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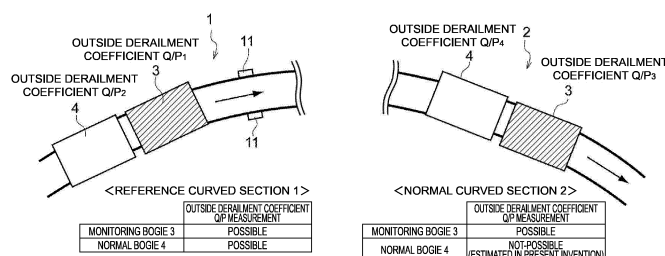
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(54) **METHOD, DEVICE, AND PROGRAM FOR ESTIMATING DERAILMENT COEFFICIENT**

(57) The estimation method according to the present invention generates a first estimation equation to estimate an outside derailment coefficient Q/P_1 of a monitoring bogie 3 in a reference curved section 1, generates a second estimation equation to estimate an outside derailment coefficient Q/P_2 of a normal bogie 4 on the reference curved section, generates a third estimation equation to estimate an outside derailment coefficient Q/P_3 of the monitoring bogie on the normal curved section 2, generates correction coefficients for the explanatory variables in the second estimation equation based on the coefficients of the explanatory variables in the first estimation equation, the coefficients of the explanatory variables in the third estimation equation, and the like,

generates a fourth estimation equation to estimate an outside derailment coefficient Q/P_4 of the normal bogie on the normal curved section by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation, measures wheel load and lateral force of the normal bogie with the measurement equipment 11 on the reference curved section, and then estimates the outside derailment coefficient Q/P_4 by inputting the fourth estimation with computed values computed from these as explanatory variables. A method capable of estimating an outside derailment coefficient of a normal bogie on a normal curved section is accordingly provided.

FIG. 1



Description

Technical Field

[0001] The present invention relates to a method, device, and program for estimating a derailment coefficient when a bogie provided to rolling stock is traveling along a curved section of track. In particular, the present invention relates to a method, device, and program capable of estimating a derailment coefficient of a normal bogie (a bogie lacking wheel load and lateral force measurement capabilities) on a normal curved section (a curved section not installed with measurement equipment having wheel load and lateral force measuring capabilities).

Background Art

[0002] Evaluating indicators of derailment for rolling stock, and taking countermeasures according to the evaluation results, is important to improve travel safety of rolling stock.

[0003] Hitherto, a derailment coefficient Q/P , i.e. a value arrived at by dividing a lateral force Q that is the force acting in a horizontal direction between wheel and rail, by a wheel load P that is the force acting in a vertical direction between wheel and rail, has been widely employed as an indicator of derailment. In particular, a derailment coefficient (outside derailment coefficient) Q/P for an outside wheel on the front axle of a rolling stock bogie when the rolling stock is traveling on a curved section of track is widely employed.

[0004] The following are two known methods for measuring the wheel load P and the lateral force Q to compute the derailment coefficient Q/P .

(1) Ground side measurement: these are methods in which measurement equipment having wheel load P and lateral force Q measuring capabilities is installed on a curved section to detect the forces acting on rails. In these methods the wheel load P and lateral force Q for a bogie traveling on a curved section is measured with the installed measurement equipment (see, for example, Japanese Patent Application Laid-Open (JP-A) No. H10-185666).

(2) Vehicle side measurement: these are methods to measure the wheel load P and lateral force Q for a bogie traveling on a curved section using a bogie, called a PQ monitoring bogie, that is attached with sensors having wheel load P and lateral force Q measuring capabilities to detect the forces acting on wheels (see, for example, JP-A No. 2014-54881).

[0005] Ground side measurement is capable of measuring the wheel load P and lateral force Q of all bogies traveling on curved sections installed with measurement equipment. However, ground side measurement is not able to measure the wheel load P and lateral force Q for curved sections not installed with the measurement equipment. Installing measurement equipment to all curved sections is not realistic due to the dramatic rise in cost this would incur and to the resulting increase in maintenance effort.

[0006] Vehicle side measurement is capable of measuring the wheel load P and lateral force Q at all curved sections that the PQ monitoring bogie is traveling along. However, the wheel load P and lateral force Q are not able to be measured for bogies other than PQ monitoring bogies, i.e. for bogies lacking wheel load and lateral force measurement capabilities. Making all bogies PQ monitoring bogies is not realistic due to the dramatic rise in cost this would incur and to the resulting increase in maintenance effort.

[0007] As described above, there is a problem with wheel load P and lateral force Q measurement methods for both ground side measurements and vehicle side measurements in that they are not able to compute an outside derailment coefficient Q/P for when a normal bogie travels on a normal curved section since the wheel load P and lateral force Q are not able to be measured by a normal bogie (bogie lacking wheel load P and lateral force Q measurement capabilities) traveling on a normal curved section (curved section not installed with measurement equipment having wheel load P and lateral force Q measuring capabilities).

SUMMARY OF INVENTION

Technical Problem

[0008] In order to solve the problem arising with conventional technology described above, the present invention addresses the provision of a method capable of estimating a derailment coefficient of a normal bogie (bogie lacking wheel load and lateral force measurement capabilities) on a normal curved section (curved section not installed with measurement equipment having wheel load and lateral force measuring capabilities).

Solution to Problem

[0009] A derailment coefficient estimation method according to a first aspect is a method of estimating a derailment coefficient in a case in which a bogie provided to rolling stock is traveling on a curved section of track. The derailment coefficient estimation method includes a first estimation equation generation step, a second estimation equation generation step, a third estimation equation generation step, a correction coefficient generation step, a fourth estimation equation generation step, and an estimation step. The first estimation equation generation step includes measuring a wheel load and lateral force of a monitoring bogie using measurement equipment in a case in which the monitoring bogie, which can measure wheel load and lateral force, is traveling on a reference curved section of track installed with the measurement equipment, which can measure wheel load and lateral force, and generating a first estimation equation that estimates a derailment coefficient of the monitoring bogie on the reference curved section by performing multivariate analysis using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables. The second estimation equation generation step includes measuring a wheel load and lateral force of a normal bogie using the measurement equipment in a case in which the normal bogie which cannot measure wheel load and lateral force is traveling on the reference curved section, and generating a second estimation equation that estimates a derailment coefficient of the normal bogie on the reference curved section by performing multivariate analysis using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the normal bogie as explanatory variables. The third estimation equation generation step includes measuring a wheel load and lateral force of the monitoring bogie using the monitoring bogie itself in a case in which the monitoring bogie, which can measure wheel load and lateral force, is traveling on a normal curved section of track not installed with measurement equipment, which can measure wheel load and lateral force, and generating a third estimation equation that estimates a derailment coefficient of the monitoring bogie on the normal curved section by performing multivariate analysis using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables. The correction coefficient generation step includes generating correction coefficients for the explanatory variables in the second estimation equation based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, values of the explanatory variables employed when the first estimation equation was generated, and values of the explanatory variables employed when the third estimation equation was generated. The fourth estimation equation generation step includes generating a fourth estimation equation that estimates a derailment coefficient of the normal bogie on the normal curved section by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation. The estimation step includes estimating a derailment coefficient of the normal bogie on the normal curved section by measuring the wheel load and lateral force of the normal bogie using the measurement equipment in a case in which the normal bogie is traveling along the reference curved section, and inputting, into the fourth estimation equation, at least a specific computation value that is computed from the measured wheel load and lateral force as well as the travel velocity of the normal bogie.

[0010] A derailment coefficient estimating device according to a second aspect is a device to estimate a derailment coefficient in a case in which a bogie provided to rolling stock is traveling on a curved section of track. The derailment coefficient estimation device includes a first estimation equation generation section, a second estimation equation generation section, a third estimation equation generation section, a correction coefficient generation section, a fourth estimation equation generation section, and an estimation section. The first estimation equation generation section is employed to generate a first estimation equation that estimates a derailment coefficient of a monitoring bogie on a reference curved section of track installed with measurement equipment, which can measure wheel load and lateral force, by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the monitoring bogie using the measurement equipment in a case in which the monitoring bogie, which can measure wheel load and lateral force, is traveling on the reference curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables. The second estimation equation generation section is employed to generate a second estimation equation to estimate a derailment coefficient of the normal bogie on the reference curved section by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the normal bogie using the measurement equipment in a case in which the normal bogie, which cannot measure wheel load and lateral force, is traveling on the reference curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the normal bogie as explanatory variables. The third estimation equation generation

section is employed to generate a third estimation equation to estimate a derailment coefficient of the monitoring bogie on the normal curved section of track not installed with measurement equipment, which can measure wheel load and lateral force, by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the monitoring bogie using the monitoring bogie itself in a case in which the monitoring bogie, which can measure wheel load and lateral force, is traveling on the normal curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables. The correction coefficient generation section is employed to generate correction coefficients for the explanatory variables in the second estimation equation based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, values of the explanatory variables employed when the first estimation equation was generated, and values of the explanatory variables employed when the third estimation equation was generated. The fourth estimation equation generation section is employed to generate a fourth estimation equation to estimate a derailment coefficient of the normal bogie on the normal curved section by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation. The estimation section is employed to estimate a derailment coefficient of the normal bogie on the normal curved section by using input of results of measuring the wheel load and lateral force of the normal bogie using the measurement equipment in a case in which the normal bogie is traveling along the reference curved section, and inputting, into the fourth estimation equation, at least a specific computation value that is computed from the measured wheel load and lateral force as well as the travel velocity of the normal bogie.

[0011] A program according to a third aspect is a program to estimate a derailment coefficient in a case in which a bogie provided to rolling stock is traveling on a curved section of track. The program causes a computer to execute processing including generating a first estimation equation, generating a second estimation equation, generating a third estimation equation, generate correction coefficients, generating a fourth estimation equation, and estimating a derailment coefficient. The first estimation equation is to estimate a derailment coefficient of a monitoring bogie on a reference curved section of track installed with the measurement equipment, which can measure wheel load and lateral force, by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the monitoring bogie using the measurement equipment in a case in which the monitoring bogie, which can measure wheel load and lateral force, is traveling on the reference curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables. The second estimation equation is to estimate a derailment coefficient of a normal bogie on the reference curved section by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the normal bogie using the measurement equipment in a case in which the normal bogie, which cannot measure wheel load and lateral force, is traveling on the reference curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the normal bogie as explanatory variables. The third estimation equation is to estimate a derailment coefficient of the monitoring bogie on the normal curved section of track not installed with measurement equipment, which can measure wheel load and lateral force, by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the monitoring bogie using the monitoring bogie itself in a case in which the monitoring bogie which can measure wheel load and lateral force, is traveling on the normal curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables. The correction coefficients for the explanatory variables in the second estimation equation are generated based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, values of the explanatory variables employed when the first estimation equation was generated, and values of the explanatory variables employed when the third estimation equation was generated. The fourth estimation equation to estimate a derailment coefficient of the normal bogie on the normal curved section is generated by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation. The derailment coefficient of the normal bogie on the normal curved section is estimated by using input of results of measuring the wheel load and lateral force of the normal bogie using the measurement equipment in a case in which the normal bogie is traveling along the reference curved section, and inputting, into the fourth estimation equation, at least a specific computation value that is computed from the measured wheel load and lateral force as well as the travel velocity of the normal bogie.

Advantageous Effects

[0012] The present invention enables a derailment coefficient to be estimated for a normal bogie on a normal curved section.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

Fig. 1 is a plan view to schematically explain an outside derailment coefficient estimation method according to an exemplary embodiment of the present invention.

Fig. 2 is a flowchart illustrating an outline procedure of an outside derailment coefficient estimation method according to an exemplary embodiment of the present invention.

Fig. 3A is a diagram illustrating an example of results comparing estimated values and measured values of an outside derailment coefficient Q/P_1 .

Fig. 3B is a diagram illustrating an example of results comparing estimated values and measured values of an outside derailment coefficient Q/P_2 .

Fig. 4A is a diagram illustrating an example of results comparing estimated values and measured values of an outside derailment coefficient Q/P_3 .

Fig. 4B is a diagram illustrating an example of results comparing estimated values and measured values of an outside derailment coefficient Q/P_4 .

Fig. 5 is a schematic diagram illustrating an outline configuration of an outside derailment coefficient estimation device according to an exemplary embodiment of the present invention.

Fig. 6 is a schematic block diagram of an example of a computer functioning as an outside derailment coefficient estimation device.

DESCRIPTION OF EMBODIMENTS

[0014] Explanation follows regarding an outside derailment coefficient estimation method according to an exemplary embodiment of the present invention, with reference to the appended drawings.

Overview of Exemplary Embodiment of Present Invention

[0015] As a result of diligent investigations, the present inventors have conjectured using multivariate analysis, in which data measurable with measurement equipment and the like is employed as explanatory variables, to generate an estimation equation for estimating an outside derailment coefficient when a monitoring bogie having wheel load and lateral force measuring capabilities is traveling on a reference curved section that is installed with measurement equipment having wheel load and lateral force measuring capabilities (i.e. that is capable of ground side measurement). Similarly, they have conjectured using multivariate analysis in which data measurable by a monitoring bogie and the like is employed as explanatory variables to generate an estimation equation for estimating an outside derailment coefficient when the monitoring bogie is traveling on a normal curved section that is not installed with measurement equipment having wheel load and lateral force measuring capabilities (i.e. that is not capable of ground side measurement). They have then conjectured the possibility of extracting the effect of changing the curved section (changing from the reference curved section to the normal curved section) in changes to the estimation equation by comparing these two estimation equations.

[0016] An estimation equation to estimate an outside derailment coefficient when a normal bogie is traveling on a reference curved section is then generated using multivariate analysis in which data measurable with the measurement equipment and the like is employed as explanatory variables. The present inventors have conjectured that, as long as the effect of changing the curved section in changes to the estimation equation could indeed be extracted by taking account of the extracted effect of changing the curved section to the generated estimation equations, it would be possible to generate an estimation equation to estimate an outside derailment coefficient when a normal bogie is traveling on a normal curved section, a computation not hitherto possible.

[0017] As a result of further diligent investigations based on the above idea, the present inventors have completed the outside derailment coefficient estimation method according to an exemplary embodiment of the present invention.

[0018] An exemplary embodiment of the present invention provides a method to estimate an outside derailment coefficient for when a bogie provided to rolling stock is traveling along a curved section of track, and provides an outside derailment coefficient estimation method including each of the following steps.

(1) A first estimation equation generation step: measuring a wheel load and lateral force of a monitoring bogie with measurement equipment when the monitoring bogie having wheel load and lateral force measuring capabilities is traveling on a reference curved section installed with the measurement equipment having wheel load and lateral force measuring capabilities, and generating a first estimation equation to estimate an outside derailment coefficient of the monitoring bogie on the reference curved section by performing multivariate analysis using an outside derailment coefficient computed from the measured wheel load and lateral force as an objective variable and using at

least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables.

(2) A second estimation equation generation step: measuring a wheel load and lateral force of a normal bogie with the measurement equipment when the normal bogie lacking wheel load and lateral force measurement capabilities is traveling on the reference curved section, and generating a second estimation equation to estimate an outside derailment coefficient of the normal bogie on the reference curved section by performing multivariate analysis using an outside derailment coefficient computed from the measured wheel load and lateral force as an objective variable and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the normal bogie as explanatory variables.

(3) Third estimation equation generation step: measuring a wheel load and lateral force of the monitoring bogie with the monitoring bogie itself when the monitoring bogie having wheel load and lateral force measuring capabilities is traveling on a normal curved section not installed with measurement equipment having wheel load and lateral force measuring capabilities, and generating a third estimation equation to estimate an outside derailment coefficient of the monitoring bogie on the normal curved section by performing multivariate analysis using an outside derailment coefficient computed from the measured wheel load and lateral force as an objective variable and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables.

(4) Correction coefficient generation step: generating correction coefficients for the explanatory variables in the second estimation equation based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, the explanatory variables employed when the first estimation equation was generated, and the explanatory variables employed when the third estimation equation was generated.

(5) Fourth estimation equation generation step: generating a fourth estimation equation to estimate the outside derailment coefficient of the normal bogie on the normal curved section by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation.

(6) Estimation step: estimating an outside derailment coefficient of the normal bogie on the normal curved section by measuring the wheel load and lateral force of the normal bogie with the measurement equipment when the normal bogie is traveling along the reference curved section, and inputting the fourth estimation equation with at least a specific computation value that is computed from the measured wheel load and lateral force as well as the travel velocity of the normal bogie.

[0019] According to the outside derailment coefficient estimation method according to an exemplary embodiment present invention, the second estimation equation (estimation equation to estimate the outside derailment coefficient of the normal bogie on the reference curved section) is generated in the second estimation equation generation step. Moreover, in the correction coefficient generation step, the effect of changing the curved section (changing from the reference curved section to the normal curved section) in changes to the estimation equation are extracted using the first estimation equation generated in the first estimation equation generation step (the estimation equation to estimate the outside derailment coefficient of the monitoring bogie on the reference curved section) and the third estimation equation generated in the third estimation equation generation step (the estimation equation to estimate the outside derailment coefficient of the monitoring bogie on the normal curved section) are used to extract. More specifically, in the correction coefficient generation step, the correction coefficients are generated for the explanatory variables in the second estimation equation based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, the explanatory variables employed when the first estimation equation was generated by multivariate analysis, and the explanatory variables employed when the third estimation equation was generated.

[0020] Then, in the fourth estimation equation generation step, the outside derailment coefficient estimation method according to an exemplary embodiment of the present invention enables the fourth estimation equation (estimation equation to estimate the outside derailment coefficient of the normal bogie on the normal curved section) to be generated by taking account of the correction coefficients (taking account of the effect of changing the curved section) in the second estimation equation (the estimation equation to estimate the outside derailment coefficient of the normal bogie on the reference curved section). More specifically, the fourth estimation equation can be generated by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation.

[0021] Finally, in the estimation step, the outside derailment coefficient estimation method according to the exemplary embodiment of the present invention enables the outside derailment coefficient of the normal bogie on the normal curved section to be estimated by measuring the wheel load and lateral force of the normal bogie with the measurement equipment when the normal bogie is traveling along the reference curved section and inputting these into the fourth estimation equation.

[0022] The outside derailment coefficient estimation method according to an exemplary embodiment of the present

invention enables the outside derailment coefficient to be estimated when a normal bogie is traveling on a normal curved section, which has hitherto not been computable. Increasing the number of normal curved sections applied with the outside derailment coefficient estimation method according to the present invention enables the outside derailment coefficient to be estimated for when the normal bogie is traveling along all of the curved sections. Moreover, re-executing the first estimation equation generation step to the third estimation equation generation step at appropriate timings increases the number of data for objective variables and explanatory variables for employing in multivariate analysis, enabling appropriate data to be employed for the objective variable and explanatory variables that is appropriate to the change in the state of the curved section. This enables the estimation precision of the first estimation equation to the third estimation equation to be improved. Also re-executing the correction coefficient generation step and the fourth estimation equation generation step, at the timings when the first estimation equation generation step to the third estimation equation generation step are re-executed, enables the estimation precision of the fourth estimation equation to be improved, and enables the outside derailment coefficient to be estimated in the estimation step with good precision.

[0023] Note that the outside derailment coefficient estimation method according to the exemplary embodiment of the present invention is not limited to always employing only a computation value computed from the wheel load and lateral force as well as the travel velocity of the bogie (monitoring bogie or normal bogie) as the explanatory variables in the first estimation equation to the fourth estimation equation. As well as these, other parameters than that effect the outside derailment coefficient (for example, radius of curvature of the reference curved section or the normal curved section, wheel load itself, and the like) may also be added to the explanatory variables.

[0024] Moreover, the outside derailment coefficient estimation method according to the exemplary embodiment of the present invention is not limited to always executing the first estimation equation generation step, the second estimation equation generation step, the third estimation equation generation step, the correction coefficient generation step, the fourth estimation equation generation step, and the estimation step in this sequence. Although the correction coefficient generation step, the fourth estimation equation generation step, and the estimation step need always to be executed in this sequence, the executing sequence of the other steps may be altered as appropriate. However, the first estimation equation generation step and the third estimation equation generation step need to be executed prior to the correction coefficient generation step. Moreover, the second estimation equation generation step needs to be executed prior to the fourth estimation equation generation step.

[0025] In the outside derailment coefficient estimation method according to the exemplary embodiment of the present invention, preferably in the correction coefficient generation step the correction coefficients for the explanatory variables in the second estimation equation are generated by multiplying together respective ratios of coefficients of the explanatory variables in the third estimation equation with respect to coefficients of the explanatory variables in the first estimation equation, by multiplying with respective ratios of average values of the explanatory variables employed when the third estimation equation was generated with respect to the average values of the explanatory variables employed when the first estimation equation was generated. In the fourth estimation equation generation step, the fourth estimation equation to estimate the outside derailment coefficient of the normal bogie on the normal curved section is generated by multiplying coefficients of the explanatory variables in the second estimation equation with the correction coefficients.

[0026] Employing the preferable method described above when generating the correction coefficients is conjectured to enable change in the degree of contribution of the respective explanatory variables as the curved section is changed to be reflected in the second estimation equation after correction (i.e. in the fourth estimation equation generated thereby) by employing respective ratios of the coefficients of the explanatory variables in the third estimation equation with respect to the coefficients of the explanatory variables in the first estimation equation. Furthermore, when generating the correction coefficients, employing ratios of the average values of the explanatory variables employed when the third estimation equation was generated with respect to the average values of the explanatory variables employed when the first estimation equation was generated is conjectured to enable changes to values of the explanatory variables as the curved section is changed to be reflected in the second estimation equation after correction (i.e. in the fourth estimation equation generated thereby).

[0027] The preferable method described above enables the outside derailment coefficient to be estimated with good precision.

[0028] Furthermore, in the outside derailment coefficient estimation method according to the exemplary embodiment of the present invention, the computation value preferably employs at least one parameter from out of an inside derailment coefficient, a front axle left-right wheel load balance, or a rear axle left-right wheel load balance.

[0029] The inside derailment coefficient means a derailment coefficient (a value of the lateral force divided by the wheel load) for the inside wheel on the front axle installed on a bogie (the monitoring bogie or the normal bogie).

[0030] The front axle left-right wheel load balance means a value calculated by $(P1 - P2)/(P1 + P2)$, wherein P1 is the wheel load of the left wheel on the front axle with respect to the direction of travel of the bogie and P2 is the wheel load of the right wheel of the front axle. The rear axle left-right wheel load balance is similarly defined.

[0031] The preferable method described above enables the outside derailment coefficient to be estimated with good precision.

[0032] Furthermore, in the outside derailment coefficient estimation method according to an exemplary embodiment of the present invention, a first order polynomial equation of the explanatory variables may be employed for the first estimation equation, the second estimation equation, the third estimation equation, and the fourth estimation equation.

[0033] However, the exemplary embodiment of the present invention is not limited thereto, and a second order or higher polynomial equation of the explanatory variables may be employed for the first estimation equation to the fourth estimation equation. Moreover, polynomials including the explanatory variables may be of different orders from each other.

[0034] Fig. 1 is a plan view to schematically explain an outside derailment coefficient estimation method according to the present exemplary embodiment. Fig. 2 is a flowchart illustrating an outline procedure of an outside derailment coefficient estimation method according to the present exemplary embodiment.

[0035] As illustrated in Fig. 1, the outside derailment coefficient estimation method according to the present exemplary embodiment is a method to estimate the outside derailment coefficient when a bogie provided to rolling stock is traveling along a curved section of track. As illustrated in Fig. 1, hitherto use of measurement values by measurement equipment 11 (or a monitoring bogie 3) has enabled computation of an outside derailment coefficient Q/P_1 when a monitoring bogie 3 having wheel load P and lateral force Q measuring capabilities is traveling on a reference curved section 1 installed with measurement equipment 11 having wheel load P and lateral force Q measuring capabilities. Moreover, hitherto use of measurement values by the measurement equipment 11 has enabled computation of an outside derailment coefficient Q/P_2 when a normal bogie 4 lacking wheel load P and lateral force Q measurement capabilities is traveling on the reference curved section 1. Furthermore, hitherto use of measurement values by the monitoring bogie 3 has enabled computation of an outside derailment coefficient Q/P_3 when the monitoring bogie 3 is traveling on a normal curved section 2 not installed with the measurement equipment 11 having wheel load P and lateral force Q measuring capabilities. However, hitherto the computation of an outside derailment coefficient Q/P_4 when the normal bogie 4 is traveling on the normal curved section 2 has not been possible. The outside derailment coefficient estimation method according to the present exemplary embodiment is a method to estimate the outside derailment coefficient Q/P_4 when the normal bogie 4 is traveling on the normal curved section 2, which has not hitherto been possible to compute.

[0036] As illustrated in Fig. 2, the method of estimating the outside derailment coefficient Q/P_4 according to the present exemplary embodiment includes a first estimation equation generation step S1, a second estimation equation generation step S2, a third estimation equation generation step S3, a correction coefficient generation step S4, a fourth estimation equation generation step S5, and an estimation step S6. Explanation follows in sequence regarding each of the steps S1 to S6.

First Estimation Equation Generation Step S1

[0037] At the first estimation equation generation step S1, the wheel load P and lateral force Q of the monitoring bogie 3 are measured with the measurement equipment 11 when the monitoring bogie 3 is traveling along the reference curved section 1. A known PQ monitoring bogie, such as that described in JP-A No. 2014-54881, for example, is applicable as the monitoring bogie 3. Moreover, known measurement equipment, such as that described in JP-A No. H10-185666, for example, may be applicable as the measurement equipment 11. The measurement referred to above is repeatedly performed on the same reference curved section 1 by the same monitoring bogie 3 to acquire plural measurement data of wheel load P and lateral force Q.

[0038] Then at the first estimation equation generation step S1, a first estimation equation to estimate the outside derailment coefficient Q/P_1 of the monitoring bogie 3 on the reference curved section 1 is generated by performing multivariate analysis using the outside derailment coefficient Q/P_1 computed from the measured wheel load P and lateral force Q as an objective variable, and using at least a specific computation value that is computed from the measured wheel load P and lateral force Q (excluding the outside derailment coefficient Q/P_1) as well as the travel velocity of the monitoring bogie 3 as explanatory variables. Note that the travel velocity of the monitoring bogie 3 may be easily measured using a speedometer generally provided to rolling stock.

[0039] In the present exemplary embodiment, a first order polynomial equation of explanatory variables is employed as the first estimation equation. For example, the first estimation equation may be represented by the following Equation (1), wherein V_1 is the travel velocity of the monitoring bogie 3, and X_1 , Y_1 , Z_1 are employed as three computation values computed from the wheel load P and lateral force Q.

$$Q/P_1 = a_1 \cdot V_1 + b_1 \cdot X_1 + c_1 \cdot Y_1 + d_1 \cdot Z_1 + e_1 \quad \dots (1).$$

[0040] In multivariate analysis, the coefficients a_1 to d_1 of the explanatory variables of Equation (1) and e_1 that is a constant of Equation (1) may be identified by employing a least-squares method, for example, on plural data computed

for the computation values X_1 to Z_1 based on the plural measurement data for the wheel load P and lateral force Q acquired in the first estimation equation generation step, on plural data measured for the travel velocity V_1 , and on plural data computed for the outside derailment coefficient Q/P_1 .

Second Estimation Equation Generation Step S2

[0041] At the second estimation equation generation step S2, the wheel load P and lateral force Q of the normal bogie 4 are measured with the measurement equipment 11 when the normal bogie 4 is traveling along the reference curved section 1. The above measurements are repeatedly performed on the same reference curved section 1 for the same normal bogie 4 to acquire plural measurement data of wheel load P and lateral force Q.

[0042] Then at the second estimation equation generation step S2, a second estimation equation to estimate an outside derailment coefficient Q/P_2 of the normal bogie 4 on the reference curved section 1 is generated by performing multivariate analysis using the outside derailment coefficient Q/P_2 computed from the measured wheel load P and lateral force Q as an objective variable, and using at least a specific computation value that is computed from the measured wheel load P and lateral force Q (excluding the outside derailment coefficient Q/P_2) as well as the travel velocity of the normal bogie 4 as explanatory variables. Note that the travel velocity of the normal bogie 4 may be easily measured using a speedometer generally provided to rolling stock.

[0043] In the present exemplary embodiment, similarly to the first estimation equation, a first order polynomial equation of explanatory variables is employed as the second estimation equation. For example, the second estimation equation may be represented by the following Equation (2), wherein V_2 is the travel velocity of the normal bogie 4, and X_2 , Y_2 , Z_2 are respectively employed as three computation values computed from the wheel load P and lateral force Q.

$$Q/P_2 = a_2 \cdot V_2 + b_2 \cdot X_2 + c_2 \cdot Y_2 + d_2 \cdot Z_2 + e_2 \quad \dots (2)$$

X_2 to Z_2 are each similar types of computation value to X_1 to Z_1 of the first estimation equation.

[0044] In multivariate analysis, the coefficients a_2 to d_2 that are the explanatory variables of Equation (2) and e_2 that is a constant term of Equation (2) may be identified by employing a least-squares method, for example, on plural data for the computed values X_2 to Z_2 computed based on the plural measurement data for the wheel load P and lateral force Q acquired in the second estimation equation generation step, on plural data measured for the travel velocity V_2 , and on plural data computed for the outside derailment coefficient Q/P_2 .

Third Estimation Equation Generation Step S3

[0045] At the third estimation equation generation step S3, the wheel load P and lateral force Q of the monitoring bogie 3 are measured with the monitoring bogie 3 when the monitoring bogie 3 is traveling along the normal curved section 2. The measurement referred to above is repeatedly performed on the same normal curved section 2 for the same monitoring bogie 3 to acquire plural measurement data of the wheel load P and lateral force Q.

[0046] Then at the third estimation equation generation step S3, the third estimation equation to estimate the outside derailment coefficient Q/P_3 of the monitoring bogie 3 on the normal curved section 2 is generated by performing multivariate analysis using the outside derailment coefficient Q/P_3 computed from the measured wheel load P and lateral force Q as an objective variable and using at least a specific computation value that is computed from the measured wheel load P and lateral force Q (excluding the outside derailment coefficient Q/P_3) as well as the travel velocity of the monitoring bogie 3 as explanatory variables.

[0047] In the present exemplary embodiment, similarly to the first estimation equation and the second estimation equation, a first order polynomial equation of explanatory variables is employed as the third estimation equation. For example, the third estimation equation may be represented by the following Equation (3), wherein V_3 is the travel velocity of the monitoring bogie 3, and X_3 , Y_3 , Z_3 are respectively employed as three computation values computed from the wheel load P and lateral force Q.

$$Q/P_3 = a_3 \cdot V_3 + b_3 \cdot X_3 + c_3 \cdot Y_3 + d_3 \cdot Z_3 + e_3 \quad \dots (3)$$

X_3 to Z_3 are each similar types of computation values to X_1 to Z_1 of the first estimation equation and X_2 to Z_2 of the second estimation equation.

[0048] In multivariate analysis, the coefficients a_3 to d_3 that are the explanatory variables of Equation (3) and e_3 that is a constant term of Equation (3) may be identified by employing a least-squares method, for example, on plural data

for the computed values X_3 to Z_3 computed based on the plural measurement data for the wheel load P and lateral force Q acquired in the third estimation equation generation step, on plural data measured for the travel velocity V_3 , and on plural data computed for the outside derailment coefficient Q/P_3 .

5 Correction Coefficient Generation Step S4

[0049] At the correction coefficient generation step S4, correction coefficients are generated for the explanatory variables V_2 and X_2 to Z_2 in the second estimation equation represented by Equation (2) based on the coefficients a_1 to d_1 of the explanatory variables V_1 and X_1 to Z_1 in the first estimation equation represented by Equation (1), the coefficients a_3 to d_3 of the explanatory variables V_3 and X_3 to Z_3 in the third estimation equation represented by Equation (3), the plural data of the explanatory variable V_1 and X_1 to Z_1 employed when the first estimation equation was generated (for example, the plural data of the explanatory variables V_1 and X_1 to Z_1 employed when using a least-squares method), and the plural data of the explanatory variable V_3 and X_3 to Z_3 employed when the third estimation equation was generated (for example, the plural data of the explanatory variables V_3 and X_3 to Z_3 employed when using a least-squares method).

[0050] In the present exemplary embodiment, the correction coefficients are generated for the explanatory variables V_2 and X_2 to Z_2 in the second estimation equation by multiplying together respective ratios of the coefficients a_3 to d_3 of the explanatory variables V_3 and X_3 to Z_3 in the third estimation equation with respect to the coefficients a_1 to d_1 of the explanatory variables V_1 and X_1 to Z_1 of the first estimation equation, by multiplying with the respective ratios of the average values of the explanatory variables V_3 and X_3 to Z_3 employed when the third estimation equation was generated with respect to the average values of the explanatory variables V_1 and X_1 to Z_1 employed when the first estimation equation was generated.

[0051] Namely, correction coefficients α , β , γ , and δ are the respective correction coefficients α , β , γ , and δ for the explanatory variables V_2 and X_2 to Z_2 of the second estimation equation and are represented by the following Equations (4) to (7), wherein V_{1ave} and X_{1ave} to Z_{1ave} are respective average values of the explanatory variables V_1 and X_1 to Z_1 employed when the first estimation equation was generated, and V_{3ave} and X_{3ave} to Z_{3ave} are respective average values of the explanatory variables V_3 and X_3 to Z_3 employed when the third estimation equation was generated.

$$\alpha = (a_3/a_1) \cdot (V_{3ave}/V_{1ave}) \quad \dots (4)$$

$$\beta = (b_3/b_1) \cdot (X_{3ave}/X_{1ave}) \quad \dots (5)$$

$$\gamma = (c_3/c_1) \cdot (Y_{3ave}/Y_{1ave}) \quad \dots (6)$$

$$\delta = (d_3/d_1) \cdot (Z_{3ave}/Z_{1ave}) \quad \dots (7)$$

[0052] Note that at the correction coefficient generation step S4 of the present exemplary embodiment, a correction coefficient is also generated for the constant term e_2 in the second estimation equation. In the present exemplary embodiment, the correction coefficient for the constant term e_2 in the second estimation equation is generated by taking the square of the ratio of the constant term e_3 in the third estimation equation with respect to the constant term e_1 in the first estimation equation.

[0053] Namely, if the correction coefficient for the constant term e_2 in the second estimation equation is denoted ε , then the correction coefficient ε is represented by the following Equation (8).

$$\varepsilon = (e_3/e_1)^2 \quad \dots (8)$$

Fourth Estimation Equation Generation Step S5

[0054] At the fourth estimation equation generation step S5, the fourth estimation equation to estimate the outside derailment coefficient Q/P_4 of the normal bogie 4 on the normal curved section 2 is generated by taking account of the correction coefficients α , β , γ , and δ in the coefficients a_3 to d_3 of the explanatory variables V_2 and X_2 to Z_2 in the second estimation equation. Note that in the present exemplary embodiment, the fourth estimation equation to estimate the outside derailment coefficient Q/P_4 of the normal bogie 4 on the normal curved section 2 is generated by also taking

account of the correction coefficient ε in the constant term e_2 of the second estimation equation.

[0055] More specifically, at the fourth estimation equation generation step S5 in the present exemplary embodiment, the fourth estimation equation to estimate the outside derailment coefficient Q/P_4 of the normal bogie 4 on the normal curved section 2 is generated by multiplying the coefficients a_2 to d_2 of the explanatory variables V_2 and X_2 to Z_2 in the second estimation equation with the correction coefficients α , β , γ , and δ . Moreover, in the present exemplary embodiment, the fourth estimation equation to estimate the outside derailment coefficient Q/P_4 of the normal bogie 4 on the normal curved section 2 is generated by multiplying the constant term e_2 in the second estimation equation by the correction coefficient ε .

[0056] Namely, the fourth estimation equation is represented by the following Equation (9).

$$Q/P_4 = \alpha \cdot a_2 \cdot V_2 + \beta \cdot b_2 \cdot X_2 + \gamma \cdot c_2 \cdot Y_2 + \delta \cdot d_2 \cdot Z_2 + \varepsilon \cdot e_2 \quad \dots (9)$$

[0057] The fourth estimation equation generated in the above described manner is stored and employed in the next estimation step S6.

Estimation Step S6

[0058] At the estimation step S6, the wheel load P and lateral force Q of the normal bogie 4 are measured with the measurement equipment 11 when the normal bogie 4 is traveling along the reference curved section 1.

[0059] Then at the estimation step S6, the outside derailment coefficient Q/P_4 of the normal bogie 4 on the normal curved section 2 is estimated by inputting the fourth estimation equation with at least a specific computation value that is computed from the measured wheel load P and lateral force Q (X_2 , Y_2 , Z_2 in the present exemplary embodiment) as well as with the travel velocity V_2 of the normal bogie 4.

[0060] Fig. 3A, Fig. 3B, Fig. 4A, and Fig. 4B are diagrams illustrating examples of results of comparing estimated values of the outside derailment coefficient Q/P_1 to Q/P_4 estimated using the Equations (1) to (3) and (9), against measured values of the outside derailment coefficient Q/P_1 to Q/P_4 measured using the measurement equipment 11 or the monitoring bogie 3. An inside derailment coefficient is employed as the explanatory variables X_1 to X_3 for all of the Equations (1) to (3) and (9). The front axle left-right wheel load balance is employed as the explanatory variables Y_1 to Y_3 . Furthermore, the rear axle left-right wheel load balance is employed as the explanatory variables Z_1 to Z_3 .

[0061] Fig. 3A illustrates results of comparing the estimated values and the measured values of the outside derailment coefficient Q/P_1 . The measured values of the outside derailment coefficient Q/P_1 are measured using the measurement equipment 11. Fig. 3B illustrates results of comparing the estimated values and the measured values of the outside derailment coefficient Q/P_2 . The measured values of the outside derailment coefficient Q/P_2 are measured using the measurement equipment 11. Fig. 4A illustrates results of comparing the estimated values and the measured values of the outside derailment coefficient Q/P_3 . The measured values of the outside derailment coefficient Q/P_3 are measured using the monitoring bogie 3. Fig. 4B illustrates results of comparing the estimated values and the measured values of the outside derailment coefficient Q/P_4 . The results illustrated in Fig. 4B are measured by temporarily installing the measurement equipment 11 on the normal curved section 2 to evaluate the estimated values of the outside derailment coefficient Q/P_4 , and are measured values measured with the measurement equipment 11.

[0062] As illustrated in Fig. 3A, Fig. 3B, and Fig. 4A, the outside derailment coefficients Q/P_1 to Q/P_3 can be estimated with comparatively good precision. By employing these results, it is apparent that, as illustrated in Fig. 4B, the outside derailment coefficient Q/P_4 when the normal bogie 4 is traveling along the normal curved section 2 can be estimated with good precision, a computation that hitherto has not been possible.

Configuration of Outside Derailment Coefficient Estimation Device

[0063] Fig. 5 is a schematic diagram illustrating an outline configuration of an outside derailment coefficient estimation device according to an exemplary embodiment of the present invention. As illustrated in Fig. 5, an outside derailment coefficient estimation device 100 according to the present exemplary embodiment includes a measurement data storage section 10, a first estimation equation generation section 12, a second estimation equation generation section 14, a third estimation equation generation section 16, a correction coefficient generation section 17, a fourth estimation equation generation section 18, and an outside derailment coefficient estimation section 20.

[0064] The measurement data storage section 10 is stored with plural measurement data for the wheel load P , the lateral force Q , and the travel velocity V acquired by measuring the wheel load P and lateral force Q of the monitoring bogie 3 with the measurement equipment 11 when the monitoring bogie 3 is traveling along the reference curved section 1, and by repeatedly performing these measurements in the same reference curved section 1 for the same monitoring

bogie 3.

[0065] Moreover, the measurement data storage section 10 is stored with plural measurement data of the wheel load P, lateral force Q, and travel velocity V acquired by measuring the wheel load P and lateral force Q of the normal bogie 4 with the measurement equipment 11 when the normal bogie 4 is traveling along the reference curved section 1, and by repeatedly performing these measurements on the same reference curved section 1 with the same normal bogie 4.

[0066] Moreover, the measurement data storage section 10 is stored with plural measurement data of the wheel load P, lateral force Q, and travel velocity V acquired by measuring the wheel load P and lateral force Q of the monitoring bogie 3 with the monitoring bogie 3 itself when the monitoring bogie 3 is traveling along the normal curved section 2, and by repeatedly performing these measurements on the same normal curved section 2 with the same monitoring bogie 3.

[0067] Moreover, the measurement data storage section 10 is stored with measurement data of the wheel load P, lateral force Q, and travel velocity V acquired by measuring the wheel load P and lateral force Q of the normal bogie 4 with the measurement equipment 11 when the normal bogie 4 is traveling along the reference curved section 1.

[0068] Based on the plural measurement data stored in the measurement data storage section 10 for the wheel load P and lateral force Q of the monitoring bogie 3 measured with the measurement equipment 11 when the monitoring bogie 3 is traveling along the reference curved section 1, the first estimation equation generation section 12 generates the first estimation equation by identifying coefficients of the explanatory variables and the constant term of the first estimation equation represented by Equation (1) to estimate the outside derailment coefficient Q/P_1 of the monitoring bogie 3 on the reference curved section 1. Such identification is achieved by performing multivariate analysis using the outside derailment coefficient Q/P_1 computed from the measured wheel load P and lateral force Q as an objective variable, and using at least a specific computation value that is computed from the measured wheel load P and lateral force Q (excluding the outside derailment coefficient Q/P_1) as well as the travel velocity of the monitoring bogie 3 as explanatory variables.

[0069] Based on the plural measurement data stored in the measurement data storage section 10 for the wheel load P and lateral force Q of the normal bogie 4 measured with the measurement equipment 11 when the normal bogie 4 is traveling along the reference curved section 1, the second estimation equation generation section 14 generates the second estimation equation by identifying coefficients of the explanatory variables and the constant term of the second estimation equation represented by Equation (2) to estimate the outside derailment coefficient Q/P_2 of the normal bogie 4 on the reference curved section 1. Such identification is achieved by performing multivariate analysis using the outside derailment coefficient Q/P_2 computed from the measured wheel load P and lateral force Q as an objective variable, and using at least a specific computation value that is computed from the measured wheel load P and lateral force Q (excluding the outside derailment coefficient Q/P_2) as well as the travel velocity of the normal bogie 4 as explanatory variables.

[0070] Based on the plural measurement data stored in the measurement data storage section 10 for the wheel load P and lateral force Q of the monitoring bogie 3 measured with the monitoring bogie 3 when the monitoring bogie 3 is traveling along the normal curved section 2, the third estimation equation generation section 16 generates the third estimation equation by identifying coefficients of the explanatory variables and the constant term of the third estimation equation represented by Equation (3) to estimate the outside derailment coefficient Q/P_3 of the monitoring bogie 3 on the normal curved section 2. Such identification is achieved by performing multivariate analysis using the outside derailment coefficient Q/P_3 computed from the measured wheel load P and lateral force Q as an objective variable, and using at least a specific computation value that is computed from the measured wheel load P and lateral force Q (excluding the outside derailment coefficient Q/P_3) as well as the travel velocity of the monitoring bogie 3 as explanatory variables.

[0071] Based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, the plural data of the explanatory variables employed when the first estimation equation was generated, and the plural data of the explanatory variables employed when the third estimation equation was generated, the correction coefficient generation section 17 generates the respective correction coefficients for the explanatory variables of the second estimation equation according to Equation (4) to Equation (7).

[0072] Moreover, based on the ratio of the constant term in the third estimation equation with respect to the constant term in the first estimation equation, the correction coefficient generation section 17 generates the correction coefficient for the constant term in the second estimation equation according to Equation (8).

[0073] The fourth estimation equation generation section 18 then generates the fourth estimation equation represented by Equation (9) to estimate the outside derailment coefficient Q/P_4 of the normal bogie 4 on the normal curved section 2 by taking account of the respective correction coefficients in the coefficients of the explanatory variables and the constant term in the second estimation equation.

[0074] Based on the measurement data stored in the measurement data storage section 10 for the wheel load P and lateral force Q of the normal bogie 4 measured with the measurement equipment 11 when the normal bogie 4 is traveling along the reference curved section 1, the outside derailment coefficient estimation section 20 estimates the outside derailment coefficient Q/P_4 of the normal bogie 4 on the normal curved section 2 by inputting the fourth estimation equation represented by Equation (9) with at least a specific computation value that is computed from the measured wheel load P and lateral force Q (X_2, Y_2, Z_2 in the present exemplary embodiment) as well as the travel velocity V_2 of

the normal bogie 4.

[0075] The outside derailment coefficient estimation device 100 is, for example, implemented using a computer 64, illustrated in Fig. 6. The computer 64 includes a CPU 66, memory 68, a storage section 70 stored with an outside derailment coefficient estimation program 76, a display section 26 including a monitor, and an input section 28 including a keyboard and a mouse. The CPU 66, the memory 68, the storage section 70, the display section 26, and the input section 28 are mutually connected through a bus 74.

[0076] The storage section 70 may be implemented by a HDD, SSD, flash memory, or the like. The outside derailment coefficient estimation program 76 stored in the storage section 70 is employed to cause the computer 64 to function as the outside derailment coefficient estimation device 100. The CPU 66 reads the outside derailment coefficient estimation program 76 from the storage section 70, expands the outside derailment coefficient estimation program 76 into the memory 68, and executes the outside derailment coefficient estimation program 76. Note that the outside derailment coefficient estimation program 76 may be provided stored on a computer-readable medium.

Operation of Outside Derailment Coefficient Estimation Device

[0077] First, an operator inputs measurement data to the outside derailment coefficient estimation device 100. The measurement data includes plural measurement data of the wheel load P and lateral force Q of the monitoring bogie 3 measured with the measurement equipment 11 when the monitoring bogie 3 is traveling along the reference curved section 1, plural measurement data of the wheel load P and lateral force Q of the normal bogie 4 measured with the measurement equipment 11 when the normal bogie 4 is traveling along the reference curved section 1, measurement data of the wheel load P and lateral force Q of the monitoring bogie 3 measured with the monitoring bogie 3 when the monitoring bogie 3 is traveling along the normal curved section 2, and measurement data of the wheel load P and lateral force Q of the normal bogie 4 measured with the measurement equipment 11 when the normal bogie 4 is traveling along the reference curved section 1. Then on instigation by an operation performed by the operator, such as instructing start of outside derailment coefficient estimation processing, the outside derailment coefficient estimation processing is executed in the outside derailment coefficient estimation device 100. Explanation follows regarding the outside derailment coefficient estimation processing, with reference to Fig. 2. Note that the flow illustrating the flow of the outside derailment coefficient estimation processing is similar to the flow illustrating the outline procedure of the outside derailment coefficient estimation method of Fig. 2, and so will be described with the same reference signs appended thereto.

[0078] At step S1 of the outside derailment coefficient estimation processing, based on the plural measurement data stored in the measurement data storage section 10 for the wheel load P and lateral force Q of the monitoring bogie 3 measured with the measurement equipment 11 when the monitoring bogie 3 is traveling along the reference curved section 1, the first estimation equation generation section 12 generates the first estimation equation by identifying coefficients of the explanatory variables and the constant term of the first estimation equation represented by Equation (1) to estimate the outside derailment coefficient Q/P_1 of the monitoring bogie 3 on the reference curved section 1. Such identification is achieved by performing multivariate analysis using the outside derailment coefficient Q/P_1 computed from the measured wheel load P and lateral force Q as an objective variable, and using at least a specific computation value that is computed from the measured wheel load P and lateral force Q (excluding the outside derailment coefficient Q/P_1) as well as the travel velocity of the monitoring bogie 3 as explanatory variables.

[0079] At step S2, based on the plural measurement data stored in the measurement data storage section 10 for the wheel load P and lateral force Q of the normal bogie 4 measured with the measurement equipment 11 when the normal bogie 4 is traveling along the reference curved section 1, the second estimation equation generation section 14 generates the second estimation equation by identifying coefficients of the explanatory variables and the constant term of the second estimation equation represented by Equation (2) to estimate the outside derailment coefficient Q/P_2 of the normal bogie 4 on the reference curved section 1. Such identification is achieved by performing multivariate analysis using the outside derailment coefficient Q/P_2 computed from the measured wheel load P and lateral force Q as an objective variable, and using at least a specific computation value that is computed from the measured wheel load P and lateral force Q (excluding the outside derailment coefficient Q/P_2) as well as the travel velocity of the normal bogie 4 as explanatory variables.

[0080] At step S3, based on the plural measurement data stored in the measurement data storage section 10 for the wheel load P and lateral force Q of the monitoring bogie 3 measured with the monitoring bogie 3 when the monitoring bogie 3 is traveling along the normal curved section 2, the third estimation equation generation section 16 generates the third estimation equation by identifying coefficients of the explanatory variables and the constant term of the third estimation equation represented by Equation (3) to estimate the outside derailment coefficient Q/P_3 of the monitoring bogie 3 on the normal curved section 2. Such identification is achieved by performing multivariate analysis using the outside derailment coefficient Q/P_3 computed from the measured wheel load P and lateral force Q as an objective variable, and using at least a specific computation value that is computed from the measured wheel load P and lateral force Q (excluding the outside derailment coefficient Q/P_3) as well as the travel velocity of the monitoring bogie 3 as

explanatory variables.

[0081] At step S4, based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, the plural data of the explanatory variables employed when the first estimation equation was generated, and the plural data of the explanatory variables employed when the third estimation equation was generated, the correction coefficient generation section 17 generates the respective correction coefficients for the explanatory variables of the second estimation equation according to Equation (4) to Equation (7).

[0082] Furthermore, based on the ratio of the constant term in the third estimation equation with respect to the constant term in the first estimation equation, the correction coefficient generation section 17 generates the correction coefficient for the constant term in the second estimation equation according to Equation (8).

[0083] At step S5, the fourth estimation equation generation section 18 then generates the fourth estimation equation represented by Equation (9) to estimate the outside derailment coefficient Q/P_4 of the normal bogie 4 on the normal curved section 2 by taking account of the respective correction coefficients in the coefficients of the explanatory variables and the constant term in the second estimation equation.

[0084] At step S6, based on the measurement data stored in the measurement data storage section 10 for the wheel load P and lateral force Q of the normal bogie 4 measured with the measurement equipment 11 when the normal bogie 4 is traveling along the reference curved section 1, the outside derailment coefficient estimation section 20 estimates the outside derailment coefficient Q/P_4 of the normal bogie 4 on the normal curved section 2 by inputting the fourth estimation equation represented by Equation (9) with at least a specific computation value that is computed from the measured wheel load P and lateral force Q (X_2 , Y_2 , Z_2 in the present exemplary embodiment) as well as with the travel velocity V_2 of the normal bogie 4.

[0085] As described above, the outside derailment coefficient estimation device 100 according to the present exemplary embodiment enables a derailment coefficient to be estimated for a normal bogie (bogie lacking wheel load and lateral force measurement capabilities) on a normal curved section (curved section not installed with measurement equipment having wheel load and lateral force measuring capabilities).

[0086] The disclosure of Japanese Patent Application No. 2018-011509 is incorporated in its entirety by reference herein.

[0087] All cited documents, patent applications, or technical standards mentioned in the present specification are incorporated by reference in the present specification to the same extent as if each individual cited document, patent application, or technical standard was specifically and individually indicated to be incorporated by reference.

[0088] The following supplements are also disclosed in relation to the exemplary embodiment described above.

Supplement 1

[0089] A method to estimate a derailment coefficient when a bogie provided to rolling stock is traveling on a curved section of track, the derailment coefficient estimation method including:

a first estimation equation generation step of measuring a wheel load and lateral force of a monitoring bogie with measurement equipment when the monitoring bogie having wheel load and lateral force measuring capabilities is traveling on a reference curved section of track installed with the measurement equipment having wheel load and lateral force measuring capabilities, and generating a first estimation equation to estimate a derailment coefficient of the monitoring bogie on the reference curved section by performing multivariate analysis using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

a second estimation equation generation step of measuring a wheel load and lateral force of a normal bogie with the measurement equipment when the normal bogie lacking wheel load and lateral force measurement capabilities is traveling on the reference curved section, and generating a second estimation equation to estimate a derailment coefficient of the normal bogie on the reference curved section by performing multivariate analysis using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the normal bogie as explanatory variables;

a third estimation equation generation step of measuring a wheel load and lateral force of the monitoring bogie with the monitoring bogie itself when the monitoring bogie having wheel load and lateral force measuring capabilities is traveling on a normal curved section of track not installed with measurement equipment having wheel load and lateral force measuring capabilities, and generating a third estimation equation to estimate a derailment coefficient of the monitoring bogie on the normal curved section by performing multivariate analysis using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of

the monitoring bogie as explanatory variables;

a correction coefficient generation step of generating correction coefficients for the explanatory variables in the second estimation equation based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, values of the explanatory variables employed when the first estimation equation was generated, and values of the explanatory variables employed when the third estimation equation was generated;

a fourth estimation equation generation step of generating a fourth estimation equation to estimate a derailment coefficient of the normal bogie on the normal curved section by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation; and

an estimation step of estimating a derailment coefficient of the normal bogie on the normal curved section by measuring the wheel load and lateral force of the normal bogie with the measurement equipment when the normal bogie is traveling along the reference curved section, and inputting the fourth estimation equation with at least a specific computation value that is computed from the measured wheel load and lateral force as well as the travel velocity of the normal bogie.

Supplement 2

[0090] The derailment coefficient estimation method of Supplement 1, wherein:

in the correction coefficient generation step, the correction coefficients for the explanatory variables in the second estimation equation are generated by multiplying together respective ratios of coefficients of the explanatory variables in the third estimation equation with respect to coefficients of the explanatory variables in the first estimation equation, by multiplying with respective ratios of average values of the explanatory variables employed when the third estimation equation was generated with respect to the average values of the explanatory variables employed when the first estimation equation was generated; and

in the fourth estimation equation generation step, the fourth estimation equation to estimate the derailment coefficient of the normal bogie on the normal curved section is generated by multiplying coefficients of the explanatory variables in the second estimation equation with the correction coefficients.

Supplement 3

[0091] The derailment coefficient estimation method of Supplement 1 or Supplement 2, wherein at least one parameter is employed as the computation value from out of an inside derailment coefficient, a front axle left-right wheel load balance, or a rear axle left-right wheel load balance.

Supplement 4

[0092] The derailment coefficient estimation method of any one of Supplement 1 to Supplement 3, wherein the first estimation equation, the second estimation equation, the third estimation equation, and the fourth estimation equation are first order polynomial equations of the explanatory variables.

Supplement 5

[0093] The derailment coefficient estimation method of any one of Supplement 1 to Supplement 4, wherein the derailment coefficient is a derailment coefficient of an outside wheel.

Supplement 6

[0094] A device to estimate a derailment coefficient when a bogie provided to rolling stock is traveling on a curved section of track, the derailment coefficient estimation device including:

a first estimation equation generation section to generate a first estimation equation to estimate a derailment coefficient of a monitoring bogie in a reference curved section by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the monitoring bogie with measurement equipment when the monitoring bogie having wheel load and lateral force measuring capabilities is traveling on the reference curved section of track installed with the measurement equipment having wheel load and lateral force measuring capabilities, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a

travel velocity of the monitoring bogie as explanatory variables;

a second estimation equation generation section to generate a second estimation equation to estimate a derailment coefficient of the normal bogie on the reference curved section by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the normal bogie with the measurement equipment when the normal bogie lacking wheel load and lateral force measurement capabilities is traveling on the reference curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the normal bogie as explanatory variables;

a third estimation equation generation section to generate a third estimation equation to estimate a derailment coefficient of the monitoring bogie on the normal curved section by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the monitoring bogie with the monitoring bogie itself when the monitoring bogie having wheel load and lateral force measuring capabilities is traveling on a normal curved section of track not installed with measurement equipment having wheel load and lateral force measuring capabilities, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

a correction coefficient generation section to generate correction coefficients for the explanatory variables in the second estimation equation based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, values of the explanatory variables employed when the first estimation equation was generated, and values of the explanatory variables employed when the third estimation equation was generated;

a fourth estimation equation generation section to generate a fourth estimation equation to estimate a derailment coefficient of the normal bogie on the normal curved section by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation; and

an estimation section to estimate a derailment coefficient of the normal bogie on the normal curved section by using input of results of measuring the wheel load and lateral force of the normal bogie with the measurement equipment when the normal bogie is traveling along the reference curved section, and inputting the fourth estimation equation with at least a specific computation value that is computed from the measured wheel load and lateral force as well as the travel velocity of the normal bogie.

Supplement 7. The derailment coefficient estimation device of Supplement 6, wherein:

in the correction coefficient generation section, the correction coefficients for the explanatory variables in the second estimation equation are generated by multiplying together respective ratios of coefficients of the explanatory variables in the third estimation equation with respect to coefficients of the explanatory variables in the first estimation equation, by multiplying with respective ratios of average values of the explanatory variables employed when the third estimation equation was generated with respect to the average values of the explanatory variables employed when the first estimation equation was generated; and

in the fourth estimation equation generation section, the fourth estimation equation to estimate the derailment coefficient of the normal bogie on the normal curved section is generated by multiplying coefficients of the explanatory variables in the second estimation equation with the correction coefficients.

Supplement 8. The derailment coefficient estimation device of Supplement 6 or Supplement 7, wherein at least one parameter is employed as the computation value from out of an inside derailment coefficient, a front axle left-right wheel load balance, or a rear axle left-right wheel load balance.

Supplement 9

[0095] The derailment coefficient estimation device of any one of Supplement 6 to Supplement 8, wherein the first estimation equation, the second estimation equation, the third estimation equation, and the fourth estimation equation are first order polynomial equations of the explanatory variables.

Supplement 10.

[0096] The derailment coefficient estimation device of any one of Supplement 6 to Supplement 9, wherein the derailment coefficient is a derailment coefficient of an outside wheel.

Supplement 11

[0097] A program to estimate a derailment coefficient when a bogie provided to rolling stock is traveling on a curved section of track, the program causing a computer to execute processing including:

generating a first estimation equation to estimate a derailment coefficient of a monitoring bogie in a reference curved section by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the monitoring bogie with measurement equipment when the monitoring bogie having wheel load and lateral force measuring capabilities is traveling on the reference curved section of track installed with the measurement equipment having wheel load and lateral force measuring capabilities, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

generating a second estimation equation to estimate a derailment coefficient of the normal bogie on the reference curved section by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the normal bogie with the measurement equipment when the normal bogie lacking wheel load and lateral force measurement capabilities is traveling on the reference curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the normal bogie as explanatory variables;

generating a third estimation equation to estimate a derailment coefficient of the monitoring bogie on the normal curved section by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the monitoring bogie with the monitoring bogie itself when the monitoring bogie having wheel load and lateral force measuring capabilities is traveling on a normal curved section of track not installed with measurement equipment having wheel load and lateral force measuring capabilities, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

generating correction coefficients for the explanatory variables in the second estimation equation based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, values of the explanatory variables employed when the first estimation equation was generated, and values of the explanatory variables employed when the third estimation equation was generated;

generating a fourth estimation equation to estimate a derailment coefficient of the normal bogie on the normal curved section by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation; and

estimating a derailment coefficient of the normal bogie on the normal curved section by using input of results of measuring the wheel load and lateral force of the normal bogie with the measurement equipment when the normal bogie is traveling along the reference curved section, and inputting the fourth estimation equation with at least a specific computation value that is computed from the measured wheel load and lateral force as well as the travel velocity of the normal bogie.

Supplement 12

[0098] The derailment program of Supplement 12, wherein:

in generating the correction coefficient, the correction coefficients for the explanatory variables in the second estimation equation are generated by multiplying together respective ratios of coefficients of the explanatory variables in the third estimation equation with respect to coefficients of the explanatory variables in the first estimation equation, by multiplying with respective ratios of average values of the explanatory variables employed when the third estimation equation was generated with respect to the average values of the explanatory variables employed when the first estimation equation was generated; and

in the fourth estimation equation generation section, the fourth estimation equation to estimate the derailment coefficient of the normal bogie on the normal curved section is generated by multiplying coefficients of the explanatory variables in the second estimation equation with the correction coefficients.

Supplement 13

[0099] The derailment coefficient estimation device of Supplement 11 or Supplement 12, wherein at least one parameter

is employed as the computation value from out of an inside derailment coefficient, a front axle left-right wheel load balance, or a rear axle left-right wheel load balance.

Supplement 14

[0100] The derailment coefficient estimation device of any one of Supplement 11 to Supplement 13, wherein the first estimation equation, the second estimation equation, the third estimation equation, and the fourth estimation equation are first order polynomial equations of the explanatory variables.

Supplement 15

[0101] The derailment coefficient estimation device of any one of Supplement 11 to Supplement 14, wherein the derailment coefficient is a derailment coefficient of an outside wheel.

Supplement 16

[0102] A computer-readable medium stored with a program to estimate a derailment coefficient when a bogie provided to rolling stock is traveling on a curved section of track, the program causing a computer to execute processing including:

generating a first estimation equation to estimate a derailment coefficient of a monitoring bogie in a reference curved section by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the monitoring bogie with measurement equipment when the monitoring bogie having wheel load and lateral force measuring capabilities is traveling on the reference curved section of track installed with the measurement equipment having wheel load and lateral force measuring capabilities, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

generating a second estimation equation to estimate a derailment coefficient of the normal bogie on the reference curved section by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the normal bogie with the measurement equipment when the normal bogie lacking wheel load and lateral force measurement capabilities is traveling on the reference curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the normal bogie as explanatory variables;

generating a third estimation equation to estimate a derailment coefficient of the monitoring bogie on the normal curved section by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the monitoring bogie with the monitoring bogie itself when the monitoring bogie having wheel load and lateral force measuring capabilities is traveling on a normal curved section of track not installed with measurement equipment having wheel load and lateral force measuring capabilities, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

generating correction coefficients for the explanatory variables in the second estimation equation based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, values of the explanatory variables employed when the first estimation equation was generated, and values of the explanatory variables employed when the third estimation equation was generated; generating a fourth estimation equation to estimate a derailment coefficient of the normal bogie on the normal curved section by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation; and

estimating a derailment coefficient of the normal bogie on the normal curved section by using input of results of measuring the wheel load and lateral force of the normal bogie with the measurement equipment when the normal bogie is traveling along the reference curved section, and inputting the fourth estimation equation with at least a specific computation value that is computed from the measured wheel load and lateral force as well as the travel velocity of the normal bogie.

Claims

1. A method of estimating a derailment coefficient in a case in which a bogie provided to rolling stock is traveling on a curved section of track, the derailment coefficient estimation method comprising:

a first estimation equation generation step of measuring a wheel load and a lateral force of a monitoring bogie using measurement equipment in a case in which the monitoring bogie, which can measure wheel load and lateral force, is traveling on a reference curved section of track installed with the measurement equipment, which can measure wheel load and lateral force, and generating a first estimation equation that estimates a derailment coefficient of the monitoring bogie on the reference curved section by performing multivariate analysis using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

a second estimation equation generation step of measuring a wheel load and a lateral force of a normal bogie using the measurement equipment in a case in which the normal bogie, which cannot measure wheel load and lateral force, is traveling on the reference curved section, and generating a second estimation equation that estimates a derailment coefficient of the normal bogie on the reference curved section by performing multivariate analysis using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the normal bogie as explanatory variables;

a third estimation equation generation step of measuring a wheel load and a lateral force of the monitoring bogie using the monitoring bogie itself in a case in which the monitoring bogie, which can measure wheel load and lateral force, is traveling on a normal curved section of track not installed with measurement equipment, which can measure wheel load and lateral force, and generating a third estimation equation that estimates a derailment coefficient of the monitoring bogie on the normal curved section by performing multivariate analysis using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

a correction coefficient generation step of generating correction coefficients for the explanatory variables in the second estimation equation based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, values of the explanatory variables employed when the first estimation equation was generated, and values of the explanatory variables employed when the third estimation equation was generated;

a fourth estimation equation generation step of generating a fourth estimation equation that estimates a derailment coefficient of the normal bogie on the normal curved section by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation; and

an estimation step of estimating a derailment coefficient of the normal bogie on the normal curved section by measuring the wheel load and the lateral force of the normal bogie using the measurement equipment in a case in which the normal bogie is traveling along the reference curved section, and inputting, into the fourth estimation equation, at least a specific computation value that is computed from the measured wheel load and lateral force as well as the travel velocity of the normal bogie.

2. The derailment coefficient estimation method of claim 1, wherein:

in the correction coefficient generation step, the correction coefficients for the explanatory variables in the second estimation equation are generated by multiplying together respective ratios of coefficients of the explanatory variables in the third estimation equation with respect to coefficients of the explanatory variables in the first estimation equation, with respective ratios of average values of the explanatory variables employed when the third estimation equation was generated with respect to the average values of the explanatory variables employed when the first estimation equation was generated; and

in the fourth estimation equation generation step, the fourth estimation equation that estimates the derailment coefficient of the normal bogie on the normal curved section is generated by multiplying coefficients of the explanatory variables in the second estimation equation with the correction coefficients.

3. The derailment coefficient estimation method of claim 1 or claim 2, wherein at least one parameter among an inside derailment coefficient, a front axle left-right wheel load balance, or a rear axle left-right wheel load balance, is employed as the computation value.

4. The derailment coefficient estimation method of any one of claim 1 to claim 3, wherein the first estimation equation, the second estimation equation, the third estimation equation, and the fourth estimation equation are first order polynomial equations of the explanatory variables.
5. The derailment coefficient estimation method of any one of claim 1 to claim 4, wherein the derailment coefficient is a derailment coefficient of an outside wheel.
6. A device to estimate a derailment coefficient in a case in which a bogie provided to rolling stock is traveling on a curved section of track, the derailment coefficient estimation device comprising:

a first estimation equation generation section that generates a first estimation equation that estimates a derailment coefficient of a monitoring bogie on a reference curved section of track installed with measurement equipment, which can measure wheel load and lateral force, by performing multivariate analysis using input of results of measuring a wheel load and a lateral force of the monitoring bogie using the measurement equipment in a case in which the monitoring bogie, which can measure wheel load and lateral force, is traveling on the reference curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

a second estimation equation generation section that generates a second estimation equation that estimates a derailment coefficient of a normal bogie on the reference curved section by performing multivariate analysis using input of results of measuring a wheel load and a lateral force of the normal bogie using the measurement equipment in a case in which the normal bogie, which cannot measure wheel load and lateral force, is traveling on the reference curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the normal bogie as explanatory variables;

a third estimation equation generation section that generates a third estimation equation that estimates a derailment coefficient of the monitoring bogie on a normal curved section of track not installed with measurement equipment, which can measure wheel load and lateral force, by performing multivariate analysis using input of results of measuring a wheel load and lateral force of the monitoring bogie using the monitoring bogie itself in a case in which the monitoring bogie, which can measure wheel load and lateral force, is traveling on the normal curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

a correction coefficient generation section that generates correction coefficients for the explanatory variables in the second estimation equation based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, values of the explanatory variables employed when the first estimation equation was generated, and values of the explanatory variables employed when the third estimation equation was generated;

a fourth estimation equation generation section that generates a fourth estimation equation that estimates a derailment coefficient of the normal bogie on the normal curved section by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation; and

an estimation section that estimates a derailment coefficient of the normal bogie on the normal curved section by using input of results of measuring the wheel load and the lateral force of the normal bogie using the measurement equipment in a case in which the normal bogie is traveling along the reference curved section, and inputting, into the fourth estimation equation, at least a specific computation value that is computed from the measured wheel load and lateral force as well as the travel velocity of the normal bogie.

7. The derailment coefficient estimation device of claim 6, wherein:

in the correction coefficient generation section, the correction coefficients for the explanatory variables in the second estimation equation are generated by multiplying together respective ratios of coefficients of the explanatory variables in the third estimation equation with respect to coefficients of the explanatory variables in the first estimation equation, with respective ratios of average values of the explanatory variables employed when the third estimation equation was generated with respect to the average values of the explanatory variables employed when the first estimation equation was generated; and

in the fourth estimation equation generation section, the fourth estimation equation that estimates the derailment coefficient of the normal bogie on the normal curved section is generated by multiplying coefficients of the explanatory variables in the second estimation equation with the correction coefficients.

8. The derailment coefficient estimation device of claim 6 or claim 7, wherein at least one parameter among an inside derailment coefficient, a front axle left-right wheel load balance, or a rear axle left-right wheel load balance, is employed as the computation value.
9. The derailment coefficient estimation device of any one of claim 6 to claim 8, wherein the first estimation equation, the second estimation equation, the third estimation equation, and the fourth estimation equation are first order polynomial equations of the explanatory variables.
10. The derailment coefficient estimation device of any one of claim 6 to claim 9, wherein the derailment coefficient is a derailment coefficient of an outside wheel.
11. A program that estimates a derailment coefficient in a case in which a bogie provided to rolling stock is traveling on a curved section of track, the program causing a computer to execute processing comprising:

generating a first estimation equation that estimates a derailment coefficient of a monitoring bogie on a reference curved section of track installed with the measurement equipment, which can measure wheel load and lateral force, by performing multivariate analysis using input of results of measuring a wheel load and a lateral force of the monitoring bogie using the measurement equipment in a case in which the monitoring bogie, which can measure wheel load and lateral force, is traveling on the reference curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

generating a second estimation equation that estimates a derailment coefficient of a normal bogie on the reference curved section by performing multivariate analysis using input of results of measuring a wheel load and a lateral force of the normal bogie using the measurement equipment in a case in which the normal bogie, which cannot measure wheel load and lateral force, is traveling on the reference curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the normal bogie as explanatory variables;

generating a third estimation equation that estimates a derailment coefficient of the monitoring bogie on a normal curved section of track not installed with measurement equipment, which can measure wheel load and lateral force, by performing multivariate analysis using input of results of measuring a wheel load and a lateral force of the monitoring bogie using the monitoring bogie itself in a case in which the monitoring bogie, which can measure wheel load and lateral force, is traveling on the normal curved section, using a derailment coefficient computed from the measured wheel load and lateral force as an objective variable, and using at least a specific computation value that is computed from the measured wheel load and lateral force as well as a travel velocity of the monitoring bogie as explanatory variables;

generating correction coefficients for the explanatory variables in the second estimation equation based on coefficients of the explanatory variables in the first estimation equation, coefficients of the explanatory variables in the third estimation equation, values of the explanatory variables employed when the first estimation equation was generated, and values of the explanatory variables employed when the third estimation equation was generated;

generating a fourth estimation equation that estimates a derailment coefficient of the normal bogie on the normal curved section by taking account of the correction coefficients in the coefficients of the explanatory variables in the second estimation equation; and

estimating a derailment coefficient of the normal bogie on the normal curved section by using input of results of measuring the wheel load and the lateral force of the normal bogie using the measurement equipment in a case in which the normal bogie is traveling along the reference curved section, and inputting, into the fourth estimation equation, at least a specific computation value that is computed from the measured wheel load and lateral force as well as the travel velocity of the normal bogie.

FIG. 1

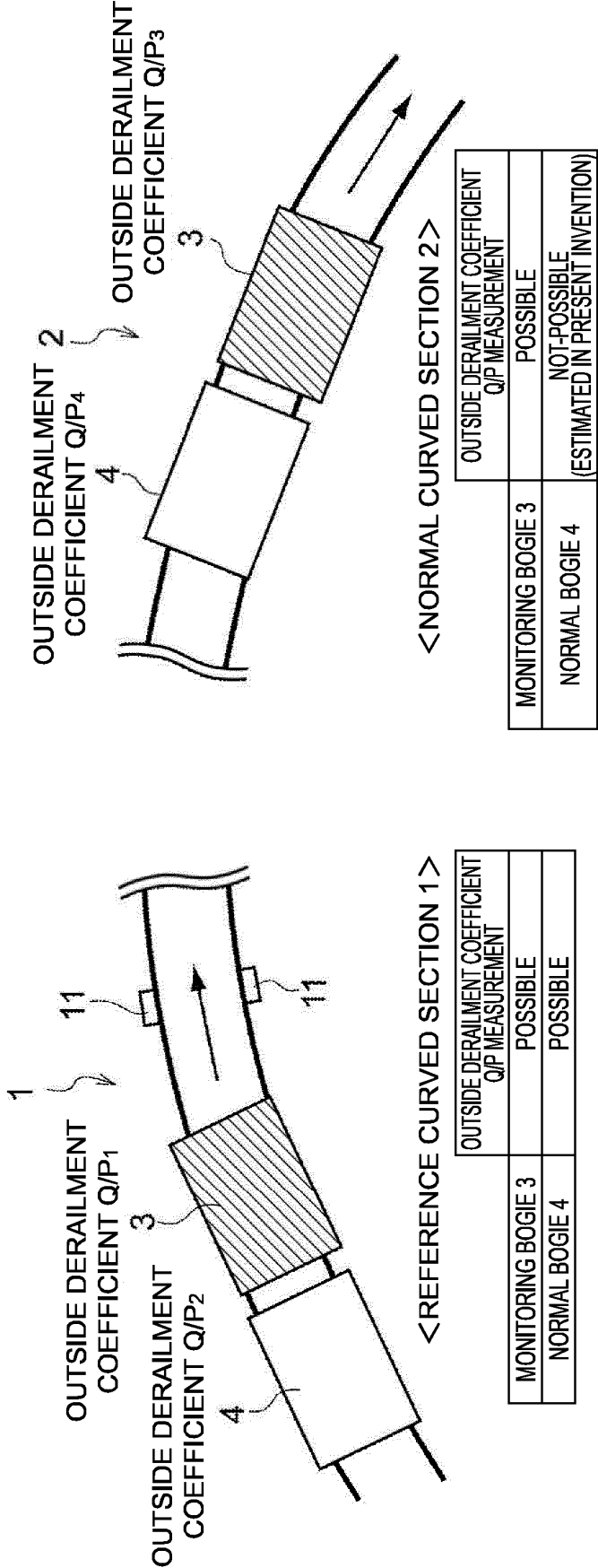


FIG. 2

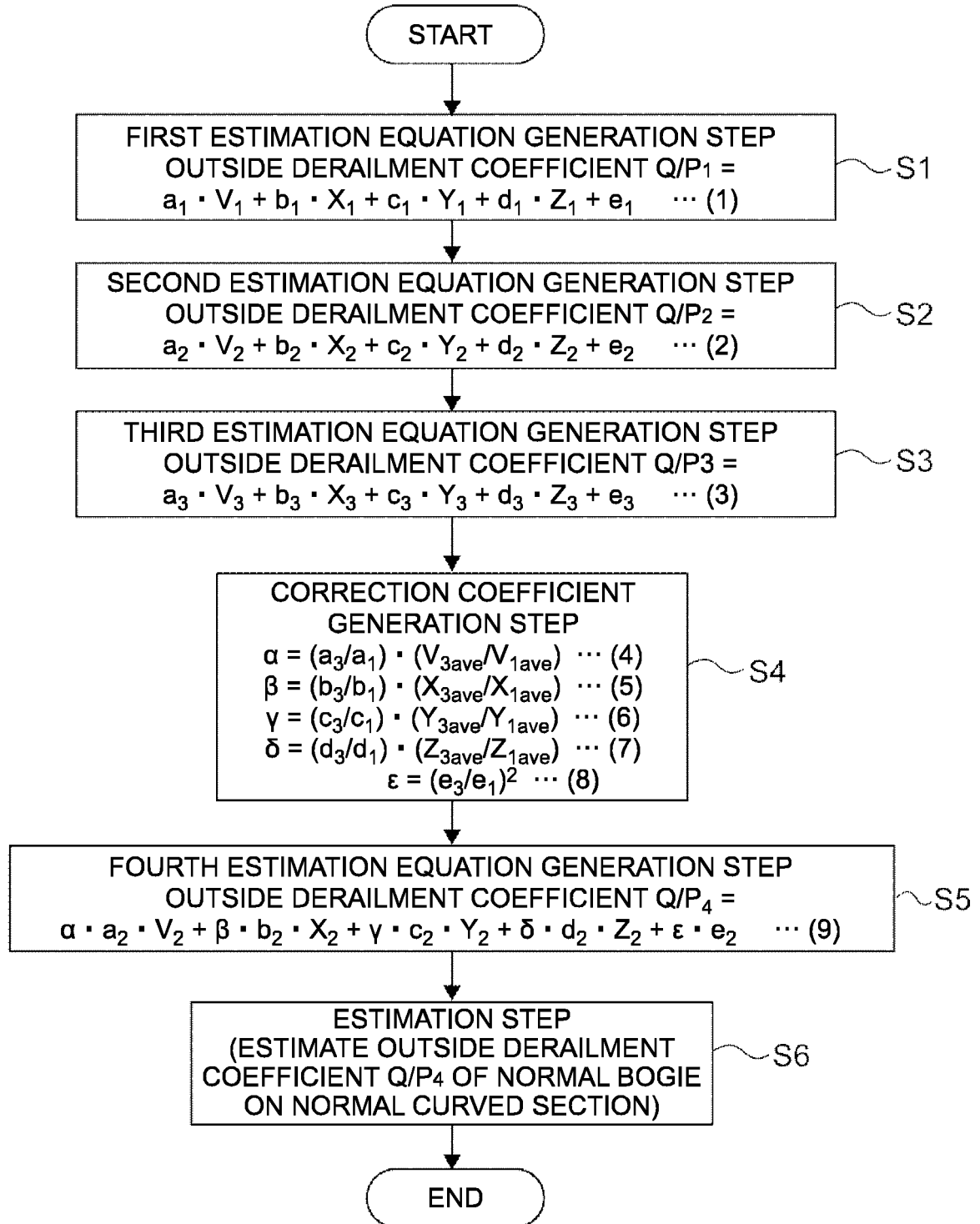


FIG. 3A

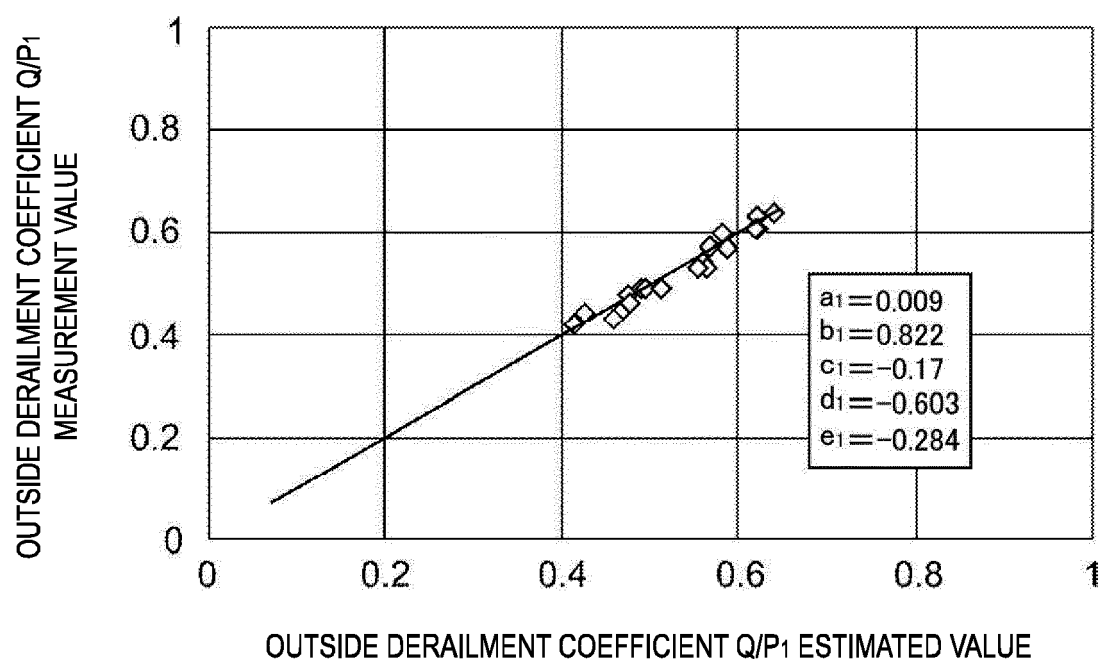


FIG. 3B

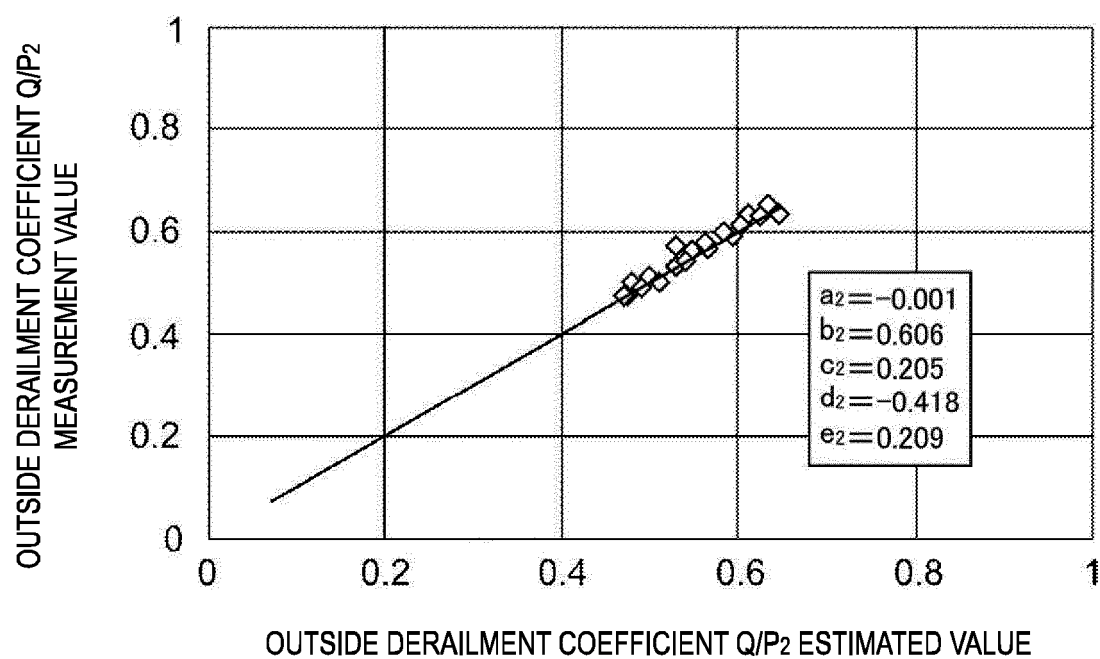


FIG. 4A

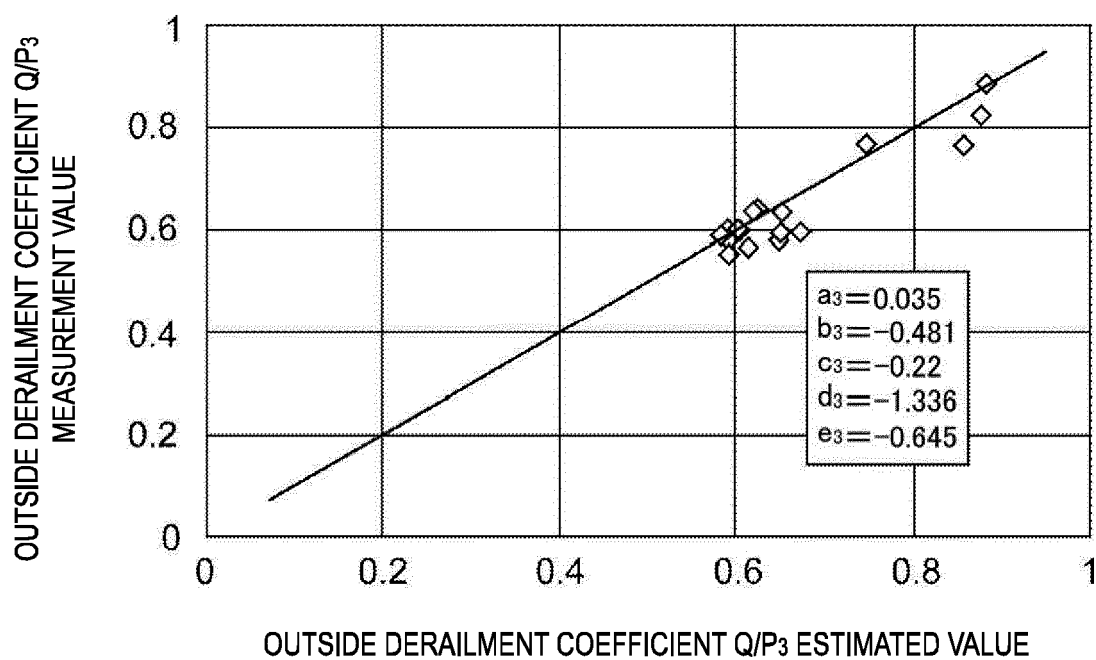


FIG. 4B

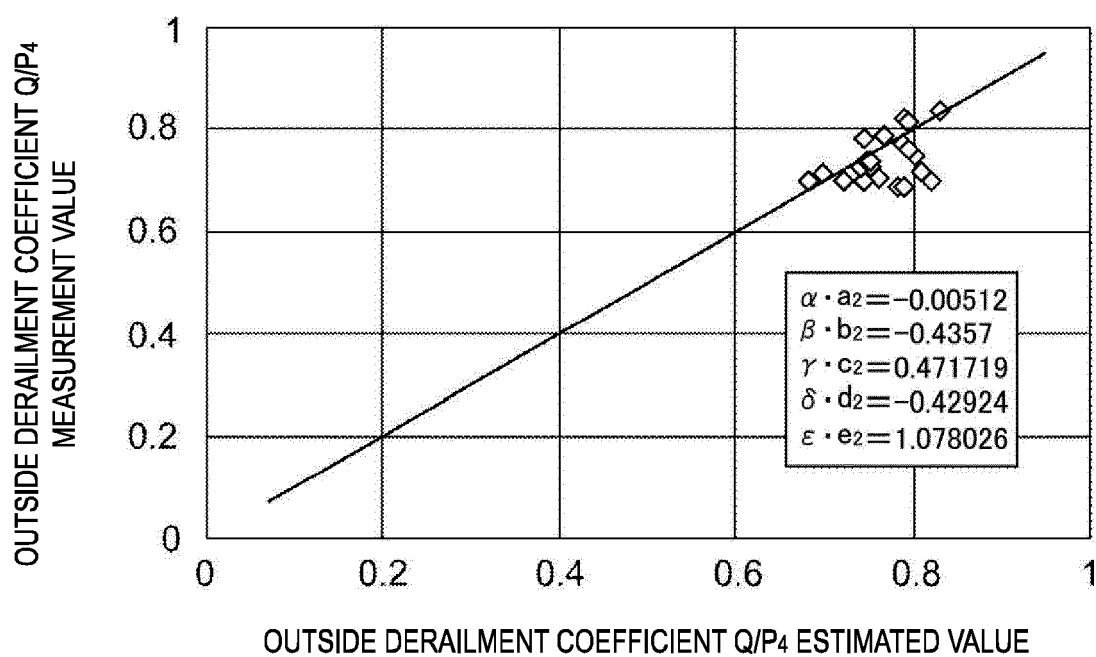


FIG. 5

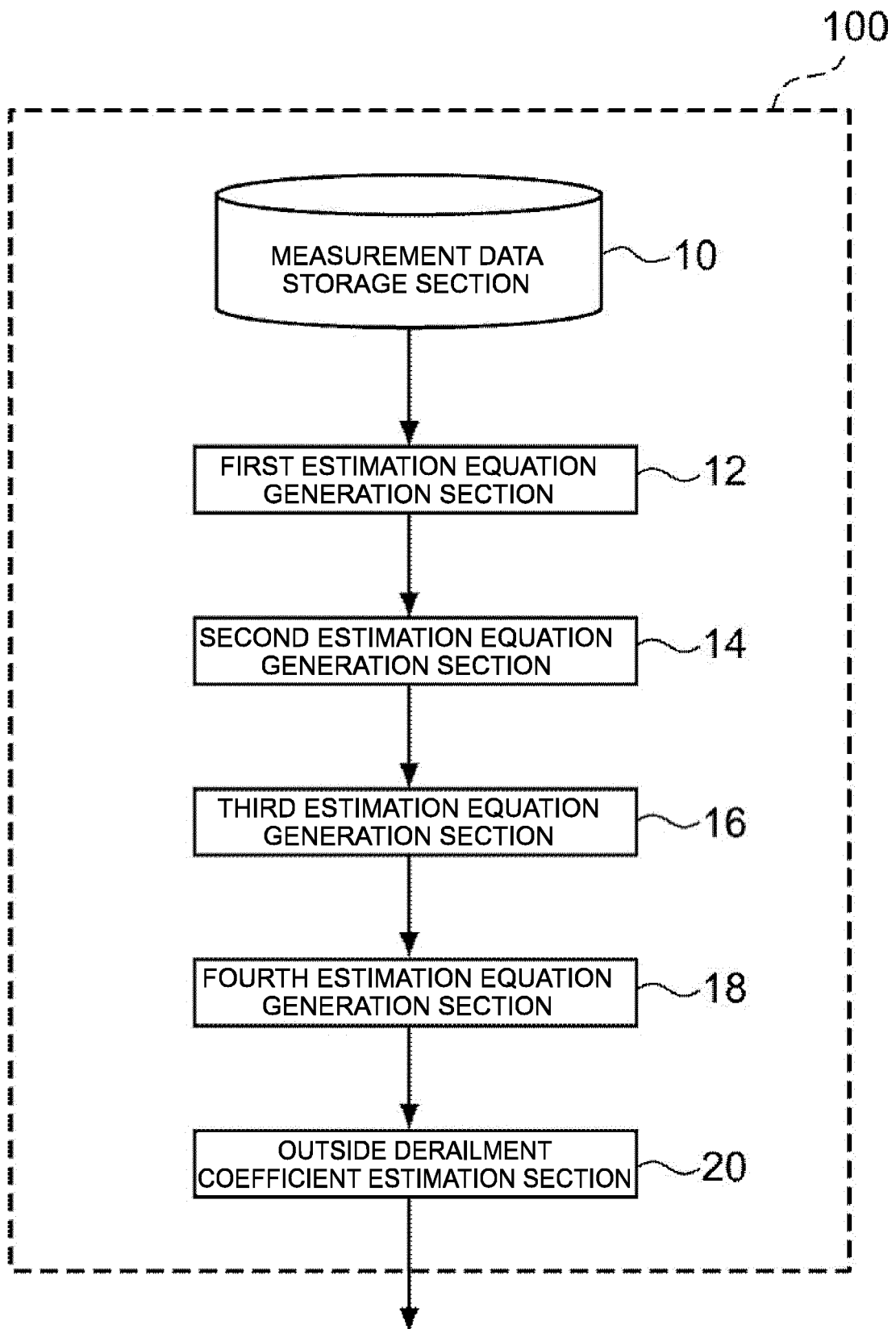
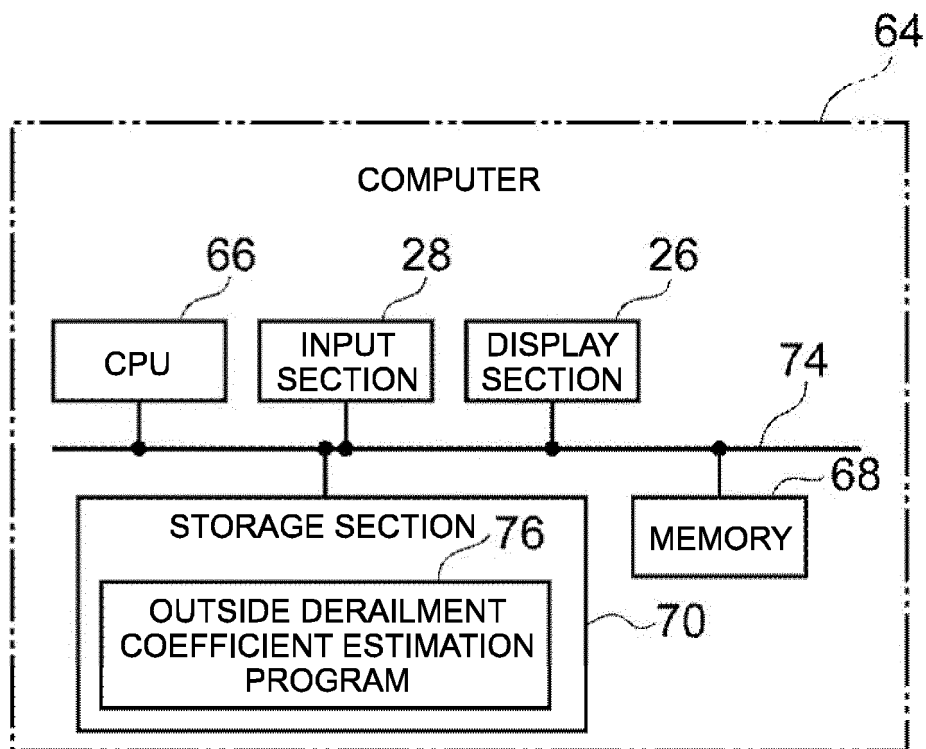


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/001357

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. B61K9/08 (2006.01) i, B61K13/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. B61K9/08, B61K13/00, B61F9/00, G01M17/08, G01L5/16, G01L5/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2019

Registered utility model specifications of Japan 1996-2019

Published registered utility model applications of Japan 1994-2019

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2013-121774 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 20 June 2013, entire text, all drawings (Family: none)	1-11
A	KR 10-2013-0013133 A (SEOUL NATIONAL UNIVERSITY OF TECHNOLOGY CENTER FOR INDUSTRY COLLABORATION) 06 February 2013, entire text, all drawings (Family: none)	1-11
A	JP 10-185666 A (UNYUSHO SENPAKU GIJUTSU KENKYUSHO) 14 July 1998, entire text, all drawings (Family: none)	1-11

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search

28.03.2019

Date of mailing of the international search report

09.04.2019

Name and mailing address of the ISA/

Japan Patent Office

3-4-3, Kasumigaseki, Chiyoda-ku,

Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/001357

5	C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
10	A	JP 2014-54881 A (KAWASAKI HEAVY IND LTD.) 27 March 2014, entire text, all drawings & US 2015/0247782 A1, entire text, all drawings & WO 2014/042123 A1 & TW 201425898 A & CN 104619571 A	1-11
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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H10185666 A [0004] [0037]
- JP 2014054881 A [0004] [0037]
- JP 2018011509 A [0086]