



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
20.11.2019 Bulletin 2019/47

(51) Int Cl.:
B61L 3/00 (2006.01)
B61L 27/00 (2006.01)
B61L 25/02 (2006.01)

(21) Application number: **18172150.7**

(22) Date of filing: **14.05.2018**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(54) **METHOD OF AND ARRANGEMENT FOR DETERMINING A VEHICLE SPEED RECOMMENDATION FOR OPERATING A RAILWAY VEHICLE**

(57) The invention relates to a method of determining a vehicle speed recommendation (SR) for operating a railway vehicle (4) comprising the following steps:
a) obtaining a first speed determination value (SD1) from an information transfer device (2) which is in particular arranged at least partly at a fixed position relative to the railway and determining a first speed value (S1) by using the first speed determination value (SD1),
b) obtaining a position value (PV) of a railway vehicle position by means of a position determination system;
c) determining a second speed determination value (SD2) from a data storage (7) by using the position value

(PV), wherein the data storage (7) contains position-dependent speed determination values, and determining a second speed value (S2) by using the second speed determination value (SD2), wherein the second speed determination value (SD2) and/or the second speed value (S2) depend(s) on expected and/or actual wear of the railway vehicle (4) and/or on passenger comfort of passengers within the railway vehicle (4);
d) outputting the vehicle speed recommendation (SR) as one of the first speed value (S1) and the second speed value (S2) according to a predetermined procedure.

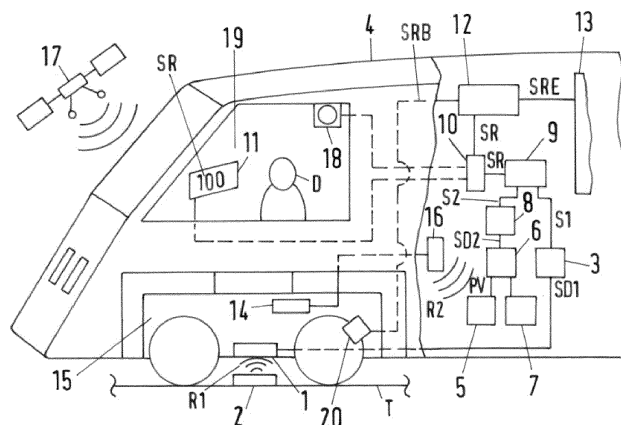


Fig.2

Description

[0001] The invention relates to a method of determining a vehicle speed recommendation for operating a railway vehicle and an arrangement for determining a vehicle speed recommendation for operating a railway vehicle.

[0002] It is beneficial to operate a railway vehicle at a maximum possible driving speed, so that the travel time for passengers and/or freight is reduced. A maximum speed of a railway vehicle which has to be observed during operation depends on several factors. Driving safety has to be kept on the required level. Speed limiting reasons can result from the technical characteristics of the railway vehicle and of the track on which the railway vehicle is traveling. Of course, speed limits set by a regulatory authority must not be exceeded. In addition, passenger comfort should be taken into account. Another issue relates to wear and fatigue of the railway vehicle and/or of one of its components.

[0003] Typically, a driver of the railway vehicle controls the speed of the railway vehicle. Additionally or alternatively, the speed of the railway vehicle can be recommended and/or observed and/or controlled by an auxiliary system or arrangement, in particular in order to assist the driver or an automatic drive system of the railway vehicle. Such an auxiliary system can be configured to check the speed of the railway vehicle during operation and to prevent an operation of the railway vehicle at a speed exceeding a recommended and/or permitted speed. In particular, speed reduction or emergency braking can be recommended or triggered by the auxiliary system, which can be considered as a vehicle protection system. Generally speaking, the auxiliary system may comprise a unit on board the vehicle and optionally also at least one unit outside of the vehicle, for example on the wayside of the track.

[0004] During operation of the auxiliary system information can be received from an information transfer device, which is arranged outside the railway vehicle, for example at a fixed position relative to the railway. By way of example, the use of balises which are arranged along the railway track is well known state of the art. Balises can be used to transmit a speed value or a speed determination value to the railway vehicle during operation. In particular, speed values and/or values that can be used to determine a speed value ("speed determination values") can be determined in advance with regard to general properties of the track section on which the vehicle drives. In particular, the value may correspond to the horizontal and/or vertical track curvature, the curve radius rate of change or the noises and vibrations at trackside caused by the railway vehicle when passing by. A speed determination value is any type of value which can be used to determine a speed value, particularly by calculation.

[0005] Balises can be arranged in a repetitive manner along a railway track. Each balise may be configured to

transmit a speed value and/or a speed determination value and/or a speed profile to the railway vehicle. The speed value and/or speed determination value and/or speed profile has been set to take into consideration the properties of a current or a subsequent track section. The local resolution of such a train protection system thus depends on the intervals between two subsequent balises and/or on intervals defined in the speed profiles.

[0006] Typically, the same railway track is used by different types of railway vehicles which comprise different driving capabilities. Such different driving capabilities result in different maximum speeds that also depend on the respective track section. To take advantage of different speed capabilities of the different types of railway vehicles, speed determination values transmitted to the railway vehicle can be interpreted on board with regard to the type of railway vehicle, for example by using speed classes, as explained hereinafter.

[0007] It is known that railway vehicles can be classified into speed classes. Such a speed class can be assigned to a railway vehicle. A speed class may, in particular, represent a maximum lateral plane track acceleration admissible in operation of the railway vehicle. By way of example, a high-speed railway vehicle comprising a tiltable car body can be classified in a higher speed class allowing a higher maximum lateral plane track acceleration than a freight train or a passenger train without a tiltable car body. From a speed determination value obtained by using the train protection system a speed value can be determined taking into account the speed class of the respective railway vehicle. A speed value obtained in this way can be, for example, multiplied by an in particular predetermined dimensionless factor with regard to the speed class of the respective railway vehicle. If the railway vehicle has high speed capabilities, the dimensionless factor can be high in comparison to a railway vehicle with low speed capabilities.

[0008] A railway vehicle may be able to travel at a certain maximum speed on a particular track or track section with regard to driving safety. Considering passenger comfort and/or expected or actual wear of the railway vehicle and/or of one of its components, traveling at the maximum speed may have unfavourable effects, especially when traveling on track sections which comprise curves and/or inclinations and/or superelevations. By way of example, traveling at the maximum speed may lead to significantly increased mechanical abrasion on wheels and/or bogies and/or wheel bearings and/or increased lateral accelerations negatively affecting the passengers when traveling through such a track section. Similarly, traveling at the maximum speed may cause values of the jerk (the first derivative of the acceleration with respect to time) which negatively affects passenger comfort.

[0009] Therefore, a railway vehicle may be able to travel at a certain maximum speed on a particular track or track section with regard to wear of the railway vehicle and/or passenger comfort. Concerning driving safety, the

railway vehicle may be able to travel at a higher maximum speed at the expense of the wear of the railway vehicle and/or the passenger comfort.

[0010] In some cases, the classification of railway vehicles into speed classes may lead to the consequence, that the specific speed capabilities of a specific type of railway vehicle are not fully exploited in operation, since the same speed class is commonly assigned to different types of railway vehicles. On the other hand, a railway vehicle may be classified into a high speed class, which ensures safe operation on a track section but leads to an unacceptable level of actual and/or expected wear of the railway vehicle and/or one of its components or to low passenger comfort. The reason may be high lateral accelerations, in particular when driving on curved track sections.

[0011] The speed capability of a railway vehicle on a certain track section with respect to passenger comfort is typically different from the speed capability with respect to expected or actual wear. Traveling on a track section at a certain speed may be acceptable with respect to actual or expected wear but still may be unacceptable with respect to passenger comfort.

[0012] GB 2 406 395 A discloses a rail vehicle comprising a speed controller and an accelerometer, the accelerometer being arranged to detect lateral acceleration of the rail vehicle and to provide a signal indicative of the lateral acceleration to the speed controller, the speed controller controlling the speed of the rail vehicle in response to the signal.

[0013] US 2007/0233364 A1 discloses a system for operating a vehicle including an engine operating on at least one type of fuel is provided. The system includes a locator element to determine a location of the vehicle, a characterization element to provide information about a terrain of the vehicle, a database to store characteristic information for each type of fuel, and a processor operable to receive information from the locator element, the characterization element, and the database. An algorithm is embodied within the processor with access to the information for creating a trip plan that optimizes performance of the vehicle in accordance with one or more operational criteria for the vehicle.

[0014] DE 10 2011 103 679 A1 discloses a method, which involves loading physical properties of a rail vehicle in a control unit, where the rail vehicle forms a train unit. A costing model is selected for calculating a desired speed profile based on traction of the rail vehicle. A target speed profile is calculated for a route to be traveled, and a travel instruction is updated while driving with respect to current position and speed of the rail vehicle and data that is stored in data memory.

[0015] DE 100 18 083 A1 discloses a system that has a device for manual entry of a first vehicle speed demand, an automatic controller for automatically determining a second vehicle speed demand according to a boundary condition stored in a memory device and an inference system that determines the lower speed demand and

outputs it as the demanded speed to a speed governor for regulating the vehicle speed.

[0016] It is an object of the present invention to provide a method of and an arrangement for determining a vehicle speed recommendation for operating a railway vehicle that improve the speed recommendation of systems which are based on the transfer of speed determination values from the wayside to the vehicle and, in particular, are based on speed classes.

[0017] When determining the vehicle speed recommendation, it is proposed to take into account information that is available on board the vehicle. In particular, the information can be stored in a data storage which is preferably located on board. In particular, this information can relate to the speed capability of the railway vehicle with respect to safety, passenger comfort and/or wear. In addition it is proposed to consider the location of the vehicle and, thereby, the track section for which the speed recommendation is to be determined. This allows for considering the location of the vehicle when retrieving and/or using the information, in particular from the data storage. In particular, the information within the data storage relates to different track sections and, therefore, to different vehicle locations. In this case, the part of the information can be retrieved from the data storage which relates to the actual vehicle position obtained by a position determination system. In addition or alternatively, the information which is retrieved from the data storage may be processed depending on the actual vehicle position.

[0018] Existing ways of transferring information about speed limits from the wayside to the vehicle, in particular those based on speed classes, can be combined with the solution according to the present invention.

[0019] According to the invention, information on board the vehicle is used in order to determine the vehicle speed recommendation for a predetermined track section which is in particular a recommendation for the maximum speed on the predetermined track section. This improves in particular the determination of a vehicle speed recommendation of existing systems which are based on different types of vehicles being classified in the same speed class. With on board information, the arrangement within the respective vehicle can differentiate the uniform vehicle speed class.

[0020] In particular, a method of determining a vehicle speed recommendation for operating a railway vehicle is proposed. The method comprises the following steps:

a) receiving a first speed determination value from an information transfer device, which can be arranged in particular at least partly at a fixed position relative to the railway, and determining a first speed value by using the first speed determination value,

b) obtaining a position value of a railway vehicle position by means of a position determination system;

c) determining a second speed determination value from a data storage by using the position value, wherein the data storage contains position-dependent speed determination values, and determining a second speed value by using the second speed determination value, wherein the second speed determination value and/or the second speed value depend(s) on expected and/or actual wear of the railway vehicle and/or on passenger comfort of passengers within the railway vehicle;

d) outputting the vehicle speed recommendation as one of the first speed value and the second speed value according to a predetermined procedure.

[0021] Steps a), b) and c) can be performed in arbitrary order one after each other and/or at least partially parallel to each other. In particular, all steps a) to d) are repeatedly performed, for example in periodic cycles or every time when a first speed determination value is received by the vehicle.

[0022] Each of the first and second speed determination value can be a speed value (e.g. a numerical value, for example in km/h, m/s or mph) or can be a value, based on which a speed value can be determined and/or calculated. A speed determination value can also be any kind of value, for example a letter or a number, a combination of a letter and a number or a binary code, based on which a speed value can be determined.

[0023] The information transfer device mentioned in step a) may be any kind of device capable of transferring information from the wayside to the vehicle, such as a balise, a plurality of balises and/or a part of an electric and/or magnetic system and/or an inductive system and/or a coded track circuit-based system and/or a transponder based system and/or a radio-based system and/or a wireless signaling system. The information transfer device may be a part of a train protection system known in the art.

[0024] The information transfer device or the part of the information transfer device, which is arranged at a fixed position relative to the railway, can be arranged close to the railway and/or arranged below and/or between its rails. It can also be arranged at a distance to the rails, particularly in case of a wireless signaling system or a radio-based system.

[0025] A plurality of such devices or parts can be arranged along a railway track. In particular, in each case at least one information transfer device (or part of) may be arranged at a plurality of different track sections of the railway track, for example at a distance or close to the entry of the track section, so that the first speed determination value can be transmitted to the traveling railway vehicle before it enters the track section.

[0026] However, it is not necessarily required that the first speed determination value is transferred from the wayside to the vehicle. Rather, the second speed determination value can be determined outside of the railway.

In this case, the information transfer device is adapted to transfer the first speed determination value to a processing unit outside of the railway vehicle and the processing unit determines the second speed determination value. This processing unit receives the obtained position value from the position determination system, which can be located on board the vehicle or outside the vehicle.

[0027] Then, the second speed determination value can be processed by a processing unit within or outside of the railway vehicle so that the second speed value is determined.

[0028] Furthermore, based on the first speed value and based on the second speed value, a processing unit within or outside of the railway vehicle can output the vehicle speed recommendation. In particular, if the vehicle speed recommendation is output by a processing unit outside of the railway vehicle, the vehicle speed recommendation can be transferred to the railway vehicle. More particularly, the output of the vehicle speed recommendation which is based on the second speed value may be performed only if required, i.e. if the second speed value is the vehicle speed recommendation. Optionally, it can be determined before the second speed determination value is determined if this determination is required or is likely to be required, i.e. if it is likely or expected that the second speed value will be output as the vehicle speed recommendation.

[0029] The first speed determination value, as explained above, can be any kind of value to which a certain speed value can be associated, for example by using a calculation rule or a lookup-table. If the first speed determination value is a speed value by itself, further processing of the speed value may not be necessary and the first speed determination value can be taken as the first speed value. Alternatively, the first speed determination value may be processed in order to obtain the first speed value. The processing may differ depending on the speed class of the vehicle. For all vehicles within the same speed class, the same processing of the first speed determination value may be performed and, therefore, the same speed value is obtained. For example, the processing may comprise or consist of a multiplication of the speed determination value with an in particular dimensionless factor. In addition or alternatively, the processing may comprise adding or subtracting a certain amount of speed to/from the first speed determination value to obtain the first speed value.

[0030] In particular, the first speed determination value may have been defined based on properties, which are in particular safety-related, of the railway vehicle and/or of the respective track section. Therefore, by using the first speed determination value, safety-related parameters may be taken into account. In addition or alternatively, it may be based on regulations and/or legal specifications.

[0031] As mentioned above, the first speed determination value can be defined as a value being valid for a

first speed class of vehicles, in particular for the speed class with the lowest first speed value of all speed classes. In this case, the first speed value is obtained on board of the vehicle by increasing the speed determination value, if the vehicle is assigned to a speed class that is not the first speed class. Consequently, the information about the speed class of the vehicle is available on board the vehicle

[0032] A first speed determination value which is assigned to a low or the lowest available speed class and which is a speed value can be called "base speed". Alternatively or additionally, a first speed determination value can be or comprise an information concerning an applicability of a higher speed class. For example, a first speed determination value can comprise a base speed of a track section and an additional information which specifies if an enhanced speed according to a higher speed class is admissible on the track section. The first speed determination value may also be a speed value and the additional information may be a separate additional value, which is obtained separately from the information transfer device or a further information transfer device.

[0033] A speed class can for example be predefined or set by the driver according to the railway vehicle. If for example the first speed determination value is a base speed of a track section and a separate additional value specifies that an enhanced speed is allowed, the base speed may be multiplied by a dimensionless factor according to the speed class predefined or set by the driver in order to obtain the first speed value.

[0034] In particular, the additional value may have been defined based on properties, which are in particular safety-related, of the railway vehicle and/or of the respective track section. Therefore, by using the additional value, safety-related parameters can be taken into account. In addition or alternatively, it may be based on regulations and/or legal specifications.

[0035] In general, "safety" may relate to several aspects, in particular to de-railing, structural integrity of the rail vehicle and/or of the track and the capability of stopping the vehicle within prescribed and/or desired time and/or distance.

[0036] A first speed determination value, an additional value and a speed class of the railway vehicle may be defined particularly in advance of a commissioning of the railway vehicle and/or using the railway vehicle and/or an opening of the railway and/or using the railway. A first speed determination value for example may correspond to a critical value of lateral acceleration or to a critical value of cant deficiency. The cant deficiency is an important item to be considered with respect to safety. By observing such a critical value, it is particularly ensured that the railway vehicle does not derail when driving through curves. Of course, a maximum speed or a maximum admissible speed of the railway vehicle, which can or must not be surpassed, also has to be taken into account.

[0037] Speed classes can for example be defined by

admissible values of lateral plane track acceleration. By way of illustration, speed class "A" may correspond to a maximum lateral plane track acceleration of 0.65 m/s^2 , speed class "B" may correspond to a maximum lateral plane track acceleration of 1.00 m/s^2 , speed class "C" may correspond to a maximum lateral plane track acceleration of 1.20 m/s^2 . The highest speed class "S" may correspond to a maximum lateral plane track acceleration of 1.60 m/s^2 .

[0038] As already explained, according to the speed class of the railway vehicle, a dimensionless factor can be set by which a first speed determination value, which is a base speed, is multiplied to obtain a first speed value. This leads to rising dimensionless factors corresponding to speed classes A to S. For example, the dimensionless factor corresponding to the slowest speed class A can be the value 1, whereas the dimensionless factor corresponding to the fastest speed class "S" can be the value 1.3. The dimensionless factors corresponding to the speed classes B and C then are situated in between the dimensionless factors of classes A and S.

[0039] In step b), a position value of a current railway vehicle position is obtained from a position determination system. The position determination system may be a global navigation satellite system (GNSS). Alternatively or additionally, it may be an odometer measuring the distance covered by the railway vehicle on a known railway track, wherein the start of a measuring distance can be a fixed reference position on the railway track. The position determination system may for example comprise wayside arranged devices each of which transmitting and/or indicating a position determination signal to a receiving unit of the position determination system.

[0040] The position value can be a set of coordinates and/or a value indicating the traveled distance. Particularly, if the position determination system is a global navigation satellite system, the local resolution of the position determination system along a track can be high, for example less than 20 meters, so that a quasi-continuous position determination is possible. As mentioned above, the position determination system can alternatively or additionally be based on wayside arranged devices and/or an odometer measuring the distance covered by the railway vehicle. In these cases, the maximum local resolution of the position determination system may still be comparatively high, but limited particularly by the accuracy of the measurements of the odometer.

[0041] In step c) a second speed determination value is determined from the data storage, wherein the data storage contains position-dependent speed determination values. Since a current position of the railway vehicle is known from the position determination system, the second speed determination value can be a position-dependent speed determination value.

[0042] The data storage particularly can be any kind of read-only memory or random access memory or hard disk or memory chip. Particularly, it can comprise a database containing second position-dependent speed de-

termination values, each of which applicable to determine a second speed value. The second speed determination value contained in the data storage can be predefined by considering the aspects of passenger comfort and/or wear of the railway vehicle, particularly with regard to curved track sections. If the second speed determination value from the data storage is predefined in a way that it does not depend on the aspects of wear and/or passenger comfort, the second speed value is determined in a way that it depends on at least one of the aforesaid aspects. Also, both of the second speed determination value and the second speed value may have been predefined/determined in a way that they take into account at least one of the aforesaid aspects.

[0043] Passenger comfort is an aspect which is subjectively experienced and which depends to a great extent on physical quantities. Concerning passenger comfort of railway vehicles, particularly acceleration and jerk are relevant. Low values of both quantities are desirable for high passenger comfort, particularly with regard to curved track sections.

[0044] Wear of the railway vehicle is as well related to physical quantities. Lateral acceleration and jerk and correspondingly occurring forces and/or stresses and/or strains are particularly relevant, particularly concerning fatigue, for example at the bogies. Furthermore, mechanical abrasion can be caused, for example at the frictional contact between wheel and rail, at wheel bearings and/or at a suspension system (i. e. bogie, spring elements, damping elements), as well as crack initiation and crack propagation, for example at the aforementioned parts. Low values of the mentioned quantities are desirable for low wear, especially in curved track sections.

[0045] Second speed determination values/second speed values can be predefined/determined by considering not only the curvature of the track, but also further track conditions, for example the smoothness of the track and the rails, irregularities of the track, expected or measured values of trackside noises and vibrations occurring when the railway vehicle is passing by, different expected loading conditions of the railway vehicle and superelevations of the track. Besides the conditions of the track and the environment, the properties of the railway vehicle can be taken into account, particularly with regard to wear and passenger comfort. This may refer to constructional aspects related to wear and passenger comfort, for example properties of a suspension system of the railway vehicle, the stiffness of a car body of the railway vehicle and/or driving characteristics of a bogie of the railway vehicle and/or the question whether the railway vehicle comprises a tiltable car body or not. Of course, a maximum speed and/or a maximum admissible speed of the railway vehicle which cannot and/or must not be surpassed also has/have to be taken into account.

[0046] Measurements, particularly long time measurements, of lateral forces and/or lateral accelerations and/or stresses and/or strains occurring on the railway vehicle and the corresponding speed values during op-

eration can be used to define second speed determination values/determine second speed values. With the aid of such measurements, relations between speed values and comfort and/or wear can be evaluated and advantageous speed values to be used henceforth can be determined. Additionally, estimations of the remaining lifetime of components of the railway vehicle exposed to fatigue and/or abrasion can be carried out. This is described in detail below.

[0047] The data storage can be arranged on board the railway vehicle. This can be advantageous, since it allows for a simple implementation of the proposed method.

[0048] In step c) a second speed value is determined by using the second speed determination value. For example the data storage may comprise second speed values in a database each of which corresponds to a second speed determination value. Also, the use of a calculation method is possible to determine the second speed value. As described above, the second speed value can be determined depending on expected and/or actual wear of the railway vehicle and/or depends on passenger comfort. That is, the second speed value and/or a determination method of the second speed value can be determined with regard to the railway vehicle and the track and/or the track section it is driving on, since wear and passenger comfort depend on the properties of both the railway track and the railway vehicle, as further explained below.

[0049] By way of example, a railway vehicle can be classified in a high speed class, for example the fastest speed class "S", by default. Such a speed class may be reserved for railway vehicles with tiltable car body. Generally, railway vehicles with tiltable car body can achieve comparatively high speeds in curved track sections. Nevertheless, a railway vehicle without tiltable car body also can be configured so that it can be operated in the fastest speed class "S". That means, it is constructed to operate at speeds provided in the highest speed class in straight or nearly straight track sections but also in curved track sections with regard to driving safety.

[0050] Concerning passenger comfort and wear, an operation in the fastest speed class "S" could be disadvantageous, resulting in unacceptably high wear, particularly in curved track sections, and unacceptably low passenger comfort, particularly concerning high values of lateral acceleration and jerk in curved track sections.

[0051] To avoid such negative effects, second speed values can be determined and used for curved track sections, which second speed values are lower than the first speed values for the corresponding track sections. This allows for operating the railway vehicle at acceptable speeds regarding safety, passenger comfort and wear in curved track sections and operating the railway vehicle at acceptable speeds regarding safety in straight or nearly straight track sections, since wear generally is comparatively low and passenger comfort generally is typically comparatively high in straight or nearly straight track sections. Such an adjustment of the railway vehicle

speed on a track is not possible when using only first speed values.

[0052] In particular, there may be comparatively long track sections for which only one first speed value is available and/or exists. In this case, it is preferred to update the second speed values continuously or repeatedly.

[0053] Generally, second speed values can be determined and/or used for all of the track sections of a train route. Alternatively, second speed values can be determined and/or used only for one or a plurality of track sections, but not for all track sections. Second speed values are preferably determined and/or used for track sections, for which it can be expected and/or is known that the first speed value is not sufficient and/or not appropriate. This may be the case, for example, in long track sections, in curved track sections and/or track sections with curved and straight parts.

[0054] Track sections for which first speed values are too high regarding wear and passenger comfort can be track sections with inclinations and/or superelevations and/or other characteristics reducing passenger comfort and/or increasing wear, for example track sections in which the underground the rails are laying on is rough or in which a railway switch is installed.

[0055] By way of example, a railway vehicle can be classified in a low or medium speed class, for example speed class "C", by default. Such a speed class may include railway vehicles without a tiltable car body. Generally, railway vehicles without a tiltable car body can only be operated at lower speeds in curved track sections than railway vehicles with a tiltable car body. Nevertheless, a railway vehicle without tiltable car body also can be configured so that it can be operated at higher speeds than the speeds permitted according to speed class "C" with regard to driving safety. For example, the railway vehicle can be operated in the fastest speed class "S" with regard to driving safety.

[0056] Concerning passenger comfort and wear, an operation in the fastest speed class "S" can be disadvantageous concerning curved track sections, resulting in unacceptably high wear and unacceptably low passenger comfort, particularly causing high values of lateral acceleration and jerk in curved track sections. An operation in speed class "C" could as well be disadvantageous, since speeds permitted in speed class "C" do not exploit the speed capabilities of the railway vehicle.

[0057] To avoid such negative effects, second speed values can be determined for curved track sections, which are higher than the first speed values for the corresponding track sections. This allows for operating the railway vehicle at acceptable speeds regarding passenger comfort and wear in curved track sections and operating the railway vehicle at acceptable speeds regarding safety in straight or nearly straight track sections. Such an adjustment of the railway vehicle speed on a track is not possible when using only first speed values.

[0058] In step d), the vehicle speed recommendation is output according to a predetermined procedure. The

predetermined procedure can comprise a determination of the minimum of the first speed value and the second speed value. A comparison of both values is carried out and the minimum is output as a vehicle speed recommendation so that it can be used to adjust the current speed of the railway vehicle. This implies, that the proposed method can be carried out concerning a certain track section before the railway vehicle reaches it. If a track section for example requires a low vehicle speed due to its properties, the current speed of the railway vehicle already has to be adjusted before the railway vehicle enters the track section.

[0059] The speed recommendation can be output to the driver and/or to a control system of the railway vehicle, which is configured to adjust the current speed considering the speed recommendation. This is explained in more detail below.

[0060] It is an advantage of the present invention that it is implementable together with an existing speed control system, particularly a train protection system, which can be failsafe. A failsafe train protection system, as already explained above, is a common system used generally in modern rail transport. In case of a malfunction or a human error or a system breakdown, a reduction of speed and/or an emergency stop can be triggered automatically. The failsafe operation of a train protection system allows for combining it with the proposed method for determining a vehicle speed recommendation, wherein the method does not have to be failsafe or implemented in a failsafe way. This is advantageous, since it allows for a simple and cost-effective implementation of the method. In case of a failure or a malfunction of the proposed method, the current speed of the railway vehicle is regulated by the failsafe train protection system which ensures an operation of the railway vehicle generally at a safe driving speed. That means with respect to the above-mentioned example that the driving speed could increase generally or in certain track sections, particularly curved track sections, at the expense of wear and passenger comfort.

[0061] Additionally, longtime measurements of lateral forces and/or lateral accelerations and/or stresses and/or strains occurring at the railway vehicle and the corresponding speed values during operation can be used to monitor such events of a failure or a malfunction, so that the effect on wear of the railway vehicle and/or of one of its components and/or of the railway can be examined.

[0062] If an automatic train control system which is based on the first speed values includes emergency braking in case of the vehicle exceeding the first speed value and/or if exceeding the first speed value is generally prohibited or prevented, the second speed value can only be used to limit the vehicle speed to a lower maximum value. In case of a failure or a malfunction of the proposed method, the current speed of the railway vehicle is regulated by the failsafe train protection system which ensures an operation of the railway vehicle generally at a safe driving speed.

[0063] In a further embodiment of the invention, the first speed value is determined in step a) by using the first speed determination value (SD1) and by applying a predetermined vehicle speed augmentation rule that depends on a type of the railway vehicle.

[0064] The first speed determination value particularly can be a value taking into account the properties of the corresponding track section but not the properties of the railway vehicle. By this means, the information transfer device and/or a part of the information transfer device, which is arranged at a fixed position relative to the railway, for example a balise, from which the first speed determination value is obtained, only needs to provide a very limited amount of information. This allows for a simple implementation of the information transfer device.

[0065] It is then advantageous to determine the first speed value with regard to the type of the railway vehicle, since the speed capabilities of the railway vehicle shall be exploited in operation. In order to achieve this, the predetermined vehicle speed augmentation rule is applied. The augmentation rule can comprise a classification of the railway vehicle in a speed class. The railway vehicle can be classified according to its speed capabilities, which are related to constructional aspects of the railway vehicle. Particularly, the augmentation rule may comprise a dimensionless factor, particularly a dimensionless factor which depends on a speed class assigned to the railway vehicle. Such a dimensionless factor can be used as a multiplication factor for a base speed to obtain the first speed value. Particularly, the dimensionless factor may have a value higher than 1, for example 1.30 in case of the highest speed class "S" as explained above.

[0066] Alternatively or additionally, the first speed value can be determined by using the first speed determination value and a speed profile as a vehicle speed augmentation rule, which has been defined with regard to the type of the railway vehicle and/or the track section on which the railway vehicle is driving. Such a speed profile can comprise individual augmentations of the speeds which are determined using the first speed determination value. A speed profile can be realized for example as a lookup-table and/or a calculation rule.

[0067] In a further embodiment of the invention, the vehicle speed recommendation is output, when the railway vehicle approaches and/or enters and/or passes through a track section in which a maximum speed has to be observed. By this, the current speed of the railway vehicle can be adjusted in time, so that it is in accordance with the vehicle speed recommendation when approaching and/or entering and/or passing through the track section. This aspect is particularly important when the railway vehicle enters a second track section coming from a first track section, wherein both track sections comprise different vehicle speed recommendations. By way of example, the vehicle speed recommendation of a straight and flat track section may be a higher value than the vehicle speed recommendation of a subsequent track

section comprising a sharp curve. In this case, a speed reduction has to be initiated and completed before entering the second track section and/or before entering the curve.

[0068] Additionally or alternatively, the vehicle speed recommendation can be output when entering and/or passing through the track section. This is advantageous, since the driver and/or the control system may require the current speed recommendation value also after entering the track section. On the one hand, the driver may want to verify, that he/she set the current speed in accordance with the vehicle speed recommendation. On the other hand, the control system may require the current speed recommendation value to check the current speed permanently. Since the local resolution of second speed values can be high as explained above, it is possible, that the vehicle speed recommendation changes within a track section, which comprises only one information transfer device or only one part of an information transfer device.

[0069] The described embodiment of the method enables the driver and/or the control system to adjust the current speed before and when passing through a track section. Due to the potentially high local resolution of the second speed value, the current speed may be adjustable in quick succession. This way, it is taken advantage of the speed capabilities of the railway vehicle in a precise and comprehensive way.

[0070] In a further embodiment of the invention, the track section is a curved track section. A curved track section particularly requires a vehicle speed recommendation, which takes into account the properties of the railway vehicle and the track section. In a curved track section, the speed capability of the railway vehicle concerning safety may differ significantly from the speed capability concerning passenger comfort or the speed capability concerning wear of the railway vehicle. Since the first speed value may only consider safety, but not passenger comfort and wear, the first speed value may be disadvantageous concerning these latter aspects with regard to the curved track section. Therefore, the second speed value is of high importance considering curved track sections.

[0071] This may particularly apply to a railway vehicle which is classified in a high speed class, for example "S", even though the car body is not tiltable. Even if a safe operation in curves is made sure, speeds in curves can be disadvantageous concerning wear and passenger comfort when operating in speed class "S". It is therefore beneficial to take into account the second speed value by means of the vehicle speed recommendation. This may lead to second speed values and speed recommendations which are lower than first speed values of class "S" but still higher than first speed values of class "C", which is the speed class below class "S".

[0072] Concerning a railway vehicle classified in a low or medium speed class, for example speed class "C", which could be operated in a higher speed class, for ex-

ample "S" with regard to driving safety, an operation in the higher speed class could be disadvantageous concerning passenger comfort and wear. It is therefore beneficial to take into account the second speed value by means of the vehicle speed recommendation. This may lead to second speed values and speed recommendations which are higher than first speed values of class "C" and lower than first speed values of class "S".

[0073] In a further embodiment of the invention, the vehicle speed recommendation and/or an intermediate value derived from the first speed determination value and/or from the position value is output to a driver of the railway vehicle by means of an indication device and/or the vehicle speed recommendation is output to a control unit of the train, which adjusts the current speed of the railway vehicle with regard to the vehicle speed recommendation. Instead or in addition to the output of the intermediate value derived from the first speed determination value and/or from the position value to the driver or to the control unit of the train, the vehicle speed recommendation and/or the intermediate value can be output to a control device outside of the railway vehicle, for example using an indication device in a control room. In this manner, another member of the staff can take notice of the vehicle speed recommendation. This means, that the vehicle speed recommendation could be determined outside of the rail vehicle based on the intermediate value.

[0074] The indication device can be a display which is arranged in front of the driver. In particular, it can be an ERTMS display, wherein "ERTMS" means "European Rail Traffic Management System". Alternatively, the indication device can be a device outputting an acoustic signal, for example a loudspeaker, or can be a force-feedback appliance outputting a tactile feedback, for example a vibration. The vehicle speed recommendation may not be output by itself, but a warning signal, possibly indicating a current speed which exceeds the speed recommendation or is significantly lower than the speed recommendation. A warning signal can also be output by another kind of indication device.

[0075] An output of the vehicle speed recommendation to the driver may be present permanently during driving. A corresponding warning signal may be triggered only in situations, in which the vehicle speed recommendation is reached and/or exceeded or is about to be reached and/or exceeded. Such a situation may occur primarily, if the railway vehicle is about to reach a track section in which a maximum speed has to be observed.

[0076] An output to a control unit of the train may be beneficial to avoid human failure concerning the adjustment of the current speed considering the vehicle speed recommendation. If a train driver does not react, the control unit may adjust the current speed automatically. Also, if no reaction of the driver is detected within a certain time period, an emergency braking may be triggered by the control unit. Alternatively and/or additionally, the output to the control unit and an automatic adjustment of the

current speed can support and/or relieve the driver.

[0077] In a further embodiment of the invention, a current acceleration value and/or a current force value and/or a current stress value and/or a current strain value of the railway vehicle is/are calculated and/or measured and the current acceleration value and/or the current force value and/or the current stress value and/or the current strain value of the railway vehicle is/are logged by a log system.

[0078] The measurement of at least one of the mentioned physical quantities can be performed by at least one sensor, for example an accelerometer and/or a force sensor and/or a strain gauge. The at least one sensor can be placed at a position and/or a component of the railway vehicle on which at least one of the physical quantities appear. This can particularly be a wheel, an axle or a bogie. A measurement of an acceleration generally is possible anywhere on or in the railway vehicle.

[0079] The at least one physical quantity is logged by a log system during operation of the railway vehicle. The log system can comprise an input unit, a processing unit and a data storage, wherein the data storage may be a random access memory or any kind of hard disk or memory chip. The at least one logged physical quantity can be used to monitor the wear of the railway vehicle or one of its components, since the occurrence of wear can be related to at least one physical quantity. For example, logged values of stresses and/or strains can be analysed with regard to fatigue by using a stress-cycle curve and/or a strain-cycle curve. Such curves are known as Wohler curves. This is of particular importance when driving situations have occurred during a logging period, in which the second speed value, hence a possible reduction of driving speed, was not available. Using the first speed value can be uncritical regarding safety, but may lead to increased wear, when considering a railway vehicle, whose speed class proposes high speeds in curved track sections. By using logged values of at least one physical quantity, a simple way of assessing cumulative wear may be performed. Additionally, second speed determination values and/or second speed values may be changed with regard to logged values of at least one of the mentioned physical quantities if unacceptably high wear has been detected.

[0080] Besides wear, the at least one logged physical quantity can also be used to improve passenger comfort, particularly concerning acceleration values and/or values of the jerk and/or force values. If high values of these physical quantities are detected frequently, changes of second speed determination values and/or second speed values concerning the corresponding track sections which can be used to predefine lower speeds during operation may be recommended.

[0081] Railway vehicles which comprise a tiltable body car generally comprise lateral acceleration sensors for further reasons. The lateral acceleration values measured by these sensors can be used in terms of the invention.

[0082] In a further embodiment of the invention, the current acceleration value and/or the current force value and/or the current stress value and/or the current strain value of the railway vehicle is/are measured by using at least one sensor attached to at least one bogie of the railway vehicle and/or calculated by using a value which is measured by at least one sensor attached to at least one bogie of the railway vehicle.

[0083] The at least one bogie is a preferable position to attach and to use the at least one sensor, since it serves as an important force transmission element between wheels/axles and the car body. It is therefore a critical part affected by comparably high forces, stresses and strains during an operation of the railway vehicle. Additionally, it is highly relevant for safety and integrity of the whole railway vehicle. It is thus a preferable component to assess concerning wear and it is therefore preferred to measure at least one of said physical quantities directly at the bogie.

[0084] Alternatively, at least one of the physical quantities can be calculated by using values which are measured by the at least one sensor. By way of example, a stress value could be easily calculated by using a force value measured by the sensor if the relevant cross-section on which the force acts is known. Further, a strain value could be calculated using Hooke's law.

[0085] In a further embodiment of the invention, a maintenance interval and/or an inspection interval and/or a replacement interval of at least one of the components of the railway vehicle is determined by a determination and/or calculation model, which takes into account the acceleration values and/or force values and/or stress values and/or strain values logged by the log system.

[0086] Operational safety of a railway vehicle generally has to be ensured by an operating company and/or a responsible authority. This includes regular maintenance and service works including maintaining, inspecting and/or replacing of components of the railway vehicle, particularly components exposed to wear. A maintenance and/or inspection and/or replacement interval can be specified according empirical or analytical calculation models and/or experience values.

[0087] The occurrence of wear can be related to the mentioned physical quantities, as already explained above. Since values of the mentioned physical quantities also depend on the operational speeds, an operation of the railway vehicle at operational speeds which differ significantly from predefined speed values, for example from using predetermined vehicle speed classes, causes wear, which may not be estimated reliably by using existing experience values and/or calculation models. Furthermore, wear may be increased, if driving situations occur/have occurred in which a second speed value, which may be lower than a corresponding first speed value, is/was not available, for example due to system failure. It is therefore preferable to use the logged values of the mentioned physical quantities to define and/or calculate and/or determine a maintenance interval and/or

an inspection interval and/or a replacement interval of at least one of the components of the railway vehicle.

[0088] Such a model could include weighting factors, each of which is assigned to a logged value or to a plurality of logged values of at least one of the mentioned physical quantities. The products of the logged value or of the plurality of logged values and the corresponding weighting factor can be summed up. If the sum reaches a threshold value which may correspond to a critical amount of wear, a maintenance and/or an inspection and/or a replacement of at least one of the components of the railway vehicle may be necessary.

[0089] A log system logging at least one of the mentioned physical quantities and a determination and/or calculation model to determine a maintenance interval and/or an inspection interval and/or a replacement interval are particularly necessary concerning the above-mentioned example, in which a railway vehicle without tiltable body is classified in a fast speed class, for example "S", at the expense of wear and passenger comfort. In this case, by using the second speed value, operational speeds can be reduced particularly in curved track sections, but second speed values do not refer to any predetermined speed class. Additionally, unexpected operating conditions may occur, in which second speed values are not available, for example because of a system failure, causing the railway vehicle to operate at the speed of the first speed value also in curved track sections. Under such conditions, wear can be increased, also in comparison to a permanent operation within a lower speed class, so that a maintenance and/or inspection and/or replacement interval of at least one of the components of the railway vehicle has to be specified individually.

[0090] Such an interval can be defined with regard to a current operation period of the railway vehicle by evaluating logged values of at least one of the mentioned physical quantities during an operation period. Alternatively or additionally, the interval can also be defined with regard to at least one previous operation period, for which logged values of at least one of the mentioned physical quantities and corresponding wear have been analysed in retrospective. An operation period can be an operation time interval or a fixed timespan not taking into account whether the railway vehicle was operated or not. Alternatively or additionally, an interval can also be defined with regard to a driving distance of the railway vehicle. Alternatively or additionally, an interval can be determined by a method taking into account an operation time interval or a fixed timespan in combination with a traveled distance and/or an aggregated exposure to wear. The exposure to wear can be evaluated in real time, for example by measuring at least one of the mentioned physical quantities.

[0091] In a further embodiment of the invention, the data storage containing position-dependent speed determination values contains different position-dependent speed determination values which are adapted for differ-

ent railway vehicle types.

[0092] Therefore the method can be applied to different railway vehicle types, taking into account the respective individual type properties. The vehicle type can be defined in advance, so that suitable speed determination values are used from the data storage.

[0093] Additionally, an arrangement for determining a vehicle speed recommendation for operating a railway vehicle is proposed which comprises:

a) a receiving unit configured to receive a first speed determination value from an information transfer device which can be arranged in particular at least partly at a fixed position relative to the railway;

b) a processing unit configured to determine a first speed value by using the first speed determination value,

c) a position determination system configured to determine a position value of a railway vehicle position;

d) a processing unit configured to determine a second speed determination value from a data storage by using the position value, wherein the data storage contains position-dependent speed determination values;

e) a processing unit configured to determine a second speed value by using the second speed determination value, wherein the second speed determination value and/or the second speed value depend on expected and/or actual wear of the railway vehicle and/or on passenger comfort of passengers within the railway vehicle;

f) a processing unit configured to output the vehicle speed recommendation as one of the first speed value and the second speed value according to a predetermined procedure.

[0094] The arrangement can be configured to perform the method according to one of the embodiments mentioned above or below.

[0095] In particular the arrangement can be completely on board the railway vehicle. However, it is possible that at least one part of the arrangement can be located outside of the railway vehicle, for example in connection with or as a part of a control device for controlling an operation of the railway vehicle. Therefore, for example as described above, at least a part of the method of determining a vehicle speed recommendation can be performed outside of the railway vehicle. In particular, the control device could perform at least a part of the method, e.g. the determination of the vehicle speed recommendation could be determined outside of the rail vehicle based on the intermediate value or, generally speaking based on the first speed determination value and based on the po-

sition value.

[0096] In particular, the arrangement may comprise an indication device which is configured to receive and display the vehicle speed recommendation and/or to receive and display an intermediate value derived from the first speed determination value (SD1) and/or from the position value (PV), wherein the indication device is located in a driver control area (e.g. a driver compartment) of the railway vehicle where a driver of the railway vehicle can control operation of the railway vehicle. Alternatively, the indication device may be part of a control device outside of the railway vehicle.

[0097] As already mentioned, the receiving unit of step a) and the processing unit of step b) configured to determine the first speed value can be part of an auxiliary system, particularly a train protection system. The receiving unit can comprise an antenna and/or a magnetic sensor and an interface for receiving analogue and/or digital signals, which can be arranged on board the railway vehicle. Particularly, the receiving unit can comprise a Specific Transmission Module (STM) or a Balise Transmission Module, as used as signaling components within the European Rail Traffic Management System (ERTMS). The processing unit configured to determine the first speed value may be a microprocessor which may be arranged on board the railway vehicle. It can particularly be integrated in a computer system.

[0098] As explained above, the position determination system of step c) may be a global navigation satellite system (GNSS) arranged on board the railway vehicle and/or an odometer and/or a system which is based on wayside arranged devices. A global navigation satellite system is preferred due to simple implementability.

[0099] The processing unit of step d) configured to determine a second speed determination value from a data storage again can be a microprocessor. The data storage can be implemented as explained above. The processing unit of step e) again can be a microprocessor on board the railway vehicle. Particularly, it can be the same microprocessor which is used in step d). The processing unit of step f) receives the first speed value and the second speed value from the processing unit of step b) and the processing unit of step e) outputs the vehicle speed recommendation according to a predefined procedure as already explained. The vehicle speed recommendation can for example be output to a driver of the railway vehicle by means of an indication device, as explained above, or to a control unit to adjust the current speed of the railway vehicle. The vehicle speed recommendation also can be output to a log system, particularly a log system which also logs at least one of the physical quantities mentioned above.

[0100] Exemplary embodiments of the invention will now be described with reference to the accompanying drawing. The individual figures of the drawing show:

Fig. 1 an example of a railway vehicle driving on a track and approaching a curved track section,

wherein the railway vehicle comprises an arrangement for determining a vehicle speed recommendation according to the proposed invention,

Fig. 2 a detailed view of the railway vehicle pictured in Fig. 1,

Fig. 3 a schematic diagram describing a method of determining a vehicle speed recommendation for operating a railway vehicle according to the proposed invention.

[0101] Fig. 1 shows a railway vehicle 4 driving on a track T and approaching a curved track section T1 comprising a curve C, wherein the railway vehicle 4 comprises an arrangement for determining a speed recommendation SR as proposed. Alternatively or additionally, the track section T1 may comprise an inclination and/or a superelevation and/or another attribute which can affect passenger comfort and/or which can increase wear, for example a rough underground the rails are laying on or a railway switch.

[0102] An information transfer device 2, which may be a balise, is arranged at the track T. The information transfer device 2 is configured to transmit a signal which comprises a speed determination value to a receiving unit 1 of the railway vehicle 4. The information transfer device 2 particularly can be configured to transmit a signal by means of electromagnetic waves, for example by means of an inductive and/or a radio-based and/or a wireless signalling system. The receiving unit 1 is configured to receive a signal from the information transfer device 2 and/or from equivalent and/or similar information transfer devices.

[0103] The information transfer device 2 is situated in driving direction at a distance from the start of the curved track section T1. The distance is long enough to perform an alteration of a current speed of the railway vehicle, so that the alteration is completed before the railway vehicle reaches the curved track section T1.

[0104] The railway vehicle 4 is operated by a driver D. Alternatively or additionally, the railway vehicle can also be operated by an automatic driving system relieving the driver or an autonomous driving system, for example a driverless system.

[0105] In the driver's cabin 19, a display 11 is arranged which is configured to indicate a value of a speed recommendation SR to the driver D. Further, a speaker 18 is arranged in the driver's cabin which is configured to output a warning signal to the driver D, for example a warning signal to indicate that a current speed of the railway vehicle 4 exceeds the speed recommendation SR. A sensor 14 is arranged on a bogie 15 of the railway vehicle 4 configured to measure a physical quantity, which can be for example an acceleration, particularly a lateral acceleration, a jerk, particularly a lateral jerk, a force, a stress and/or a strain. Alternatively, the sensor can be arranged at another part of the railway vehicle, for example a car body.

[0106] The railway vehicle 4 shown in Fig. 1 does not comprise a tiltable car body. Alternatively, it may comprise a tiltable car body. The railway vehicle may be assigned to a high speed class, for example speed class "S". The railway vehicle is configured and/or designed in a way that using first speed values of speed class "S" as actual driving speeds would result in unacceptably high wear and/or unacceptably low passenger comfort.

[0107] Fig. 2 shows a more detailed and schematic view of the railway vehicle 4 shown in Fig. 1. The information transfer device 2 is configured to transmit a first speed determination value SD1, as already described above. Between the receiving unit 1 and a processing unit 3, a data connection is arranged, configured to transfer the first speed determination value SD1, for example a network cable. Alternatively, a wireless connection can be used. The receiving unit 1 and/or the processing unit 3 can be part of a train protection system. Both units can be integrated in a single system, particularly a system comprising a single microprocessor performing calculations for both the receiving unit 1 and the processing unit 3.

[0108] The processing unit 3 is configured to determine a first speed value S1, for example by means of a lookup-table and/or a calculation model taking into account the speed class "S" or by using a dimensionless factor for multiplying the first speed determination value SD1, if the first speed determination value SD1 is a numerical speed value. The first speed determination value SD1 particularly can be a numerical value of a base speed.

[0109] The railway vehicle 4 comprises a position information receiver 5. The position information receiver is configured to receive a signal R2, for example a radio signal, and to output a position value PV, for example comprising coordinate values. It can be configured as a receiver of signals from a global navigation satellite system (GNSS), wherein the global navigation satellite system comprises satellites one of which is indicated (satellite 17). Alternatively or additionally, the position information receiver 5 may be an odometer which is configured to measure a distance covered by the railway vehicle 4 on the track T. In this case, the position information receiver does not receive a signal R2. Alternatively or additionally, the position information receiver 5 can be configured to receive signals from wayside arranged devices each of which transmitting a position determination signal.

[0110] A processing unit 6 is configured to receive the position value PV via a data connection, for example a network cable, and/or a wireless connection, from the position information receiver 5. Further, the processing unit 6 is configured to determine and/or calculate a second speed determination value SD2. A data storage 7 contains position-dependent speed determination values and is connected to the processing unit 6 via a data connection, for example a network cable, and/or a wireless connection. The position-dependent speed determination values may be stored in a database. The data

storage 7 can be any type of random access memory or read only memory, for example a memory chip or a hard disk drive. The processing unit 6 is configured to output a second speed determination value SD2. A processing unit 8 is configured to determine and/or calculate a second speed value S2. Both the processing unit 6 and the processing unit 8 can be microprocessors. Particularly, both processing units 6 and 8 can be integrated in one single processor. In Fig. 2, the processing unit 6 and the processing unit 8 are separate units, which are connected via a data connection, for example a network cable, and/or a wireless connection.

[0111] A comparison unit 9, which is connected to the processing unit 8 and the processing unit 3 via data connections, for example network cables, and/or a wireless connections, is configured to compare the first speed value S1 and the second speed value S2 and to determine the lower value of both values as a minimum. The minimum is the vehicle speed recommendation SR. The comparison unit 9 can comprise a processing unit, particularly a microprocessor. Alternatively, the comparison unit 9 can be a processing unit which is configured to determine and output a vehicle speed recommendation SR according to a predetermined procedure which allows a determination of a vehicle speed recommendation SR by another method, particularly a calculation method.

[0112] An output unit 10, which is configured to receive and output the speed recommendation SR, is connected to the comparison unit 9 via a data connection, for example a network cable, and/or a wireless connection. The output unit 10 may comprise a microprocessor or a plurality of microprocessors. The comparison unit 9 and the output unit 10 can alternatively be integrated in the same microprocessor or in the same microprocessor as the processing unit 6 and/or the processing unit 8. The output unit 10 may comprise a graphics card and/or a GPU (graphics processing unit) and/or a sound card and/or a sound processing unit. The output unit 10 is configured to transmit a graphics signal to the display 11, which can be a number to be indicated on the display 11, for example "100", and an audio signal to the speaker 18, so that the driver D is able to perceive the speed recommendation SR in the form of an optical signal and/or an acoustic signal.

[0113] A control unit 12, which can be an automatic train operation device (ATO), is configured to receive the speed recommendation SR from the output unit 10 via a data connection, for example a network cable, and/or a wireless connection. The control unit 12 can be a microprocessor which can be embedded in a computer system. Such a computer system can be part of a train protection system. Further, the control unit 12 is configured to transform the speed recommendation SR to a first speed control signal SRE, which is transferred to an engine 13 of the railway vehicle via a data connection, for example a network cable, and/or a wireless connection, and/or to a second speed control signal SRB, which is transferred to a brake 20 of the railway vehicle via a data

connection, for example a network cable, and/or a wireless connection. The engine may be an electric motor and/or an internal combustion engine, for example a Diesel engine. The brake may be a disc brake and/or an electrical brake generating a braking force by an electromagnetic field. Particularly, the control unit 12 may comprise a comparison unit, which compares the current speed and the speed recommendation SR in order to control the current speed according to the speed recommendation SR.

[0114] The railway vehicle 4 comprises the sensor 14 which is also shown in Fig. 1 and which is connected to a log system 16 via a data connection, for example a network cable, and/or a wireless connection. The sensor 4 is arranged on the bogie 15. The sensor 14 and/or further sensors, which may additionally be connected to the log system 16, may be arranged at another or several other parts of the railway vehicle 4.

[0115] A log system 16 is configured to receive an output of the sensor 14 via a data connection, for example a network cable, and/or a wireless connection. The log system 16 can comprise a data storage which can be any type of read-only or random access memory, for example a memory chip or a hard disk drive.

[0116] An embodiment of the proposed method of determining a vehicle speed recommendation for operating a railway vehicle can be realised by the arrangement shown in Fig. 1 and Fig. 2 as follows. The information transfer device 2 transmits a first speed determination value SD1 to the receiving unit 1. The first speed determination value SD1 particularly can be a signal meaning "base speed", wherein "base speed" may be a comparatively low speed, as described above, for example 100 km/h, since the railway vehicle 4 is approaching the curved track section T1.

[0117] The first speed determination value SD1 is further transferred to the processing unit 3 which determines a first speed value S1. In the processing unit 3, a speed value is determined. In case that the speed determination value SD1 is a signal meaning "base speed", that is, the first speed determination value SD1 is a speed value by itself, the first speed determination value SD1 can be taken over as first speed value S1. Alternatively, if the first speed determination value SD1 is a base speed, the first speed determination value SD1 may be multiplied with an in particular dimensionless factor which depends on a speed class of the railway vehicle 4 in order to obtain the first speed value S1. Alternatively, the first speed determination value SD1 may be processed in another way in order to obtain the first speed value S1.

[0118] By means of the signal R2, the position value PV is received by the position information receiver 5. The position value PV is then transferred to the processing unit 6 to determine the second speed determination value SD2. To determine the second speed determination value SD2, the data storage 7 containing position-dependent speed determination values is used.

[0119] Output of the processing unit 6 is a second

speed determination value SD2, which is transferred to the processing unit 8 in order to determine a second speed value S2, for example by using a calculation model.

[0120] The first speed value S1 and the second speed value S2 are compared in the comparison unit 9, which determines the lower value of both values. The lower value is used as speed recommendation SR, which is then transferred to the output unit 10. The output unit 10 transmits a graphics signal to the display 11, which can be a number to be indicated on the display 11, for example "100", and an audio signal to the speaker 18, for example a computer-generated voice reading "100".

[0121] Alternatively a comparison in the comparison unit 9 may be performed in order to determine the higher value of both values. The higher value then may be used as speed recommendation SR. Alternatively, the speed recommendation SR may be determined according to a predetermined procedure.

[0122] Additionally, the speed recommendation SR is transmitted to the control unit 12. The control unit 12 transforms the speed recommendation SR to the first speed control signal SRE, which is transferred to the engine 13 of the railway vehicle, and/or to the second speed control signal SRB, which is transferred to the brake 20 of the railway vehicle. By way of example, both signals lead to a decreased rotational speed and/or a decreased power of the engine 13 and an actuation of the brake 20. By controlling the engine 13 and/or the brake 20, an alteration of the current speed of the railway vehicle 4 according to the speed recommendation SR can be performed.

[0123] The sensor 14 is measuring a physical quantity, for example lateral acceleration. The output of the sensor 14 is transmitted to the log system 16, in which it is saved. Logged values of the physical quantity are evaluated after a certain time interval to determine a maintenance interval of the railway vehicle 4, for example by using an empiric or analytic calculation model.

[0124] Fig. 3 shows a schematic diagram describing an embodiment of the proposed method of determining a vehicle speed recommendation for operating a railway vehicle. In step 1a, a first speed determination value SD1 is obtained, for example if the railway vehicle 4 passes an information transfer device 2, which may be arranged on or nearby the railway. The first speed determination value SD1 may be determined with regard to properties of a corresponding track section, which may be a curved track section. In a subsequent step 2a, a first speed value S1 is determined. The first speed value S1 may be determined with regard to properties of the corresponding track section and on a vehicle speed class, for example speed class "S", particularly with regard to driving safety. The first speed value S1 may be determined by multiplication with a dimensionless factor which takes into account the speed class of the railway vehicle. In this case, the first speed determination value SD1 is a speed value by itself, particularly a base speed.

[0125] In step 1b, a position value PV is determined by using a position determination system, for example the position information receiver 5. The position value PV serves as an input for the subsequent step 1c in which a second speed determination value SD2 is determined. In a subsequent step 1d a second speed value S2 is determined, which depends on the second speed determination value SD2. Both, the second speed determination value SD2 and the second speed value S2 may be determined with regard to the properties of the railway vehicle 4 and/or on the properties of the corresponding railway track, particularly with regard to passenger comfort and actual and/or expected wear of the railway vehicle. The second speed determination value SD2 and the second speed value S2 may change according to a high spatial resolution and may be defined by using a lookup table, which can be available in the form of a database in the data storage 7.

[0126] In the next step 3, a comparison of the first speed value S1 and a second speed value S2 is performed. The lower of both value, the minimum, is the vehicle speed recommendation SR. Alternatively, the vehicle speed recommendation can be determined according to a predetermined procedure in step 3. In step 4a, the vehicle speed recommendation SR is output to a driver D, for example by means of an indication device mounted in the driver's cabin. Additionally, the vehicle speed recommendation SR is output to a control unit 12 in step 4b.

[0127] Further, in step 4b, a first speed control signal SRE and a second speed control signal SRB are set up according to the vehicle speed recommendation SR and are transmitted to an engine 13 respectively a brake 20 of the railway vehicle 4. In a next step 5b the current speed of the railway vehicle 4 is adjusted according to the speed recommendation SR by means of controlling the engine 13 and/or the brake 20. Alternatively and/or additionally, the driver D of the railway vehicle 4 may adjust the speed of the railway vehicle according to the speed recommendation SR output to him in step 5a.

[0128] Furthermore, in step 11, at least one physical quantity, for example an acceleration value, is measured by a sensor 14, which may be arranged at any place in or on the railway vehicle 4, particularly at a bogie 15. The measurement of the at least one physical quantity can be carried out over a certain time period or a certain running distance of the railway vehicle 4. In a following step 12, the at least one physical quantity is logged by a log system 16. In step 13, a maintenance interval of the railway vehicle 4 is determined with regard to the data of the at least one physical quantity logged by the log system 16.

Reference signs

[0129]

1 receiving unit

2	information transfer device	
3	processing unit configured to determine and/or calculate a first speed value S1	
4	railway vehicle	
5	position information receiver	5
6	processing unit configured to determine and/or calculate a second speed determination value SD2	
7	data storage	
8	processing unit configured to determine and/or calculate a second speed value S2	10
9	comparison unit	
10	output unit	
11	display	
12	control unit	15
13	engine	
14	sensor	
15	bogie	
16	log system	
17	global navigation satellite system	20
18	speaker	
19	driver's cabin	
20	braking system	
C	curve	
D	driver	25
PV	position value	
R1	electromagnetic field	
R2	signal	
S1	first speed value	
S2	second speed value	30
SD1	first speed determination value	
SD2	second speed determination value	
SR	speed recommendation	
SRB	second speed control signal	
SRE	first speed control signal	35
T1	curved track section	
T	track	

Claims

1. A method of determining a vehicle speed recommendation (SR) for operating a railway vehicle (4) comprising the following steps:
 - a) receiving a first speed determination value (SD1) from an information transfer device (2) and determining a first speed value (S1) by using the first speed determination value (SD1),
 - b) obtaining a position value (PV) of a railway vehicle position by means of a position determination system;
 - c) determining a second speed determination value (SD2) from a data storage (7) by using the position value (PV), wherein the data storage (7) contains position-dependent speed determination values, and determining a second speed value (S2) by using the second speed determi-

nation value (SD2), wherein the second speed determination value (SD2) and/or the second speed value (S2) depend(s) on expected and/or actual wear of the railway vehicle (4) and/or on passenger comfort of passengers within the railway vehicle (4);
 d) outputting the vehicle speed recommendation (SR) as one of the first speed value (S1) and the second speed value (S2) according to a predetermined procedure.

2. The method according to claim 1, **characterized in that** the first speed value (S1) is determined in step a) by using the first speed determination value (SD1) and by applying a predetermined vehicle speed augmentation rule that depends on a type of the railway vehicle.
3. The method according to claim 1 or 2, **characterized in that** the vehicle speed recommendation (SR) is output, when the railway vehicle (4) approaches and/or enters and/or passes through a track section in which a maximum speed has to be observed.
4. The method according to claim 3, **characterized in that** the track section is a curved track section (T1).
5. The method according to one of claims 1 to 4, **characterized in that** the vehicle speed recommendation (SR) is output to the driver (D) by means of an indication device and/or that the vehicle speed recommendation (SR) is output to a control unit (12) of the railway vehicle (4), which adjusts the current speed of the railway vehicle (4) with regard to the vehicle speed recommendation (SR).
6. The method according to one of claims 1 to 5, **characterized in that** a current acceleration value and/or a current force value and/or a current stress value and/or a current strain value of the railway vehicle (4) is/are calculated and/or measured and that the current acceleration value and/or the current force value and/or the current stress value and/or the current strain value of the railway vehicle (4) is/are logged by a log system (16).
7. The method according to claim 6, **characterized in that** the current acceleration value and/or the current force value and/or the current stress value and/or the current strain value of the railway vehicle (4) is/are measured by using at least one sensor (14) attached to at least one bogie (15) of the railway vehicle (4) and/or calculated by using a value which is measured by at least one sensor (4) attached to at least one bogie (15) of the railway vehicle (4).
8. The method according to claim 6 or 7, **characterized in that** a maintenance interval and/or an inspection

interval and/or a replacement interval of at least one of the components of the railway vehicle (4) is determined by a determination and/or calculation model, which takes into account the acceleration values and/or force values and/or stress values and/or strain values logged by the log system (16). 5

9. The method according to one of claims 1 to 8, **characterized in that** the data storage (7) contains different position-dependent speed determination values which are adapted for different railway vehicle types. 10

10. An arrangement for determining a vehicle speed recommendation (SR) for operating a railway vehicle (4) which comprises: 15

- a) a receiving unit (1) configured to receive a first speed determination value (SD1) from an information transfer device (2); 20
- b) a processing unit (3) configured to determine a first speed value (S1) by using the first speed determination value (SD1),
- c) a position determination system configured to determine a position value (PV) of a railway vehicle position; 25
- d) a processing unit (6) configured to determine a second speed determination value (SD2) from a data storage (7) by using the position value (PV), wherein the data storage (7) contains position-dependent speed determination values; 30
- e) a processing unit (8) configured to determine a second speed value (S2) by using the second speed determination value (SD2), wherein the second speed determination value (SD2) and/or the second speed value (S2) depend(s) on expected and/or actual wear of the railway vehicle (4) and/or on passenger comfort of passengers within the railway vehicle (4); 35
- f) a processing unit (10) configured to output the vehicle speed recommendation (SR) as one of the first speed value (S1) and the second speed value (S2) according to a predetermined procedure. 40

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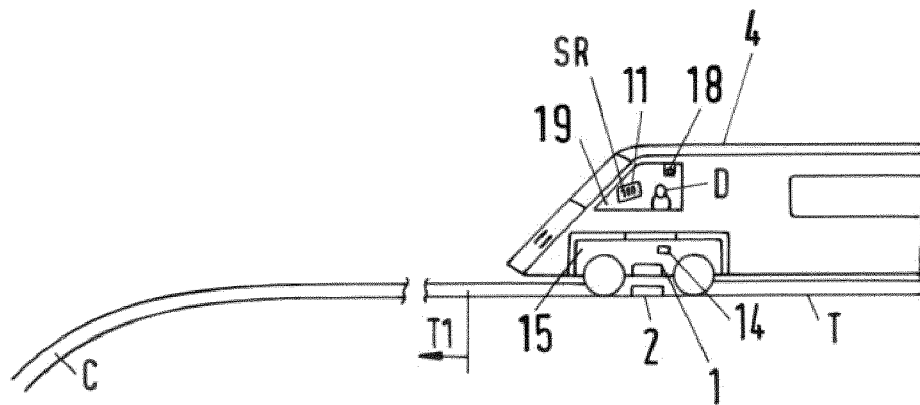


Fig.1

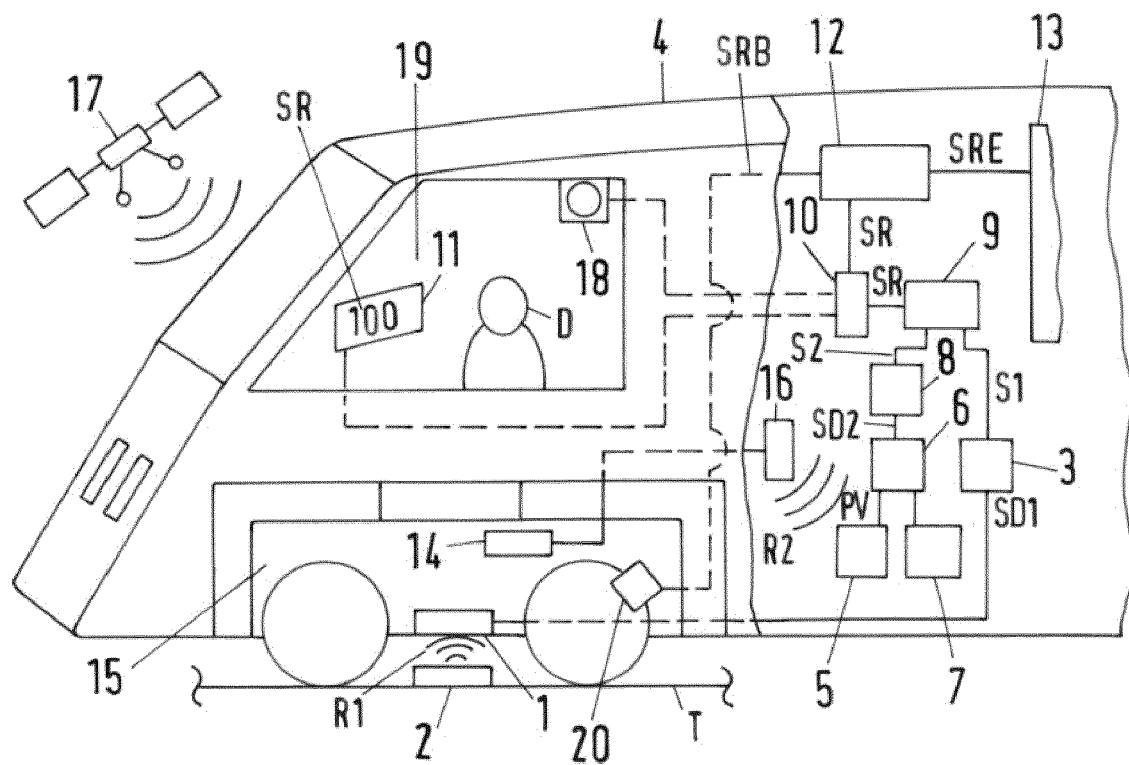


Fig.2

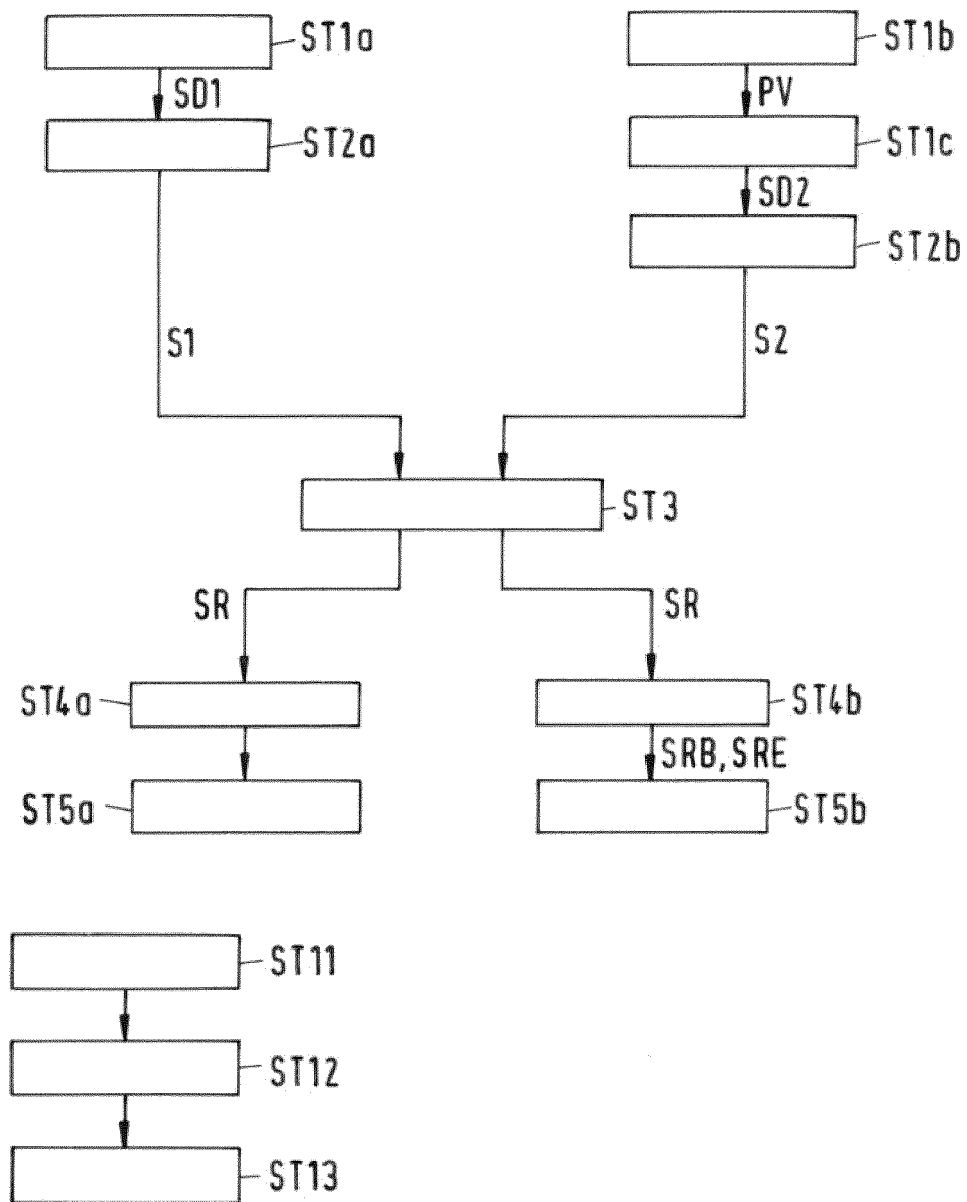


Fig.3



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Application Number
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