

VEHICLE BRAKING METHOD AND DEVICE, AND TRAIN

[0001] This application claims priority to Chinese Patent Application No. 202011118479.0, titled "VEHICLE BRAKING METHOD AND DEVICE, AND TRAIN", filed on October 19, 2020 with the China National Intellectual Property Administration (CNIPA), which is incorporated herein by reference in its entirety.

FIELD

[0002] The present disclosure relates to the technical field of computers, and in particular to a method for braking a vehicle, a device for braking a vehicle and a train.

BACKGROUND

[0003] In the conventional rail transit, an automatic train protection system (ATP) is usually used to measure the speed of the train. After the ATP is cut-off, a radar auxiliary protection system is used to measure the distance between a vehicle and a preceding vehicle in the same traveling direction in real time. In order to improve the safety of the train, it is significant to eliminate the risk of rear-end collision between the train and the preceding vehicle in the same traveling direction. Therefore, the train should be decelerated according to the braking capacity of the train itself before colliding with the preceding vehicle. However, it is insufficient to improve the safety of the train and reduce the risk of rear-end collisions relying on the driving experience of the train conductor alone.

[0004] In conclusion, the conventional radar auxiliary protection system after cutting-off ATP has a high risk of rear-end collision, resulting in a low safety of the train.

SUMMARY

[0005] For purpose of improving travelling safety of the train with the radar auxiliary protection system after cutting-off ATP in the conventional technology, a method for braking a vehicle, a device for braking a vehicle and a train are provided according to the embodiments of the present disclosure, which can effectively lower the risk of rear-end collision with the

preceding vehicle and improve the safety of train operation.

[0006] A method for braking a vehicle is provided according to the present disclosure, the method includes:

acquiring a distance between the vehicle and a preceding vehicle;

5 issuing an alarm in a case that the distance is less than or equal to a first threshold;
and

 receiving a first braking command triggered by a user, and braking the vehicle at a first preset deceleration, based on the first braking command; where the first threshold is obtained based on a sum of a target equivalent virtual stopping distance and an emergency
10 braking distance, the target equivalent virtual stopping distance is obtained based on at least one of a first equivalent virtual stopping distance and a second equivalent virtual stopping distance, the first equivalent virtual stopping distance is a distance traveled by the vehicle during acquiring the distance between the vehicle and the preceding vehicle, the second equivalent virtual stopping distance is a distance traveled by the vehicle during triggering the
15 first braking command by the user, and the emergency braking distance is a distance traveled by the vehicle once braking the vehicle at the first preset deceleration.

[0007] In an embodiment, the target equivalent virtual stopping distance is a sum of the first equivalent virtual stopping distance and the second equivalent virtual stopping distance.

[0008] In an embodiment, the emergency braking distance is obtained based on at least one
20 of a first braking distance, a second braking distance and a third braking distance, and the first braking distance is a distance traveled by the vehicle in a case that all bogies are used for braking in a normal operating status, the second braking distance is a distance traveled by the vehicle in a case that all bogies are used for braking in a wet rail status, and the third braking distance is a distance traveled by the vehicle while braking in the wet rail status with a preset
25 number of bogies being cut-off.

[0009] In an embodiment, the emergency braking distance is a maximum value among the first braking distance, the second braking distance and the third braking distance.

[0010] In an embodiment, the method further includes:

[0011] in a case that the distance is less than or equal to a second threshold, issuing an
30 alarm, where the second threshold is greater than the first threshold, the second threshold is

determined based on the first threshold and a minimum alarm interval; and

[0012] receiving a second braking command triggered by the user, and braking the vehicle at a second preset deceleration, based on the second braking command, where the second preset deceleration is less than the first preset deceleration.

5 **[0013]** A device for braking a vehicle is provided according to the present disclosure, the device includes:

[0014] an acquisition unit, configured to acquire a distance between the vehicle and a preceding vehicle;

10 **[0015]** a first alarm unit, configured to issue an alarm in a case that the distance is less than or equal to a first threshold; and

[0016] a first braking unit, configured to receive a first braking command triggered by a user, and brake the vehicle at a first preset deceleration based on the first braking command; wherein, the first threshold is obtained based on a sum of a target equivalent virtual stopping distance and an emergency braking distance, the target equivalent virtual stopping distance is obtained based on at least one of a first equivalent virtual stopping distance and a second equivalent virtual stopping distance, the first equivalent virtual stopping distance is a distance traveled by the vehicle during acquiring the distance between the vehicle and the preceding vehicle, the second equivalent virtual stopping distance is a distance traveled by the vehicle during triggering the first braking command by the user, and the emergency braking distance is a distance traveled by the vehicle once braking the vehicle at the first preset deceleration.

[0017] In an embodiment, the target equivalent virtual stopping distance is a sum of the first equivalent virtual stopping distance and the second equivalent virtual stopping distance.

25 **[0018]** In an embodiment, the emergency braking distance is obtained based on at least one of a first braking distance, a second braking distance and a third braking distance, and the first braking distance is a distance traveled by the vehicle in a case that all bogies are used for braking in a normal operating status, the second braking distance is a distance traveled by the vehicle in a case that all bogies are used for braking in a wet rail status, and the third braking distance is a distance traveled by the vehicle while braking in the wet rail status with a preset number of bogies being cut-off.

30 **[0019]** In an embodiment, the emergency braking distance is a maximum value among the

first braking distance, the second braking distance and the third braking distance.

[0020] In an embodiment, the device further includes:

[0021] a second alarm unit, configured to issue an alarm in a case that the distance is less than or equal to a second threshold, where the second threshold is greater than the first threshold, the second threshold is determined based on the first threshold and a minimum alarm interval; and

[0022] a second braking unit, configured to receive a second braking command triggered by the user, and brake the vehicle at a second preset deceleration based on the second braking command, wherein the second preset deceleration is less than the first preset deceleration.

[0023] A train is provided according to the present disclosure, the train includes a device for braking a vehicle, where the device for braking a vehicle is configured to implement the method for braking a vehicle according to the embodiments of the present disclosure.

[0024] Compared with the conventional technology, the present disclosure has advantages as follows.

[0025] A method for braking a vehicle is provided according to the present disclosure, the method includes: acquiring a distance between the vehicle and a preceding vehicle; issuing an alarm in a case that the distance is less than or equal to a first threshold; and receiving a first braking command triggered by a user, and braking the vehicle at a first preset deceleration, based on the first braking command; where the first threshold is obtained based on a sum of a target equivalent virtual stopping distance and an emergency braking distance, the target equivalent virtual stopping distance is obtained based on at least one of a first equivalent virtual stopping distance and a second equivalent virtual stopping distance, the first equivalent virtual stopping distance is a distance traveled by the vehicle during acquiring the distance between the vehicle and the preceding vehicle, the second equivalent virtual stopping distance is a distance traveled by the vehicle during triggering the first braking command by the user, and the emergency braking distance is a distance traveled by the vehicle once braking the vehicle at the first preset deceleration. It can be seen that, in the embodiments of the present disclosure, the distance with the preceding vehicle is measured and compared with a threshold. In a case that the measured distance is less than or equal to the threshold, braking of the train is started. The threshold of braking is determined by the equivalent virtual stopping distance

and the emergency braking distance limited by the braking performance of the train itself. The method for braking a vehicle provided according to the embodiments of the present disclosure can effectively reduce the risk of rear-end collision with the preceding vehicle and improve the train operation safety by determining the threshold of braking considering both the ranging capability of the radar protection system and the emergency braking performance of the train.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] In order to more clearly explain the technical solutions in the embodiments of the present disclosure or in the conventional technology, the drawings used in the description of the embodiments or the conventional technology are briefly introduced hereinafter. It is apparent that the drawings in the following description illustrate only some embodiments of the present disclosure. Other drawings may be obtained by those skilled in the art without creative efforts based on the provided drawings.

[0027] Figure 1 is a flow chart of a method for braking a vehicle according to an embodiment of the present disclosure; and

[0028] Figure 2 is a structural block diagram of a device for braking a vehicle according to an embodiment of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

[0029] In order to enable those skilled in the art to better understand the solution of the present disclosure, the technical solutions in the embodiment of the present disclosure will be clearly and completely described below in conjunction with the drawings in the embodiments of the present disclosure. It is apparent that the described embodiments are only part of the embodiments of the present disclosure, rather than all of the embodiments. Based on the embodiments of the present disclosure, all other embodiments obtained by those of ordinary skilled in the art without creative efforts fall within the protection scope of the present disclosure.

[0030] It can be seen from the background technology that after the train cuts-off ATP during operation, the radar auxiliary protection system is used for measuring the distance with

the preceding vehicle (i.e., the vehicle ahead). Currently, the ranging capability of the radar auxiliary protection system is 1 kilometer (km). For the sake of lowering the risk of rear-end collision with vehicle ahead, both the ranging performance of the radar auxiliary protection system and the braking capability of the train itself should be considered when it comes to improving the train operation safety.

[0031] Hence, in the embodiments of the present disclosure, the distance with the preceding vehicle is measured and compared with a threshold. In a case that the measured distance is less than or equal to the threshold, braking of the train is started. The threshold of braking is determined by the equivalent virtual stopping distance and the braking distance limited by the braking performance of the train itself. The method for braking a vehicle provided according to the embodiments of the present disclosure can effectively reduce the risk of rear-end collision with the preceding vehicle and improve the train operation safety by determining the threshold of braking based on both the ranging capability of the radar protection system and the emergency braking performance of the train.

[0032] Referring to Figure 1, Figure 1 is a flow chart of a method for braking a vehicle according to an embodiment of the present disclosure.

[0033] According to the present disclosure, the method for braking a vehicle may be applied, for example, to a vehicle controller. The method specifically includes steps as follows.

[0034] In step 101, a distance between the vehicle and a preceding vehicle is acquired.

[0035] According to an embodiment of the present disclosure, when the train is traveling, a distance between the vehicle and the preceding vehicle in the same traveling direction is obtained in real time, so as to perform subsequent processing based on the obtained distance. The radar auxiliary protection system may be used to obtain the distance between the vehicle and the preceding vehicle, that is, the radar auxiliary protection system is used for detecting the distance and sending the detecting result to the controller of the train. Specifically, the radar auxiliary protection system utilizes radio frequency technology. The radar auxiliary protection system of the vehicle first sends the electromagnetic wave for ranging to the radar auxiliary protection system of the preceding vehicle. And then, the radar auxiliary protection system of the preceding vehicle identifies that the received electromagnetic wave is from the radar auxiliary protection system of vehicle behind, and returns response electromagnetic

wave to the radar auxiliary protection system of the vehicle behind. The radar auxiliary protection system of the vehicle determines the distance between the vehicle and the preceding vehicle based on the transmission speed of the electromagnetic wave and the round-trip time once receiving the response electromagnetic wave from the radar auxiliary protection system of the preceding vehicle.

[0036] Obviously, in addition to the radar auxiliary protection system, the embodiment of the present disclosure may also use other ranging means to detect the distance between the vehicle and the preceding vehicle, such as infrared rays, etc., which will not be detailed here. For the convenience of description, the radar auxiliary protection system is used as an example for illustration below.

[0037] In step 102, an alarm is issued in a case that the distance is less than or equal to a first threshold.

[0038] According to the embodiment of the present disclosure, the first threshold represents that the distance between the vehicle and the preceding vehicle is at a certain constant value, and this value is irrelevant to the relative speed of the vehicle and the preceding vehicle. If the detected distance between the vehicle and the preceding vehicle is less than or equal to the first threshold, it indicates that the distance between the vehicle and the preceding vehicle may be too close and the risk of rear-end collision may be high. In this case, the vehicle driver may be alerted to remind the safety issues of the vehicle so as to reduce the probability of rear-end collision accidents.

[0039] In step 103, a first braking command triggered by a user is received and braking of the vehicle is implemented at a first preset deceleration based on the first braking command. The first threshold is obtained based on a sum of a target equivalent virtual stopping distance and an emergency braking distance. The target equivalent virtual stopping distance is obtained based on at least one of a first equivalent virtual stopping distance and a second equivalent virtual stopping distance. The first equivalent virtual stopping distance is a distance traveled by the vehicle during acquiring the distance between the vehicle and the preceding vehicle. The second equivalent virtual stopping distance is a distance traveled by the vehicle during triggering the first braking command by the user. The emergency braking distance is a distance traveled by the vehicle after braking the vehicle at the first preset deceleration.

[0040] According to the embodiment of the present disclosure, after detecting that the

distance between the vehicle and the preceding vehicle is less than or equal to the first threshold, the controller of the vehicle performs alarm processing. After receiving the alarm, the user triggers the first braking command. The first braking command refers to a command to brake the vehicle. While braking the train according to the first braking command, there is a corresponding first preset deceleration for braking. The first preset deceleration corresponds to the first braking command, and the first preset deceleration is at a constant value. Specifically, the first preset deceleration may be the deceleration for emergency braking. As an example, the first preset deceleration may be the maximum deceleration under emergency braking, and the maximum deceleration under emergency braking may represent the braking performance of the vehicle.

[0041] While traveling, the vehicle constantly detects whether the distance between the vehicle and the preceding vehicle is less than or equal to the first threshold, and the first threshold is the sum of the target equivalent virtual stopping distance and the emergency braking distance. The target equivalent virtual stopping distance represents the distance traveled by the vehicle before braking. Because the train is still traveling during the time interval of detecting the distance between vehicles, issuing the alarm, and receiving the alarm to start to brake, the distance traveled by the train during this time interval is the target equivalent virtual stopping distance. The emergency braking distance represents the distance traveled by the vehicle in the interval from braking the vehicle to the vehicle being stopped. In actual situations, the radar auxiliary protection system may have a ranging deviation. Hence, for the safety of the train, the ranging deviation of the radar auxiliary protection system may be set. Specifically, the first threshold is determined by the ranging deviation and the sum of the target equivalent virtual stopping distance and the emergency braking distance. As an example, the first threshold is a product of the sum of the target equivalent virtual stopping distance and the emergency braking distance multiplying the ranging deviation.

[0042] Since the first threshold is the sum of the target equivalent virtual stopping distance and the emergency braking distance, the target equivalent virtual stopping distance is to be determined in order to determine the first threshold. The target equivalent virtual stopping distance may be obtained based on at least one of a first equivalent virtual stopping distance and a second equivalent virtual stopping distance.

[0043] In an implementation, the target equivalent virtual stopping distance may be

obtained based on the first equivalent virtual stopping distance. The first equivalent virtual stopping distance refers to the distance traveled by the vehicle during detecting the distance between the vehicle and the preceding vehicle. In other words, the vehicle is still traveling during the time period of detecting the distance between the vehicle and the preceding vehicle.

5 Specifically, the first equivalent virtual stopping distance may be determined by from the time spent by the radar protection system in distance detection and the maximum traveling speed of the vehicle. As an example, the time spent by the radar protection system in distance detection is t_1 in unit of e.g. seconds (s); the maximum traveling speed of the vehicle is v_1 in unit of e.g. meters per second (m/s); then the first equivalent virtual stopping distance L_1 may
10 be the product of the time spent by the radar protection system in distance detection multiplying the maximum traveling speed of the vehicle, that is, the following relationship: $L_1 = v_1 \times t_1$, in the unit of e.g. meter (m).

[0044] In another implementation, the target equivalent virtual stopping distance may be obtained based on the second equivalent virtual stopping distance. The second equivalent
15 virtual stopping distance refers to the distance traveled by the vehicle in the process of the user triggering the braking command, that is, the time spent by the user from receiving the distance alarm to triggering the braking command. Specifically, the second equivalent virtual stopping distance may be determined by a certain constant user reaction time and the traveling speed of the vehicle. As an example, the constant user reaction time is t_2 in the unit of e.g.
20 seconds (s); the maximum traveling speed of the vehicle is v_1 in the unit of e.g. meter per second (m/s); then the second equivalent virtual stopping distance L_2 may be the product of the constant user reaction time multiplying the maximum traveling speed of the vehicle, that is, the following relationship: $L_2 = v_1 \times t_2$.

[0045] In yet another implementation, the target equivalent virtual stopping distance may be
25 obtained jointly based on the first equivalent virtual stopping distance and the second equivalent virtual stopping distance. Specifically, the target equivalent virtual stopping distance L may be the sum of the first equivalent virtual stopping distance and the second equivalent virtual stopping distance, that is, $L = L_1 + L_2$. As an example, in the calculation of the first equivalent virtual stopping distance, the time t_1 spent by the radar protection system
30 in detecting the distance is 1s, and the maximum traveling speed v_1 of the vehicle is 120 kilometers per hour (km/h), then the first equivalent virtual stopping distance $L_1 = v_1 \times t_1 = 120 \text{ km/h} \div 3.6 \times 1\text{s} = 33.3 \text{ m}$, where the division by 3.6 in the equation is to convert the unit

of the maximum traveling speed from kilometer per hour to meter per second. In the calculation of the second equivalent virtual stopping distance, the constant user reaction time t_2 is 1.15 s, and the maximum traveling speed v_1 of the vehicle is 120km/h, then the second equivalent virtual stopping distance $L_2 = v_1 \times t_2 = 120 \text{ km/h} \div 3.6 \times 1.15 \text{ s} = 38.3 \text{ m}$, where the division by 3.6 in the equation is to convert the unit of the maximum traveling speed from kilometer per hour to meter per second. The target equivalent virtual stopping distance may be the sum of the first equivalent virtual stopping distance and the second equivalent virtual stopping distance, i.e., the target equivalent virtual stopping distance $L = L_1 + L_2 = 33.3 + 38.3 = 71.6 \text{ m}$.

[0046] Since the first threshold is the sum of the target equivalent virtual stopping distance and the emergency braking distance, the emergency braking distance is to be determined in order to determine the first threshold. The emergency braking distance may be the distance traveled by the vehicle after braking the vehicle at the first preset deceleration. The emergency braking distance may be obtained based on at least one of the first braking distance, the second braking distance and the third braking distance.

[0047] In an implementation, the emergency braking distance may be obtained based on the first braking distance. The first braking distance is a distance traveled by the vehicle in a case that all bogies are used for braking in a normal operating status. The first braking distance may be determined by using the first preset deceleration and the traveling speed of the vehicle. Specifically, the first preset deceleration may be the maximum deceleration when using all bogies for emergency braking in the normal operating status. The traveling speed of the vehicle may be the maximum traveling speed. As an example, in the normal operating status, the maximum deceleration when all bogies are used for emergency braking is a_1 in the unit of e.g. meter per second squared (m/s^2); and the maximum traveling speed of the vehicle is v_1 in the unit of e.g. meter per second (m/s); then the first braking distance S_1 may be the ratio of the square of the maximum traveling speed of the vehicle to the maximum deceleration in case of using all bogies for emergency braking in the normal operating status, i.e., the following relationship: $S_1 = v_1^2 / 2a_1$.

[0048] In another implementation, the emergency braking distance may be obtained based on the second braking distance. The second braking distance is a distance traveled by the vehicle in a case that all bogies are used for braking in a wet rail status. The second braking

distance may be determined by using the first preset deceleration and the traveling speed of the vehicle. Specifically, the first preset deceleration may be the maximum deceleration in the case that all bogies are used for emergency braking in the wet rail status, and the maximum deceleration in the case that all bogies are used for emergency braking in the wet rail status is less than the maximum deceleration in the case that all bogies are used for emergency braking in the normal operating status. The traveling speed of the vehicle may be the maximum traveling speed. As an example, the maximum deceleration in the case that all bogies are used for emergency braking in the wet rail status is a_2 in the unit of meter per second squared (m/s^2); and the maximum traveling speed of the vehicle is v_1 in the unit of e.g. meter per second (m/s); then the second braking distance S_2 may be the ratio of the square of the maximum traveling speed of the vehicle to the maximum deceleration in the case that all bogies are used for emergency braking in the wet rail status, i.e., the following relationship: $S_2 = v_1^2 / 2a_2$.

[0049] In yet another implementation, the emergency braking distance may be obtained based on the third braking distance. The third braking distance is a distance traveled by the vehicle while braking in a wet rail status with a preset number of bogies being cut-off. The third braking distance may be determined by using the first preset deceleration and the traveling speed of the vehicle. Specifically, the first preset deceleration may be the maximum deceleration while implementing emergency braking in the wet rail status with a preset number of bogies being cut-off, and the traveling speed of the vehicle may be a limited speed of the vehicle with a preset number of bogies being cut-off. As an example, the maximum deceleration while implementing emergency braking in the wet rail status with a preset number of bogies being cut-off is a_3 , where $a_3 = a_2 \times \text{remaining number of bogies} \div \text{total number of bogies}$, and the unit is meter per second squared (m/s^2); the limited speed of the vehicle with a preset number of bogies being cut-off is v_2 in the unit of e.g. meter per second (m/s); then the third braking distance S_3 may be the ratio of the square of the limited speed of the vehicle with a preset number of bogies being cut-off to the maximum deceleration while implementing emergency braking in the wet rail status with a preset number of bogies being cut-off, i.e., the following relationship: $S_3 = v_2^2 / 2a_3$. Cutting-off the preset number of bogies is determined according to actual conditions, as an example, one bogie may be cut-off.

[0050] In yet another implementation, the emergency braking distance may be jointly obtained according to the first braking distance, the second braking distance, and the third

braking distance. Specifically, the emergency braking distance S may be the maximum value among the first braking distance, the second braking distance and the third braking distance. As an example, in the calculation of the first braking distance, the maximum deceleration a_1 in the normal operating status with all bogies being used for emergency braking is 1.2 m/s^2 , the maximum traveling speed v_1 of the vehicle is 120 km/h , then the first braking distance $S_1 = v_1^2 / 2a_1 = (120 \text{ km/h} \div 3.6) \times (120 \text{ km/h} \div 3.6) / (2 \times 1.2 \text{ m/s}^2) = 463.0 \text{ m}$. In the calculation of the second braking distance, the maximum deceleration a_2 in the wet rail status with all bogies being used for emergency braking is 0.91 m/s^2 , and the maximum traveling speed v_1 of the vehicle is 120 km/h , then the second braking distance $S_2 = v_1^2 / 2a_2 = (120 \text{ km/h} \div 3.6) \times (120 \text{ km/h} \div 3.6) / (2 \times 0.91 \text{ m/s}^2) = 610.5 \text{ m}$. In the calculation of the third braking distance, the maximum deceleration a_3 while implementing emergency braking in the wet rail status with a preset number of bogies being cut-off is $0.9 \text{ m/s}^2 \times 11 \div 12$, the limited speed v_2 of the vehicle with a preset number of bogies being cut-off is 110 km/h , then the third braking distance $S_3 = v_2^2 / 2a_3 = (110 \text{ km/h} \div 3.6) \times (110 \text{ km/h} \div 3.6) / (2 \times 0.91 \text{ m/s}^2 \times 11 \div 12) = 559.6 \text{ m}$. Since emergency braking distance may be the maximum value among the first braking distance, the second braking distance and the third braking distance, the emergency braking distance is the second braking distance, i.e., $S = S_2 = 610.5 \text{ m}$.

[0051] The first threshold Y_1 is the sum of the target equivalent virtual stopping distance and the emergency braking distance, i.e., $Y_1 = L + S$. As an example, the first threshold $Y_1 = L + S = 71.6 \text{ m} + 610.5 \text{ m} = 682.1 \text{ m}$. In actual conditions, given that the ranging deviation issue of the radar auxiliary protection system, in order to increase the safety of the train, the ranging deviation may be 5% , the first threshold $Y_1 = (L + S) \times (1 + 5\%) = 682.1 \times (1 + 5\%) = 716.2 \text{ m}$. In addition, considering the redundancy of the braking distance for the train in the actual conditions, the first threshold may be rounded up to the nearest integer, i.e., the first threshold may be 720 m .

[0052] In the actual conditions of train traveling, the alarm for the first threshold corresponds to the situation of emergency braking of the train. In other words, if the distance between the vehicle and the preceding vehicle is less than the first threshold, there is a greater risk of rear-end collision unless emergency braking is performed. In order to improve the safety of the train, before detecting the first threshold corresponding to emergency braking, the second threshold corresponding to service braking may also be detected. Compared with emergency braking, service braking has a longer braking distance, which can allow a longer

distance for the train to brake and can further reduce the risk of rear-end collision of the train.

[0053] In the embodiment of the present disclosure, the distance between the vehicle and the preceding vehicle may be compared with the second threshold. In a case that the detected distance is less than or equal to the second threshold, an alarm process is performed, where
5 the second threshold is greater than the first threshold. The second threshold is greater than the first threshold corresponding to emergency braking, that is, the second threshold corresponds to the alarm distance for service braking. The detected distance between the vehicle and the preceding vehicle is less than or equal to the second threshold, indicating that
10 the distance between the vehicle and the preceding vehicle is less than or equal to a certain constant value, i.e., the vehicle is approaching to the preceding vehicle and there may be a risk of rear-end collision, the vehicle driver can be alarmed so as to remind the safety issue of the vehicle and reduce the probability of rear-end collisions.

[0054] The second threshold may be determined based on the first threshold and a minimum alarm interval. The minimum alarm interval is the time interval between the alarm
15 for the first threshold and the alarm for the second threshold. The time interval cannot be too short, otherwise there will be continuous alarms and confusion to the judgment of the user, causing unnecessary driving risks. Specifically, the second threshold may be determined based on the first threshold, the minimum alarm interval and the traveling speed of the vehicle. As an example, the traveling speed of the vehicle may be the maximum traveling speed v_1 in
20 the unit of e.g. meter per second (m/s), the minimum alarm interval may be t_3 in the unit of e.g. seconds(s), then the second threshold Y_2 may be the sum of the first threshold Y_1 and the product of the maximum traveling speed and the minimum alarm interval, that is, the following relationship: $Y_2=Y_1+v_1\times t_3$. When specifically calculating the second threshold, the traveling speed of the vehicle may be the maximum traveling speed v_1 , v_1 is 120km/h,
25 and the minimum alarm interval t_3 is 5s, then the second threshold $Y_2=Y_1+v_1\times t_3=720m+120km/h\div 3.6\times 5s=886.7m$.

[0055] In the embodiment of the present disclosure, after detecting that the distance between the vehicle and the preceding vehicle is less than or equal to the second threshold, an alarm process is performed. After receiving the alarm, the user triggers a second braking
30 command. The second braking command refers to the command to brake the vehicle. When braking according to the second braking command, there is a corresponding second preset

deceleration for braking. The second preset deceleration corresponds to the second braking command. The second preset deceleration is less than the first preset deceleration, and the second preset deceleration is a constant value. Specifically, the second preset deceleration may be the deceleration during service braking. As an example, the second preset deceleration may be the deceleration during service braking, and the deceleration during service braking may be 1.0 m/s^2 .

[0056] In actual conditions, the second threshold may be determined based on the sum of the target equivalent virtual stopping distance and the service braking distance. The target equivalent virtual stopping distance of the second threshold may be identical to the target equivalent virtual stopping distance of the first threshold, that is, the target equivalent virtual stopping distance may be obtained jointly based on the first equivalent virtual stopping distance and the second equivalent virtual stopping distance. Specifically, the target equivalent virtual stopping distance L may be the sum of the first equivalent virtual stopping distance and the second equivalent virtual stopping distance, i.e., $L=L_1+L_2= 71.6\text{m}$. The service braking distance is the distance traveled by the vehicle when braking at the second preset deceleration. The second preset deceleration is less than the first preset deceleration. The service braking distance may be obtained based on at least one of the first service braking distance, the second service braking distance and the third service braking distance. Specifically, the service braking distance S' may be the maximum value among the first service braking distance, the second service braking distance and the third service braking distance. As an example, in the calculation of the first service braking distance, the maximum deceleration a_1' when all bogies are used for service braking in the normal operating status is 1.0 m/s^2 , the maximum traveling speed v_1 of the vehicle is 120 km/h , then the first service braking distance $S_1' = v_1^2 / 2a_1' = (120 \text{ km/h} \div 3.6) \times (120 \text{ km/h} \div 3.6) / (2 \times 1.0 \text{ m/s}^2) = 555.6 \text{ m}$. In the calculation of the second service braking distance, the maximum deceleration a_2 when all bogies are used for service braking in the wet rail status is 0.91 m/s^2 , and the maximum traveling speed v_1 of the vehicle is 120 km/h , then the second service braking distance $S_2' = v_1^2 / 2a_2 = (120 \text{ km/h} \div 3.6) \times (120 \text{ km/h} \div 3.6) / (2 \times 0.91 \text{ m/s}^2) = 610.5 \text{ m}$. In the calculation of the third service braking distance, the maximum deceleration a_3 while implementing emergency braking in the wet rail status with one bogie being cut-off is $0.91 \text{ m/s}^2 \times 11 \div 12$, and the limited speed v_2 of the vehicle with one bogie being cut-off is 110 km/h , then the third service braking distance $S_3' = v_2^2 / 2a_3 = (110 \text{ km/h} \div 3.6) \times (110 \text{ km/h} \div 3.6) /$

$(2 \times 0.91 \text{ m/s}^2 \times 11 \div 12) = 559.6 \text{ m}$. Since the service braking distance may be the maximum value among the first service braking distance, the second service braking distance and the third service braking distance, the service braking distance is the second service braking distance, that is, $S' = S2' = 610.5 \text{ m}$. The second threshold Y2 is the sum of the target equivalent virtual stopping distance and the service braking distance, i.e., $Y2 = L + S'$. As an example, the second threshold $Y2 = L + S' = 71.6 \text{ m} + 610.5 \text{ m} = 682.1 \text{ m}$. In actual conditions, given the ranging deviation of the radar auxiliary protection system, in order to increase the safety of the train, the maximum value of the ranging deviation may be 5%, then the second threshold $Y2 = (L + S') \times (1 + 5\%) = 682.1 \times (1 + 5\%) = 716.2 \text{ m}$.

[0057] According to an embodiment of the present disclosure, the value determined by the first threshold and the minimum alarm interval may be compared with the maximum value of the sum of the target equivalent virtual stopping distance and the service braking distance. In this case, the larger one of the two may be determined as the second threshold. As an example, the first threshold and the minimum alarm interval determine the second threshold $Y2 = Y1 + v1 \times t3 = 720 \text{ m} + 120 \text{ km/h} \div 3.6 \times 5 \text{ s} = 886.7 \text{ m}$. While, the sum of the target equivalent virtual stopping distance and the service braking distance determines the second threshold $Y2 = (L + S') \times (1 + 5\%) = 682.1 \times (1 + 5\%) = 716.2 \text{ m}$. After numerical comparison, it can be seen that the value determined by using the first threshold and the minimum alarm time is a larger value of the second threshold, hence, the value determined by using the first threshold and the minimum alarm interval is determined as the second threshold.

[0058] It can be seen that, in the embodiments of the present disclosure, the distance with the preceding vehicle is measured and compared with a threshold. In a case that the measured distance is less than or equal to the threshold, braking of the train is started. The threshold of braking is determined by the equivalent virtual stopping distance and the braking distance limited by the braking performance of the train itself. The method for braking a vehicle provided according to the embodiments of the present disclosure can effectively reduce the risk of rear-end collision with the preceding vehicle and improve the train operation safety by determining the threshold of braking considering both the ranging capability of the radar protection system and the braking performance of the train.

[0059] Based on the method for braking a vehicle provided in the above embodiments, a device for braking a vehicle is further provided according to the embodiment of the present

disclosure, the operating principle of which will be described in detail below with reference to the drawing.

[0060] Referring to Figure 2, Figure 2 is a structural block diagram of a device 200 for braking a vehicle according to an embodiment of the present disclosure.

5 **[0061]** The device 200 for braking a vehicle provided according to the embodiment of the present disclosure includes:

an acquisition unit 210, configured to acquire a distance between the vehicle and a preceding vehicle;

10 a first alarm unit 220, configured to issue an alarm in a case that the distance is less than or equal to a first threshold; and

a first braking unit 230, configured to receive a first braking command triggered by a user, and brake the vehicle at a first preset deceleration according to the first braking command; wherein, the first threshold is obtained based on a sum of a target equivalent virtual stopping distance and an emergency braking distance, the target equivalent virtual
15 stopping distance is obtained based on at least one of a first equivalent virtual stopping distance and a second equivalent virtual stopping distance, the first equivalent virtual stopping distance is a distance traveled by the vehicle during acquiring the distance between the vehicle and the preceding vehicle, the second equivalent virtual stopping distance is a distance traveled by the vehicle during triggering the first braking command by the user, and the
20 emergency braking distance is a distance traveled by the vehicle once braking the vehicle at the first preset deceleration.

[0062] In a possible implementation, the target equivalent virtual stopping distance is a sum of the first equivalent virtual stopping distance and the second equivalent virtual stopping distance.

25 **[0063]** In a possible implementation, the emergency braking distance is obtained based on at least one of a first braking distance, a second braking distance and a third braking distance, and the first braking distance is a distance traveled by the vehicle in a case that all bogies are used for braking in a normal operating status, the second braking distance is a distance traveled by the vehicle in a case that all bogies are used for braking in a wet rail status, and
30 the third braking distance is a distance traveled by the vehicle while braking in the wet rail

status with a preset number of bogies being cut-off.

[0064] In a possible implementation, the emergency braking distance is the maximum value among the first braking distance, the second braking distance and the third braking distance.

[0065] In a possible implementation, the device for braking a vehicle 200 further includes:

5 a second alarm unit, configured to issue an alarm in a case that the distance is less than or equal to a second threshold; where the second threshold is greater than the first threshold, and the second threshold is determined based on the first threshold and a minimum alarm interval; and

10 a second braking unit, configured to receive a second braking command triggered by the user, and brake the vehicle at a second preset deceleration based on the second braking command, where the second preset deceleration is less than the first preset deceleration.

[0066] Since the device 200 for braking a vehicle corresponds to the method for braking a vehicle provided in the above method embodiments, the specific implementation of each unit of the device 200 is of the same concept as the above method embodiment, the specific
15 implementation of each unit of the vehicle braking device 200 may be referred to the description of the above method embodiments, which will not be repeated here.

[0067] According to an embodiment of the present disclosure, a train is provided, including a device for braking a vehicle, where the device for braking a vehicle may be used to implement the method for braking a vehicle according to any one of the embodiments of the
20 present disclosure.

[0068] When introducing elements of the various embodiments of the present disclosure, the articles "a," "an," "the," and "said" are intended to indicate that there are one or more of elements. The words "comprising", "containing" and "having" are all inclusive and indicate that there may be other elements in addition to the listed elements.

25 **[0069]** It should be noted that those of ordinary skill in the art can understand that all or part of the processes in the above method embodiments may be implemented by hardware under instruction of a computer program, and the program may be stored in a computer-readable storage medium. When the program is executed, the processes of the above-mentioned method embodiments may be implemented. The storage medium may be a magnetic disk, an
30 optical disk, a read-only memory (ROM) or a random access memory (RAM), etc.

[0070] The embodiments of the disclosure are described in a progressive way, each of which emphasizes the differences from others, and the same or similar elements among the embodiments can be referred to each other. In particular, since the device embodiments are basically similar to the method embodiments, the description is relatively simple and for relevant matters references may be made to the description of the method. The device embodiments described above are merely illustrative, in which the units and modules described as separate components may be or may not be physically separated. Part or all of the units and modules may be selected according to practical needs to achieve the purpose of the solution of the embodiments. It can be understood and implemented by those skilled in the art without creative efforts.

[0071] Specific embodiments of the present invention are set forth above. However, it is to be noted that various changes and modifications may be made by those skilled in the art without departing from the principle of the invention, and these changes and modifications should fall in the scope of protection of this disclosure.

CLAIMS

1. A method for braking a vehicle, comprising:

acquiring a distance between the vehicle and a preceding vehicle;

5 issuing an alarm in a case that the distance is less than or equal to a first threshold;

receiving a first braking command triggered by a user; and

braking the vehicle at a first preset deceleration, according to the first braking command;

wherein the first threshold is obtained from a sum of a target equivalent virtual stopping distance and an emergency braking distance, the target equivalent virtual stopping distance is
10 obtained based on at least one of a first equivalent virtual stopping distance and a second equivalent virtual stopping distance, the first equivalent virtual stopping distance is a distance traveled by the vehicle during acquiring the distance between the vehicle and the preceding vehicle, the second equivalent virtual stopping distance is a distance traveled by the vehicle during triggering the first braking command by the user, and the emergency braking distance
15 is a distance traveled by the vehicle once braking the vehicle at the first preset deceleration.

2. The method according to claim 1, wherein the target equivalent virtual stopping distance is a sum of the first equivalent virtual stopping distance and the second equivalent virtual stopping distance.

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3. The method according to claim 1, wherein the emergency braking distance is obtained based on at least one of a first braking distance, a second braking distance and a third braking distance, and the first braking distance is a distance traveled by the vehicle in a case that all bogies are used for braking in a normal operating status, the second braking distance is a
25 distance traveled by the vehicle in a case that all bogies are used for braking in a wet rail status, and the third braking distance is a distance traveled by the vehicle while braking in the wet rail status with a preset number of bogies being cut-off.

4. The method according to claim 3, wherein the emergency braking distance is a
30 maximum value among the first braking distance, the second braking distance and the third braking distance.

5. The method according to any one of claims 1-4, further comprising:

in a case that the distance is less than or equal to a second threshold, issuing an alarm, wherein the second threshold is greater than the first threshold, and the second threshold is determined based on the first threshold and a minimum alarm interval;

5 receiving a second braking command triggered by the user; and

braking the vehicle at a second preset deceleration, based on the second braking command, wherein the second preset deceleration is less than the first preset deceleration.

6. A device for braking a vehicle, comprising:

10 an acquisition unit, configured to acquire a distance between the vehicle and a preceding vehicle;

a first alarm unit, configured to issue an alarm in a case that the distance is less than or equal to a first threshold; and

15 a first braking unit, configured to receive a first braking command triggered by a user, and brake the vehicle at a first preset deceleration based on the first braking command;

wherein the first threshold is obtained from a sum of a target equivalent virtual stopping distance and an emergency braking distance, the target equivalent virtual stopping distance is obtained based on at least one of a first equivalent virtual stopping distance and a second equivalent virtual stopping distance, the first equivalent virtual stopping distance is a distance
20 traveled by the vehicle during acquiring the distance between the vehicle and the preceding vehicle, the second equivalent virtual stopping distance is a distance traveled by the vehicle during triggering the first braking command by the user, and the emergency braking distance is a distance traveled by the vehicle once braking the vehicle at the first preset deceleration.

25 7. The device according to claim 6, wherein the target equivalent virtual stopping distance is a sum of the first equivalent virtual stopping distance and the second equivalent virtual stopping distance.

8. The device according to claim 6, wherein the emergency braking distance is obtained
30 based on at least one of a first braking distance, a second braking distance and a third braking distance, and the first braking distance is a distance traveled by the vehicle in a case that all bogies are used for braking in a normal operating status, the second braking distance is a

distance traveled by the vehicle in a case that all bogies are used for braking in a wet rail status, and the third braking distance is a distance traveled by the vehicle while braking in the wet rail status with a preset number of bogies being cut-off.

5 9. The device according to claim 8, wherein the emergency braking distance is a maximum value among the first braking distance, the second braking distance and the third braking distance.

10 10. The device according to any one of claims 6-9, further comprising:

 a second alarm unit, configured to issue an alarm in a case that the distance is less than or equal to a second threshold, wherein the second threshold is greater than the first threshold, the second threshold is determined based on the first threshold and a minimum alarm interval; and

 a second braking unit, configured to receive a second braking command triggered by the user, and brake the vehicle at a second preset deceleration based on the second braking command, wherein the second preset deceleration is less than the first preset deceleration.

15 11. A train comprising a device for braking a vehicle, wherein the device is configured to implement the method according to any one of claims 1 to 5.