Description

Title: BRAKE PARTICLE CAPTURE METHOD AND SYSTEM

Technical field

[1] This disclosure relates to the field of vehicle braking systems (for motor or rail vehicles) or industrial 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, fluidically 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] Thus, existing systems consistently advocate activating the suction during braking phases and deactivating it after braking phases. It has been observed that a peak in particle generation occurs very rapidly after the onset of braking. To capture the majority of these particles, the suction means must therefore react quickly to the initiation of braking: a powerful motor is required to ensure that the acceleration of the suction fan is sufficient to reach full operating speed in the shortest possible time, thereby capturing the maximum number of particles generated during this peak. Motors powerful enough to achieve the requisite acceleration curves are expensive and create a significant surge in electrical current drawn by the fan at the moment of its acceleration.

[6] A solution presented in document FR 3 088 393 A1 aims to anticipate the starting of the suction fan by detecting the activation of a regenerative brake. However, this solution suffers from the disadvantage of over-activating the particle collection system: the friction brake is not systematically activated when regenerative braking is employed. In addition, this solution is only feasible for vehicles equipped with regenerative braking.

Summary

[7] The present disclosure thus proposes a method for implementing a particle capture system that enables an efficient suction of brake particles without the use of a powerful and expensive motor which would generate significant spikes in electrical power consumption when it begins to rotate.

[8] A method is therefore proposed for implementing a particle capture system for capturing brake particles from a disc brake, the particle capture system comprising particle suction devices and a control unit configured to control whether the suction devices are in an active or inactive state, the

method comprising a series of cycles, each cycle comprising a first step of a first duration, during which the suction devices are controlled by the control unit to be in an active state, and a second step of a second duration, during which the suction devices are controlled by the control unit to be in an inactive state.

[9] The inventors have surprisingly demonstrated that regularly activating and deactivating suction, and doing so independently of brake activation, allows capturing a significant and sufficient amount of particles. Without wishing to be bound by any theory, these positive results appear to stem from two factors. The first factor appears to be the fact that the suction area of the brake pad (for example, a groove at the pad's trailing edge or a peripheral groove) can serve as a particle reservoir during braking phases, even in the absence of suction. The second factor is the fact that, during suction, particles trapped within the surface irregularities of the disc are suctioned out, whether the suction occurs during brake application or in the absence of braking. By activating suction cyclically, i.e. independently of brake activation, this eliminates the need to rapidly activate suction at the precise moment of braking to capture particles at the peak discussed above. As a result, there is no longer any need to equip the system with a powerful motor that causes peaks in electrical power consumption.

[10] Cyclic activation and deactivation is to be understood as an alternation, or a continuous and direct succession of switching, between the active state and the inactive state.

[11] 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.

[12] The "suction devices" comprise one or more elements configured to create a negative-pressure flow near the interface between the disc and the friction lining. The documents cited above provide examples of structures that allow generating this negative-pressure flow. Examples include a caliper cover, a suction nozzle, and a brake lining having a groove and a through-hole. The source of the negative pressure may be a fan driven by a motor. The "active" state corresponds to the motor when running, while the "inactive" state corresponds to the motor when stopped. The method described herein therefore alternates between running and stopping the motor, thereby eliminating the need to equip the system with a powerful motor capable of ensuring rapid rotational acceleration when the onset of a braking phase is detected. The system can therefore be equipped with a smaller, less expensive, lighter motor that draws less power.

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

[14] Furthermore, it is implicit that the first and second durations are non-zero; otherwise, the suction would be either continuous or completely inactive.

[15] The intended application encompasses disc brakes for motor or rail vehicles, or industrial disc brakes. In this type of brake, one or more brake pads come into contact with one or more discs. It is

understood that the particle capture system of this disclosure is also capable of capturing particles from other types of brakes, in particular drum brakes.

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

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

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

[19] According to another aspect, the control unit receives a signal indicative of the rotational speed of the disc, and the suction devices are controlled to remain inactive if the rotational speed of the disc is below a threshold. This is particularly advantageous for a brake equipping a vehicle: suction may prove risky at low speeds when the vehicle is fording water, since water can enter the suction circuit. Above a certain speed, this risk no longer exists. Tests have shown that driving in the rain does not present this risk of water being drawn into the pneumatic circuit. The threshold speed may depend on the vehicle in question and may be around 2 to 3 revolutions per second (25 to 30 km/h).

[20] According to another aspect, a degree of wear of the disc is monitored, and the first and second durations are adjusted such that the ratio between the first duration and the second duration increases with the wear of the disc.

[21] According to another aspect, the brake comprises a pair of linings; a disc having two annular friction surfaces which are the respective sites of friction between the linings and the disc, each annular friction surface being delimited by an inner circle and an outer circle; and the particle capture system comprises two grooves fluidically connected to the negative pressure source and positioned at a distance from the friction linings, each groove being positioned facing a respective annular friction surface, and each groove extending from the inner circle to the outer circle.

[22] The invention also relates to a particle capture system for capturing brake particles emitted by a disc brake, the particle capture system comprising: particle suction devices capable of assuming an active or an inactive state; and a control unit configured to switch the suction devices alternately between an active state and an inactive state in accordance with the method described above.

[23] The invention also relates to a disc brake comprising a particle capture system as described above, wherein the active or inactive state of the suction devices is regulated independently of the activation of the brake.

[24] According to another aspect, the brake comprises a pair of brake pads, each having a particle collection groove, the suction devices of the particle capture system being fluidically connected to the particle collection grooves.

[25] According to another aspect, the brake comprises a pair of friction linings; a disc having two annular friction surfaces which are the respective sites of the friction of the linings against the disc, each annular friction surface being delimited by an inner circle and an outer circle; and a brake

particle capture system comprising a negative pressure source and two suction grooves fluidically connected to the negative pressure source and positioned at a distance from the friction linings, each groove being positioned facing a respective annular friction surface and each groove extending from the inner circle to the outer circle.

[26] "Each groove extending from the inner circle to the outer circle" is understood to mean that, as the disc rotates, the groove will overhang the entirety of one of the friction surfaces. The groove may be slightly larger or slightly smaller (for example, +/- 10%) than the distance between the inner circle and the outer circle.

[27] According to another aspect, each groove is substantially rectilinear and has a width, measured in a circumferential direction, that is between 1 and 6 mm, and is preferably 2 or 4 mm.

[28] The groove may be configured to create a suction flow that is perpendicular to the annular friction surfaces. In one variant, the flow is parallel to the radial direction.

[29] According to another aspect, each groove is arranged in a respective nozzle. There are thus two nozzles facing one another on opposite sides of the disk.

[30] According to another aspect, each nozzle features at least one bleed hole in fluid communication with the groove. Such a hole serves to initiate an airflow in a direction counter to the direction of the disk's movement. In one variant, the nozzle comprises two holes on two opposite faces (upstream and downstream) of the nozzle. In another variant, two bleed holes may be provided on a rear face of the nozzle, and suction can then be applied through a suction hole that is centered relative to the two bleed holes, in order to minimize the path traveled by the air within the grooves and enhance suction efficiency.

[31] According to another aspect, each nozzle is positioned at an axial distance of less than three millimeters, preferably less than 0.1 mm, from the respective annular friction surface.

[32] According to another aspect, each nozzle comprises a downstream edge provided with a seal or a brush in contact with the respective annular friction surface. Thus, an upstream edge of the nozzle, i.e. the first edge encountered by a point on the disc as it rotates, can be at a distance from the disc, while the downstream edge, provided with the seal, is in contact with the disc. This seal serves to scrape away any particles, thereby further enhancing their suctioning.

[33] According to another aspect, each nozzle comprises an upstream edge and a downstream edge, the downstream edge being further away from its respective annular friction surface than the upstream edge. This allows suctioning air downstream of the nozzle and initiating an airflow that is counter to the direction of the disc's movement.

[34] According to another aspect, the groove of each nozzle has a longitudinal direction that is aligned with a radius of the disc; this radius is preferably angularly offset from a median radius of the linings by an angle of between 20° and 60°. This angle defines the clearance between the brake pads and the nozzles. An angle that is too small imposes design constraints on the nozzles due to

their proximity to the caliper. An angle that is too large complicates the mounting of the nozzles, as they can no longer be attached to the caliper.

[35] According to another aspect, the brake comprises a fixed caliper or a floating caliper that slides relative to a caliper carrier; the nozzles are attached to either the fixed caliper or the caliper carrier. This serves in particular to avoid having a complex system for mounting the nozzles to the vehicle.

[36] According another aspect, the particle capture system comprises two rigid lines, each connected to a respective nozzle, by means of which the nozzles are held in position facing the disc.

[37] According another aspect, a mounting bracket connects the rigid lines to the caliper or caliper carrier, the mounting bracket comprising two holes traversed by the rigid lines.

[38] According another aspect, the two grooves are provided in a single nozzle. This single nozzle may have the same features set forth above for the pair of nozzles, particularly concerning the bleed hole(s), the upstream edge and/or downstream edge, the seal, the distance from the disc, the clearance angle relative to the linings, or the attachment to the caliper by means of a bracket.

[39] According another aspect, an auxiliary groove, which straddles the edge of the disc, connects the two suction grooves together. This auxiliary groove may be narrower than the two suction grooves.

[40] According another aspect, the disc is covered with a ceramic coating. The coating may be tungsten carbide or chromium carbide. Since these types of discs undergo less wear (approximately 0.2 to 0.3 mm of thickness lost between the new state and the worn state, compared to 1 mm for a cast iron disc), the positioning of the nozzles is easier and suction efficiency is maintained throughout the service life of the disc.

[41] The invention also relates to a motor or rail vehicle comprising a brake as described above, wherein the control unit receives a signal indicative of the vehicle speed, and the suction devices are controlled to remain inactive if the vehicle speed is below a threshold. It is thus possible to avoid water intake when fording water.

Brief description of drawings

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

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

[44] FIG. 2A shows a flowchart of a method for implementing the capture system.

[45] FIG. 2B shows a timing diagram of the method of FIG. 2A.

[46] FIG. 3 illustrates three examples of brake pads.

[47] FIG. 4 illustrates an isometric view of a disc brake.

[48] FIG. 5 represents an isometric view of a suction nozzle.

[49] FIG. 6 shows a cross-section view of suction nozzles mounted around the disc.

[50] FIG. 7 schematically illustrates a front view of the nozzles' positioning.

[51] FIG. 8 represents a design variant for a nozzle.

[52] FIG. 9 shows a design variant for a nozzle.

[53] FIG. 10 illustrates an example of a single nozzle accommodating two grooves.

Description of embodiments

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

[55] FIG. 1 illustrates one possible application for this disclosure. A vehicle 1, whether a road vehicle (car, van, truck, etc.) or a rail vehicle (train, tram, subway, etc.), comprises a disc brake type of braking device 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.).

[56] 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 represented 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.

[57] 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.

[58] 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 Technologie(s) company.

[59] 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 an area near 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 replaceable simultaneously with the replacement of the linings 10, 12. The filter 26 may be located upstream or downstream of the fan 22.

[60] 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.).

[61] 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 created 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 produced. In such case, the suction devices 20, 22, 24, 26 are said to be in an active state, regardless of the speed (non-zero) of the fan and/or the amplitude of the electric current (non-zero) supplied to the motor.

[62] 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.

[63] FIG. 2A illustrates a method 100 for making use of the capture system 20 shown in FIG. 1. In a first step 110 of a first duration T1, the suction devices are controlled to be active. In a second step 120 of a second duration T2, the suction devices are controlled to be inactive.

[64] The two steps 110, 120 constitute a cycle C, which is repeated. The two steps immediately follow one another temporally.

[65] This temporal sequence is also illustrated in FIG. 2B. The horizontal axis represents the time axis. The graph shows the square waves corresponding to the state changes between the active state and the inactive state, with each state being maintained for a respective duration, T1 or T2.

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

Standard pad without groove or suction hole	Pad with collection groove		
No suction	Continuous suction	Suction only during braking phases	No suction
8.0	1.8	2.7	3.8

Table 1

[67] One will observe that the mere presence of a collection groove halves the amount of particles that escape into the environment. This confirms that it is not strictly necessary to suction particles at the precise times of braking in order to have an impact on the amount of captured particles. Of course, if no suction is ever applied, the groove will fill up and its capacity to serve as a reservoir will be lost.

[68] The above tests were conducted using a groove positioned in the downstream portion of the brake lining, meaning the portion of the lining encountered last by any given point on the disc as it follows its path. This arrangement is generally considered optimal for collecting particles that have been abraded from the lining.

[69] Additional tests, conducted with a groove positioned in the upstream portion of the lining (or performed using the same system but with the disc rotating in the opposite direction), have demonstrated that whether the suction is continuous or limited to braking phases, it allows capturing approximately 40% of the particles produced. This indicates that it is possible to capture particles that were not only those recently abraded from the pad. In all likelihood, these particles are therefore those that settled into the surface irregularities of the disc.

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

No suction (standard pad)	Continuous suction	Suction only during braking phases	Cyclic suction (T1=1min; T2=6min)
8.0	1.8	2.7	2.6

Table 2

[71] It is apparent that cyclic suction is as effective as suction limited to braking sequences. The capture rate is approximately 67% of the PM10 particles produced. 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 still have the same particle capture rate.

[72] 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 3

[73] 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 a high electrical power consumption.

[74] 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.

[75] 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.

[76] The values for T1 and T2 may be fixed. Alternatively, they may be adjustable over the service life of a brake/vehicle/machine. For example, the degree of disc wear may be monitored (e.g., thickness of the material, surface flatness defects (warping)). For example, an operator may measure this degree of wear during a maintenance inspection and communicate it to the control unit 30. The control unit may be programmed to adjust the durations T1 and T2 according to the disc wear, for example so that the ratio T1/T2 increases as the disc wears. Indeed, disc wear can exacerbate surface defects and consequently increase the amount of particles that may become lodged therein. It may be advantageous to suction the particles for a longer duration by increasing T1 (or the ratio T1/T2).

[77] It may be possible to have the vehicle speed (V in FIG. 1) or the disc speed (W) be a condition for the activation/deactivation of the suction devices. To this end, a speed sensor that is either dedicated or embedded in the vehicle or machine may be provided. This sensor sends a signal to the control unit indicating the speed of the disc or vehicle. The control unit may be programmed to compare the actual speed against a threshold and to keep the suction devices deactivated if the speed is below this threshold.

[78] FIG. 3 illustrates three examples of brake pads 40, 50, 60 that may be used with the particle capture system. Other variants are also conceivable.

[79] 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.

[80] 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.

[81] 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.

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

[83] FIGS. 4 to 10 illustrate particle collection means that may serve as an alternative to, or be complementary to, the grooves 44, 54, 64.

[84] FIG. 4 shows an isometric view of suction devices arranged adjacent to the disc 4. The disc 4 comprises, on each side, an annular friction surface 5 delimited by an inner circle C1 of radius R1 and an outer circle C2 of radius R2. The annular friction surface 5 is the set of points encountered by the linings 10, 12 during the rotation of the disc 4.

[85] In this example, the caliper 8 is a floating caliper, i.e. slidably movable relative to a carrier 9 fixed to the wheel hub. The invention is, of course, adaptable to a brake with a fixed caliper.

[86] In order to suction particles lodged within surface irregularities or on the surface of the disc 4, two nozzles 140 are positioned in proximity to the disc 4, each facing one of the two annular friction surfaces 5. Rigid lines 148, 149 are provided, which fluidically connect the nozzles 140 to the negative pressure source 22, and also hold the nozzles 140 in position facing the disc 4.

[87] A mounting bracket 150 serves to secure the rigid lines 148, 149 to the carrier 9. The rigid lines 148, 149 fit tightly through two holes 152 in the bracket 150. A third hole serves for attaching the bracket 150 to the carrier 9. The bracket 150 may be V-shaped. In a variant, the bracket is formed in the carrier 9. The lines 148, 149 protrude from the bracket 150. They may be connected to the negative pressure source 22 by means of hoses (not shown).

[88] Line 148 may be U-shaped, while line 149 may be rectilinear.

[89] FIG. 5 shows an isometric view of a nozzle 140. The nozzle comprises an upstream edge 141 (i.e., the edge encountered first by a point on the disc) and a downstream edge 142 (encountered last). The downstream edge 142 may be fitted with a seal (for example, a brush seal or elastomer seal) that scrapes against the disc 4. Additionally or alternatively, the downstream edge 142 may be positioned further away from the disc than the upstream edge, for example at a distance that is at least 50% greater.

[90] A groove 146 serves to create a suction airflow having a direction that is primarily perpendicular to the surface 5 of the disc 4. The groove may be parallel to the longitudinal direction A of the nozzle 140. In the circumferential direction, the groove 146 may have a substantially constant width along its entire radial length. The width of the groove 146 may be between 1 and 6 mm, and is preferably 4 mm. The groove may have a depth of a few millimeters, preferably approximately 0.5 mm. An excessive depth (for example, 15 mm) is not conducive to effective suction.

[91] At least one bleed hole 143 may be provided on a rear face of the nozzle. This hole 143 is in fluid communication with the groove and encourages the creation of a flow having a component that is counter to the direction of the disc's movement; this arrangement may offer advantages in preventing particles from becoming trapped within the groove. The position and number of bleed holes 143 may vary: two holes 143 may be provided, not only on the downstream face (as illustrated in FIG. 5) but also on the upstream face of the nozzle 140. A bleed hole 143 may be provided at the rear of the nozzle (the face of the nozzle opposite to the face that faces the disc). In such a configuration, the suction hole 147 may be located at one end (along axis A) of the groove 146, and the bleed hole 143 may be located at the other end of the groove 146.

[92] The nozzle 140 may have a substantially longitudinal, elliptical, or oval shape, with a longitudinal axis A. In a variant that is not illustrated, the nozzle 140 has a different shape, for example a crescent shape.

[93] The lines 148, 149 create suction within the groove 146. A suction hole 147 is provided in the nozzle 140 for this purpose.

[94] FIG. 6 shows a cross-section view of the installation of the nozzles 140. In this example, the suction hole 147 is centered relative to the groove 146 in the longitudinal direction A. The groove 146 of the nozzles 140 faces the friction surfaces 5 of the disc 4. The nozzles 140 are at a distance B from the friction surfaces 5. The distance B may be less than 3 millimeters, or even less than 0.1 millimeter.

[95] Line 148 has a U-shape, and line 149 is straight. In this example, the lines 148, 149 are coplanar, but other designs are conceivable.

[96] In the examples shown in FIGS. 4 to 6, the nozzles 140 are arranged symmetrically, but other arrangements are possible. They may be angularly offset relative to one another or may be of different designs.

[97] FIG. 7 schematically illustrates the positioning of the nozzles 140. The linings 10, 12 may define a median radius R0, and the longitudinal axis A of the nozzles 140 may be arranged in alignment with a radius R, angularly offset from radius R0 by an angle α. This angle is preferably between 20° and 160°. The caliper does not always allow a smaller angle. An angle that is too large is not necessarily compatible with attaching the nozzles via a bracket and may therefore complicate the nozzle attachment process.

[98] FIGS. 8 and 9 illustrate two design variants for the nozzle 140.

[99] In FIG. 8, the suction line 148, 149 is parallel to the groove 146. The suction flow is in a direction substantially perpendicular to the surface of the disc.

[100] FIG. 9 shows a pair of nozzles 140 having two bleed holes 143 located at the two radial ends of the groove 146. Air is drawn in both from the disc side and through the holes 143, thereby inducing an airflow within the groove that is parallel to the friction surfaces of the disc.

[101] FIG. 10 shows an example in which a single nozzle 140 receives both grooves 146. This nozzle may have a general U shape. Suction may be applied via a single line 48, positioned within the plane of the disc. A narrower auxiliary groove 160 may connect the two grooves 146. For example, the circumferential width of the auxiliary groove may be half that of the grooves 146. The auxiliary groove 160 straddles the edge of the disc.

[102] It is understood that the invention is not limited to the examples described herein, and that a person skilled in the art would be able to envisage variants without departing from the scope of protection conferred by the appended claims.

Claims

[**Claim 1]** A method (100) for implementing a particle capture system (20) for capturing brake particles from a disc brake, the particle capture system (20) comprising particle suction devices (22, 24, 26) and a control unit (30) configured to control whether the suction devices (22, 24, 26) are in an active or inactive state, the method comprising a series of cycles (C), each cycle (C) comprising a first step (110) of a first duration (T1) during which the suction devices (22, 24, 26) are controlled by the control unit (30) to be in an active state, and a second step (120) of a second duration (T2) during which the suction devices (22, 24, 26) are controlled by the control unit to be in an inactive state.

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

[Claim 3] Method (100) according to claim 1 or 2, wherein the second duration (T2) is between 30 seconds and 30 minutes, preferably between 4 and 10 minutes.

[Claim 4] Method (100) according to any one of claims 1 to 3, wherein the ratio between the first duration (T1) and the second duration (T2) is between 1/3 and 1/10.

[Claim 5] Method (100) according to one of claims 1 to 4, wherein the control unit (30) receives a signal indicative of the rotational speed (W) of the disc (4), and the suction devices (22, 24, 26) are controlled to remain inactive if the rotational speed (W) of the disc (4) is below a threshold.

[Claim 6] Method (100) according to one of claims 1 to 5, wherein a degree of wear of the disc is monitored, and the first and second durations (T1, T2) are adjusted such that the ratio between the first duration (T1) and the second duration (T2) increases with the wear of the disc.

[Claim 7] Method (100) according to one of claims 1 to 6, wherein the brake comprises a pair of linings (10, 12), each having a particle collection element (44, 54, 64), the suction devices (22, 24, 26) of the particle capture system (20) being fluidically connected to the particle collection elements (44, 54, 64).

[Claim 8] Method (100) according to one of claims 1 to 7, wherein the brake comprises a pair of linings (10, 12); a disc (4) having two annular friction surfaces (5) which are the respective sites of the friction of the linings (10, 12) against the disc (4), each annular friction surface (5) being delimited by an inner circle (C1) and an outer circle (C2); and the particle capture system (20) comprises two grooves (146) fluidically connected to the negative pressure source (22) and positioned at a distance from the friction linings (10, 12), each of the grooves (146) being positioned facing a respective annular friction surface (5) and each groove (146) extending from the inner circle (C1) to the outer circle (C2).

[Claim 9] A particle capture system (20) for capturing brake particles emitted by a disc brake (2), the particle capture system (20) comprising:

- particle suction devices (22, 24, 26) capable of assuming an active or an inactive state; and

- a control unit (30) configured to switch the suction devices (22, 24, 26) alternately between an active state and an inactive state in accordance with the method of one of the preceding claims.

[Claim 10] A disc brake (2) comprising a particle capture system (20) according to claim 9, wherein the active or inactive state of the suction devices (22, 24, 26) is regulated independently of the activation of the brake (2).

[Claim 11] Brake (2) according to claim 10, comprising a pair of brake linings (10, 12), each having a particle collection element (44, 54, 64), the suction devices (22, 24, 26) of the particle capture system (20) being fluidically connected to the particle collection elements (44, 54, 64).

[**Claim 12]** Brake according to claim 10 or 11, comprising a pair of linings (10, 12); a disc (4) having two annular friction surfaces (5) which are the respective sites of the friction of the linings (10, 12) against the disc (4), each annular friction surface (5) being delimited by an inner circle (C1) and an outer circle (C2); the particle capture system (20) comprising two suction grooves (146) fluidically connected to the negative pressure source (22) and positioned at a distance from the friction linings (10, 12), each groove (146) being positioned facing a respective annular friction surface (5) and each groove (146) extending from the inner circle (C1) to the outer circle (C2).

[Claim 13] Brake according to claim 12, wherein each groove (146) is substantially rectilinear and has a width, measured in a circumferential direction, that is between 1 and 6 mm, and is preferably 2 or 4 mm.

[**Claim 14]** Brake according to one of claims 12 or 13, wherein each groove (146) is arranged in a respective nozzle (140).

[Claim 15] Brake according to claim 14, wherein each nozzle (140) features at least one bleed hole (143) in fluid communication with the groove (146).

[Claim 16] Brake according to one of claims 14 or 15, wherein each nozzle (140) is positioned at an axial distance (B) of less than three millimeters, preferably less than 0.1 mm, from the respective annular friction surface (5).

[Claim 17] Brake according to one of claims 14 to 16, wherein each nozzle (140) comprises a downstream edge (42) provided with a seal (44) or a brush in contact with the respective annular friction surface.

[**Claim 18]** Brake according to one of claims 14 to 17, wherein each nozzle (140) comprises an upstream edge (141) and a downstream edge (142), the downstream edge (142) being further away from its respective annular friction surface (5) than the upstream edge (141).

[Claim 19] Brake according to one of claims 14 to 18, wherein the groove (146) of each nozzle (140) has a longitudinal direction (A) that is aligned with a radius (R) of the disc (4), said radius (R) preferably being angularly offset from a median radius (R0) of the linings (10, 12) by an angle (α) of between 20° and 60°.

[Claim 20] Brake according to one of claims 14 to 19, wherein the brake (2) comprises a fixed caliper or a floating caliper (8) that slides relative to a caliper carrier (9), the nozzles (140) being attached to either the fixed caliper or to the caliper carrier (9).

[Claim 21] Brake according to one of claims 14 to 20, wherein the particle capture system (20) comprises two rigid lines (148, 149), each connected to a respective nozzle (140), by means of which the nozzles (140) are held in position facing the disc (4).

[Claim 22] Brake according to claims 20 and 21, wherein a mounting bracket (150) connects the rigid lines (148, 149) to the caliper or to the caliper carrier (9), the mounting bracket (150) comprising two holes (152) traversed by the rigid lines (148, 149).

[Claim 23] Brake according to one of claims 12 or 13, wherein the two grooves (146) are provided in a single nozzle (140).

[Claim 24] Brake according to claim 23, wherein an auxiliary groove (160), which straddles the edge of the disc, connects the two suction grooves (146) together.

[Claim 25] Brake according to one of claims 10 to 24, wherein the disc (4) is covered with a ceramic coating.

[Claim 26] A motor or rail vehicle (1) comprising a brake according to one of claims 10 to 25, wherein the control unit (30) receives a signal indicative of the vehicle speed (V), and the suction devices (22, 24, 26) are controlled to remain inactive if the vehicle speed (V) is below a threshold.