Description

Title: VEHICLE AND METHOD FOR IMPLEMENTING SAME

Technical field

[1] This disclosure relates to the field of road or rail vehicles, and in particular to their braking systems. The context specifically concerns the aspects of protecting the environment by suctioning brake particles emitted by friction brakes, particularly disc brakes.

Prior art

[2] Document FR 3 057 040 A1 describes a disc brake lining equipped with a collection groove and a through-hole, fluidly connected to suction means. This lining allows an efficient suctioning of brake dust along the entire radial height of the lining. The suction means comprise a fan that generates negative pressure to draw the dust towards a collection filter.

[3] Documents DE 198 46 887 A1 and DE 196 43 869 A1 illustrate two examples of controlling the suction means to have the maximum amount of suction during braking.

[4] Document FR 3 088 395 A1 introduces the concept of suction compensation based on the fill level of the collection filter: to ensure satisfactory suction throughout the filter's service life, the suction power can be increased as needed.

[5] The existing systems are therefore satisfied with systematically advocating only the activation of suction during braking phases and the deactivation of suction after braking phases.

[6] However, when driving in a hostile environment, for example when fording water, activating the particle suction system causes water to be drawn into the pneumatic circuit, rendering it inoperative. None of the above disclosures identify this problem or offer a solution to it.

Summary

[7] The present disclosure thus proposes a vehicle and a method for utilizing the vehicle that do not impair the functioning of the brake particle capture system when fording water.

[8] A vehicle is thus proposed comprising at least one disc brake comprising: a pair of friction linings having a brake particle collection element; and particle suction devices fluidically connected to each collection element and controlled by a control unit to switch between an active state and an inactive state, the control unit being configured to keep the suction devices inactive when the vehicle speed is below a threshold speed.

[9] The inventors have demonstrated that the pad's collection elements (for example a groove at the trailing edge of the pad, a peripheral groove, a central suction hole, a caliper housing, a suction nozzle, etc.), when in contact with the disc, can surprisingly serve as a reservoir for particles during braking phases, even in the absence of suction. It is therefore possible to capture brake particles without necessarily applying suction at the exact moment of braking. Suction can therefore be controlled so as not to activate when fording water, a maneuver that is certain to be performed at

speeds lower than a typical cruising speed for a motor vehicle, without compromising particle suction efficiency and, consequently, environmental and human protection.

[10] The "active" state corresponds to the generation of negative pressure and therefore of a suction airflow, whereas the "inactive" state corresponds to an absence of suction.

[11] The term "control unit" is understood to mean a hardware and/or software component dedicated to controlling the capture system or integrated into one of the main controllers of the vehicle (CAN, ECU, EMS, etc.).

[12] According to another aspect, the threshold speed is between 20 km/h and 30 km/h. The speed at which water is forded is generally lower than the values within this range.

[13] According to another aspect, the control unit is configured to control a series of cycles, each of the cycles comprising a first step of a first duration, during which the suction devices are active, and a second step of a second duration, during which the suction devices are inactive. The inventors have demonstrated that during suction, particles trapped in the surface irregularities of the disc are suctioned off, whether the suctioning occurs during brake activation or when not braking. It is therefore possible to maintain suction efficiency by programming a cyclic suction that is not necessarily linked to brake activation. Cyclic activation and deactivation is to be understood as an alternation, or a continuous and direct sequence of switching between the active and inactive states. Furthermore, it is implicit that the first and second durations are non-zero; otherwise, the suctioning would be continuous or completely inactive.

[14] According to another aspect, the control unit is configured to control the active or inactive state of the suction devices independently of the activation of the brake. By activating suction in a manner uncorrelated with brake activation, this eliminates the need to activate suction quickly at the very moment of braking; indeed, when braking begins this produces a spike in particle generation that requires immediately creating negative pressure to capture a significant portion of the particles. There is therefore no longer a need to equip the system with a powerful motor that causes spikes in the electrical power consumption.

[15] According to another aspect, the control unit is configured to activate the suction devices upon activation of the brake, and to maintain them in the active state until the end of the activation of the brake or until a few seconds after the end of the activation of the brake. In this case, the majority of the particles produced during braking are captured.

[16] According to another aspect, each collection element is a groove, optionally a peripheral groove entirely surrounding the lining.

[17] The invention also relates to a method for utilizing a vehicle according to one of the embodiments described above, the method comprising: receiving a speed signal at the control unit, and controlling the suction devices, via the control unit, to keep the suction devices inactive when the vehicle speed is below a threshold speed.

[18] According to another aspect, the threshold speed is between 20 km/h and 30 km/h.

[19] According to another aspect, the method comprises a cyclic phase of controlling the suction devices, the cyclic phase comprising a series of cycles, each of the cycles comprising a first step of a first duration during which the suction devices are active and a second step of a second duration during which the suction devices are inactive.

[20] According to another aspect, the first duration is between 5 seconds and 2 minutes, preferably between 10 seconds and 1 minute.

[21] According to another aspect, the second duration is between 30 seconds and 30 minutes, preferably between 4 and 10 minutes.

[22] According to another aspect, the ratio of the first duration to the second duration is between 1/3 and 1/10.

[23] According to another aspect, the active or inactive state of the suction devices is controlled independently of the activation of the brake. In this case, the suction devices are controlled exclusively according to the cyclic phase (and provided that the speed is above the threshold speed).

[24] According to another aspect, upon activation of the brake, the suction devices are activated and remain active until the end of the activation of the brake or for a few seconds after the end of the activation of the brake. This braking phase interrupts the cyclic phase, which resumes after braking. This strategy combines effective particle capture when not braking and effective capture when braking.

[25] According to another aspect, each collection element is a groove, optionally a peripheral groove entirely surrounding the lining.

Brief description of drawings

[26] Other features, details, and advantages will become apparent upon reading the detailed description below and analyzing the accompanying drawings, in which:

[27] FIG. 1 shows a vehicle, a disc brake, and a particle capture system.

[28] FIG. 2 illustrates various examples of brake pads.

[29] FIG. 3 shows a flowchart of a method for utilizing the brake.

[30] FIG. 4A represents a flowchart of a suction process.

[31] FIG. 4B shows a timing diagram for the process of FIG. 4A.

[32] FIG. 5 illustrates a timing diagram where suction is activated during braking, with the speed remaining above the threshold speed.

[33] FIG. 6 illustrates a timing diagram where suction is activated during braking, with the speed dropping below the threshold speed.

Description of embodiments

[34] The figures schematically represent different aspects of the invention. Unless explicitly stated otherwise, each aspect shown in a figure may be combined with other aspects presented in other figures, in any technically feasible combination.

[35] FIG. 1 illustrates a vehicle 1, whether a road vehicle (car, van, truck, etc.) or a rail vehicle (train, tram, subway, etc.), which comprises a disc brake 2. It is understood that the invention is not limited to this type of vehicle or to this type of brake: indeed, a person skilled in the art will be able to adapt the invention for other vehicles (motorcycles, bicycles, etc.) or for other types of brakes (drum, multi-disc, etc.).

[36] The brake 2 essentially consists of a disc 4 secured to a wheel of the vehicle 1 and rotating about an axis 6 at a rotational speed denoted W. The rotational speed W is proportional to the linear speed V of the vehicle 1. A caliper 8 which straddles part of the periphery of the disc 4 encloses two brake pads formed of a backing plate and a lining 10, 12. For example, the pads may be those depicted in FIG. 3 and inspired by FIG. 1 of document FR 3 087 238 A1, FIG. 3A of document GB 2 533 476 A, or FIGS. 3 or 4 of document KR 2020 0016 690 A. Applying a force parallel to the axis 6 by means of one or more pistons generates braking torque via the friction of the linings 10, 12 on the respective faces of the disc 4.

[37] During a braking operation, the friction of the linings 10, 12 on the disc 4 generates particles (dust, PM10, PM2.5, etc.). These particles are harmful to the environment: their composition may contain elements that are difficult for the environment to assimilate and are harmful to the respiratory functions of people who are repeatedly exposed.

[38] A particle capture system 20 is therefore provided for recovering the particles. Such a system 20 may, for example, be in the form presented in document FR 3 057 040 A1 or in some other form, in particular according to the examples in the patent literature published in the name of the Tallano Technologies company.

[39] The capture system 20 may thus comprise a negative pressure source 22, here represented as a fan, which is fluidically connected, for example by means of a line 24 (hose), to a collection element at the interface between the linings 10, 12 and the disc 4. In one example, the linings 10, 12 may be provided with a through-hole and the line 24 may be connected to the rear face of the linings 10, 12. The line 24 may comprise a filter 26 or a particle collection tank. This filter 26 may, for example, be sized to require no maintenance and to be replaced simultaneously with the replacement of the linings 10, 12. The filter 26 may be located upstream or downstream of the fan 22.

[40] The operation of the fan 22 can be controlled, via a connection 28, by a control unit 30. The control unit 30 is represented schematically here. It may comprise memory, a processor, and communication buses. It may be in the form of hardware and/or software components dedicated to controlling the capture system or may be integrated into one of the main controllers of the vehicle (CAN, ECU, EMS, etc.).

[41] The control unit 30 regulates the amount of current supplied to the motor driving the fan 22, thereby controlling its speed. When no electric current is supplied to the motor driving the fan 22, the

fan 22 remains stationary, and no negative pressure is generated within the line 24. No particle suction occurs. In such case, the suction devices 20, 22, 24, 26 are said to be in an inactive state. When electric current is supplied to the motor driving the fan 22, the fan begins to rotate and suction is generated. In such case, the suction devices 20, 22, 24, 26 are said to be in an active state, regardless of the speed (provided it is non-zero) of the fan and/or the amplitude of the electric current (provided it is non-zero) supplied to the motor.

[42] In a variant, the active or inactive state of the suction devices is regulated by a valve positioned within the pneumatic suction circuit, and the fan may rotate continuously.

[43] FIG. 2 shows three examples of brake pads 40, 50, 60 that can be used with the particle capture system. Other variants are also possible.

[44] Brake pad 40 comprises a backing plate 42 to which the friction lining 10 is attached. A particle collection groove 44 is formed in the lining 10. This groove is connected to suction devices.

[45] Pad 50 comprises a peripheral groove 54 that follows the profile of the lining 10. An air inlet is provided at the center of the lining 10, and an air outlet is located in the groove 54.

[46] Pad 60 is formed by a lining 10 and a skirt 62 designed to be positioned around the lining 10 in order to form a suction zone 64 between the lining 10 and the skirt 62.

[47] Thus, various collection elements 44, 54, 64 may be provided on a pad for the suctioning of particles.

[48] FIG. 3 shows a method 100 of utilization in a vehicle (1 in FIG. 1). The various steps are presented as occurring sequentially in order to facilitate understanding the method, but these steps may occur continuously or sometimes concurrently. The method 100 comprises a step 110 of receiving a vehicle speed signal V at the control unit 30. The signal may be transmitted by any suitable sensor or computing unit of the vehicle. This step may, for example, be performed continuously or sequentially at a frequency of between 1 and 50 Hz.

[49] In step 120, the speed V (current speed) received by the control unit 30 is compared to a threshold speed V0. The threshold speed may be any value, in particular an integer value, between 20 km/h and 30 km/h.

[50] If the speed V is lower than V0, the method 100 proceeds to step 130, which controls the suction devices to be (or remain) inactive. The system thus ensures that no particle suction operation is performed at low speeds and that water does not enter the suction circuit when fording water. Experience has shown that driving at higher speeds, even in the rain, does not present this risk of water intake into the circuit.

[51] If the speed V is greater than V0, suction can be controlled in step 140 according to one of the following modes: (a) suction is triggered at the moment of brake activation and ceases when brake activation is stopped; (b) suction is triggered at the moment of brake activation and ceases a few seconds (for example 1, 2, 3, 4, 5, 6, or 7 seconds) after brake activation is stopped; (c) suction is cyclical and independent of brake activation: whether or not the brake is activated, suctioning

maintains its cyclical rhythm; (d) suction is cyclical, and the suction devices are additionally activated at brake activation, as described in modes (a) or (b) above. Regardless of the operating mode, if the speed drops below V0, all suction ceases.

[52] The control unit may be configured to remain in one of these operating modes. Alternatively, the control unit may switch from one mode to another in a predetermined manner, according to predefined parameters (for example, a wear level of the linings or disc, a filter clogging level, etc.). In a variant, the switch is made by user selection.

[53] Because the speed V is continuously monitored, step 140 ceases as soon as a speed V lower than V0 is detected.

[54] Operating modes (a) and (b), which correspond to applying suction at the moment of braking, require no further explanation: as long as the speed V remains above V0, suction is activated at the moment of braking and stops when braking ends, possibly after a delay of a few seconds.

[55] Cyclic suction 1000 (mode (c) above) is illustrated in FIGS. 4A and 4B. In a first step 1100 of a first duration T1, the suction devices are controlled to be active. In a second step 1200 of a second duration T2, the suction devices are controlled to be inactive.

[56] The two steps 1100, 1200 form a cycle C that is repeated (as long as the vehicle speed remains above the threshold V0 and independently of brake activation). The two steps immediately follow one another temporally.

[57] This temporal sequence is also shown in FIG. 4B. The horizontal axis represents time. The graph shows the square waves corresponding to state changes between the active and inactive states, with each state maintained for a respective duration T1, T2.

[58] It is apparent that cyclic suction is as effective as suction limited to braking sequences. Approximately 67% of the PM10 particles produced are captured. Cyclic suction allows selecting a lower fan acceleration rate, as there is no need to ramp up the fan speed quickly in order to capture the spike in particles that occurs during braking. A smaller motor can thus be selected and have the same particle capture rate.

[59] The following table shows the amounts of PM10 particles detected (produced by the brake and not captured) during a standardized WLTP cycle, for various suction configurations (in mg per km and per vehicle brake):

Continuous suction	Cyclic suction (T1=1min; T2=3min)	Cyclic suction (T1=1min; T2=6min)	Cyclic suction (T1=1min; T2=13min)	Cyclic suction (T1=1min; T2=27min)
1.8	2.2	2.6	3.6	3.7

Table 1

[60] Tests using various values for T1 and T2 show that when the T1/T2 ratio is less than 10%, the amount of detected particles (produced and not captured) is approximately 3.7 mg/km/brake, which is the amount detected in the absence of suction. For a T1/T2 ratio between 15% and 30%, the

efficiency is acceptable. Above 30%, the benefits from capturing particles are offset by high electrical power consumption.

[61] As for the duration values, the duration T1 may be between 5 seconds and 2 minutes, preferably between 10 seconds and 1 minute. Below this range, it becomes necessary to provide for a rapid acceleration of the fan so that it quickly reaches a steady state (therefore requiring a powerful, high-consumption motor) before T1 ends. Above this range, the electrical power consumption is high.

[62] The second duration T2 may be between 30 seconds and 30 minutes, preferably between 4 and 10 minutes. For the reasons mentioned above, the duration T2 is selected such that the ratio of the first duration T1 to the second duration T2 is between 1/3 and 1/10.

[63] The following table shows the amounts of PM10 particles detected (produced by the brake and not captured) during a standardized WLTP cycle, for various suction configurations (in mg per km and per vehicle brake):

Cyclic suction (T1=1min; T2=6min)	Suction 2x for 30 seconds with 5 minutes below V0 in between	Suction for 20 seconds then 3 minutes below V0 then suction for 40 seconds
2.6	2.7	2.7

Table 2

[64] Suction tests with interruptions (due to the speed dropping below the threshold V0) appear to confirm that suction efficiency is substantially maintained, whether suction is applied one time for 1 minute or suction is applied multiple times (totaling 1 minute of cumulative time).

[65] FIGS. 5 and 6 show timing diagrams corresponding to operating mode (d) mentioned above.

[66] FIG. 5 illustrates a situation where the speed V remains above V0. The suction devices are controlled in a cyclic phase up to braking start time TD. Braking stops at braking end time TF. The speed decreased between TD and TF but without dropping below V0. At time TD, if the suction devices are active according to the imposed cycle, they remain active; if they are inactive according to the imposed cycle, they are activated. The suction devices remain active until the end of braking TF, optionally increased by a delay d. Thus, in the illustrated example, the suction devices become inactive again at time TF+d.

[67] A new cyclic phase begins after braking.

[68] FIG. 6 illustrates a situation where the speed V drops below V0. In this example – which initially resembles the one in FIG. 5 – the speed drops below the threshold V0 at time T0 during braking. At that moment, suction becomes inactive, even though braking is in progress. After braking, in the illustrated case, the speed remains below V0 and suction remains inactive. If the speed V were to rise above V0 again, cyclic suction would resume.

[69] In other words, FIGS. 5 and 6 show that in mode (d), suction is cyclical by default but brake activation prioritizes suction, but also that no suction is performed when the vehicle speed is below V0, regardless of whether or not the brake is activated.

[70] This strategy makes it possible to achieve a good compromise between particle capture efficiency and system reliability, avoiding the risk of flooding the system.

Claims

[Claim 1] A vehicle (1) comprising at least one disc brake (2) comprising:

- a pair of friction linings (10, 12) having a brake particle collection element (44, 54, 64); and
- particle suction devices (22, 24, 26) fluidically connected to each collection element and controlled by a control unit (30) to switch between an active and an inactive state, the control unit (30) being configured to
    - keep the suction devices (22, 24, 26) inactive when the speed (V) of the vehicle (1) is below a threshold speed (V0); and
    - deactivate the suction devices (22, 24, 26) if they are active when the speed decreases and falls below the threshold speed (V0).

[Claim 2] Vehicle (1) according to claim 1, wherein the threshold speed (V0) is between 20 km/h and 30 km/h.

[Claim 3] Vehicle (1) according to claim 1 or 2, wherein the control unit (30) is configured to control a series of cycles (C), each of the cycles (C) comprising a first step (1100) of a first duration (T1) during which the suction devices (22, 24, 26) are active and a second step (1200) of a second duration (T2) during which the suction devices (22, 24, 26) are inactive.

[Claim 4] Vehicle (1) according to any one of claims 1 to 3, wherein the control unit (30) is configured to control the active or inactive state of the suction devices (22, 24, 26) independently of the activation of the brake (2).

[Claim 5] Vehicle (1) according to any one of claims 1 to 3, wherein the control unit (30) is configured to activate the suction devices (22, 24, 26) upon activation of the brake (2), and to maintain them in the active state until the end of the activation of the brake (2) or until a few seconds after the end of the activation of the brake (2).

[Claim 6] Vehicle (1) according to any one of claims 1 to 5, wherein each collection element is a groove (44, 54, 64), optionally a peripheral groove (54) entirely surrounding the lining.

[Claim 7] A method (100) for utilizing a vehicle according to any one of claims 1 to 6, the method comprising: receiving (110) a signal for the speed (V) at the control unit (30) and controlling (130) the suction devices (22, 24, 26), via the control unit (30), to keep the suction devices (22, 24, 26) inactive when the speed (V) of the vehicle (1) is below a threshold speed (V0) and to render the suction devices (22, 24, 26) inactive if they are active when the speed decreases and falls below the threshold speed (V0).

[Claim 8] Method (100) according to claim 7, wherein the threshold speed (V0) is between 20 km/h and 30 km/h.

[Claim 9] Method (100) according to claim 7 or 8, comprising a cyclic phase (1000) of controlling the suction devices, the cyclic phase (1000) comprising a series of cycles (C), each of the cycles (C) comprising a first step (1100) of a first duration (T1) during which the suction devices (22, 24, 26) are

active and a second step (1200) of a second duration (T2) during which the suction devices (22, 24, 26) are inactive.

[Claim 10] Method (100) according to claim 9, wherein the first duration (T1) is between 5 seconds and 2 minutes, preferably between 10 seconds and 1 minute.

[Claim 11] Method (100) according to claim 9 or 10, wherein the second duration (T2) is between 30 seconds and 30 minutes, preferably between 4 and 10 minutes.

[Claim 12] Method (100) according to any one of claims 9 to 12, wherein the ratio of the first duration (T1) to the second duration (T2) is between 1/3 and 1/10.

[Claim 13] Method (100) according to any one of claims 7 to 12, wherein the active or inactive state of the suction devices (22, 24, 26) is controlled independently of the activation of the brake (2).

[Claim 14] Method (100) according to any one of claims 7 to 12, wherein, upon activation of the brake, the suction devices (22, 24, 26) are activated and remain active until the end of the activation of the brake or for a few seconds after the end of activation of the brake.

[Claim 15] Method (100) according to any one of claims 7 to 14, wherein each collection element is a groove (44, 54, 64), optionally a peripheral groove (54) entirely surrounding the lining.