revised or when a new line schedule is created. Moreover, provided that an optimal running-pattern has been input to an automatic train operation system as a target running-pattern, when a train is controlled to track this pattern, it can run with small energy consumption and riding comfort in conformity with the designated running distance, the designated running time, and the designated restricted speed.

Third Embodiment

Next, with reference to Figs. 10 to 14, a third embodiment in accordance with the present invention will be described. The third embodiment is an optimal running-pattern calculating system which is provided with the optimal running-pattern calculating apparatus of the first embodiment or the second embodiment.

Fig. 10 is a block diagram showing a stationary optimal running-pattern calculating system. As shown in Fig. 10, the optimal running-pattern calculating system comprises a database 202, an interface 201, a running-pattern calculating unit 203 (which has been described in the first and second embodiments), a storing unit 204, and an output unit 205.

The database 202 stores operation condition data (for example train numbers and running schedules), line data (for example, station names, the distance between each station, grades, curves, branches, and restricted speeds), and car data (for example, the weight and length of each car, the composition of each train, the acceleration and deceleration of each train, the formulas of grade resistance, curve resistance, and running resistance for each weather condition, passenger capacity and the crowdedness of each time zone). The running-pattern calculating unit 203 uses these data to calculate a running-pattern. These data can be referenced when necessary. A storage medium such as an IC card can be used instead of the database 202.

By using the interface 201, the user can easily perform the following operation through an operation screen such as shown in Fig. 11 with an input device such as a mouse and/or a keyboard:

(a) input the section, time, and weather for calculating a running-pattern, the type of a running-pattern (normal/fast/slow/fastest and deviation of running time), conditions of the running-pattern, and so forth,

(b) select the automatic/manual adjustment mode, change the initial values of the notch switching parameters in the automatic adjustment mode, and set the notch switching parameters in the manual adjustment mode,

(c) command the calculation of a running-pattern,

(d) display a running-pattern calculated and results of notch switching parameters adjusted,

(e) output a running-pattern calculated and change the destination of the output of the running-pattern calculated, and

(f) as an auxiliary function, change data of the database (such as revising the running schedule, changing/adding models of cars).

Four types of running-patterns according to running times (standard/fast/slow/fastest) are available. The deviation of each running time can be selected when necessary.

As described in the first and second embodiments, the running-pattern calculating unit 203 calculates a running-pattern for a train to run with riding comfort and small energy consumption in a predetermined running time in an section designated by the interface 201 in accordance with data being read from the database 202.

The storing unit 204 stores the running-pattern calculated by the running-pattern calculating unit 203. The output unit 205 outputs the running-pattern which is calculated by the running-pattern calculating unit 203 or stored in the storing unit to an ATO system 213 on the train through a storage medium such as an IC card or a communication system 212.

Next, the operation of this embodiment will be described.

First, through the interface 201, the user designates a section for calculating a running-pattern. With the mouse and/or the keyboard, for example, the user inputs data of a line name, an operation type, and a running section, data of a running section and a train number, or data of a running section and a departure time. Thus, the user designates a running-pattern for a train to run at what time and in what section.

After the section for calculating the running-pattern has been designated through the interface 201, items of operation condition data and train data which have not been input through the interface 201 are read from the database 202 and displayed.

Through the interface 201, the user can also change the car type, weather condition, the type of the running-pattern of standard/fast/slow/fastest, and the conditions of the running-pattern and the initial values of the notch switching parameters.

The type of the running-pattern can be changed to standard/fast/slow/fastest so as to select a target running-pattern in accordance with the deviation from the running schedule. In addition to the selection of standard/fast/ slow/fastest, through the interface 201, the user can designate the length of time to be changed or the ratio of the time to the running time.

To input the conditions of a running-pattern through the interface 201, when the user selects a pattern condition button on the interface 201, a condition inputting sub-window as shown in Fig. 12 is open. In this window, the user can change a margin to a restricted speed, notches for the power/brake for use in creating a running-pattern, a tracking margin in a pattern tracking operation, and a time fitting accuracy from their default values.

In Fig. 12, the margin to the restricted speed is a speed difference to be provided between a running speed and a restricted speed so as to tolerate a small amount of deviation from the running-pattern in the pattern tracking operation. As the margin, the value of the speed difference or percentage to the restricted speed is input.

For the power and the brake for use in creating a running-pattern, one notch for the power and two notches for the brake which are a stop type and a deceleration type are chosen. The deceleration type brake is used to prevent the running speed from exceeding an upper limit speed. It is necessary to designate a lower brake notch as the deceleration type brake notch than the stop type brake notch so as to prevent the riding comfortableness from degrading. In Fig. 12, one power notch with a number "4" is shown to be used in creating a running-pattern. On the other hand, two brake notches with numbers "2" and "5" are shown to be used in creating a running-pattern.

The tracking margin defines a margin of running-pattern which offsets an outer disturbance in a pattern tracking operation. When the tracking margin is increased, the time for which a weak brake is used to improve the riding comfort at the last of the stop brake (just before the train stops) is prolonged. Then, if the running of a real train largely deviates from the running-pattern due to an outer disturbance in the pattern tracking operation, the margin which offsets the deviation becomes large.

The time fitting accuracy defines the accuracy of a running time with the size of permissible error or percentage to the running time.

The initial values of the notch switching parameters for the brake-on (deceleration brake start) speed and the power-on speed can be designated by raising/lowering the bars for these parameters on the interface 201 or by inputting these values therefrom.

After the conditions of the running-pattern have been set, by selecting the calculation button on the interface 201, the user commands the calculation of the running-pattern.

When the calculation of the running-pattern is commanded through the interface 201, the running-pattern calculating unit 203 reads required data from the database 202 and calculates the running-pattern in the nearly same manner as that of the first embodiment shown in Fig. 1.

In other words, as shown in Fig. 1, the running simulation means 3 simulates the running of a train by using various data received from the input means 1, backward curves, one set of notch switching parameters, and upper limit speeds and calculates a running-pattern for the train to run for a predetermined running distance at a speed below a restricted speed.

The initial value of a upper limit value is a value where a margin designated through the interface 201 is subtracted from a restricted speed. The resultant value is input from the parameter initializing means 10 to the running simulation means 3. From points where the upper limit speed increases, backward power curves are obtained. From points where the upper limit speed decreases and at the end point, backward brake curves are obtained. These curves are input from the backward curve calculating means 4 to the running simulation means 3. During the running simulation, when the running curve intersects with a backward curve, the running-pattern is drawn along this curve. When necessary, from points where the upper limit speed increases and from points where a backward brake curves intersect with the upper limit speed, backward neutral curves are obtained. Along these curves, a running-pattern is created. In this case, since unnecessary switching of notches is not performed, a running-pattern for a train to run with riding comfort can be obtained. In addition, since the number of adjusting times of notch switching parameters is decreased, the running-pattern can be more effectively calculated.

The notch switching parameters which consist of four parameters of power-on/off and brake-on/off are criteria for switching notches. The individual value of each parameter is represented with percentage to an upper limit value. The individual value is uniquely defined between a station and the next station. The power-off parameter and the brake-off parameter have two values in accordance with the cases where the speed of the train increases or decreases in the neutral state, respectively. The notches are switched in accordance with notch switching criteria speeds which are obtained by multiplying the upper limit speed at a point the train is running by the individual values of notch switching parameters.

Before the running curve intersects with a backward brake curve, when the speed thereof increases to the brake-on speed and the brake notch is turned on, a brake with a weak notch is used so as to not degrade the riding comfort. In addition, for a particular time just before the stop position on a backward brake curve starting from the end point, the weak notch is used so that when the train stops, the riding comfort thereof is not degraded. In addition, when a real train deviates from a running-pattern in the pattern tracking operation, the switching to the weak brake provides a margin which offsets the deviation.

When the running time obtained in the running simulation means 3 (see Fig. 1) differs from that designated, the time fitting means 5 adjusts the upper limit speed. Thereafter, the running simulation means 3 recalculates the running-pattern. These operations are repeated so that the simulated running time fits that designated.

When the running time fits the predetermined running time, the pattern optimizing means 7 adjusts the notch switching parameters in accordance with the line data and the car data so that the values of the evaluation functions with respect to the energy consumption and riding comfortableness become minimal. The running simulation means 3 repeatedly calculates the running-pattern. These operations are repeated until an optimal running-pattern for the train to run with small energy consumption and riding comfort and in conformity with the restricted conditions such as running distance, running time, and restricted limit can be obtained. Thus, the optimal running-pattern can be quickly and securely calculated.

As described above, each notch switching parameter has an individual value constant between a station and the next station as criteria for switching the notches. In comparison with the case where a section between two stations is divided into several portions and absolute values of speeds at which the notches are switched are defined for each portion, when the values of the parameters are represented with percentage (%) to an upper limit speed, the parameters can be effectively adjusted and thereby a running-pattern can be optimized.

In the case where the notch switching parameters are manually adjusted, the user switches the adjustment mode from the automatic mode to the manual mode through the interface 201. Thereafter, the user designates the values of the notch switching parameters and commands the running-pattern calculating unit 203 to calculate the running-pattern. Alternatively, the user designates notch switching points on a run curve display area (Fig. 11) of the interface 201 and commands the running-pattern calculating unit to calculate a running-pattern. Thus, the running-pattern is calculated.

Whenever the running time is fit the predetermined running time, the running-pattern obtained is displayed on the screen of the interface 201 as a run curve along with a restricted speed, grades and curves of line, and so forth. In addition, the result of the notch switching parameters adjusted is also displayed on the screen of the interface 201.

When necessary, the running-pattern is repeatedly calculated. When the user selects the output button on the operation screen of the interface 201, the resultant data is output to the ATO system 213 on the train through the storing unit 204, the output unit 205, and a storage medium such as an IC card or the communication system 212. In this case, the running-pattern data consists of a running section, a running distance, a running time, a running-pattern type (standard/fast/slow/fastest), a weather condition, positions of notch switching points, a time, a speed, notches for use, and run curve data (a position, a time, a speed, and output/effective torques of driving/braking units). When necessary, the running-pattern stored in the storing unit 204 can be displayed on and read by a command through the running-pattern reading sub-window of the interface 201 (see Fig. 13).

The destination of the output of the running-pattern data can be changed from the storing unit to the output unit or vice versa. In addition, the running-pattern stored in the storing unit 204 can be read and output to the IC card or the communication system 212. The running-pattern data stored in the storage medium such as an IC card is output from a card read unit disposed in the ATO system 213 of the train. This data is used as a target running-pattern.

When the running schedule is revised or the car type is changed or added, data stored in the database 202 can be modified through the interface 201.

Next, referring to Fig. 14, an optimal running-pattern calculating system mounted on a train is shown. In Fig. 14, the optimal running-pattern calculating system which is mounted on a train 210 comprises an interface 201, a database 202, a running-pattern calculating unit 203, a storing unit 204, and an output unit 205. The running-pattern calculating unit 203 is connected to a communication system 223. Through the communication system 223, the position and speed of a preceding train 225 can be obtained. In addition, running schedule change data and temporarily restricted speed data can be received from an operation management system 224. Moreover, the position and speed of the train 210 can be sent to a following train and the operation management system 224.

The database 202 stores line data such as station names, the distance between each station, grades, curves, branches, and restricted speeds. In addition, a storage medium such as an IC card 209 stores operation condition data (for example, train numbers and operation schedules) and car data (for example, the weight and length of each car, the composition of each train, acceleration, and deceleration thereof, a grade resistance formula, a curve resistance formula, a running resistance formula according to each weather condition, passenger capacity, the crowdedness of each time zone, and so forth. These data can be referenced when necessary.

Through the interface 201, the user can perform the following operations:

(a) input the weather, the deviation from the running schedule, and the conditions of the running-pattern,

(b) change the initial values of the notch switching parameters, and

(c) command the calculation and recalculation of the running-pattern.

In addition, through the interface 201 the user can perform the following operations in accordance with signals from the running-pattern calculating unit 203:

(d) display the running-pattern calculated and the result of the adjustment of the notch switching parameters.

Moreover, through the interface 201 the user can preform the following operations:

(e) output the running-pattern calculated to the output unit 205, and

(f) change the data of the database (namely, change the line data).

The running-pattern calculating unit 203 calculates a target running-pattern for the next section between next two stations in accordance with the data being read from the database 202 and the storage medium such as the IC card while the train is running or stopping at a station. When the operating condition or the line condition is changed, the running-pattern calculating means 203 calculates a running-pattern for the section from the present position to the next station by using a running simulation of the train in accordance with the data being read from the database 202 and the storage medium such as the IC card.

The storing unit 204 stores the running-pattern calculated by the running-pattern calculating unit 203. The output unit 205 outputs the running-pattern which calculated by the running-pattern calculating unit 203 and stored in the storing unit 204 to a tracking control unit.

Next, the operation of this embodiment will be described.

To obtain a running-pattern of the train for the next section between next two stations while the train is running or stopping, the motorman inputs the current weather condition and deviation from the running schedule when necessary. In addition, like the embodiment shown in Fig. 10, the motorman can change the conditions with respect to the running-pattern and the initial values of the notch switching parameters through the interface 201.

After the required conditions have been set, the motorman commands the running-pattern calculating unit 203 to calculate the running-pattern.

When the running of the train largely deviates from the target running-pattern in the tracking operation or when the train extremely approaches the preceding train 225, a running-pattern is recalculated by using the distance to the preceding train 225 automatically or in the judgement of the motorman. When the line condition is changed such as raining, the running-pattern is recalculated by using information received from sensors automatically or in the judgement of the motorman. When a temporarily restricted speed takes place due to a particular reason or when the running schedule is disordered due to an accident or the like, the running-pattern is recalculated automatically. When the motorman issues a command of a recalculation, the command is sent from the interface 201 to the running-pattern calculating unit 203. When a command of a recalculation is automatically issued, the command is sent from the tracking control unit or the communication system 223 to the running-pattern calculating unit 203.

When receiving the command of the calculation of the running-pattern from the interface 201, the running-pattern calculating unit 203 reads required data from the database 202 and the storage medium such as the IC card 209. With these data, the running-pattern calculating unit 203 calculates a running-pattern for the next section between next two stations. When receiving the command of the recalculation of the running-pattern, the running-pattern calculating unit 203 calculates a running-pattern in accordance with data being read from the database 202 and the storage medium such as the IC card 209 and data received from the communication system 223 and the monitor unit 208 so that the train does not approach the preceding train 225 and so that the conventional running schedule can be restored or so that the train can run in a temporary running time received from the operation management system 224 through the communication system 223.

Whenever the running time is fit the predetermined running time, the running-pattern obtained by the running-pattern calculating unit 203 is displayed on the screen of the interface 201 as a run curve along with a restricted speed, grades and curves of line, and so forth. In addition, the result of the notch switching parameters adjusted is also displayed on the screen of the interface 201.

If necessary, the running-pattern is repeatedly calculated. The data of the resultant running-pattern is output from the running-pattern calculating unit 203 to the storing unit 204. In this case, the running-pattern data consists of a running section, a running distance, a running time, a running-pattern type (standard/fast/slow/fastest), a weather condition, positions of notch switching points, a time, a speed, notches for use, and run curve data (a position, a time, a speed, and output/effective torques of driving/braking units). When necessary, the output unit 205 receives the data of the running-pattern from the storing unit 204 and then outputs the data to the tracking control unit 207. The tracking control unit 207 controls the running of the train in accordance with the running-pattern.

As an auxiliary function, the data of the database 202 can be modified through the interface 201 in the case that the line condition is changed.

In addition, the optimal running-pattern calculating system can be used properly as the stationary system and the on-board system. In other words, in the pattern tracking operation, a target running-pattern which has been calculated by the stationary optimal running-pattern calculating system (Fig. 10) is usually read from the storage medium. Only the recalculation of the running-pattern is performed by the on-board optimal running-pattern calculating system (see Fig. 14).

As described above, according to the optimal running-pattern calculating system of this embodiment, a running-pattern for a train to run with small energy consumption and riding comfortableness in conformity with a designated schedule can be easily, quickly, and securely obtained. In addition, a train which runs in a designated running time with riding comfort can be automatically operated to track a target running-pattern.

Although the present invention has been shown and described with respect to a best mode embodiment thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions, and additions in the form and detail thereof may be made therein without departing form the spirit and scope of the present invention.

Claims

1. An optimal running-pattern calculating apparatus, comprising:

input means for inputting line data and car data;

backward curve calculating means for outputting backward curves;

parameter initializing means for outputting notch switching parameters and an upper limit speed;

running simulation means for simulating the running of a train by using the data received from the input means, backward curves received from backward curve calculating means, and the notch switching parameters and upper limit speed received from the parameter initializing means, and for calculating a running-pattern for said train to run within a restricted speed in a predetermined running distance; and

time fitting means for causing upper limit speed adjusting means to adjust the upper limit speed and causing said running simulation means to recalculate said running-pattern when the running time calculated by said running simulation means is different from a predetermined running time.

2. The optimal running-pattern calculating apparatus as set forth in claim 1 further comprising:

evaluation function setting means for setting evaluation functions with respect to energy consumption and riding comfort in accordance with the various data received from said input means;

pattern optimizing means for causing parameter adjusting means to adjust the notch switching parameters in such a way that the values of said evaluation functions of the running-pattern from said time fitting means become minimal and for causing said running simulation means to recalculate the running-pattern.

3. The optimal running-pattern calculating apparatus as set forth in claim 2,

wherein said evaluation function setting means includes weight changing means for setting and changing the weight of the evaluation items with respect to energy consumption and riding comfort.

4. The optimal pattern calculating apparatus as set forth in claim 1,

wherein the notch switching parameters being input to said running simulation means have a plurality of individual values to upper limit speed, and

wherein some elements of said notch switching parameters have a plurality of individual values in accordance with a line resistance.

5. The optimal pattern calculating apparatus as set forth in claim 4,

wherein said notch switching parameters consists of four parameters of brake-on parameter, power-on parameter, brake-off parameter, and power-on parameter, the power-on and brake-off parameters having two individual values in accordance with the cases whether the line resistance is positive or negative, respectively.

6. An optimal running-pattern calculating system, comprising:

a database for storing line data, car data, and operation condition data;

a running-pattern calculating unit for calculating a running-pattern for a train to run in a predetermined section in a predetermined running time with riding comfort and small energy consumption in accordance with said line data, said car data, and said operation condition data received from said database; and

an interface for outputting a running-pattern calculating command to said running-pattern calculating means and for displaying the running-pattern being obtained.

7. The optimal running-pattern calculating system as set forth in claim 6, further comprising:

an output unit for outputting the running-pattern obtained by said running-pattern calculating unit to an external communication system.

8. The optimal running-pattern calculating system as set forth in claim 7, further comprising:

a storing unit for temporarily storing the running-pattern obtained by said running-pattern calculating unit and for outputting the running-pattern to said output unit.

9. An optimal running-pattern calculating system, comprising:

a database and/or a storage medium for storing line data, car data, and operation condition data;

a running-pattern calculating unit for calculating a running-pattern for a train to run in a predetermined section in a predetermined running time with riding comfortableness and small energy consumption in accordance with said line data, said car data, and said operation condition data received from said database and/or said storage medium;

an interface for outputting a running-pattern calculating command to said running-pattern calculating means and for displaying the running-pattern being obtained; and

a communication system for outputting data of the position and speed of a preceding train and operation management data to said running-pattern calculating unit,

wherein said database, said running-pattern calculating unit, and said interface are mounted on said train.

10. The optimum running-pattern calculating system as set forth in claim 9, further comprising:

an output unit for outputting the running-pattern obtained by said running-pattern calculating unit to the outside through a storing unit.

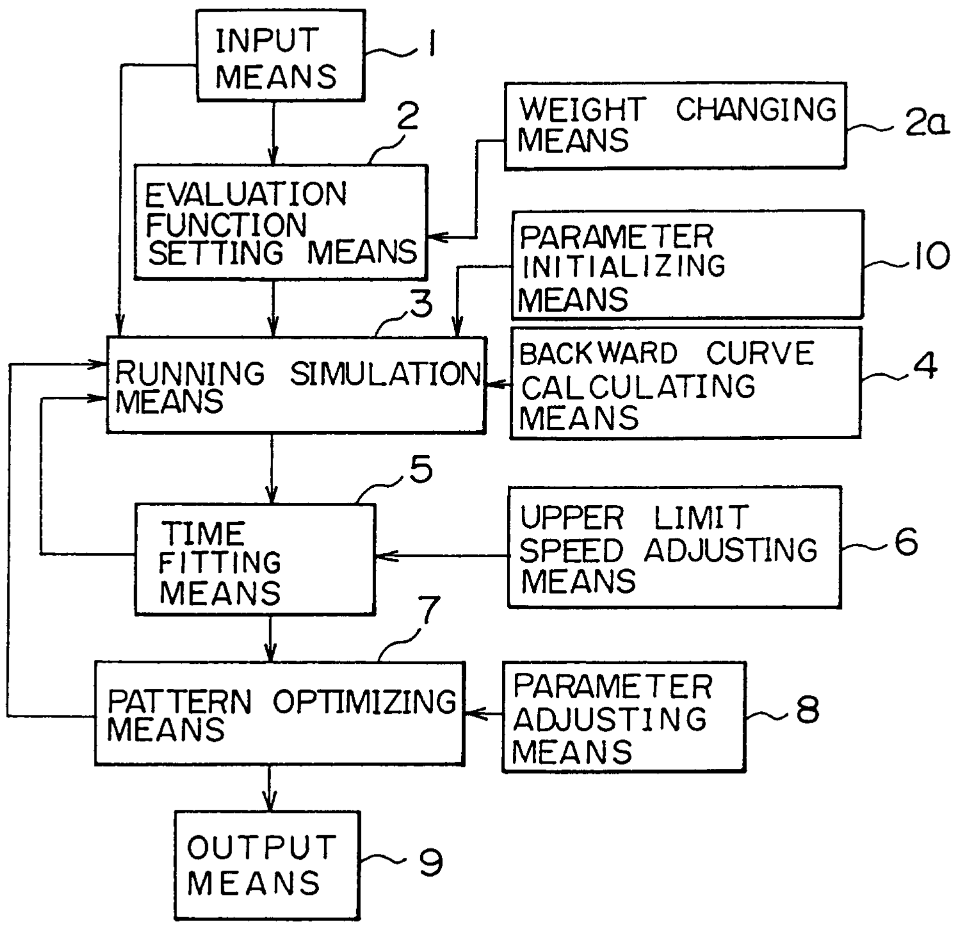
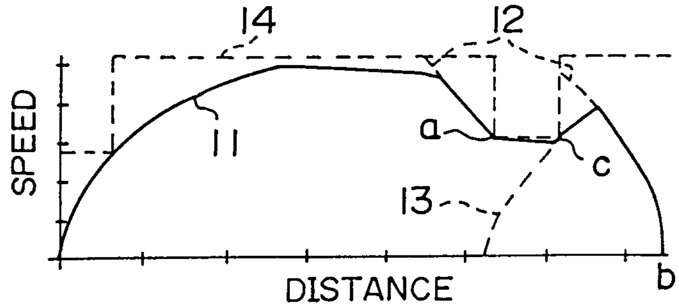
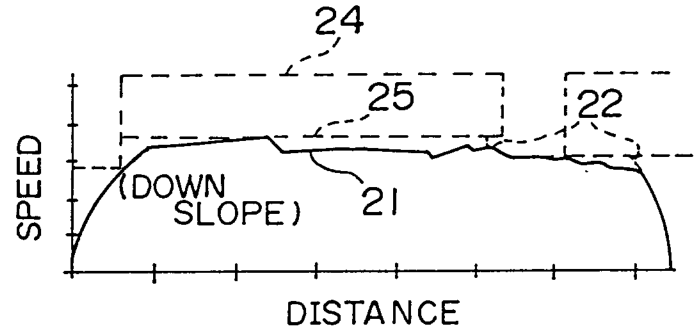

INPUT MEANS
1
2
EVALUATION FUNCTION SETTING MEANS
WEIGHT CHANGING MEANS
2a
PARAMETER INITIALIZING MEANS
10
3
RUNNING SIMULATION MEANS
BACKWARD CURVE CALCULATING MEANS
4
5
TIME FITTING MEANS
UPPER LIMIT SPEED ADJUSTING MEANS
6
7
PATTERN OPTIMIZING MEANS
PARAMETER ADJUSTING MEANS
8
OUTPUT MEANS
9

FIG. 1



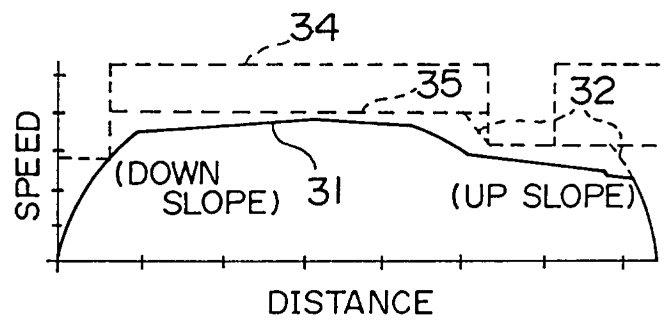
ENERGY CONSUMPTION= 6.3, NUMBER OF NOTCH SWITCHING TIMES= 6, TIME ERROR=-17.5 SEC.

FIG. 2



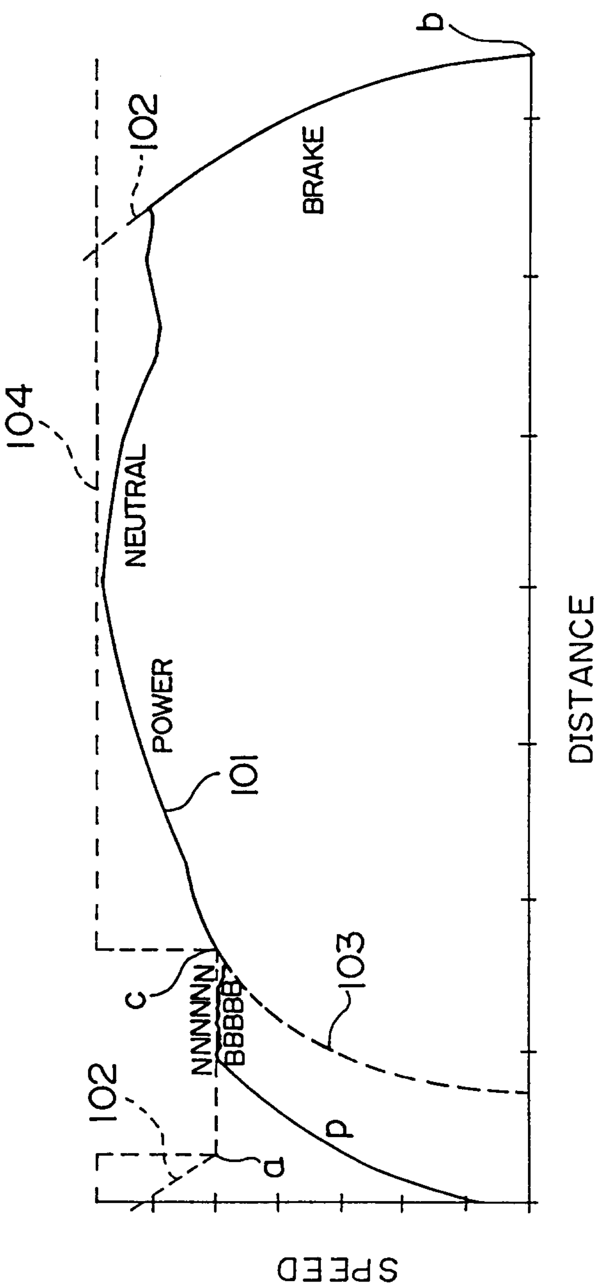
ENERGY CONSUMPTION= 3.5, NUMBER OF NOTCH SWITCHING TIMES= 8 , TIME ERROR = 0.1 SEC.

FIG. 3



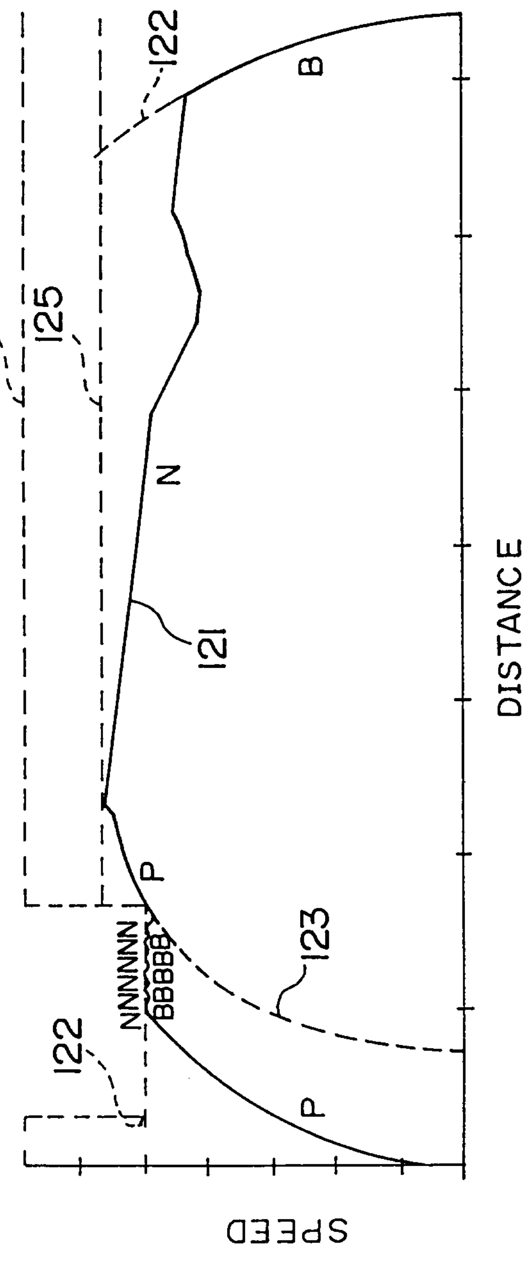
ENERGY CONSUMPTION = 2.5, NUMBER OF NOTCH SWITCHING TIMES= 2 , TIME ERROR = 0.1 SEC.

FIG. 4



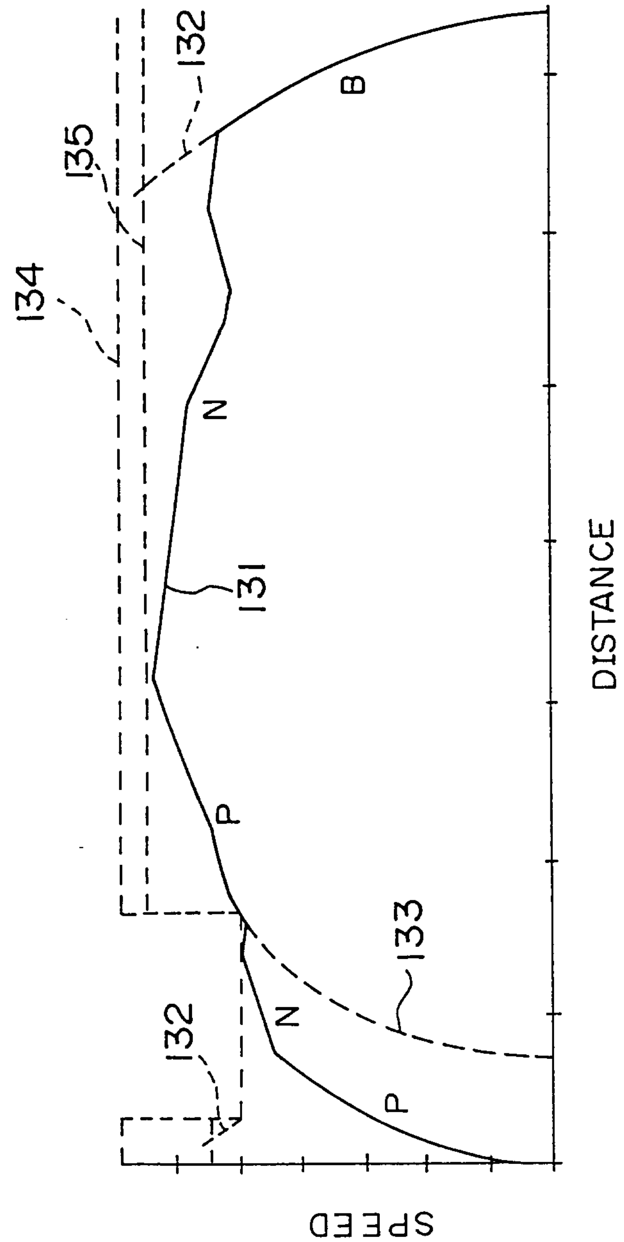
ENERGY CONSUMPTION = 1156, NUMBER OF NOTCH SELECTING TIMES = 15, RUNNING TIME ERROR = -5.616 SEC.

FIG. 5



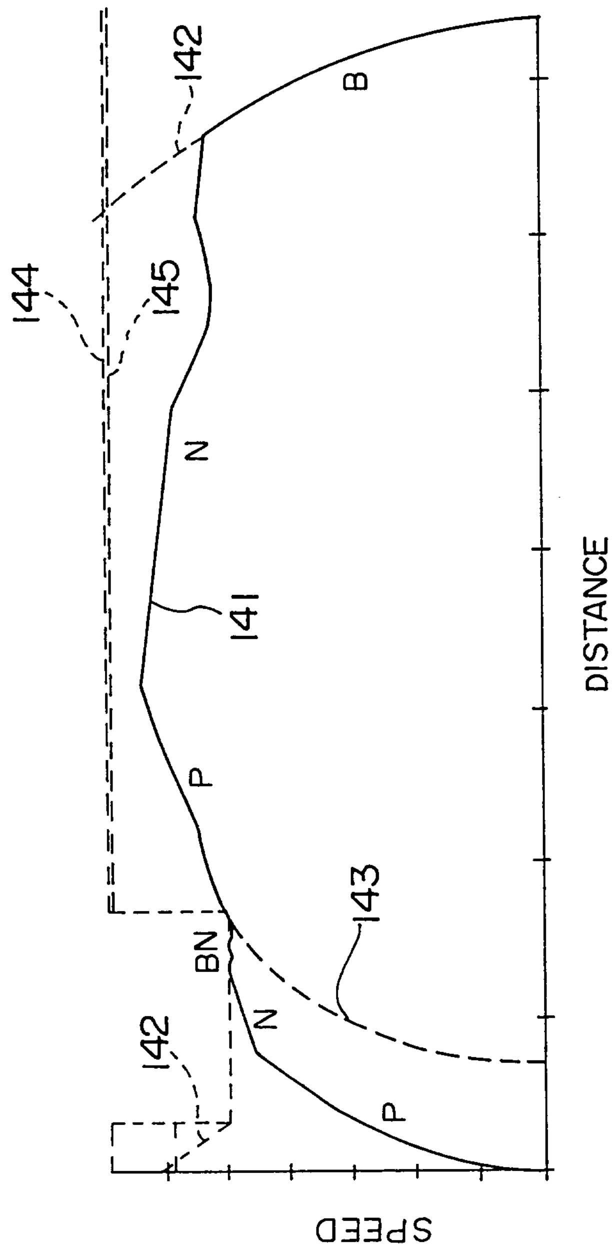
ENERGY CONSUMPTION=705, NUMBER OF NOTCH SWITCHING TIMES=15, RUNNING TIME ERROR=-0.099 SEC.

FIG. 6



ENERGY CONSUMPTIO = 896, NUMBER OF NOTCH SWITCHING TIMES = 5, RUNNING TIME ERROR = -0.138 SEC.

FIG. 7



ENRGY CONSUMPTION = 905, NUNBER OF NOTCH SWITCHING TIMES = 7, RUNNING TIME ERROR = -0.057 SEC.

FIG. 8

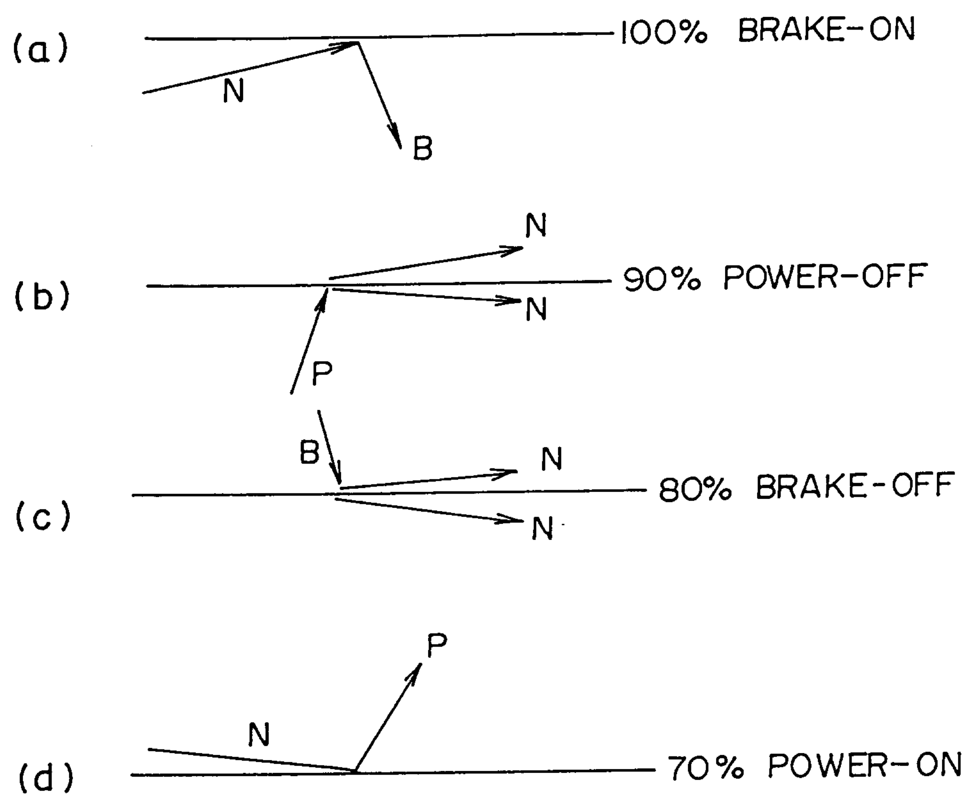

(a)
100% BRAKE-ON
N
B
(b)
N
90% POWER-OFF
N
P
B
N
(c)
80% BRAKE-OFF
N
P
N
(d)
70% POWER-ON

FIG. 9

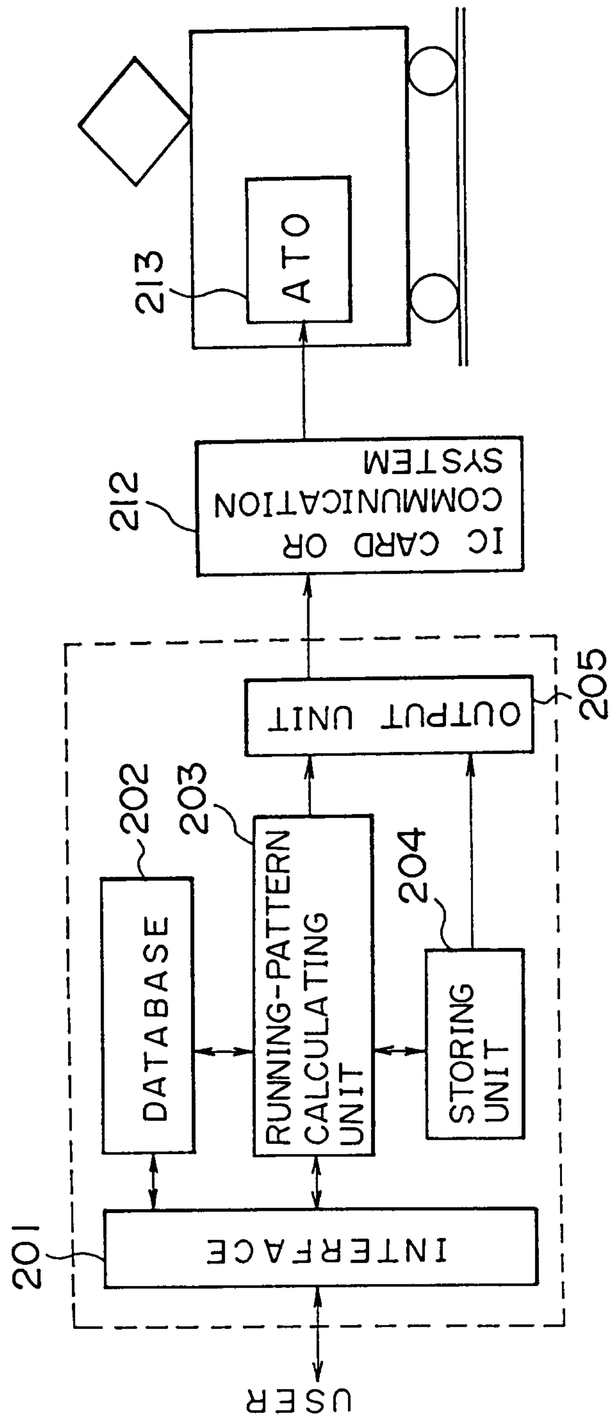

USER
201
INTERFACE
202
DATABASE
203
RUNNING-PATTERN CALCULATING UNIT
204
STORING UNIT
205
OUTPUT UNIT
212
IC CARD OR COMMUNICATION SYSTEM
213
ATO

FIG. 10

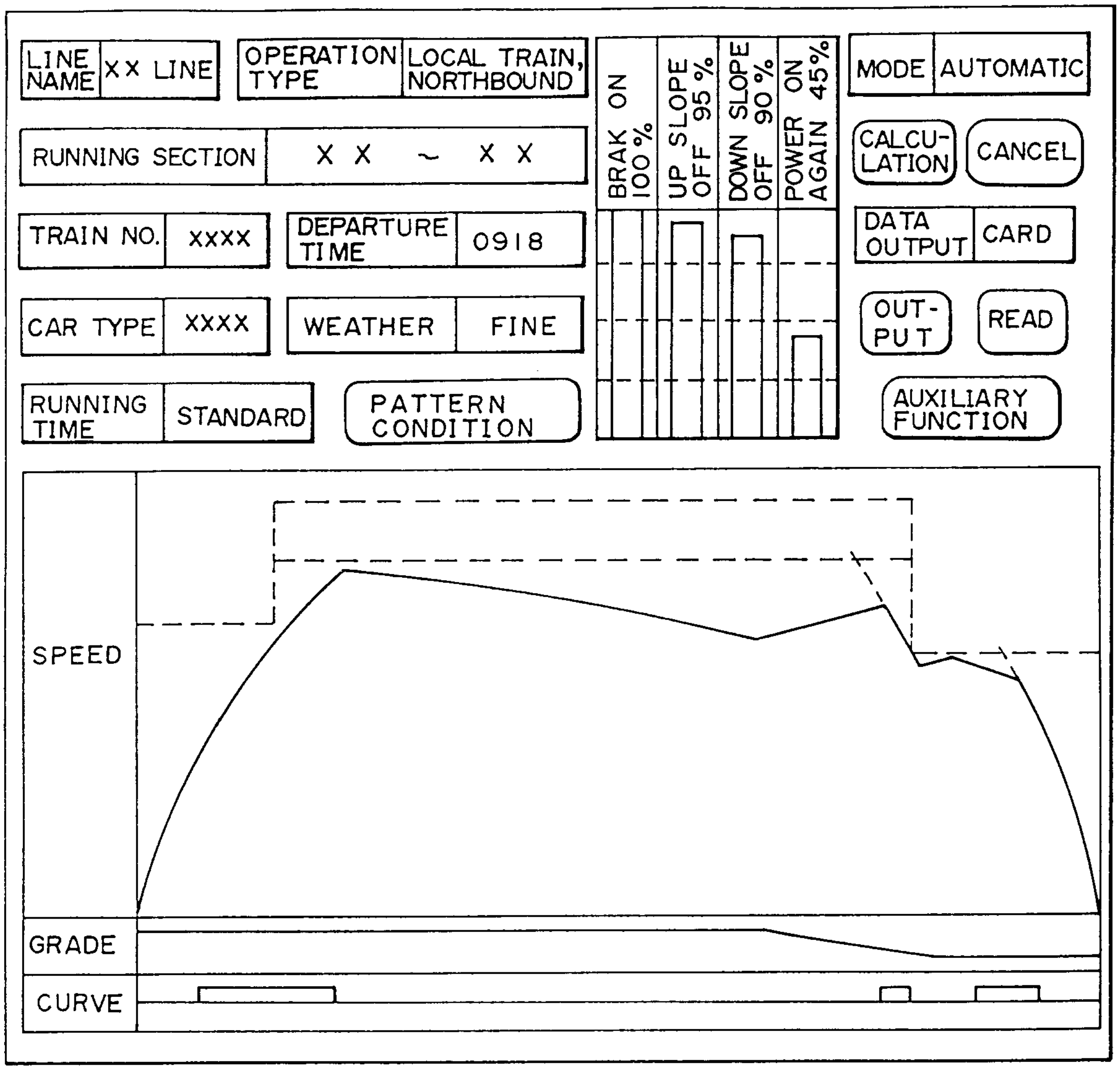

LINE NAME
XX LINE
OPERATION TYPE
LOCAL TRAIN, NORTHBOUND
BRAK ON 100 %
UP SLOPE OFF 95 %
DOWN SLOPE OFF 90 %
POWER ON AGAIN 45%
MODE
AUTOMATIC
RUNNING SECTION
X X ~ X X
CALCU-LATION
CANCEL
TRAIN NO.
XXXX
DEPARTURE TIME
0918
DATA OUTPUT
CARD
CAR TYPE
XXXX
WEATHER
FINE
OUT-PUT
READ
RUNNING TIME
STANDARD
PATTERN CONDITION
AUXILIARY FUNCTION
SPEED
GRADE
CURVE

FIG. 11

PATTERN CONDITION	USE CANCEL
MARGIN TO RESTRICTED SPEED	3km/ h
POWER NOTCH	4
DECELERATION BRAKE NOTCH	2
STOP BRAKE NOTCH	5
TRACKING MARGIN	MIDDLE
TIME FITTING ACCURACY	± 1 %

FIG. 12

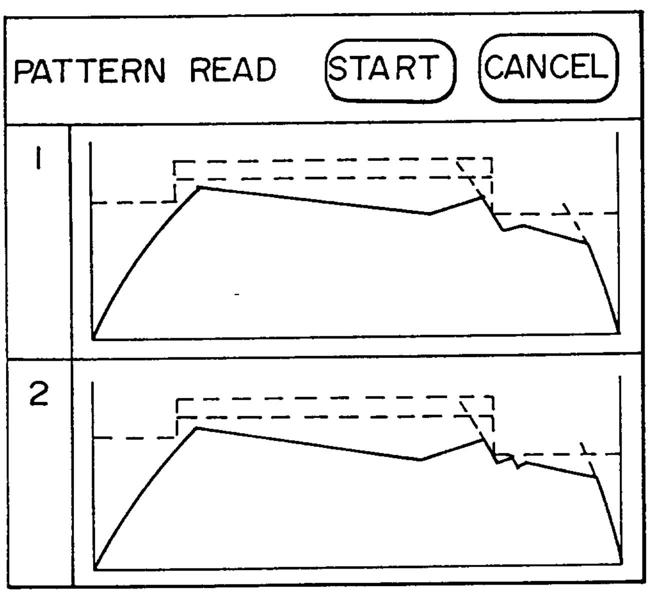


FIG. 13

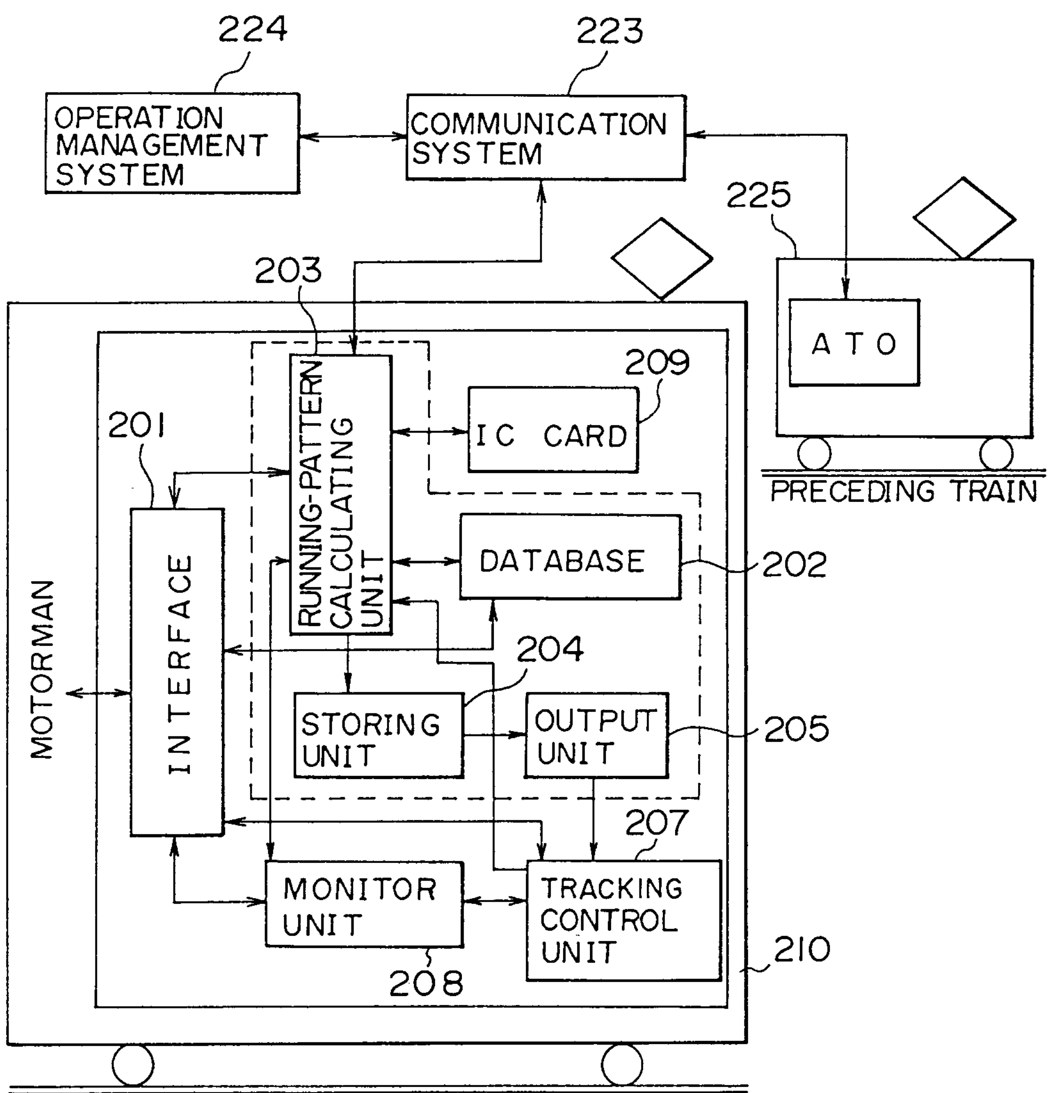

224
223
OPERATION MANAGEMENT SYSTEM
COMMUNICATION SYSTEM
225
ATO
PRECEDING TRAIN
203
RUNNING-PATTERN CALCULATING UNIT
209
IC CARD
201
INTERFACE
MOTORMAN
DATABASE
202
204
STORING UNIT
OUTPUT UNIT
205
207
MONITOR UNIT
TRACKING CONTROL UNIT
208
210

FIG. 14