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(54) Title: BRAKING ACTUATION AND MANAGEMENT METHOD AND SYSTEM FOR SIMULTANEOUSLY CONTROLLING TWO OR MORE BRAKES OF THE SAME VEHICLE ON BENCH BRAKING TESTS

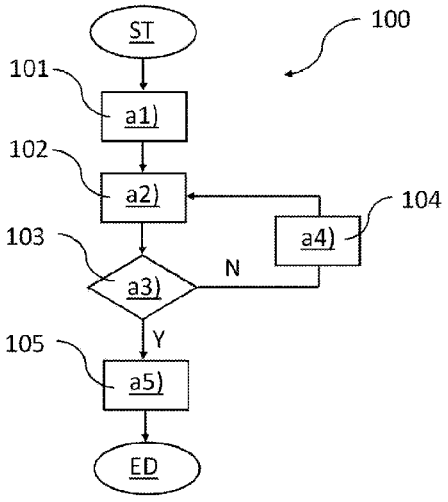


Fig. 12

(57) Abstract: A braking actuation and management method (100) for simultaneously controlling at least one first brake of a vehicle and at least one second brake of the same vehicle on bench braking tests, comprising a step of: a1) setting (101), by a data processing unit operatively connected to one or more braking test benches, at least one value of a target braking parameter required for the portion of vehicle comprising the at least one first brake and the at least one second brake. For each sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, where N is an integer, of a braking test time interval, the method (100) comprises steps of: a2) detecting (102), by one or more braking parameter detection modules, operatively connected to the data

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processing unit, one or more values of braking control parameters required for the portion of vehicle comprising the at least one first brake and the at least one second brake; a3) comparing (103), by the data processing unit, the one or more detected values of braking parameters required for the portion of vehicle comprising the at least one first brake and the at least one second brake with respective one or more limit reference values for verifying the absence or presence of the attainment of a limit condition by said one or more detected values of braking parameters; in the absence (N) of attainment of a limit condition by all of said one or more detected values of braking control parameters, the method (100) comprises a step a4) of keeping (104) unchanged, by the data processing unit, said at least one value of a target braking parameter required for the portion of vehicle comprising the at least one first brake and the at least one second brake, thus returning to the step a2) of detecting (102); in the presence (Y) of attainment of a limit condition by at least one of said one or more detected braking control parameters, the method (100) comprises a step a5) of changing (105), by the data processing unit, the at least one value of the target braking parameter previously set as a function of the braking control parameter which attained such a limit condition.

DESCRIPTION

"Braking actuation and management method and system for simultaneously controlling two or more brakes of the same vehicle on bench braking tests"

[0001]. Field of the invention

[0002]. The present invention relates to a braking actuation and management method and system for simultaneously controlling two or more brakes of the same vehicle on bench braking tests.

[0003]. Background art

[0004]. Typically, each brake of a braking system of a vehicle is tested on a test bench by employing a conventional dynamic bench and a respective control logic.

[0005]. Therefore, by testing two or more brakes of the same vehicle each through the use of a respective conventional dynamic bench, it is not possible to characterize the interaction effect between the brakes of the same vehicle which concur to attain a set braking torque (or deceleration).

[0006]. Instead, the control logics of conventional dynamic benches are not suitable to test two or more brakes of the same vehicle employing the same dynamic bench or by connecting two or more conventional dynamic benches together to test several brakes simultaneously because, again in this case, managing the interaction between the brakes of the same vehicle which concur to attain the set braking torque (or deceleration) is not allowed.

[0007]. In view of the above, a need is strongly felt nowadays for braking actuation and management methods and systems for simultaneously controlling two or more brakes of the same vehicle on bench braking tests, which allows increasing the representativeness level of the bench test compared to the corresponding road test under all braking conditions and possibly with all types of braking systems, whether conventional (i.e., of the hydraulic type with mechanical actuation) or Brake-by-Wire, B-b-W, technology (i.e., of the hydraulic type with electro-mechanical actuation or fully electro-mechanical).

[0008]. Summary of the invention

[0009]. It is the object of the present invention to provide a braking actuation and management method for simultaneously controlling two or more brakes of the same vehicle on bench braking tests, which allows at least partially obviating the drawbacks described above with reference to the prior art, and in particular which is capable of increasing the representativeness level of the bench test compared to the corresponding road test under all braking conditions and possibly with all types of braking systems, whether conventional (i.e., of the hydraulic type with mechanical actuation) or Brake-by-Wire, B-b-W, technology (i.e., of the hydraulic type with electro-mechanical actuation or fully electromechanical).

[0010]. Such an object is achieved by a method according to claim 1.

[0011]. It is a further object of the present invention to provide a braking actuation and management system for simultaneously controlling two or more brakes of the same vehicle on bench braking tests adapted to implement the aforesaid method.

[0012]. Further advantageous embodiments of the method and system are the subject of the respective dependent claims.

[0013]. Brief description of the drawings

[0014]. Further features and advantages of the method and the related system according to the invention will become apparent from the following description of preferred embodiments, given by way non-limiting indication, with reference to the accompanying drawings, in which:

[0015]. – figure 1 shows, by means of a block diagram, a braking actuation and management method for simultaneously controlling two or more brakes of the same vehicle on bench braking tests according to an embodiment;

[0016]. – figure 2 shows, by means of a block diagram, a braking actuation and management method for simultaneously controlling two or more brakes of the same vehicle on bench braking tests according to a further embodiment;

[0017]. – figure 3 shows, by means of a block diagram, a braking actuation and management method for simultaneously controlling two or more brakes of the same vehicle on bench braking tests according to a further embodiment;

[0018]. – figure 4 shows, by means of a block diagram, a braking actuation

and management method for simultaneously controlling two or more brakes of the same vehicle on bench braking tests according to a further embodiment;

[0019]. – figure 5 diagrammatically shows a control logic implementable in the method of the present invention, according to an embodiment;

[0020]. – figure 6 diagrammatically shows an additional control logic implementable in the method of the present invention, according to a further embodiment;

[0021]. – figure 7 diagrammatically shows an additional control logic implementable in the method of the present invention, according to a further embodiment;

[0022]. – figure 8 diagrammatically shows an additional control logic implementable in the method of the present invention, according to a further embodiment;

[0023]. – figure 9 diagrammatically shows an additional control logic implementable in the method of the present invention, according to a further embodiment;

[0024]. – figure 10 diagrammatically shows an additional control logic implementable in the method of the present invention, according to a further embodiment;

[0025]. – figure 11 diagrammatically shows an additional control logic implementable in the method of the present invention, according to a further embodiment;

[0026]. – figure 12 diagrammatically shows a braking actuation and management system for simultaneously controlling two or more brakes of the same vehicle on bench braking tests, according to an embodiment of the present invention, and

[0027]. – figure 13 diagrammatically shows an example of an application on a single braking test bench of a braking actuation and management system for simultaneously controlling two or more brakes of the same vehicle on bench braking tests according to the present invention.

[0028]. It should be noted that equal or similar elements in the drawings will be indicated by the same numeric or alphanumeric references.

[0029]. Description of some preferred embodiments

[0030]. A braking actuation and management method for simultaneously controlling two or more brakes of the same vehicle on bench braking tests, hereinafter also simply braking actuation and management method, or also only method, will now be described according to the present invention with reference to the figures above.

[0031]. The method according to the present invention can be implemented and used on dynamic test benches which provide the simultaneous use of two or more brakes.

[0032]. In more detail, the brakes which are part of the same axle (e.g., left front and right front), or the brakes of different axles (e.g., left front and left rear), or more than two brakes simultaneously (e.g., left front and right front, left rear and right rear) can be tested simultaneously, until all brakes of the vehicle under consideration are tested simultaneously.

[0033]. For simplicity and symmetry of the braking system configurations on the vehicle, the method of the invention will be described with reference to a simultaneous test on at least one first brake, e.g., left front, indicated by B1, of a vehicle and at least one second brake, e.g., left rear, indicated by B2, of the same vehicle.

[0034]. It should be noted that the method object of the invention can be used both when two or more brakes of the same vehicle are tested on the same test bench (e.g., according to the Dual Brake Dyno concept, an example of which is shown in figure 13), and when they are tested using two or more benches which are connected to each other.

[0035]. The logics described can be used to test all types of braking systems, whether conventional (hydraulic with mechanical actuation) or of the brake-by-wire type (e.g., hydraulic with electro-mechanical actuation or fully electro-mechanical).

[0036]. The operation of the logics will be described differentially for the two types of systems.

[0037]. The logics described below are implemented on the bench controller, which works at a frequency such that it is considered to actively listen to the

control variables at every instant of braking.

[0038]. A braking actuation and management method 100 for simultaneously controlling at least one first brake B1 of a vehicle and at least one second brake B2 of the same vehicle on bench braking tests according to the present invention is described with reference to figure 12.

[0039]. The method 100 comprises a symbolic step of starting ST.

[0040]. The method 100 comprises a step a1) of setting 101, by a data processing unit 210 (diagrammatically shown in figure 13, described below) operatively connected to one or more braking test benches BT (a single test bench is shown in figure 13), at least one value of a target braking parameter (set-point) required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2.

[0041]. "Target braking parameter" means any braking parameter which can be set during the bench test, such as for example the overall braking torque ensured by said at least one first brake B1 and said at least one second brake B2, the brake fluid pressure applied by the actuator of each brake, the force applied by the actuator of each brake, and so on.

[0042]. For each sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, where N is an integer, of the braking time interval, the method 100 comprises the following steps.

[0043]. The method 100 comprises a step a2) of detecting 102, by one or more braking parameter detection modules 220 (also diagrammatically shown in figure 13), operatively connected to the data processing unit 210, one or more values of braking control parameters required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2.

[0044]. "Braking control parameter" means any braking parameter detectable during the bench test, the monitoring of which allows a decision to be made whether or not to change the at least one value of a target braking parameter (set-point) at the beginning of the bench test.

[0045]. Examples of "braking control parameters" are the braking torque provided by an individual brake, the brake fluid pressure applied by each brake, the force applied by the actuator of each brake, the volumetric absorption of the

actuator of each brake, the stroke speed of the float actuated by the actuator of each brake, and so on.

[0046]. The method 100 comprises a step a3) of comparing 103, by the data processing unit 210, the one or more detected values of braking parameters required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 with respective one or more limit reference values for verifying the absence or presence of the attainment of a limit condition by said one or more detected values of braking parameters.

[0047]. In the absence (N) of attainment of a limit condition by all of said one or more detected values of braking control parameters, the method 100 comprises a step a4) of keeping 104 unchanged, by the data processing unit 210, said at least one value of a target braking parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2, thus returning to the step a2) of detecting 102.

[0048]. In other words, in the absence of the respective limit condition being attained by all the detected braking control parameters, the data processing unit does not perform any corrective operation on the previously set set-point.

[0049]. In the presence (Y) of attainment of a limit condition by at least one of said one or more detected values of braking control parameters, the method 100 comprises a step a5) of changing 105, by the data processing unit 210, the at least one value of the target braking parameter previously set as a function of the braking control parameter which attained such a limit condition.

[0050]. In other words, when the respective limit condition is attained by at least one of the detected braking control parameters, the data processing unit 210 varies the previously set set-point based on the limit condition attained by such a detected braking control parameter.

[0051]. The method 100 comprises a symbolic step of ending ED.

[0052]. <u>CONVENTIONAL BRAKING SYSTEM: DECELERATION CONTROL (BRAKING TORQUE)</u>

[0053]. According to an embodiment, shown in figure 1, the at least one first brake B1 and the at least one second brake B2 belong to a conventional braking system, i.e., a braking system with mechanical actuation on a hydraulic circuit.

[0054]. In this embodiment, the target braking parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the overall braking torque provided by said at least one first brake B1 and said at least one second brake B2.

[0055]. Therefore, in this embodiment, the step a1) of setting 101 is performed by the data processing unit 210 to set, as a set-point, the target value C_{TOTS} of overall braking torque required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2.

[0056]. The target value C_{TOTS} of overall braking torque is representative of a deceleration target value for the braking control.

[0057]. The target value C_{TOTS} of overall braking torque is divided into a first value C_1 of braking torque applicable by said at least one first brake B1 and a second value C_2 of braking torque applicable by said at least one second brake B2 ($C_{TOTS} = C_1 + C_2$).

[0058]. In this embodiment, said one or more braking control parameters required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 detectable by said one or more braking parameter detection modules 220 operatively connected to the data processing unit 210 comprise the braking torque applied by each of said at least one first brake B1 and said at least one second brake B2, the volumetric absorption of each actuator of said at least one first brake B1 and said at least one second brake B2, and the braking fluid pressure applied by each actuator of said at least one first brake B1 and said at least one second brake B2.

[0059]. In this embodiment, for each sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, where N is an integer, of the braking time interval, the method 100 comprises the following steps.

[0060]. In the absence (N) of attainment of a limit condition by all of said one or more detected values of braking control parameters, the step a4) of keeping 104 unchanged said at least one target value of a braking parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2, then returning to the step a2) of detecting 102, comprises a step of setting 104', by the data processing unit 210, for said at

least one first brake B1 and for said at least one second brake B2, a first value p1 of braking fluid pressure level and a second value p2 of braking fluid pressure level, respectively, equal to each other (p1 = p2).

[0061]. In the presence (Y) of attainment of a limit condition by at least one of said one or more detected values of braking control parameters, the step a5) of changing 105 comprises a step of removing 105', by the data processing unit 210, if previously set, the condition of equality between the first value p1 of braking fluid pressure level set for said at least one first brake B1 and the second value p2 of braking fluid pressure level set for said at least one second brake B2.

[0062]. Furthermore, in this condition, the step a5) of changing 105 comprise a step of setting 105'', by the data processing unit 210, a target value of braking torque of one of said at least one first brake B1 and said at least one second brake B2 in which such a limit was attained as the difference between the target value C_{TOTS} of overall braking torque required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 and the detected value of braking torque applied by the other of said at least one first brake B1 and said at least one second brake B2 during the braking test.

[0063]. Braking torque control limits

[0064]. According to an embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a conventional braking system, i.e., a braking system with mechanical actuation on a hydraulic circuit, and where the braking parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the overall braking torque provided by said at least one first brake B1 and said at least one second brake B2, as shown in figure 1, the step a3) of comparing 103 is performed, by the data processing unit 210, to compare a first information representative of the first detected value C_1 of braking torque and a second information representative of the second detected value C_2 of braking torque with a respective first information representative of a set first limit reference value C_{1LIM}

of braking torque for said at least one first brake B1 and a respective second information representative of a set second limit reference value C_{2LIM} of braking torque, respectively.

[0065]. Such braking torque limit reference values can be defined based on braking system dimensioning calculations based on vehicle characteristics and can correspond to the grip limit torque values between tire and road provided for each of said at least one first brake B1 and said at least one second brake B2.

[0066]. As long as the first information representative of the first detected value C_1 of braking torque is less than the first information representative of a set first limit reference value C_{1LIM} of braking torque for said at least one first brake B1 and the second information representative of the second detected value C_2 of braking torque is less than the respective second information representative of a set second limit reference value C_{2LIM} of braking torque, the method 100 includes the step a4) of keeping 104 unchanged the previously set target value C_{TOTS} of overall braking torque, without the need to perform any corrective operations.

[0067]. If the first information representative of the first detected value C_1 of braking torque is greater than the respective first information representative of the set first limit reference value C_{1LIM} of braking torque (grip limit torque between tire and road) and/or the second information representative of the second detected value C_2 of braking torque is greater than the respective second information representative of the set second limit reference value C_{2LIM} of braking torque (grip limit torque between tire and road), the step a5) of changing 105 comprises a step of setting 106, by the data processing unit 210, as a first target value C_{1S} of braking torque applicable by said at least one first brake B1, the set first limit reference value C_{1LIM} of braking torque for at least one first brake B1, and/or as a second target value C_{2S} of braking torque applicable by said at least one second brake B2, the set limit reference value C_{2LIM} of braking torque for said at least one second brake B2.

[0068]. Volumetric absorption limit control

[0069]. According to an embodiment, in combination with any one of those

described above, where the at least one first brake B1 and the at least one second brake B2 belong to a conventional braking system, i.e., a braking system with mechanical actuation on a hydraulic circuit, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the overall braking torque provided by said at least one first brake B1 and said at least one second brake B2, as shown in figure 1, said at least one first brake B1 and said at least one second brake B2 are on opposite sides of two different axles of the vehicle (X configuration), e.g., said at least one first brake B1 is on the left side of the front axle while said at least one second brake B2 is on the right side of the rear axle.

[0070]. In this embodiment, the step a3) of comparing 103 is performed by the data processing unit 210 to compare a sum of a first information representative of a first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 and a second information representative of a second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 with an information representative of a set limit reference value V_{TOTLIM} of overall volumetric absorption provided for a master cylinder of the vehicle adapted to act on said at least one first brake B1 and said at least one second brake B2.

[0071]. A volumetric absorption value V_1 (V_2) of an actuator can be expressed as the product of the stroke value s_1 (s_2) and the value of the area A1 (A2) of the float section actuatable by the actuator ($V_1 = s_1 \times A_1$ or $V_2 = s_2 \times A_2$).

[0072]. If the sum of the first information representative of a first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 and the second information representative of a second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 is less than the information representative of the set limit value V_{TOTLIM} of overall volumetric absorption, the method 100 performs the step a4) of keeping 104 unchanged the previously set target value C_{TOTS} of overall braking torque, without the need to perform any corrective operations.

[0073]. If the sum of the first information representative of a first detected

value V_1 of volumetric absorption of the actuator of said at least one first brake B1 and the second information representative of a second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 is greater than the information representative of the set limit value V_{TOTLIM} of overall volumetric absorption, the step a5) of changing 105 comprises a step of setting 107, by the data processing unit 210, a first target stroke value s_{1S} of the actuator of said at least one first brake B1 and a second target stroke value s_{2S} of the actuator of said at least one second brake B2 so that the sum of the first information representative of a first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 and the second information representative of a second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 is equal to the information representative of the set limit value V_{TOTLIM} of overall volumetric absorption ($V_1 + V_2 = V_{TOTLIM}$) ($s_{1S} = (V_{TOTLIM} – V_2)/A_1$), $s_{2S} = (V_{TOTLIM} – V_1)/A_2$)).

[0074]. According to a further embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a conventional braking system, i.e., a braking system with mechanical actuation on a hydraulic circuit, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the overall braking torque provided by said at least one first brake B1 and said at least one second brake B2, as shown in figure 1, said at least one first brake B1 and said at least one second brake B2 are on the same axle of the vehicle (H configuration), e.g., said at least one first brake B1 is on the left side of the front axle while said at least one second brake B2 is on the right side of the front axle.

[0075]. In this embodiment, the step a3) of comparing 103 is performed by the data processing unit 210 to compare a first information representative of a first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 with a first information representative of a set first limit reference value V_{1LIM} of volumetric absorption provided for the actuator of said at least one first brake B1 and a second information representative of a second detected value V_2 of volumetric absorption of the actuator of said at least one

second brake B2 with a second information representative of a set second limit reference value V_{2LIM} of volumetric absorption provided for the actuator of said at least one second brake B2.

[0076]. If the first information representative of the first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 is less than the first information representative of the set first limit reference value V_{1LIM} of volumetric absorption provided for the actuator of said at least one first brake B1 and the second information representative of the second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 is less than the second information representative of the set second limit reference value V_{2LIM} of volumetric absorption provided for the actuator of said at least one second brake B2, the method 100 performs the step a4) of keeping 104 unchanged the previously set target value C_{TOTS} of overall braking torque, without the need to perform any corrective operations.

[0077]. If the first information representative of the first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 is greater than the first information representative of the set first limit reference value V_{1LIM} of volumetric absorption provided for the actuator of said at least one first brake B1 and/or the second information representative of the second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 is greater than the second information representative of the set second limit reference value V_{2LIM} of volumetric absorption provided for the actuator of said at least one second brake B2, the step a5) of changing 105 comprises a step of setting 108, for the actuator of the brake in which the limit condition occurred, by the data processing unit 210, a target stroke value s_{1S} (s_{2S}) of the actuator of said brake B1 (B2) corresponding to the information representative of the set limit value V_{1LIM} (V_{2LIM}) of volumetric absorption provided for the actuator of said brake B1 (B2) ($s_{1S} = V_{1LIM}/A_1$; $s_{2S} = V_{2LIM}/A_2$).

[0078]. Pressure limit control

[0079]. According to a further embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a conventional braking system, i.e., a braking

system with mechanical actuation on a hydraulic circuit, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the overall braking torque provided by said at least one first brake B1 and said at least one second brake B2, as shown in figure 1, the step a3) of comparing 103 is performed by the data processing unit 210 to compare a first information representative of a first detected value p_1 of the braking fluid pressure applied by the actuator of said at least one first brake B1 and a second information representative of a second detected value p_2 of the braking fluid pressure applied by the actuator of said at least one second brake B2 with a first information representative of a set first limit reference value p_{1LIM} of the braking fluid provided for the actuator of said at least one first brake B1 and a second information representative of a set second pressure limit reference value p_{2LIM} of the braking fluid provided for the actuator of said at least one second brake B2, respectively.

[0080]. If the first information representative of the first detected value p_1 of the braking fluid pressure applied by the actuator of said at least one first brake B1 is less than the first information representative of the set first pressure limit reference value p_{1LIM} of the braking fluid provided for the actuator of said at least one first brake B1 and the second information representative of the second detected value p_2 of the braking fluid pressure applied by the actuator of said at least one second brake B2 is less than the second information representative of the set second pressure limit reference value p_{2LIM} of the braking fluid provided for the actuator of said at least one second brake B2, the method 100 performs the step a4) of keeping 104 unchanged the previously set target value C_{TOTS} of overall braking torque, without the need to perform any corrective operations.

[0081]. If the first information representative of the first detected value p_1 of the braking fluid pressure applied by the actuator of said at least one first brake B1 is greater than the first information representative of the set first pressure limit reference value p_{1LIM} of the braking fluid provided for the actuator of said at least one first brake B1 and/or the second information representative of the second detected value p_2 of the braking fluid pressure applied by the actuator

of said at least one second brake B2 is greater than the second information representative of the set second pressure limit reference value p_{2LIM} of the braking fluid provided for the actuator of said at least one second brake B2, the step a5) of changing 105 comprises a step of setting 109, for the actuator of the brake in which the limit condition occurred, by the data processing unit 210, a target value p_{1S} (p_{2S}) of the braking fluid pressure applicable by the actuator of said brake B1 (B2) equal to the information representative of the set pressure value p_{1LIM} (p_{2LIM}) of the braking fluid provided for the actuator of said brake B1 (B2).

[0082]. It should be noted that in the case of attaining any of the limits described above (torque limit, volumetric absorption limit, pressure limit), the target value C_{TOTS} of overall braking torque previously set is kept unchanged, as it still represents the target deceleration value with which the required braking should be performed but, in the case of attaining any of the above limits, it would not be possible to ensure it.

[0083]. By the way, this is representative of what normally occurs on the vehicle if, for example, the brake pedal has reached the limit stop and the user (driver) needs to attain a set target deceleration value by braking with the brake pedal (in other words, the driver has a set target value C_{TOTS} of overall braking torque), but that the brake pedal stroke no longer allows to attain, having attained the limit stop.

[0084]. <u>CONVENTIONAL BRAKING SYSTEM: PRESSURE CONTROL</u>

[0085]. According to a further embodiment, shown in figure 2, the at least one first brake B1 and the at least one second brake B2 belong to a conventional braking system, i.e., a braking system with mechanical actuation on a hydraulic circuit.

[0086]. In this embodiment, the target braking parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the braking fluid pressure requested to the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2.

[0087]. Therefore, in this embodiment, the step a1) of setting 101 is performed by the data processing unit 210 to set a first target value p_{1S} of

braking pressure applied by the actuator of said at least one first brake B1 and a second target value p_{2S} of braking pressure applied by the actuator of said at least one second brake B2.

[0088]. In this embodiment, said one or more braking control parameters required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 detectable by said one or more braking parameter detection modules 220 operatively connected to the data processing unit 210 are the braking torque applied by each of said at least one first brake B1 and said at least one second brake B2, the volumetric absorption of each actuator of said at least one first brake B1 and said at least one second brake B2, and the braking fluid pressure applied by each actuator of said at least one first brake B1 and said at least one second brake B2.

[0089]. In this embodiment, for each sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, where N is an integer, of the braking time interval, the method 100 comprises the following steps.

[0090]. In the absence (N) of attainment of a limit condition by all of said one or more detected values of braking control parameters, the data processing unit 210 keeps unchanged the previously set first target value p_{1S} of braking pressure applied by the actuator of said at least one first brake B1 and the second target value p_{2S} of braking pressure applied by the actuator of said at least one second brake B2.

[0091]. In the presence (Y) of attainment of a limit condition by at least one of said one or more detected values of braking control parameters, the data processing unit 210 performs the method as described below.

[0092]. <u>Braking torque limits control</u>

[0093]. According to an embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a conventional braking system, i.e., a braking system with mechanical actuation on a hydraulic circuit, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the braking fluid pressure applied by the actuator of said at least one first brake B1 and the actuator of

said at least one second brake B2, as shown in figure 2, the step a3) of comparing is performed by the data processing unit 210 to compare a first information representative of the first detected value C_1 of braking torque and a second information representative of the second detected value C_2 of braking torque with respective a first information representative of a set first limit reference value C_{1LIM} of braking torque provided for said at least one first brake B1 and a respective second information representative of a set second limit reference value C_{2LIM} of braking torque for said at least one second brake B2, respectively.

[0094]. Such braking torque limit reference values can be defined based on braking system dimensioning calculations based on vehicle characteristics and can correspond to the grip limit torque values between tire and road provided for each of said at least one first brake B1 and said at least one second brake B2.

[0095]. As long as the first information representative of the first detected value C_1 of braking torque is less than the first information representative of a set first limit reference value C_{1LIM} of braking torque (grip limit torque between tire and road) provided for said at least one first brake B1 and the second information representative of the second detected value C_2 of braking torque is less than the respective second information representative of a set second limit reference value C_{2LIM} of braking torque (grip limit torque between tire and road) provided for said at least one second brake B2, the method 100 includes the step a4) of keeping unchanged the previously set first target value p_{1S} of braking pressure applied by the actuator of said at least one first brake B1 and the second target value p_{2S} of braking pressure applied by the actuator of said at least one second brake B2.

[0096]. If the first information representative of the first detected value C_1 of braking torque is greater than the respective first information representative of the set first limit reference value C_{1LIM} of braking torque and/or the second information representative of the second detected value C_2 of braking torque is greater than the respective second information representative of the set second limit reference value C_{2LIM} of braking torque, the step a5) of changing 105

comprises a step of setting 206, by the data processing unit 210, as a first target value C_{1S} of braking torque applicable by said at least one first brake B1, the set first limit reference value C_{1LIM} of braking torque provided for said at least one first brake B1, and/or as a second target value C_{2S} of braking torque applicable by said at least one second brake B2, the set second limit reference value C_{2LIM} of braking torque provided for said at least one second brake B2.

[0097]. Volumetric absorption limits control

[0098]. According to an embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a conventional braking system, i.e., a braking system with mechanical actuation on a hydraulic circuit, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the braking fluid pressure applied by the actuator of said at least one first brake B1 and the actuator of said at least one second brake B2, as shown in figure 2, said at least one first brake B1 and said at least one second brake B2 are on opposite sides of two different axles of the vehicle (X configuration), e.g., said at least one first brake B1 is on the left side of the front axle while said at least one second brake B2 is on the right side of the rear axle.

[0099]. In this embodiment, the step a3) of comparing 103 is performed by the data processing unit 210 to compare a sum of a first information representative of a first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 and a second information representative of a second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 with an information representative of a set limit reference value V_{TOTLIM} of volumetric absorption provided for a master cylinder of the vehicle adapted to act on said at least one first brake B1 and said at least one second brake B2.

[00100]. As mentioned above, a volumetric absorption value V_1 (V_2) of an actuator can be expressed as the product of the stroke value s_1 (s_2) and the value of the area A1 (A2) of the float section actuatable by the actuator ($V_1 = s_1 \times A_1$ or $V_2 = s_2 \times A_2$).

[00101]. If the sum of the first information representative of a first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 and the second information representative of a second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 is less than the information representative of the set limit reference value V_{TOTLIM} of volumetric absorption, the method 100 includes the step a4) of keeping unchanged the previously set first target value p_{1S} of braking pressure applied by the actuator of said at least one first brake B1 and the second target value p_{2S} of braking pressure applied by the actuator of said at least one second brake B2.

[00102]. If the sum of the first information representative of a first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 and the second information representative of a second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 is greater than the information representative of the set limit reference value V_{TOTLIM} of overall volumetric absorption the step a5) of changing 105 comprises a step of setting 207, by the data processing unit 210, a first target stroke value s_{1S} of the actuator of said at least one first brake B1 and a second target stroke value s_{2S} of the actuator of the at least one second brake B2 so that the sum of the first information representative of a first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 and the second information representative of a second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 is equal to the information representative of the set limit value V_{TOTLIM} of overall volumetric absorption ($V_1 + V_2 = V_{TOTLIM}$).

[00103]. According to a further embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a conventional braking system, i.e., a braking system with mechanical actuation on a hydraulic circuit, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the braking fluid pressure applied by the actuator of said at least one first brake B1 and the actuator of

said at least one second brake B2, as shown in figure 2, said at least one first brake B1 and said at least one second brake B2 are on the same axle of the vehicle (H configuration), e.g., said at least one first brake B1 is on the left side of the front axle while said at least one second brake B2 is on the right side of the front axle.

[00104]. In this embodiment, the step a3) of comparing 103 is performed by the data processing unit 210 to compare a first information representative of a first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 with a first information representative of a set first limit reference value V_{1LIM} of volumetric absorption provided for the actuator of said at least one first brake B1 and a second information representative of a second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 with a second information representative of a set second limit reference value V_{2LIM} of volumetric absorption provided for the actuator of said at least one second brake B2 ($s_{1S} = (V_{TOTLIM} – V_2)/A_1$), $s_{2S} = (V_{TOTLIM} – V_1)/A_2$)).

[00105]. If the first information representative of the first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 is less than the first information representative of the set first limit reference value V_{1LIM} of volumetric absorption provided for the actuator of said at least one first brake B1 and the second information representative of the second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 is less than the second information representative of the set second limit reference value V_{2LIM} of volumetric absorption provided for the actuator of said at least one second brake B2, the method 100 includes the step a4) of keeping unchanged the previously set first target value p_{1S} of braking pressure applied by the actuator of said at least one first brake B1 and the second target value p_{2S} of braking pressure applied by the actuator of said at least one second brake B2.

[00106]. If the first information representative of the first detected value V_1 of volumetric absorption of the actuator of said at least one first brake B1 is greater than the first information representative of the set first limit reference value V_{1LIM} of limit volumetric absorption provided for the actuator of said at least one first

brake B1 and/or the second information representative of the second detected value V_2 of volumetric absorption of the actuator of said at least one second brake B2 is greater than the second information representative of the set second limit reference value V_{2LIM} of volumetric absorption provided for the actuator of said at least one second brake B2, the step a5) of changing 105 comprises a step of setting 208, for the actuator of the brake in which the limit condition occurred, by the data processing unit 210, a target stroke value s_{1S} (s_{2S}) of the actuator of said brake B1 (B2) so that the information representative of the detected value V_1 (V_2) of volumetric absorption of the actuator of said brake B1 (B2) is equal to the information representative of the set limit value V_{1LIM} (V_{2LIM}) of volumetric absorption provided for the actuator of said brake B1 (B2) ($s_{1S} = V_{1LIM}/A_1$; $s_{2S} = V_{2LIM}/A_2$).

[00107]. Pressure limits control

[00108]. According to a further embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a conventional braking system, i.e., a braking system with mechanical actuation on a hydraulic circuit, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the braking fluid pressure applied by the actuator of said at least one first brake B1 and the actuator of said at least one second brake B2, as shown in figure 2, the step a3) of comparing 103 is performed by the data processing unit 210 to compare a first information representative of a first detected value p_1 of the braking fluid pressure applied by the actuator of said at least one first brake B1 and a second information representative of a second detected value p_2 of the braking fluid pressure applied by the actuator of said at least one second brake B2 with a first information representative of a set first pressure limit reference value p_{1LIM} of the braking fluid provided for the actuator of said at least one first brake B1 and a second information representative of a set second pressure limit pressure value p_{2LIM} of the braking fluid provided for the actuator of said at least one second brake B2, respectively.

[00109]. If the first information representative of the first detected value p_1 of

the braking fluid pressure applied by the actuator of said at least one first brake B1 is less than the first information representative of the set first pressure limit reference value p_{1LIM} of the braking fluid provided for the actuator of said at least one first brake B1 and the second information representative of the second detected value p_2 of the braking fluid pressure applied by the actuator of said at least one second brake B2 is less than the second information representative of the set second pressure limit reference value p_{2LIM} of the braking fluid provided for the actuator of said at least one second brake B2, the method 100 includes the step a4) of keeping unchanged the previously set first target value p_{1S} of braking pressure applied by the actuator of said at least one first brake B1 and the second target value p_{2S} of braking pressure applied by the actuator of said at least one second brake B2.

[00110]. If the first information representative of the first detected value p1 of the braking fluid pressure applied by the actuator of said at least one first brake B1 is greater than the first information representative of the set first pressure limit reference value p_{1LIM} of the braking fluid provided for the actuator of said at least one first brake B1 and/or the second information representative of the second detected value p2 of the braking fluid pressure applied by the actuator of said at least one second brake B2 is greater than the second information representative of the set second pressure limit reference value p_{2LIM} of the braking fluid provided for the actuator of said at least one second brake B2, the step a5) of changing 103 comprises a step of setting 209, for the actuator of the brake in which the limit condition occurred, by the data processing unit 210, a target value p_{1S} (p_{2S}) of the braking fluid pressure applicable by the actuator of said brake B1 (B2) so that the information representative of the detected value p_1 (p_2) of the braking fluid pressure of the actuator of said brake B1 (B2) is equal to the information representative of the set pressure value p_{1LIM} (p_{2LIM}) of the braking fluid provided for the actuator of said brake B1 (B2).

[00111]. B-b-W BRAKING SYSTEM - DECELERATION CONTROL (BRAKING TORQUE)

[00112]. According to an embodiment, shown in figure 3, the at least one first brake B1 and the at least one second brake B2 belong to a braking system with

Brake-by-Wire, B-b-W, technology, i.e., a braking system with electro-mechanical actuation on a hydraulic circuit or fully electro-mechanical braking system.

[00113]. In this embodiment, the target braking parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the overall braking torque provided by said at least one first brake B1 and said at least one second brake B2.

[00114]. Therefore, in this embodiment, the step a1) of setting 101 is performed by the data processing unit 210 to set, as a set-point, the target value C_{TOTS} of overall braking torque required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2.

[00115]. The target value C_{TOTS} of overall braking torque is representative of a deceleration target value for the braking control.

[00116]. The target value C_{TOTS} of overall braking torque is divided into a first value C_1 of braking torque applicable by said at least one first brake B1 and a second value C_2 of braking torque applicable by said at least one second brake B2 ($C_{TOTS} = C_1 + C_2$).

[00117]. In this embodiment, said one or more braking control parameters required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 detectable by said one or more braking parameter detection modules 220 operatively connected to the data processing unit 210 comprise the braking torque applied by each of said at least one first brake B1 and said at least one second brake B2, the stroke speed of each actuator of said at least one first brake B1 and said at least one second brake B2, and the force applied by each actuator of said at least one first brake B1 and said at least one second brake B2.

[00118]. In this embodiment, for each sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, where N is an integer, of the braking time interval, the method 100 comprises the following steps.

[00119]. In the absence (N) of attainment of a limit condition by all of said one or more detected values of braking control parameters, the step a4) of keeping 104 unchanged said at least one target value of a braking parameter required

for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2, then returning to the step a2) of detecting 102, comprises a step of setting 304, by the data processing unit 210, for said at least one first brake B1 and said at least one second brake B2, a first value F_1 of force applied by the actuator to said at least one first brake B1 and a second value F_2 of force applied by the actuator to said at least one second brake B2, respectively, which are equal to each other ($F_1 = F_2$) so as to obtain a first target value C_{1S} of braking torque applied by said at least one first brake B1 and a second target value C_{2S} of braking torque applied by said at least one second brake B2 such as to attain in turn the target value C_{TOTS} of overall braking torque required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 ($C_{TOTS} = C_{1S} + C_{2S}$).

[00120]. In the presence (Y) of attainment of a limit condition by at least one of said one or more detected values of braking control parameters, the step a5) of changing 105 comprises a step of setting 305, by the data processing unit 210, the first value F_1 of force applied by the actuator of said at least one first brake B1 and the second value F_2 of force applied by the actuator of said at least one second brake B2 so that the target value of braking torque applied by one of said at least one first brake B1 and said at least one second brake B2 in which such a limit was attained is the difference between the target value C_{TOTS} of overall braking torque required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 and the detected value of braking torque applied by the other of said at least one first brake B1 and said at least one second brake B2 during the braking test.

[00121]. Braking torque limits control

[00122]. According to an embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a B-b-W braking system, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the overall braking torque provided by said at least one first brake B1 and said at least one second brake B2, as shown in figure 3, the step a3) of comparing 103 is performed by the

data processing unit 210 to compare a first information representative of the first detected value C_1 of braking torque and a second information representative of the second detected value C_2 of braking torque with respective a first information representative of a set first limit reference value C_{1LIM} of braking torque provided for said at least one first brake B1 and a respective second information representative of a set second limit reference value C_{2LIM} of braking torque provided for said at least one second brake B2, respectively.

[00123]. Such braking torque limit reference values can be defined based on braking system dimensioning calculations based on vehicle characteristics and can correspond to the grip limit torque values between tire and road provided for each of said at least one first brake B1 and said at least one second brake B2.

[00124]. As long as the first information representative of the first detected value C_1 of braking torque is less than the first information representative of a set first limit reference value C_{1LIM} of braking torque provided for said at least one first brake B1 and the second information representative of the second detected value C_2 of braking torque is less than the respective second information representative of a set second limit reference value C_{2LIM} of braking torque, the method 100 includes the step a4) of keeping 104 unchanged the previously set target value C_{TOTS} of overall braking torque, without the need to perform any corrective operations.

[00125]. If the first information representative of the first detected value C_1 of braking torque is greater than the respective first information representative of the set first limit reference value C_{1LIM} of braking torque and/or the second information representative of the second detected value C_2 of braking torque is greater than the respective second information representative of the set second limit reference value C_{2LIM} of braking torque, the step a5) of changing 105 comprises a step of setting 306, by the data processing unit 210, as a first target value C_{1S} of braking torque applicable by said at least one first brake B1, the set limit reference value C_{1LIM} of braking torque provided for said at least one first brake B1, and/or as a second value C_2 of braking torque applicable by said at least one second brake B2, the set limit reference value C_{2LIM} of braking

torque provided for said at least one second brake B2.

[00126]. Stroke limits control

[00127]. According to an embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a B-b-W type braking system, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the overall braking torque provided by said at least one first brake B1 and said at least one second brake B2, as shown in figure 3, the step a3) of comparing 103 is performed by the data processing unit 210 to compare a first information representative of a first detected stroke value s_1 of the actuator of said at least one first brake B1 and a second information representative of a second detected stroke value s_2 of the actuator of said at least one second brake B2 with respective a first information representative of a set first stroke limit reference value s_{1LIM} of the actuator of said at least one first brake B1 and a respective second information representative of a set second stroke limit reference value s_{2LIM} of the actuator of said at least one second brake B2, respectively.

[00128]. If the first information representative of the first detected stroke value s_1 of the actuator of said at least one first brake B1 is less than the first information representative of the set first stroke limit reference value s_{1LIM} of the actuator of said at least one first brake B1 and the second information representative of the second detected stroke value s_2 of the actuator of said at least one second brake B2 is less than the second information representative of the set second stroke limit reference value s_{2LIM} of the actuator of said at least one second brake B2, the method 100 includes the step a4) of keeping 104 unchanged the previously set target value C_{TOTS} of overall braking torque, without the need to perform any corrective operations.

[00129]. If the first information representative of the first detected stroke value s_1 of the actuator of said at least one first brake B1 is greater than the first information representative of the set first stroke limit reference value s_{1LIM} of the actuator of said at least one first brake B1 and/or the second information representative of the second detected stroke value s_2 of the actuator of said at

least one second brake B2 is greater than the second information representative of the set second stroke limit reference value s_{2LIM} of the actuator of said at least one second brake B2, the step a5) of controlling 105 comprises a step of setting 307, by the data processing unit 210, for the actuator of the brake in which the limit condition occurred, a target stroke value s_{1S} (s_{2S}) of the actuator of said brake B1 (B2) equal to the information representative of the set stroke limit value s_{1LIM} (s_{2LIM}) of the actuator of said at least one brake B1 (B2).

[00130]. Force limits control

[00131]. According to a further embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a B-b-W braking system, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the overall braking torque provided by said at least one first brake B1 and said at least one second brake B2, as shown in figure 3, the step a3) of comparing 103 is performed by the data processing unit 210 to compare a first information representative of a first detected force value F_1 of the actuator of said at least one first brake B1 and a second information representative of a second detected force value F_2 of the actuator of said at least one second brake B2 with a respective first information representative of a set first force limit reference value F_{1LIM} of the actuator of said at least one first brake B1 and a respective second information representative of a set second force limit reference value F_{2LIM} of the actuator of said at least one second brake B2, respectively.

[00132]. If the first detected force value F_1 of the actuator of said at least one first brake B1 is less than the first information representative of the set first force limit reference value F_{1LIM} of the actuator of said at least one first brake B1 and the second information representative of the second detected force value F_2 of the actuator of said at least one second brake B2 is less than the second information representative of the set second force limit reference value F_{2LIM} of the actuator of said at least one second brake B2, the method 100 includes the step a4) of keeping 104 unchanged the previously set target value C_{TOTS} of overall braking torque, without the need to perform any corrective operations.

[00133]. If the first detected force value F_1 of the actuator of said at least one first brake B1 is greater than the first information representative of the set first force limit reference value F_{1LIM} of the actuator of said at least one first brake B1 and/or the second information representative of the second detected force value F_2 of the actuator of said at least one second brake B2 is greater than the second information representative of the set second force limit reference value F_{2LIM} of the actuator of said at least one second brake B2, the step a5) of changing 105 comprises a step of setting 309, for the actuator of the brake in which the limit condition occurred, by the data processing unit 210, a force target value F_{1S} (F_{2S}) of the actuator of said brake B1 (B2) equal to the information representative of the set force limit value F_{1LIM} (F_{2LIM}) for the actuator of said brake B1 (B2) ($F_{1S} = F_{1LIM}$; $F_{2S} = F_{2LIM}$).

[00134]. It should be emphasized that in the case of attaining any of the limits described above (torque limit, stroke limit, force limit), the target value C_{TOTS} of overall braking torque previously set is kept unchanged, as it still represents the target deceleration value with which the required braking should be performed but, in the case of attaining any of the above limits, it would not be possible to ensure it.

[00135]. By the way, this is representative of what normally occurs on the vehicle if, for example, the brake pedal has reached the limit stop and the user (driver) needs to attain a set target deceleration value by braking with the brake pedal (in other words, the driver has a set target value C_{TOTS} of overall braking torque), but that the brake pedal stroke no longer allows to attain, having attained the limit stop.

[00136]. <u>B-b-W BRAKING SYSTEM - FORCE CONTROL</u>

[00137]. According to a further embodiment, shown in figure 4, the at least one first brake B1 and the at least one second brake B2 belong to a braking system with Brake-by-Wire, B-b-W, technology, i.e., a braking system with electro-mechanical actuation on a hydraulic circuit or fully electro-mechanical braking system.

[00138]. In this embodiment, the target braking parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one

second brake B2 is the force applied by each actuator requested to the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2.

[00139]. Therefore, in this embodiment, the step a1) of setting 101 is performed by the data processing unit 210 to set a first target value F_{1S} of braking force applied by the actuator of said at least one first brake B1 and the second target value F_{2S} of braking force applied by the actuator of said at least one second brake B2.

[00140]. In this embodiment, said one or more braking control parameters required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 detectable by said one or more braking parameter detection modules 220 operatively connected to the data processing unit 210 are the braking torque applied by each of said at least one first brake B1 and said at least one second brake B2, the stroke speed of each actuator of said at least one first brake B1 and said at least one second brake B2, and the force applied by each actuator of said at least one first brake B1 and said at least one second brake B2.

[00141]. In this embodiment, for each sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, where N is an integer, of the braking time interval, the method 100 comprises the following steps.

[00142]. In the absence (N) of attainment of a limit condition by all of said one or more detected values of braking control parameters, the data processing unit 210 keeps unchanged the first target value F_{1S} of the force applied by the actuator of said at least one first brake B1 and the second target value F_{2S} of the force applied by the actuator of said at least one second brake B2.

[00143]. In the presence (Y) of attainment of a limit condition by at least one of said one or more detected values of braking control parameters, the data processing unit 210 performs the method as described below.

[00144]. Braking torque limits control

[00145]. According to an embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a B-b-W braking system, and where the braking

target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the force applied by the actuator of said at least one first brake B1 and the actuator of said at least one second brake B2, as shown in figure 4, the step a3) of comparing 103 is performed by the data processing unit 210 to compare a first information representative of the first detected value C_1 of braking torque and a second information representative of the second detected value C_2 of braking torque with respective a first information representative of a set first limit reference value C_{1LIM} of braking torque provided for said at least one first brake B1 and a respective second information representative of a set second limit reference value C_{2LIM} of braking torque for said at least one second brake B2, respectively.

[00146]. Such braking torque limit reference values can be defined based on braking system dimensioning calculations based on vehicle characteristics and can correspond to the grip limit torque values between tire and road provided for each of said at least one first brake B1 and said at least one second brake B2.

[00147]. As long as the first information representative of the first detected value C_1 of braking torque is less than the first information representative of a set first limit reference value C_{1LIM} of braking torque (grip limit torque between tire and road) provided for said at least one first brake B1 and the second information representative of the second detected value C_2 of braking torque is less than the respective second information representative of a set second limit reference value C_{2LIM} of braking torque (grip limit torque between tire and road) provided for said at least one second brake B2, the method 100 includes the step a4) of keeping unchanged the first target value F_{1S} of the force applied by the actuator of said at least one first brake B1 and the second target value F_{2S} of the force applied by the actuator of said at least one second brake B2.

[00148]. If the first information representative of the first detected value C_1 of braking torque is greater than the respective first information representative of the set first limit reference value C_{1LIM} of braking torque and/or the second information representative of the second detected value C_2 of braking torque is greater than the respective second information representative of the set second

limit reference value C_{2LIM} of braking torque, the step a5) of changing 105 comprises a step of setting 406, by the data processing unit 210, as a first target value C_{1S} of braking torque applicable by said at least one first brake B1, the set first limit reference value C_{1LIM} of braking torque provided for said at least one first brake B1, and/or as a second target value C_{2S} of braking torque applicable by said at least one second brake B2, the set second limit reference value C_{2LIM} of braking torque provided for said at least one second brake B2.

[00149]. Stroke limits control

[00150]. According to an embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a B-b-W type braking system, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the force applied by each actuator of said at least one first brake B1 and of said at least one second brake B2, as shown in figure 4, the step a3) of comparing 103 is performed by the data processing unit 210 to compare a first information representative of a first detected stroke value s_1 of the actuator of said at least one first brake B1 and a second information representative of a second detected stroke value s_2 of the actuator of said at least one second brake B2 with respective a first information representative of a set first stroke limit reference value s_{1LIM} of the actuator of said at least one first brake B1 and a respective second information representative of a set second stroke limit reference value s_{2LIM} of the actuator of said at least one second brake B2, respectively.

[00151]. If the first information representative of the first detected stroke value s_1 of the actuator of said at least one first brake B1 is less than the first information representative of the set first stroke limit reference value s_{1LIM} of the actuator of said at least one first brake B1 and the second information representative of the second detected stroke value s_2 of the actuator of said at least one second brake B2 is less than the second information representative of the set second stroke limit reference value s_{2LIM} of the actuator of said at least one second brake B2, the method 100 includes the step a4) of keeping unchanged the previously set first target value F_{1S} of the force applied by the

actuator of said at least one first brake B1 and the second target value F_{2S} of the force applied by the actuator of said at least one second brake B2.

[00152]. If the first information representative of the first detected stroke value s_1 of the actuator of said at least one first brake B1 is greater than the first information representative of the set first stroke limit value s_{1LIM} of the actuator of said at least one first brake B1 and/or the second information representative of the second detected stroke value s_2 of the actuator of said at least one second brake B2 is greater than the second information representative of the set second stroke limit value s_{2LIM} of the actuator of said at least one second brake B2, the step a5) of changing 105 comprises a step of setting 407, by the data processing unit 210, for the actuator of the brake in which the limit condition occurred, a target stroke value s_{1S} (s_{2S}) of the actuator of said brake B1 (B2) equal to the information representative of the set stroke limit value s_{1LIM} (s_{2LIM}) of the actuator of said at least one brake B1 (B2).

[00153]. Force limits control

[00154]. According to a further embodiment, in combination with any one of those described above where the at least one first brake B1 and the at least one second brake B2 belong to a B-b-W braking system, and where the braking target parameter required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is the force applied by each actuator of said at least one first brake B1 and of said at least one second brake B2, as shown in figure 4, the step a3) of comparing 103 is performed by the data processing unit 210 to compare a first information representative of a first detected force value F_1 of the actuator of said at least one first brake B1 and a second information representative of a second detected force value F_2 of the actuator of said at least one second brake B2 with a respective first information representative of a set first force limit reference value F_{1LIM} of the actuator of said at least one first brake B1 and a respective second information representative of a set second force limit reference value F_{2LIM} of the actuator of said at least one second brake B2, respectively.

[00155]. If the first detected force value F_1 of the actuator of said at least one first brake B1 is less than the first information representative of the set first force

limit reference value F_{1LIM} of the actuator of said at least one first brake B1 and the second information representative of the second detected force value F_2 of the actuator of said at least one second brake B2 is less than the second information representative of the set second force limit reference value F_{2LIM} of the actuator of said at least one second brake B2, the method 100 includes the step a4) of keeping unchanged the previously set first target value F_{1S} of the force applied by the actuator of said at least one first brake B1 and the second target value F_{2S} of the force applied by the actuator of said at least one second brake B2.

[00156]. If the first detected force value F_1 of the actuator of said at least one first brake B1 is greater than the first information representative of the set first force limit reference value F_{1LIM} of the actuator of said at least one first brake B1 and/or the second information representative of the second detected force value F_2 of the actuator of said at least one second brake B2 is greater than the second information representative of the set second force limit reference value F_{2LIM} of the actuator of said at least one second brake B2, the step a5) of changing 105 comprises a step of setting 409, for the actuator of the brake in which the limit condition occurred, by the data processing unit 210, a force target value F_{1S} (F_{2S}) of the actuator of said brake B1 (B2) equal to the information representative of the set force limit value F_{1LIM} (F_{2LIM}) for the actuator of said brake B1 (B2) ($F_{1S} = F_{1LIM}$; $F_{2S} = F_{2LIM}$).

[00157]. It should be noted that in the case of attaining any of the previously described limits (torque limit, stroke limit, force limit), the first target force value F_{1S} applied by the actuator of said at least one first brake B1 and the second target force value F_{2S} applied by the actuator of said at least one second brake B2 previously set remain unchanged, as they still represent the target force values with which the required braking should be performed but, in the case of attaining one of said limits, it would not be possible to endure them.

[00158]. By the way, this is representative of what normally occurs on the vehicle if, for example, the brake pedal has reached the limit stop and the user (driver) needs to attain a set target force value by braking with the brake pedal (in other words, the driver has set braking force target values applied by the

brake actuators), but that the brake pedal stroke no longer allows to attain, having attained the limit stop.

[00159]. According to an embodiment, in combination with any one of the those described above, the at least one value of a target braking parameter (set-point) required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is an equal value in all the sampling time instants t_i of a plurality of sampling time instants $1 < i < N$, where N is an integer, of the braking time interval in which the braking test is performed.

[00160]. According to a further embodiment, alternatively to the previous one but in combination with any one of all the others, the at least one value of a target braking parameter (set-point) required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is an over-time (dynamic) varying value in the braking time interval in which the braking test is performed.

[00161]. Such a time interval includes therein instants of time t_i of sampling a plurality of sampling time instants.

[00162]. For example, in the case of a braking torque limit condition, the set first braking torque limit reference value C_{1LIM} for said at least one first brake B1 could be equal to a set first value (e.g., equal to 1200 Nm) at a first sampling time instant t_1, equal a set second value (e.g., equal to 800 Nm) at a second sampling time instant t_2, and so on.

[00163]. In greater detail, according to this example, in the at least one data processing unit 210 (or the control logic to which reference is made), the virtual vehicle models could be integrated at any level capable of providing the established limit reference values for each sampling time instant t_i of a plurality of time instants of the braking time interval in which the braking test is performed.

[00164]. For example, if a virtual vehicle model capable of providing the tire slip conditions based on road surface conditions is considered, a momentary reduction in the limit of braking torque transmittable to the ground due to the presence of ice could thus be taken into account.

[00165]. Indeed, it should be noted that such a virtual vehicle model is a separately built virtual model of vehicle dynamics in a simulation environment which, if implemented in the data processing unit operationally connected to the test bench, would be able to provide real-time prediction of vehicle behavior on the road under various test conditions.

[00166]. According to a further embodiment, in combination with any of the preceding ones, the settable at least one value of a target braking parameter (set-point) required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is a constant value (e.g., in the case of braking torque limit control, the set first limit reference value C_{1LIM} of braking torque for said at least one first brake B1 is equal to a set first value of 1200 Nm).

[00167]. According to a further embodiment, alternatively to the previous one but in combination with any one of all the others, the settable at least one value of a target braking parameter (set-point) required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is a variable value according to a set variation law as a function of the representative quantities of the vehicle.

[00168]. According to a further embodiment, in combination with the preceding one, the at least one target parameter (set-point) required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 is an over-time varying value according to a set law of variation as a function of representative quantities of the vehicle.

[00169]. Such representative quantities of the vehicle can be, for example, vehicle speed (which on sports cars, for example, is a function of aerodynamic load), vehicle inertia (always variable depending on, for example, vehicle speed or time), vehicle deceleration, limiting braking torque (for example, a function of vehicle mass), the gradient to which the vehicle is subjected, the state of electrical charge of the battery, and so on.

[00170]. It should be noted that the set law of variation could be of any type, such as linear, quadratic, cubic, parabolic, logarithmic, and so on, or it could be continuous or defined at intervals within the time interval in which the braking

test is performed.

[00171]. With reference to figures 5-11, examples of control logics implementable by the data processing unit 210 in a bench test in the case of a conventional braking system, i.e., a braking system with mechanical actuation on a hydraulic circuit, are now described.

[00172]. Such examples of control logics are not in exhaustive number since they are only some examples of control logics implementable by the data processing unit 210 in a bench test in the case of a conventional braking system.

[00173]. It should be noted that a brake actuator stroke limit condition overrides a brake fluid pressure limit condition, and a brake fluid pressure limit condition overrides a brake torque limit condition applied by the brake.

[00174]. The limit condition are controlled in the reverse order: first braking torque limit condition control, then braking fluid pressure limit condition control, and finally volumetric absorption control.

[00175]. With reference to the logic shown in figure 5, at a sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, with N being integer, of the braking time interval, an error value of braking torque E-C is calculated between the target value C_{TOTS} of overall braking torque required for the portion of vehicle comprising the at least one first brake B1 and the at least one second brake B2 and the sum between a first value C_1 of braking torque applied by said at least one first brake B1 and a second value C_2 of braking torque applied by said at least one second brake B2 detected at the previous time instant t_{i-1}.

[00176]. The braking torque error value E-C is processed (and rescaled) by a processing block 50 (e.g., a PID) and transformed into a pressure error correction value C-P (of the brake fluid) equal for said at least one first brake B1 and said at least one second brake B2.

[00177]. If the braking torque error value E-C is zero, there is no change in brake fluid pressure.

[00178]. If the braking torque error value E-C is not zero, there is an increase in braking fluid pressure if the braking torque error value E-C is positive, i.e., if the target value C_{TOTS} of overall braking torque (torque demand) is greater than the sum of the braking torques of the two brakes, or a pressure decrease in the

opposite case.

[00179]. In this regard, the control logic provides an integrative function whereby the pressure error correction value C-P is added to the pressure value of the previous time instant t_{i-1} to obtain a command value CM-P of brake fluid pressure to be applied to said at least one first brake B1 and to said at least one second brake B2.

[00180]. The pressure value which is corrected with the pressure error correction CR-P, to obtain the command pressure value CM-P to be applied to both brakes, is the maximum pressure value P_{max1-2} of the two pressure feedbacks on said at least one first brake F1 and said at least one second brake F2 of the previous time instant t_{i-1}.

[00181]. One of the two brakes is thus suffering during the bench test, because having attained a limiting condition, there is an increased action on the other brake in the following instants of time.

[00182]. If the braking torque limit conditions do not intervene, the brake fluid pressure obtained potentially becomes the pressure reference for both brakes.

[00183]. In parallel with the general braking torque control logic (according to the logic in figure 5), two other control logics are also present, shown in figures 6 and 7, respectively, one for each brake, which process the braking fluid pressures which would be required to obtain the braking torque limit reference values on said at least one first brake B1 and said at least one second brake B2.

[00184]. With reference to figures 6 and 7, if the braking torque feedback of the brake B1 is less than the respective braking torque limit reference value and the braking torque feedback of the brake B2 is less than the respective braking torque limit reference value, there are, at the current instant of time, no braking torque limit conditions and the braking fluid pressure processed by processing block 50 (figure 5) is (potentially) directed to brake B1 and brake B2 (braking with equal pressure).

[00185]. In the presence, on the other hand, of a braking torque limit condition on at least one the two brakes, the brakes in the braking torque limit condition are (potentially) directed to the braking fluid pressure calculated by the

corresponding control logics that have the braking torque limit reference values C_{1LIM} for brake B1 (figure 6) and C_{2LIM} for brake B2 (figure 7) as braking torque target values.

[00186]. If both brakes are in any limit condition, the pressure error correction values E-C1 and E-C2 output from the respective processing blocks 51 (figure 6) and 52 (figure 7), the output value of which is not used, are reset to zero so as not to generate abnormal values which would compromise exit strategies from limit conditions.

[00187]. It is worth noting that the exit from the braking torque limit condition occurs when the target value of overall braking torque decreases, or when a given brake regains its braking action, e.g., as a result of an increase in the coefficient of friction, or again when the braking torque limit condition changes, because, e.g., the ABS action ceases.

[00188]. Referring now to the control logic in figure 8, verification of exiting from the braking torque limit condition is based on comparing the braking fluid pressure command values output from each of the three control logics, i.e., the value CM-P output by the general control logic (figure 5), the value CM-P1 output by the control logic of the brake B1 (figure 6) and the value CM-P2 output by the control logic of the brake B2 (figure 7).

[00189]. It is worth noting that the exit from the braking torque limit condition occurs if the braking fluid pressure command value processed by the individual brake control logic is greater (with hysteresis) than that generated by the general control logic.

[00190]. Having obtained the braking fluid pressure command value of the individual brake, verifying braking fluid pressure limit condition (according to the control logic in figure 8) is very simple, because it is simply choose, by respective processing blocks 81 and 82, as the braking fluid pressure limit reference value P_{1S}, P_{2S} for the control logic, the minimum pressure value between the processed one and limit condition one P_{1LIM}, P_{2LIM}.

[00191]. Next, the control logic involves comparing the braking fluid pressure limit reference value P_{1S}, P_{2S} with respective braking fluid pressure commands CM-P1 and CM-P2 calculated at the previous sampling time instant t_{i-1} and, for

each brake B1 and B2, the braking fluid pressure command error value C-P1, C-P2 is processed (and rescaled) by a respective processing block 81', 82' (e.g., a PID) and transformed into target values SP-1, SP-2 of the stroke speed of the brake actuator B1, B2.

[00192]. It is worth noting that each of the target values SP-1, SP-2 of the stroke speed of the brake actuator B1, B2 are low-level target values aimed at the subsequent determination, again by the control logic, of respective target values s_{1S}, s_{2S} of the stroke of the brake actuator B1, B2 in the shortest time and under the best possible conditions. Indeed, in this case, such target values s_{1S}, s_{2S} of the stroke of the brake actuator B1, B2 are high-level target values.

[00193]. Finally, the verification of the volumetric absorption limit condition is considered, and the strategy differs between the connection between said at least one first brake B1 and said at least one second brake B2 in an H bridge-like configuration (control logic in figure 9) and the connection between said at least one first brake B1 and said at least one second brake B2 in an X bridge-like configuration (control logic in figure 10).

[00194]. In the case of an H bridge-like connection, each brake B1, B2 has a volumetric absorption limit reference value: V_{1LIM} and V_{2LIM}.

[00195]. The two brakes can be separately found in a volumetric absorption limit condition.

[00196]. For this reason, the control logic provides two independently controlled switches, SW-V_{1LIM} and SW-V_{2LIM}.

[00197]. This happens when the stroke value of the individual actuator corresponding to the volumetric absorption limit exceeds the expected volumetric absorption limit reference value.

[00198]. The exit from an absorption limit occurs when the signal representing the reference stroke value of actuator SP-1, SP-2 becomes negative (with threshold).

[00199]. In the case of an X bridge-like connection, there is only one limit condition, which is related to the overall volumetric absorption of the circuit.

[00200]. For this reason, the control logic requires only one switch SW-$V_{1\text{-}2LIM}$.

[00201]. In this case, the two brakes simultaneously go into volumetric

absorption limit condition when the sum of feedbacks of volumetric absorption values exceeds the reference limit value.

[00202]. Both control logics in figures 9 (axle X configuration) and 10 (axle H configuration) comprise respective processing blocks 90 to choose, as the braking fluid pressure limit reference value P_{1S}, P_{2S} for the control logic, the value P_{max1-2} of maximum pressure between the value P1 of braking fluid pressure of said at least one first brake B1 and the value P2 of braking fluid pressure of said at least one second brake B2.

[00203]. On the other hand, as for braking management in pressure control or force control, it is identical to that in braking torque, with the simple omission of the general braking torque control logic, because the pressure limit reference value P-REF (or force limit reference value) is already the pressure command value signal CM-P (according to the control logic in figure 11).

[00204]. A braking actuation and management system 200 for simultaneously controlling at least one first brake B1 of a vehicle and at least one second brake B2 of the same vehicle on bench braking tests, hereafter also simply braking actuation and management system or just system, will now be described with reference to figure 13.

[00205]. The system 200 comprises one or more test benches BT on which said at least one first brake B1 and said at least one second brake B2 are to be subjected to a braking test.

[00206]. The system 200 further comprises a data processing unit 210 operatively connected to said one or more test benches BT.

[00207]. The system 200 further comprises one or more braking parameter detection modules 220 operatively associated with said one or more test benches BT and operatively connected to said data processing unit 210.

[00208]. Said one or more braking parameter detection modules 220 comprise, in the case of Dual Brake logic, for each of said at least one first brake B1 and said at least one second brake B2:

[00209]. – torque meters for detecting a first value C_1 of braking torque applied by said at least one first brake B1, a second value C_2 of braking torque applied by said at least one second brake B2, an overall value C_{TOT} of braking torque

applied by said at least one first brake B1 and said at least one second brake B2;

[00210]. – pressure transducers for detecting a first value p1 of braking fluid pressure level applied by at least one first brake B1 and a second value p2 of braking fluid pressure level applied by said at least one second brake B2;

[00211]. – stroke transducers for detecting a first stroke value s_1 of the actuator of said at least one first brake B1 and a second stroke value s_2 of the actuator of said at least one second brake B2;

[00212]. - in addition to stroke transducers, volumetric absorption transducers (or flow meters) for detecting a first value V_1 of volumetric absorption of the actuator of said at least one first brake B1 and a second value V_2 of volumetric absorption of the actuator of said at least one second brake B2.

[00213]. It should be noted that the torque meters and transducers listed above, by way of non-exhaustive example, an all be functional in the definitions of bench test control logics (e.g., stroke transducers are always present), depending on the degree of refinement to be attained from the one or more test benches (e.g., there could be defined control logics that use only stroke transducers regardless of whether volumetric absorption transducers are used or not).

[00214]. The system 200 is configured to perform the braking actuation and management method for simultaneously controlling at least one first brake B1 of a vehicle and at least one second brake B2 of the same vehicle on bench braking tests according to the present invention and different embodiments.

[00215]. According to an embodiment, shown in figure 13, said one or more test benches BT comprise a single test bench BT (so-called dyno bench) on which said at least one first brake B1 and said at least one second brake B2 are subjected to a braking test, according to the Dual Brake Dyno concept.

[00216]. In greater detail, through a mechanical transmission, motion is transmitted with the same rotational speed to two braking systems, one for said at least one first brake B1 and one for said at least one second brake B2.

[00217]. The pressure actuation according to the control logics described according to the present invention is implemented by using two pressure

actuators, one for said at least one first brake B1 and one for said at least one second brake B2.

[00218]. In an embodiment, in combination with the preceding one, the data processing unit 210 is installed on said test bench BT on which said at least one first brake B1 and said at least one second brake B2 are subjected to tests.

[00219]. According to an embodiment, alternative to the preceding ones and not shown in the figures, the one or more test benches BT comprise a first test bench on which said at least one first brake B1 is subjected to tests and a second test bench on which said at least one second brake B2 is subjected to tests.

[00220]. The first test bench and the second test bench are operationally connected to each other, e.g., the connection is by cable, and data communication is by means of respective data communication protocols.

[00221]. According to an embodiment, in combination with the preceding one, the data processing unit 210 is installed on one of said first test bench and second test bench.

[00222]. In an embodiment, alternative to the preceding one, the data processing unit 210 comprises a first data processing block installed on said first test bench and a second data processing block installed on said second test bench.

[00223]. It is worth noting that the object of the present invention is fully attained.

[00224]. Indeed, with the method and related system according to the present invention, it is possible to manage dynamic bench braking on two or more brakes of the same vehicle (e.g., left front and left rear) simultaneously and taking into account the interaction between them.

[00225]. Furthermore, the control logics allow for proper simulation of vehicle behavior, in which braking control is influenced in real-time by the behavior of individual vehicle corners and is not determined a priori.

[00226]. It is thus possible to increase the representativeness of the bench test compared with the corresponding road test.

[00227]. The control logics can be applied to two or more single benches

linked together in real-time by-wire solution) or to single/conventional benches appropriately modified to test two or more brakes simultaneously (e.g., Dual Brake Dyno solution).

[00228]. Furthermore, it is possible to be able to test two identical brakes on the same bench with the same procedure if multiple repetitions of the same test are required on the same components, thereby effectively increasing the efficiency of the dynamic test bench, in addition to the improved representativeness of the bench tests that can be performed.

[00229]. Those skilled in the art may make changes and adaptations to the embodiments of the method and related system described above and can replace elements with others which are functionally equivalent in order to meet contingent needs without departing from the scope of the following claims. Each of the features described above as belonging to a possible embodiment can be implemented irrespective of the other embodiments described.

CLAIMS

1. A braking actuation and management method (100) for simultaneously controlling at least one first brake (B1) of a vehicle and at least one second brake (B2) of the same vehicle on bench braking tests, comprising a step of:

- a1) setting (101), by a data processing unit (210) operatively connected to one or more braking test benches (BT), at least one value of a target braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2);

for each sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, where N is an integer, of a braking test time interval, the method (100) comprising steps of:

- a2) detecting 102, by one or more braking parameter detection modules (220), operatively connected to the data processing unit (210), one or more values of braking control parameters required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2);

- a3) comparing (103), by the data processing unit (210), the one or more detected values of braking parameters required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) with respective one or more limit reference values for verifying the absence or presence of the attainment of a limit condition by said one or more detected values of braking parameters;

in the absence (N) of attainment of a limit condition by all of said one or more detected values of braking control parameters, the method (100) comprises a step a4) of keeping (104) unchanged, by the data processing unit (210), said at least one value of a target braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2), thus returning to the step a2) of detecting (102);

in the presence (Y) of attainment of a limit condition by at least one of said one or more detected values of braking control parameters, the method (100) comprises a step a5) of changing (105), by the data processing unit, the at least one value of the target braking parameter previously set as a function of the

braking control parameter which attained such a limit condition.

2. The method (100) according to claim 1, wherein the at least one first brake (B1) and the at least one second brake (B2) belong to a braking system with mechanical actuation on a hydraulic circuit, the target braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) being the overall braking torque (C_{TOT}) ensured by said at least one first brake (B1) and said at least one second brake (B2),

the step a1) of setting (101) being performed by the data processing unit (210) to set, as a set-point, the target value (C_{TOTS}) of overall braking torque required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2), the target value (C_{TOTS}) of overall braking torque being representative of a target deceleration value for the braking control, the target value (C_{TOTS}) of overall braking torque being divided into a first value (C_1) of braking torque applicable by said at least one first brake (B1) and a second value (C_2) of braking torque applicable by said at least one second brake B2, said one or more braking control parameters required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) detectable by said one or more braking parameter detection modules (220) operatively connected to the data processing unit (210) comprising the braking torque applied by each of said at least one first brake (B1) and said at least one second brake (B2), the volumetric absorption of each actuator of said at least one first brake (B1) and said at least one second brake (B2), and the braking fluid pressure applied by each actuator of said at least one first brake (B1) and said at least one second brake (B2),

for each sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, where N is an integer, of the braking time interval, the method 100 comprising steps of:

- in the absence (N) of attainment of a limit condition by all of said one or more detected values of braking control parameters, the step a4) keeping (104) unchanged said at least one target value of a braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least

one second brake (B2), then returning to the step a2) of detecting (102), comprises a step of setting (104'), by the data processing unit (210), for said at least one first brake (B1) and for said at least one second brake (B2), a first value (p1) of braking fluid pressure level and a second value (p2) of braking fluid pressure level, respectively, equal to each other;

- in the presence (Y) of attainment of a limit condition by at least one of said one or more detected values of braking control parameters, the step a5) of changing 105 comprises a step of removing (105'), by the data processing unit (210), if previously set, the condition of equality between the first value (p1) of braking fluid pressure level set for said at least one first brake (B1) and the second value (p2) of braking fluid pressure level set for said at least one second brake (B2), the step a5) of changing (105) comprising a step of setting (105''), by the data processing unit (210), a braking torque target value of one of said at least one first brake (B1) and said at least one second brake (B2) in which such a limit was attained as the difference between the target value (C_{TOTS}) of overall braking torque required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) and the detected value of braking torque applied by the other of said at least one first brake (B1) and said at least one second brake (B2) during the braking test.

3. The method (100) according to claim 2, wherein the step a3) of comparing (103) is performed, by the data processing unit (210), to compare a first information representative of the first detected value (C_1) of braking torque and a second information representative of the second detected value (C_2) of braking torque with a respective first information representative of a set first limit reference value (C_{1LIM}) of braking torque for said at least one first brake (B1) and a respective second information representative of a set second limit reference value (C_{2LIM}) of braking torque, respectively,

as long as the first information representative of the first detected value (C_1) of braking torque is less than the first information representative of a set first limit reference value (C_{1LIM}) of braking torque for said at least one first brake (B1) and the second information representative of the second detected value (C_2) of braking torque is less than the respective second information

representative of a set second limit reference value (C_{2LIM}) of braking torque, the method (100) includes the step a4) of keeping (104) unchanged the previously set target value (C_{TOTS}) of overall braking torque, without the need to perform any corrective operations,

if the first information representative of the first detected value (C_1) of braking torque is greater than the respective first information representative of the set first limit reference value (C_{1LIM}) of braking torque and/or the second information representative of the second detected value (C_2) of braking torque is greater than the respective second information representative of the set second limit reference value (C_{2LIM}) of braking torque, the step a5) of changing (105) comprises a step of setting (106), by the data processing unit (210), as a first target value (C_{1S}) of braking torque applicable by said at least one first brake (B1), the set limit reference value (C_{1LIM}) of braking torque for at least one first brake (B1), and/or as a second target value (C_{2S}) of braking torque applicable by said at least one second brake (B2), the set limit reference value (C_{2LIM}) of braking torque for said at least one second brake (B2).

4. The method (100) according to any one of claims 2 or 3, wherein said at least one first brake (B1) and said at least one second brake (B2) are on opposite sides of two different axles of the vehicle, the step a3) of comparing (103) being performed by the data processing unit (210) to compare a sum of a first information representative of a first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) and a second information representative of a second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) with an information representative of a set limit reference value (V_{TOTLIM}) of overall volumetric absorption provided for a master cylinder of the vehicle adapted to act on said at least one first brake (B1) and said at least one second brake (B2),

if the sum of the first information representative of a first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) and the second information representative of a second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) is less than the information representative of the set limit value (V_{TOTLIM}) of overall

volumetric absorption, the method (100) performs the step a4) of keeping (104) unchanged the previously set target value (C_{TOTS}) of overall braking torque, without the need to perform any corrective operations,

if the sum of the first information representative of a first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) and the second information representative of a second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) is greater than the information representative of the set limit value (V_{TOTLIM}) of overall volumetric absorption, the step a5) of changing (105) comprises a step of setting (107), by the data processing unit (210), a first target stroke value (s_{1S}) of the actuator of said at least one first brake (B1) and a second target stroke value (s_{2S}) of the actuator of said at least one second brake (B2) so that the sum of the first information representative of a first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) and the second information representative of a second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) is equal to the information representative of the set limit value (V_{TOTLIM}) of overall volumetric absorption.

5. The method (100) according to any one of the preceding claims from 2 to 4, said at least one first brake (B1) and said at least one second brake (B2) are on opposite sides of the same axle of the vehicle, the step a3) of comparing (103) being performed by the data processing unit (210) to compare a first information representative of a first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) with a first information representative of a set first limit reference value (V_{1LIM}) of volumetric absorption provided for the actuator of said at least one first brake (B1) and a second information representative of a second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) with a second information representative of a set second limit reference value (V_{2LIM}) of volumetric absorption provided for the actuator of said at least one second brake (B2),

if the first information representative of the first detected value (V_1) of

volumetric absorption of the actuator of said at least one first brake (B1) is less than the first information representative of the set first limit reference value (V_{1LIM}) of volumetric absorption provided for the actuator of said at least one first brake (B1) and the second information representative of the second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) is less than the second information representative of the set second limit reference value (V_{2LIM}) of volumetric absorption provided for the actuator of said at least one second brake (B2), the method (100) performs the step a4) of keeping (104) unchanged the previously set target value (C_{TOTS}) of overall braking torque, without the need to perform any corrective operations,

if the first information representative of the first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) is greater than the first information representative of the set first limit reference value (V_{1LIM}) of volumetric absorption provided for the actuator of said at least one first brake (B1) and/or the second information representative of the second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) is greater than the second information representative of the set second limit reference value (V_{2LIM}) of volumetric absorption provided for the actuator of said at least one second brake (B2), the step a5) of changing (105) comprises a step of setting (108), for the actuator of the brake in which the limit condition occurred, by the data processing unit (210), a target stroke value (s_{1S}, s_{2S}) of the actuator of said brake (B1, B2) corresponding to the information representative of the set limit value (V_{1LIM}, V_{2LIM}) of volumetric absorption provided for the actuator of said brake (B1, B2).

6. The method (100) according to any one of the preceding claims from 2 to 5, wherein the step a3) of comparing (103) is performed by the data processing unit (210) to compare a first information representative of a first detected value (p_1) of the braking fluid pressure applied by the actuator of said at least one first brake (B1) and a second information representative of a second detected value (p_2) of the braking fluid pressure applied by the actuator of said at least one second brake (B2) with a first information representative of a set first limit reference value (p_{1LIM}) of the braking fluid provided for the actuator of said at

least one first brake (B1) and a second information representative of a set second pressure limit reference value (p_{2LIM}) of the braking fluid provided for the actuator of said at least one second brake (B2), respectively,

if the first information representative of the first detected value (p_1) of the braking fluid pressure applied by the actuator of said at least one first brake (B1) is less than the first information representative of the set first pressure limit reference value (p_{1LIM}) of the braking fluid provided for the actuator of said at least one first brake (B1) and the second information representative of the second detected value (p_2) of the braking fluid pressure applied by the actuator of said at least one second brake (B2) is less than the second information representative of the set second pressure limit reference value (p_{2LIM}) of the braking fluid provided for the actuator of said at least one second brake (B2), the method (100) performs the step a4) of keeping (104) unchanged the previously set target value (C_{TOTS}) of overall braking torque, without the need to perform any corrective operations,

if the first information representative of the first detected value (p_1) of the braking fluid pressure applied by the actuator of said at least one first brake (B1) is greater than the first information representative of the set first pressure limit reference value (p_{1LIM}) of the braking fluid provided for the actuator of said at least one first brake (B1) and/or the second information representative of the second detected value (p_2) of the braking fluid pressure applied by the actuator of said at least one second brake (B2) is greater than the second information representative of the set second pressure limit reference value (p_{2LIM}) of the braking fluid provided for the actuator of said at least one second brake (B2), the step a5) of changing (105) comprises a step of setting (109), for the actuator of the brake in which the limit condition occurred, by the data processing unit (210), a target value (p_{1S}, p_{2S}) of the braking fluid pressure applicable by the actuator of said brake (B1, B2) equal to the information representative of the set pressure value (p_{1LIM}, p_{2LIM}) of the braking fluid provided for the actuator of said brake (B1, B2).

7. The method (100) according to claim 1, wherein the at least one first brake (B1) and the at least one second brake (B2) belong to a braking system with

mechanical actuation on a hydraulic circuit, the target braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) being the braking fluid pressure required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2), the step a1) of setting (101) being performed by the data processing unit (210) to set a first target value (p_{1S}) of braking pressure applied by the actuator of said at least one first brake (B1) and a second target value (p_{2S}) of braking pressure applied by the actuator of said at least one second brake (B2), said one or more braking control parameters required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) detectable by said one or more braking parameter detection modules (220) operatively connected to the data processing unit (210) being the braking torque applied by each of said at least one first brake (B1) and said at least one second brake (B2), the volumetric absorption of each actuator of said at least one first brake (B1) and said at least one second brake (B2), and the braking fluid pressure applied by each actuator of said at least one first brake (B1) and said at least one second brake (B2),

for each sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, where N is an integer, of the braking time interval, the method (100) comprises a step of:

- in the absence (N) of attainment of a limit condition by all of said one or more detected values of braking control parameters, the data processing unit (210) keeps unchanged the previously set first target value (p_{1S}) of braking pressure applied by the actuator of said at least one first brake (B1) and the second target value (p_{2S}) of braking pressure applied by the actuator of said at least one second brake (B2).

8. The method (100) according to claim 7, wherein, in the presence (Y) of attainment of a limit condition by at least one of said one or more detected values of braking control parameters, the step a3) of comparing is performed by the data processing unit (210) to compare a first information representative of the first detected value (C_1) of braking torque and a second information representative of the second detected value (C_2) of braking torque with a

respective first information representative of a set first limit reference value (C_{1LIM}) of braking torque provided for said at least one first brake (B1) and a respective second information representative of a set second limit reference value (C_{2LIM}) of braking torque for said at least one second brake (B2), respectively,

as long as the first information representative of the first detected value (C_1) of braking torque is less than the first information representative of a set first limit reference value (C_{1LIM}) of braking torque provided for said at least one first brake (B1) and the second information representative of the second detected value (C_2) of braking torque is less than the respective second information representative of a set second limit reference value (C_{2LIM}) of braking torque provided for said at least one second brake (B2), the method (100) includes the step a4) of keeping unchanged the previously set first target value (p_{1S}) of braking pressure applied by the actuator of said at least one first brake (B1) and the second target value (p_{2S}) of braking pressure applied by the actuator of said at least one second brake (B2),

if the first information representative of the first detected value (C_1) of braking torque is greater than the respective first information representative of the set first limit reference value (C_{1LIM}) of braking torque and/or the second information representative of the second detected value (C_2) of braking torque is greater than the respective second information representative of the set second limit reference value (C_{2LIM}) of braking torque, the step a5) of changing (105) comprises a step of setting (206), by the data processing unit (210), as a first target value (C_{1S}) of braking torque applicable by said at least one first brake (B1), the set first limit reference value (C_{1LIM}) of braking torque provided for said at least one first brake (B1), and/or as a second target value (C_{2S}) of braking torque applicable by said at least one second brake (B2), the set second limit reference value (C_{2LIM}) of braking torque provided for said at least one second brake (B2).

9. The method (100) according to any one of claims 7 or 8, wherein said at least one first brake (B1) and said at least one second brake (B2) are on opposite sides of two different axles of the vehicle, the step a3) of comparing

(103) being performed by the data processing unit (210) to compare a sum of a first information representative of a first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) and a second information representative of a second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) with an information representative of a set limit reference value (V_{TOTLIM}) of volumetric absorption provided for a master cylinder of the vehicle adapted to act on said at least one first brake (B1) and said at least one second brake (B2),

if the sum of the first information representative of a first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) and the second information representative of a second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) is less than the information representative of the set limit reference value (V_{TOTLIM}) of volumetric absorption, the method (100) includes the step a4) of keeping unchanged the previously set first target value (p_{1S}) of braking pressure applied by the actuator of said at least one first brake (B1) and the second target value (p_{2S}) of braking pressure applied by the actuator of said at least one second brake (B2),

if the sum of the first information representative of a first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) and the second information representative of a second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) is greater than the information representative of the set limit reference value (V_{TOTLIM}) of overall volumetric absorption the step a5) of changing (105) comprises a step of setting (207), by the data processing unit (210), a first target stroke value (s_{1S}) of the actuator of said at least one first brake (B1) and a second target stroke value (s_{2S}) of the actuator of the at least one second brake (B2) so that the sum of the first information representative of a first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) and the second information representative of a second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) is equal to the information representative of the set limit value (V_{TOTLIM}) of overall

volumetric absorption.

10. The method (100) according to any one of the preceding claims from 7 to 9, wherein said at least one first brake (B1) and said at least one second brake (B2) are on opposite sides of the same axle of the vehicle, the step a3) of comparing (103) is performed by the data processing unit (210) to compare a first information representative of a first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) with a first information representative of a set first limit reference value (V_{1LIM}) of volumetric absorption provided for the actuator of said at least one first brake (B1) and a second information representative of a second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) with a second information representative of a set second limit reference value (V_{2LIM}) of volumetric absorption provided for the actuator of said at least one second brake (B2),

if the first information representative of the first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) is less than the first information representative of the set first limit reference value (V_{1LIM}) of volumetric absorption provided for the actuator of said at least one first brake (B1) and the second information representative of the second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) is less than the second information representative of the set second limit reference value (V_{2LIM}) of volumetric absorption provided for the actuator of said at least one second brake (B2), the method (100) includes the step a4) of keeping unchanged the previously set first target value (p_{1S}) of braking pressure applied by the actuator of said at least one first brake (B1) and the second target value (p_{2S}) of braking pressure applied by the actuator of said at least one second brake (B2),

if the first information representative of the first detected value (V_1) of volumetric absorption of the actuator of said at least one first brake (B1) is greater than the first information representative of the set first limit reference value (V_{1LIM}) of limit volumetric absorption provided for the actuator of said at least one first brake (B1) and/or the second information representative of the

second detected value (V_2) of volumetric absorption of the actuator of said at least one second brake (B2) is greater than the second information representative of the set second limit reference value (V_{2LIM}) of volumetric absorption provided for the actuator of said at least one second brake (B2), the step a5) of changing (105) comprises a step of setting (208), for the actuator of the brake in which the limit condition occurred, by the data processing unit (210), a target stroke value (s_{1S}, s_{2S}) of the actuator of said brake (B1, B2) so that the information representative of the detected value (V_1, V_2) of volumetric absorption of the actuator of said brake (B1, B2) is equal to the information representative of the set limit value (V_{1LIM}, V_{2LIM}) of volumetric absorption provided for the actuator of said brake (B1, B2).

11. The method (100) according to any one of the preceding claims from 7 to 10, wherein the step a3) of comparing (103) is performed by the data processing unit (210) to compare a first information representative of a first detected value (p_1) of the braking fluid pressure applied by the actuator of said at least one first brake (B1) and a second information representative of a second detected value (p_2) of the braking fluid pressure applied by the actuator of said at least one second brake (B2) with a first information representative of a set first pressure limit reference value (p_{1LIM}) of the braking fluid provided for the actuator of said at least one first brake (B1) and a second information representative of a set second pressure limit value (p_{2LIM}) of the braking fluid provided for the actuator of said at least one second brake (B2), respectively,

if the first information representative of the first detected value (p_1) of the braking fluid pressure applied by the actuator of said at least one first brake (B1) is less than the first information representative of the set first pressure limit reference value (p_{1LIM}) of the braking fluid provided for the actuator of said at least one first brake (B1) and the second information representative of the second detected value (p_2) of the braking fluid pressure applied by the actuator of said at least one second brake (B2) is less than the second information representative of the set second pressure limit reference value (p_{2LIM}) of the braking fluid provided for the actuator of said at least one second brake (B2), the method (100) includes the step a4) of keeping unchanged the previously set

first target value (p_{1S}) of braking pressure applied by the actuator of said at least one first brake (B1) and the second target value (p_{2S}) of braking pressure applied by the actuator of said at least one second brake (B2),

if the first information representative of the first detected value (p1) of the braking fluid pressure applied by the actuator of said at least one first brake (B1) is greater than the first information representative of the set first pressure limit reference value (p_{1LIM}) of the braking fluid provided for the actuator of said at least one first brake (B1) and/or the second information representative of the second detected value (p2) of the braking fluid pressure applied by the actuator of said at least one second brake (B2) is greater than the second information representative of the set second pressure limit reference value (p_{2LIM}) of the braking fluid provided for the actuator of said at least one second brake (B2), the step a5) of changing (103) comprises a step of setting (209), for the actuator of the brake in which the limit condition occurred, by the data processing unit (210), a target value (p_{1S}, p_{2S}) of the braking fluid pressure applicable by the actuator of said brake (B1, B2) so that the information representative of the detected value (p_1, p_2) of the braking fluid pressure of the actuator of said brake (B1, B2) is equal to the information representative of the set pressure value (p_{1LIM}, p_{2LIM}) of the braking fluid provided for the actuator of said brake (B1, B2).

12. The method (100) according to claim 1, wherein the at least one first brake (B1) and the at least one second brake (B2) belong to a braking system with Brake-By-Wire, B-b-W, technology, the target braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) being the overall braking torque ensured by said at least one first brake (B1) and said at least one second brake (B2), the step a1) of setting (101) being performed by the data processing unit (210) to set, as a set-point, the target value (C_{TOTS}) of overall braking torque required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2), the target value (C_{TOTS}) of overall braking torque being representative of a target deceleration value for the braking control, the target value (C_{TOTS}) of overall braking torque being divided into a first value (C_1) of braking torque applicable by said at least one first brake (B1) and a second

value (C_2) of braking torque applicable by said at least one second brake (B2), said one or more braking control parameters required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) detectable by said one or more braking parameter detection modules (220) operatively connected to the data processing unit (210) comprising the braking torque applied by each of said at least one first brake (B1) and said at least one second brake (B2), the stroke speed of each actuator of said at least one first brake (B1) and said at least one second brake (B2), and the force applied by each actuator of said at least one first brake (B1) and said at least one second brake (B2),

for each sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, where N is an integer, of the braking time interval, the method (100) comprises steps of:

- in the absence (N) of attainment of a limit condition by all of said one or more detected values of braking control parameters, the step a4) of keeping (104) unchanged said at least one target value of a braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2), then returning to the step a2) of detecting (102), comprises a step of setting (304), by the data processing unit (210), for said at least one first brake (B1) and said at least one second brake (B2), a first value (F_1) of force applied by the actuator to said at least one first brake (B1) and a second value (F_2) of force applied by the actuator to said at least one second brake (B2), respectively, which are equal to each other so as to obtain a first target value (C_{1S}) of braking torque applied by said at least one first brake (B1) and a second target value (C_{2S}) of braking torque applied by said at least one second brake (B2) such as to attain in turn the target value (C_{TOTS}) of overall braking torque required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2);
- in the presence (Y) of attainment of a limit condition by at least one of said one or more detected values of braking control parameters, the step a5) of changing (105) comprises a step of setting (305), by the data processing unit (210), the first value (F_1) of force applied by the actuator of said at least one first

brake (B1) and the second value (F_2) of force applied by the actuator of said at least one second brake (B2) so that the target value of braking torque applied by one of said at least one first brake (B1) and said at least one second brake (B2) in which such a limit was attained is the difference between the target value (C_{TOTS}) of overall braking torque required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) and the detected value of braking torque applied by the other of said at least one first brake (B1) and said at least one second brake (B2) during the braking test.

13. The method (100) according to claim 12, the step a3) of comparing (103) is performed by the data processing unit (210) to compare a first information representative of the first detected value (C_1) of braking torque and a second information representative of the second detected value (C_2) of braking torque with respective a first information representative of a set first limit reference value (C_{1LIM}) of braking torque provided for said at least one first brake (B1) and a respective second information representative of a set second limit reference value (C_{2LIM}) of braking torque provided for said at least one second brake (B2), respectively,

as long as the first information representative of the first detected value (C_1) of braking torque is less than the first information representative of a set first limit reference value (C_{1LIM}) of braking torque for said at least one first brake (B1) and the second information representative of the second detected value (C_2) of braking torque is less than the respective second information representative of a set second limit reference value (C_{2LIM}) of braking torque, the method (100) includes the step a4) of keeping (104) unchanged the previously set target value (C_{TOTS}) of overall braking torque, without the need to perform any corrective operations,

if the first information representative of the first detected value (C_1) of braking torque is greater than the respective first information representative of the set first limit reference value (C_{1LIM}) of braking torque and/or the second information representative of the second detected value (C_2) of braking torque is greater than the respective second information representative of the set second limit reference value (C_{2LIM}) of braking torque, the step a5) of changing

(105) comprises a step of setting (306), by the data processing unit (210), as a first target value (C_{1S}) of braking torque applicable by said at least one first brake (B1), the set limit reference value (C_{1LIM}) of braking torque provided for said at least one first brake (B1), and/or as a second value (C_2) of braking torque applicable by said at least one second brake (B2), the set limit reference value (C_{2LIM}) of braking torque provided for said at least one second brake (B2).

14. The method (100) according to any one of the preceding claims 12 or 13, wherein the step a3) of comparing (103) is performed by the data processing unit (210) to compare a first information representative of a first detected stroke value (s_1) of the actuator of said at least one first brake (B1) and a second information representative of a second detected stroke value (s_2) of the actuator of said at least one second brake (B2) with respective a first information representative of a set first stroke limit reference value (s_{1LIM}) of the actuator of said at least one first brake (B1) and a respective second information representative of a set second stroke limit reference value (s_{2LIM}) of the actuator of said at least one second brake (B2), respectively,

if the first information representative of the first detected stroke value (s_1) of the actuator of said at least one first brake (B1) is less than the first information representative of the set first stroke limit reference value (s_{1LIM}) of the actuator of said at least one first brake (B1) and the second information representative of the second detected stroke value (s_2) of the actuator of said at least one second brake (B2) is less than the second information representative of the set second stroke limit reference value (s_{2LIM}) of the actuator of said at least one second brake (B2), the method (100) includes the step a4) of keeping (104) unchanged the previously set target value (C_{TOTS}) of overall braking torque, without the need to perform any corrective operations,

if the first information representative of the first detected stroke value (s_1) of the actuator of said at least one first brake (B1) is greater than the first information representative of the set first stroke limit reference value (s_{1LIM}) of the actuator of said at least one first brake (B1) and/or the second information representative of the second detected stroke value (s_2) of the actuator of said at least one second brake (B2) is greater than the second information

representative of the set second stroke limit reference value (s_{2LIM}) of the actuator of said at least one second brake (B2), the step a5) of controlling (105) comprises a step of setting (307), by the data processing unit (210), for the actuator of the brake in which the limit condition occurred, a target stroke value s_{1S} (s_{2S}) of the actuator of said brake (B1, B2) equal to the information representative of the set stroke limit value (s_{1LIM}, s_{2LIM}) of the actuator of said at least one brake (B1, B2).

15. The method (100) according to any one of the preceding claims 12 or 14, wherein the step a3) of comparing (103) is performed by the data processing unit (210) to compare a first information representative of a first detected force value (F_1) of the actuator of said at least one first brake (B1) and a second information representative of a second detected force value (F_2) of the actuator of said at least one second brake (B2) with a respective first information representative of a set first force limit reference value (F_{1LIM}) of the actuator of said at least one first brake (B1) and a respective second information representative of a set second force limit reference value (F_{2LIM}) of the actuator of said at least one second brake (B2), respectively,

if the first detected force value (F_1) of the actuator of said at least one first brake (B1) is less than the first information representative of the set first force limit reference value (F_{1LIM}) of the actuator of said at least one first brake (B1) and the second information representative of the second detected force value (F_2) of the actuator of said at least one second brake (B2) is less than the second information representative of the set second force limit reference value (F_{2LIM}) of the actuator of said at least one second brake (B2), the method (100) includes the step a4) of keeping (104) unchanged the previously set target value (C_{TOTS}) of overall braking torque, without the need to perform any corrective operations,

if the first detected force value (F_1) of the actuator of said at least one first brake (B1) is greater than the first information representative of the set first force limit reference value (F_{1LIM}) of the actuator of said at least one first brake (B1) and/or the second information representative of the second detected force value (F_2) of the actuator of said at least one second brake (B2) is greater than the

second information representative of the set second force limit reference value (F_{2LIM}) of the actuator of said at least one second brake (B2), the step a5) of changing (105) comprises a step of setting (309), for the actuator of the brake in which the limit condition occurred, by the data processing unit (210), a force target value (F_{1S}, F_{2S}) of the actuator of said brake (B1, B2) equal to the information representative of the set force limit reference value (F_{1LIM}, F_{2LIM}) for the actuator of said brake (B1, B2).

16. The method (100) according to claim 1, wherein the at least one first brake (B1) and the at least one second brake (B2) belong to a braking system with Brake-By-Wire technology, the target braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) being the force applied by each actuator required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2), the step a1) of setting (101) being performed by the data processing unit (210) to set a first target value (F_{1S}) of the force applied by the actuator of said at least one first brake (B1) and a second target value (F_{2S}) of the force applied by the actuator of said at least one second brake (B2), said one or more braking control parameters required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) detectable by said one or more braking parameter detection modules (220) operatively connected to the data processing unit (210) being the braking torque applied by each of said at least one first brake (B1) and said at least one second brake (B2), the stroke speed of each actuator of said at least one first brake (B1) and said at least one second brake (B2), and the force applied by each actuator of said at least one first brake (B1) and said at least one second brake (B2),

for each sampling time instant t_i of a plurality of sampling time instants, $1 < i < N$, where N is an integer, of the braking time interval, the method (100) comprises a step of:

- in the absence (N) of attainment of a limit condition by all of said one or more detected values of braking control parameters, the data processing unit (210) keeps unchanged the first target value (F_{1S}) of the force applied by the

actuator of said at least one first brake (B1) and the second target value (F_{2S}) of the force applied by the actuator of said at least one second brake (B2).

17. The method (100) according to claim 16, wherein:

- in the presence (Y) of attainment of a limit condition by at least one of said one or more detected values of braking control parameters, the step a3) of comparing (103) is performed by the data processing unit (210) to compare a first information representative of the first detected value (C_1) of braking torque and a second information representative of the second detected value (C_2) of braking torque with a respective first information representative of a set first limit reference value (C_{1LIM}) of braking torque provided for said at least one first brake (B1) and a respective second information representative of a set second limit reference value (C_{2LIM}) of braking torque provided for said at least one second brake (B2), respectively,

as long as the first information representative of the first detected value (C_1) of braking torque is less than the first information representative of a set first limit reference value (C_{1LIM}) of braking torque provided for said at least one first brake (B1) and the second information representative of the second detected value (C_2) of braking torque is less than the respective second information representative of a set second limit reference value (C_{2LIM}) of braking torque provided for said at least one second brake (B2), the method (100) includes the step a4) of keeping unchanged the first target value (F_{1S}) of the force applied by the actuator of said at least one first brake (B1) and the second target value (F_{2S}) of the force applied by the actuator of said at least one second brake (B2),

if the first information representative of the first detected value (C_1) of braking torque is greater than the respective first information representative of the set first limit reference value (C_{1LIM}) of braking torque and/or the second information representative of the second detected value (C_2) of braking torque is greater than the respective second information representative of the set second limit reference value (C_{2LIM}) of braking torque, the step a5) of changing (105) comprises a step of setting (406), by the data processing unit (210), as a first target value (C_{1S}) of braking torque applicable by said at least one first brake

(B1), the set first limit reference value (C_{1LIM}) of braking torque provided for said at least one first brake (B1), and/or as a second target value (C_{2S}) of braking torque applicable by said at least one second brake (B2), the set second limit reference value (C_{2LIM}) of braking torque provided for said at least one second brake (B2).

18. The method (100) according to any one of claims 16 or 17, wherein the step a3) of comparing (103) is performed by the data processing unit (210) to compare a first information representative of a first detected stroke value (s_1) of the actuator of said at least one first brake (B1) and a second information representative of a second detected stroke value (s_2) of the actuator of said at least one second brake (B2) with a respective first information representative of a set first stroke limit reference value (s_{1LIM}) of the actuator of said at least one first brake (B1) and a respective second information representative of a set second stroke limit reference value (s_{2LIM}) of the actuator of said at least one second brake (B2), respectively,

if the first information representative of the first detected stroke value (s_1) of the actuator of said at least one first brake (B1) is less than the first information representative of the set first stroke limit reference value (s_{1LIM}) of the actuator of said at least one first brake (B1) and the second information representative of the second detected stroke value (s_2) of the actuator of said at least one second brake (B2) is less than the second information representative of the set second stroke limit reference value (s_{2LIM}) of the actuator of said at least one second brake (B2), the method (100) includes the step a4) of keeping unchanged the previously set first target value (F_{1S}) of the force applied by the actuator of said at least one first brake (B1) and the second target value (F_{2S}) of the force applied by the actuator of said at least one second brake (B2),

if the first information representative of the first detected stroke value (s_1) of the actuator of said at least one first brake (B1) is greater than the first information representative of the set first stroke limit value (s_{1LIM}) of the actuator of said at least one first brake (B1) and/or the second information representative of the second detected stroke value (s_2) of the actuator of said at least one

second brake (B2) is greater than the second information representative of the set second stroke limit value (s_{2LIM}) of the actuator of said at least one second brake (B2), the step a5) of changing (105) comprises a step of setting (407), by the data processing unit (210), for the actuator of the brake in which the limit condition occurred, a target stroke value (s_{1S}, s_{2S}) of the actuator of said brake (B1, B2) equal to the information representative of the set stroke limit value (s_{1LIM}, s_{2LIM}) of the actuator of said at least one brake (B1, B2).

19. The method (100) according to any one of claims from 16 to 18, wherein the step a3) of comparing (103) is performed by the data processing unit (210) to compare a first information representative of a first detected force value (F_1) of the actuator of said at least one first brake (B1) and a second information representative of a second detected force value (F_2) of the actuator of said at least one second brake (B2) with a respective first information representative of a set first force limit reference value (F_{1LIM}) of the actuator of said at least one first brake (B1) and a respective second information representative of a set second force limit reference value (F_{2LIM}) of the actuator of said at least one second brake (B2), respectively,

if the first detected force value (F_1) of the actuator of said at least one first brake (B1) is less than the first information representative of the set first force limit reference value (F_{1LIM}) of the actuator of said at least one first brake (B1) and the second information representative of the second detected force value (F_2) of the actuator of said at least one second brake (B2) is less than the second information representative of the set second force limit reference value (F_{2LIM}) of the actuator of said at least one second brake (B2), the method (100) includes the step a4) of keeping unchanged the previously set first target value (F_{1S}) of the force applied by the actuator of said at least one first brake (B1) and the second target value (F_{2S}) of the force applied by the actuator of said at least one second brake (B2),

if the first detected force value (F_1) of the actuator of said at least one first brake (B1) is greater than the first information representative of the set first force limit reference value (F_{1LIM}) of the actuator of said at least one first brake (B1) and/or the second information representative of the second detected force value

(F_2) of the actuator of said at least one second brake (B2) is greater than the second information representative of the set second force limit reference value (F_{2LIM}) of the actuator of said at least one second brake (B2), the step a5) of changing (105) comprises a step of setting (409), for the actuator of the brake in which the limit condition occurred, by the data processing unit (210), a force target value (F_{1S}, F_{2S}) of the actuator of said brake (B1, B2) equal to the information representative of the set force limit reference value (F_{1LIM}, F_{2LIM}) for the actuator of said brake (B1, B2).

20. The method (100) according to any one of the preceding claims, wherein the settable at least one value of a target braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) is an equal value in all the sampling time instants t_i of a plurality of sampling time instants $1 < i < N$, where N is an integer, of the braking time interval in which the braking test is performed.

21. The method (100) according to any one of the preceding claims from 1 to 19, wherein the settable at least one value of a target braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) is an over-time varying value in the braking time interval in which the braking test is performed.

22. The method (100) according to any one of the preceding claims, wherein the settable at least one value of a target braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) is a constant value.

23. The method (100) according to any one of the preceding claims from 1 to 21, wherein the settable at least one value of a target braking parameter required for the portion of vehicle comprising the at least one first brake (B1) and the at least one second brake (B2) is a varying value according to a set law of variation as a function of representative quantities of the vehicle.

24. A braking actuation and management system (200) for simultaneously controlling at least one first brake (B1) of a vehicle and at least one second brake (B2) of the same vehicle on bench braking tests, comprising:

- one or more test benches (BT) on which said at least one first brake (B1)

and said at least one second brake (B2) are to be subjected to a braking test;

- a data processing unit (210) operatively connected to said one or more test benches (BT);
- one or more braking parameter detection modules (220) operatively associated with said one or more test benches (BT) and operatively connected to said data processing unit (210),

said system (200) being configured to perform the braking actuation and management method for simultaneously controlling at least one first brake (B1) of a vehicle and at least one second brake (B2) of the same vehicle on bench braking tests according to any one of the preceding claims.

25. The system (200) according to claim 24, wherein said one or more test benches (BT) comprise a single test bench (BT) on which said at least one first brake (B1) and said at least one second brake (B2) are subjected to a braking test.

26. The system (200) according to claim 25, wherein the data processing unit (210) is installed on said test bench (BT) on which said at least one first brake (B1) and said at least one second brake (B2) are subjected to tests.

27. The system (200) according to claim 24, wherein the one or more test benches (BT) comprise a first test bench on which said at least one first brake (B1) is subjected to tests and a second test bench on which said at least one second brake (B2) is subjected to tests.

28. The system (200) according to claim 27, wherein the data processing unit (210) is installed on one of said first test bench and second test bench.

29. The system (200) according to claim 27, wherein the data processing unit (210) comprises a first data processing block installed on said first test bench and a second data processing block installed on said second test bench.

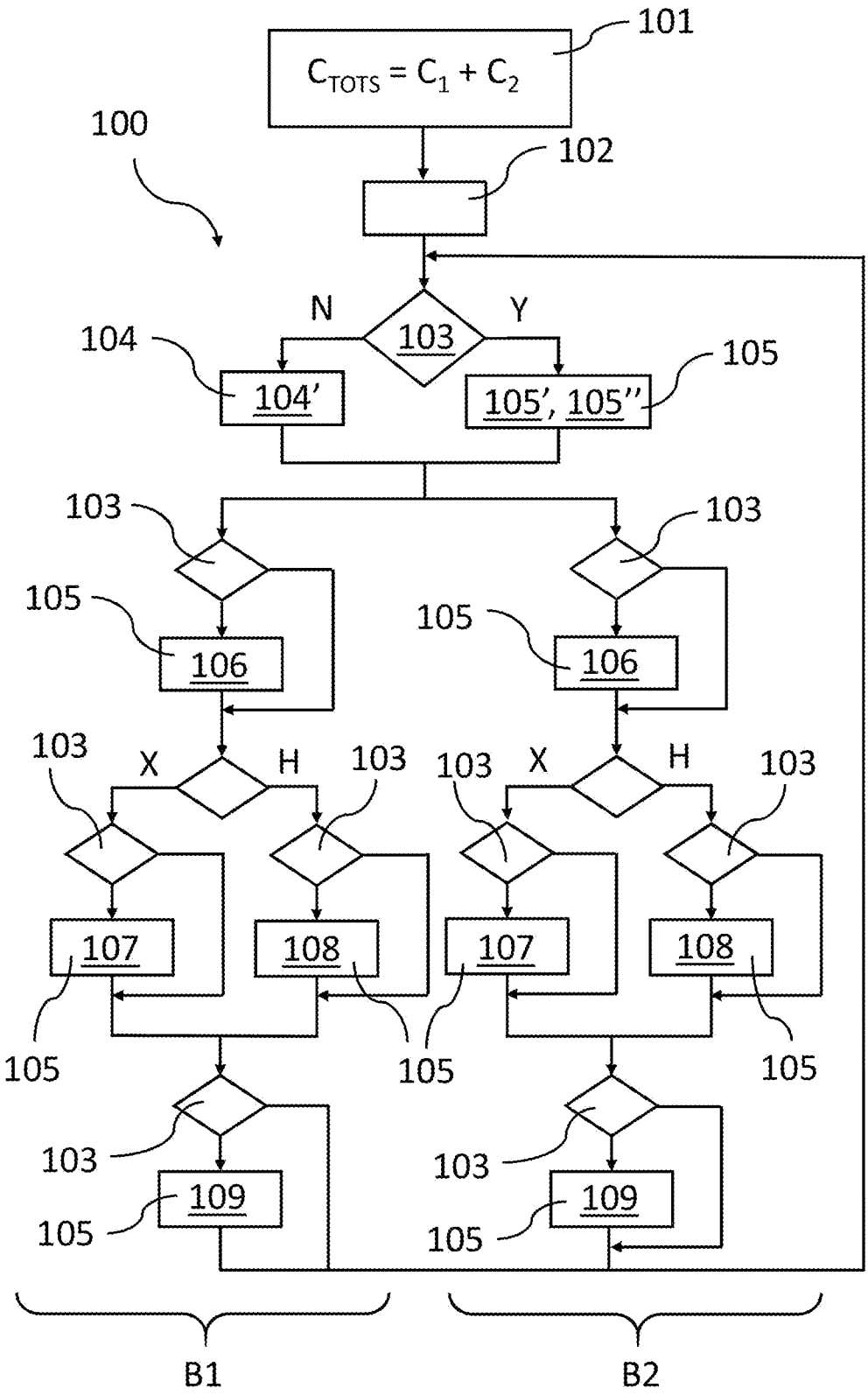

101
$C_{TOTS} = C_1 + C_2$
100
102
N
103
Y
104
104'
105
105', 105''
103
103
105
106
105
106
103
X
H
103
103
X
H
103
107
108
107
108
105
105
105
103
103
109
109
105
105
B1
B2

Fig. 1

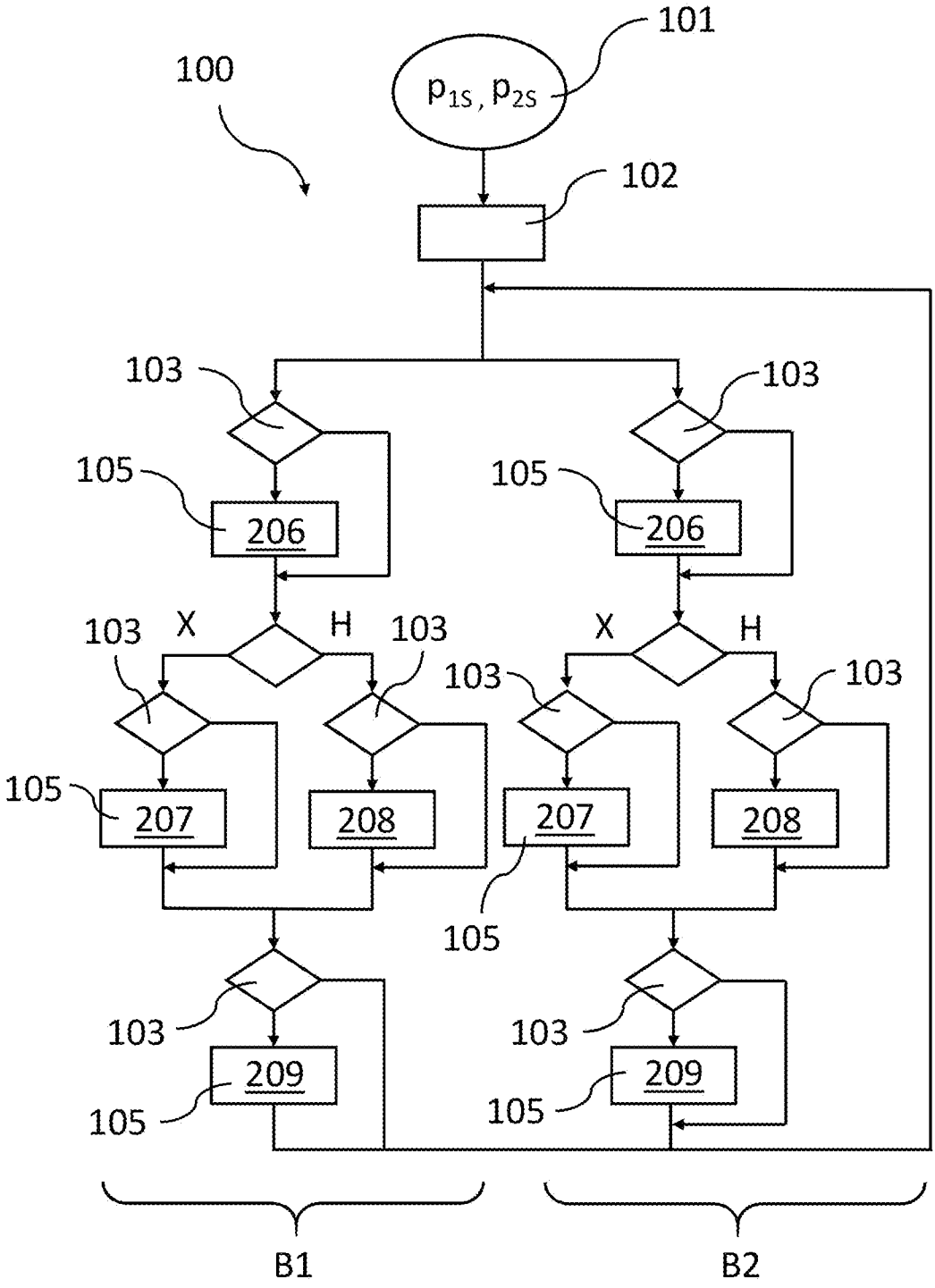


Fig. 2

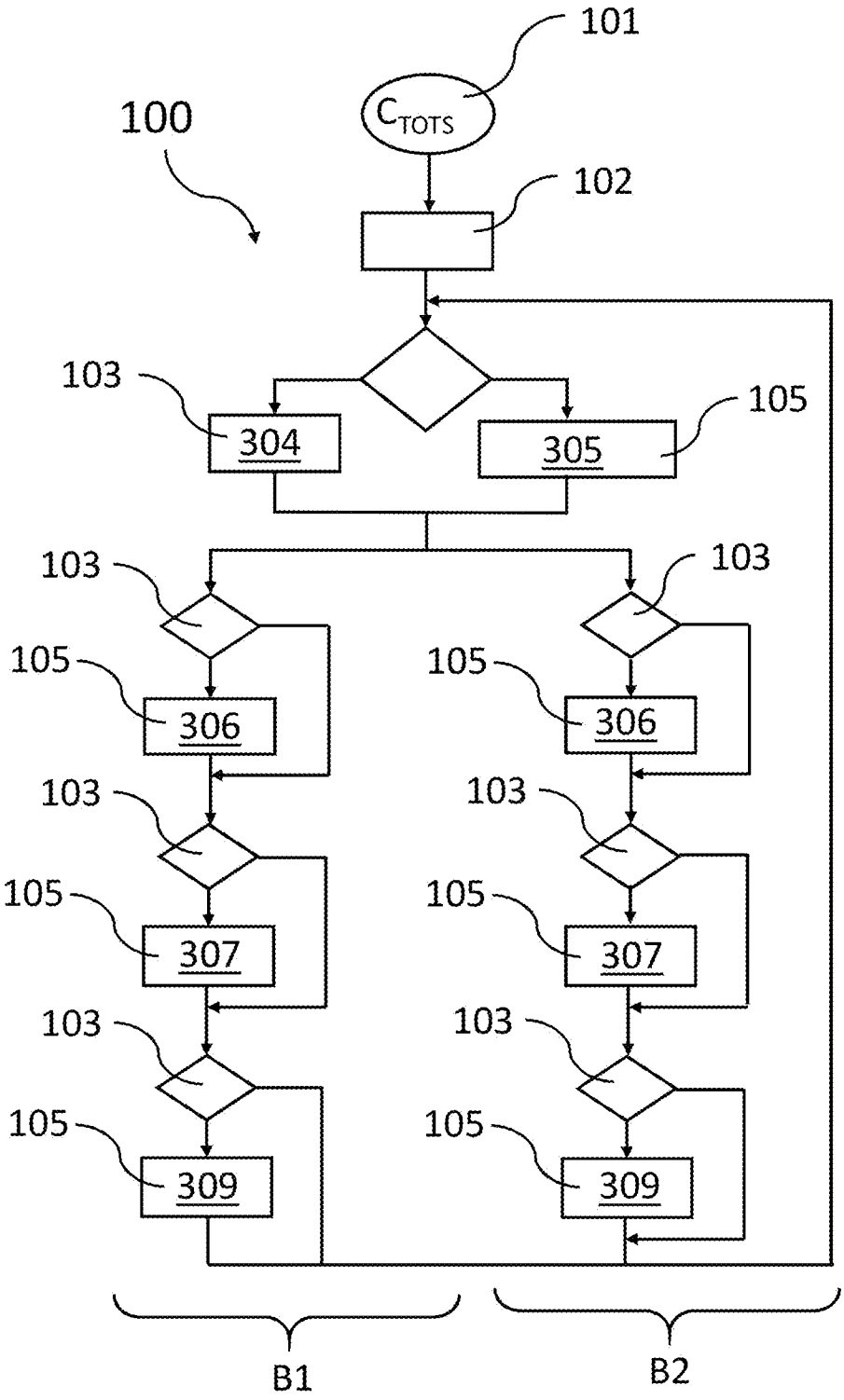

100
101
C_{TOTS}
102
103
304
305
105
103
103
105
306
105
306
103
103
105
307
105
307
103
103
105
309
105
309
B1
B2

Fig. 3

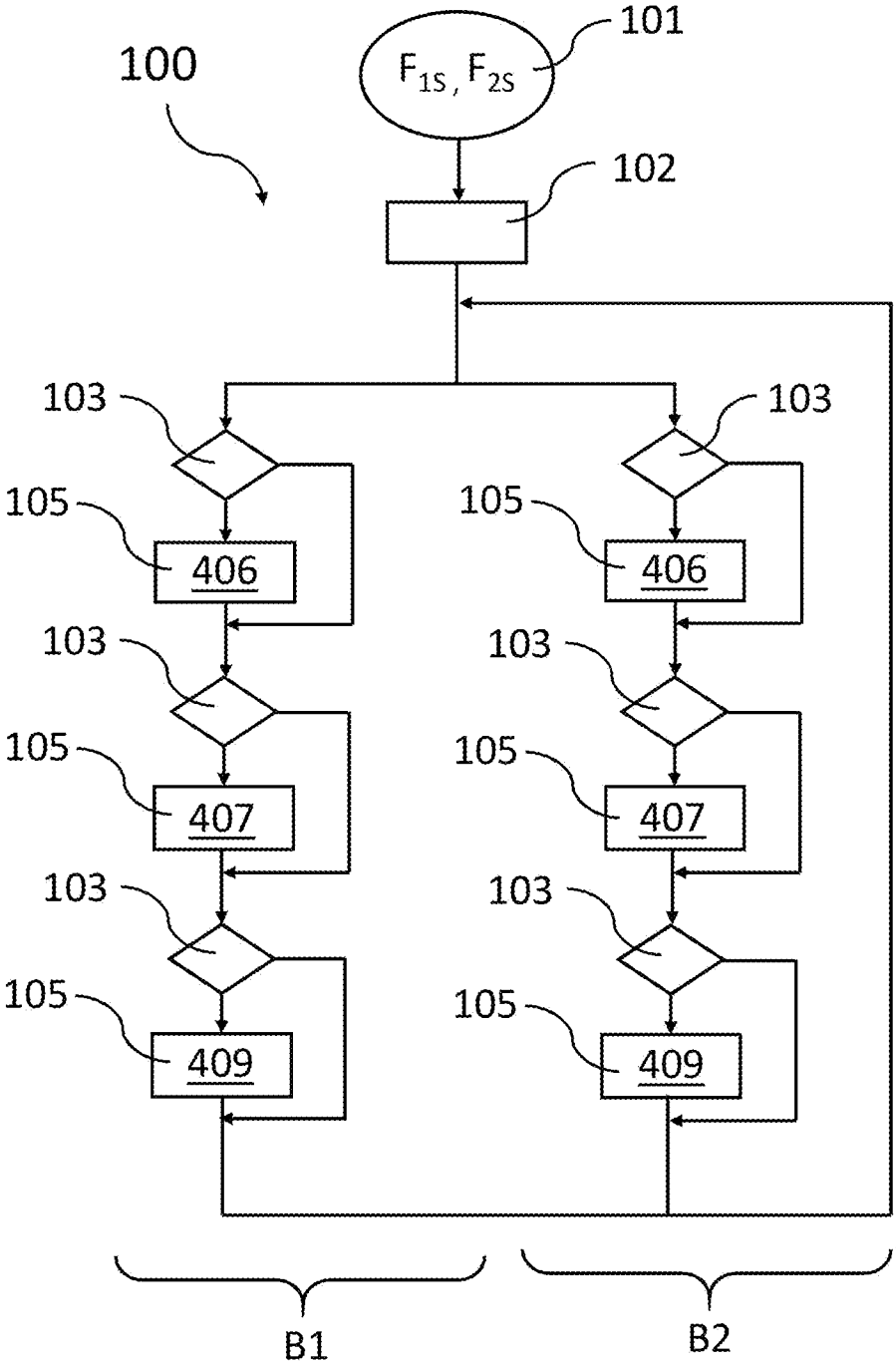


Fig. 4

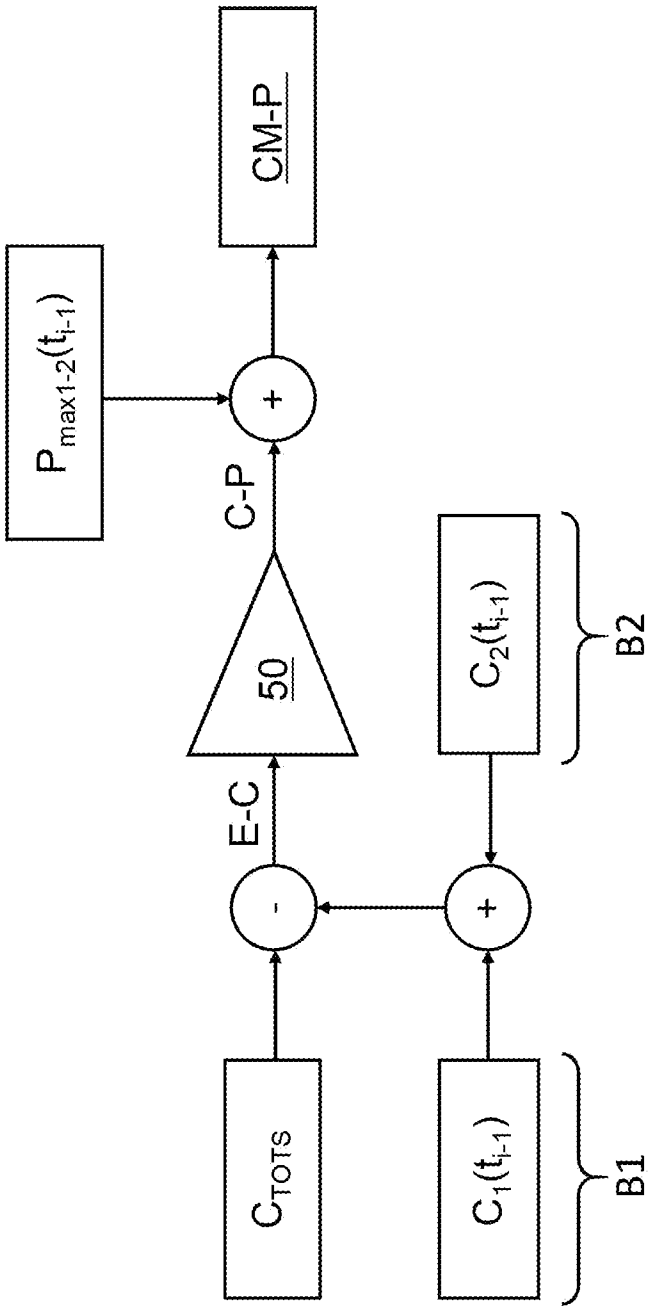


Fig. 5

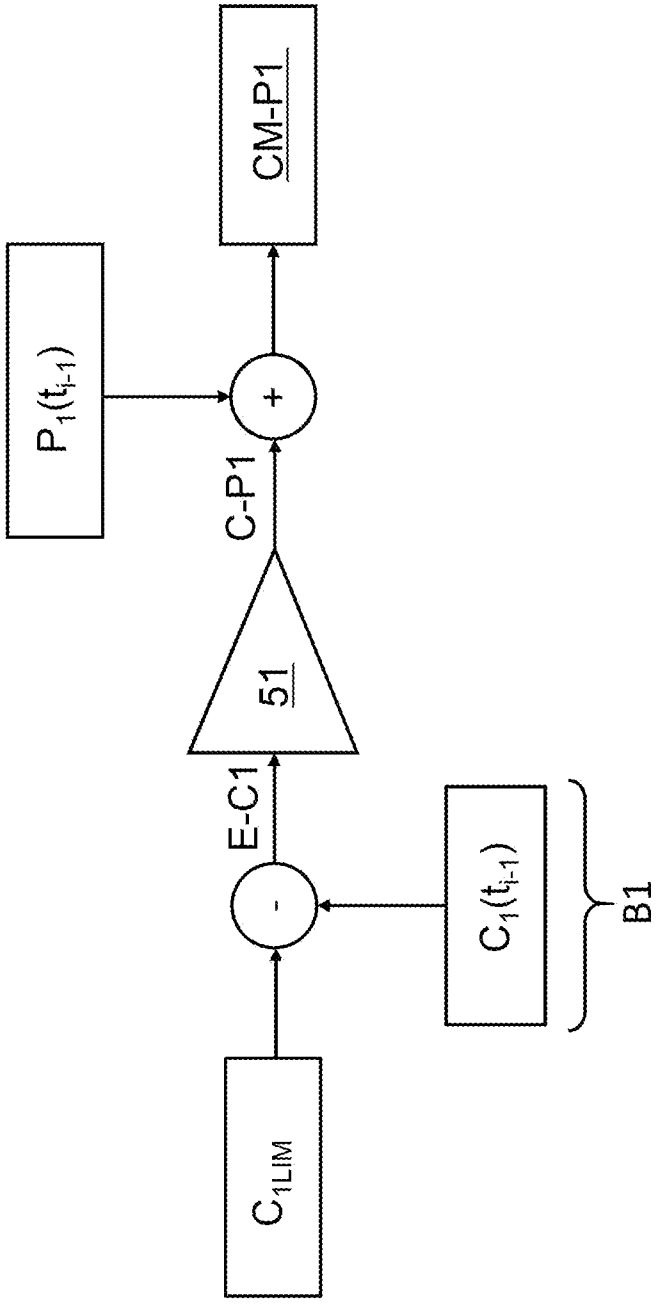


Fig. 6

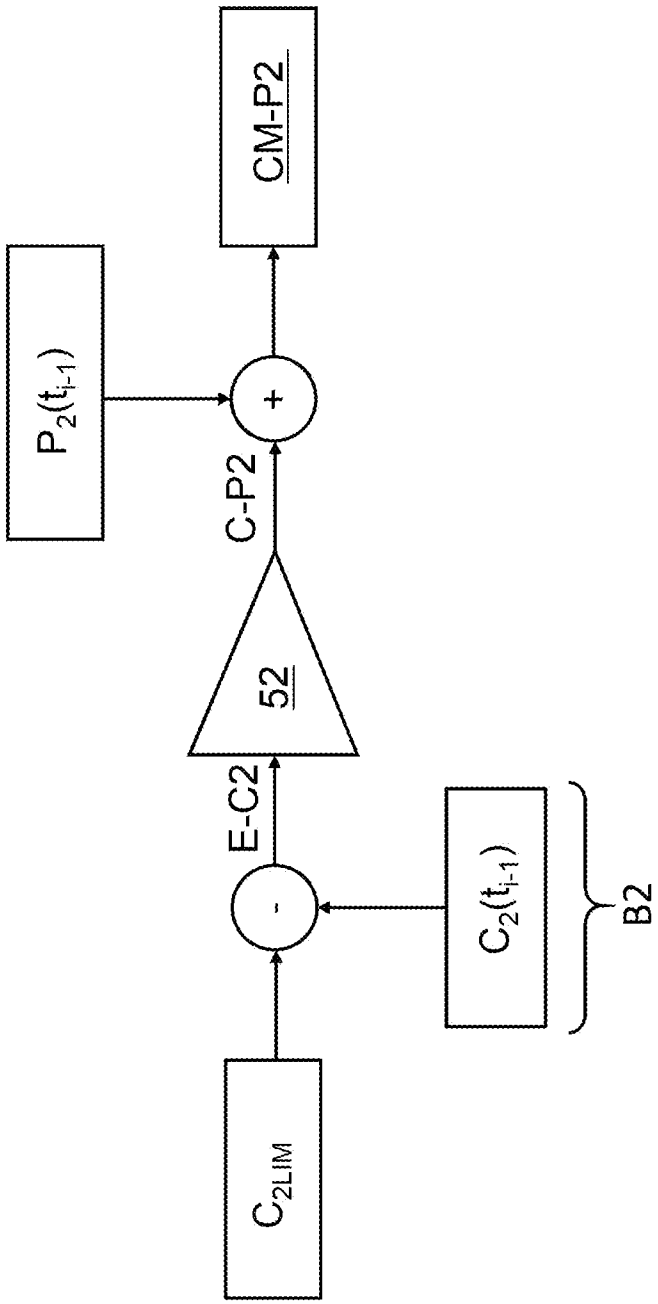


Fig. 7

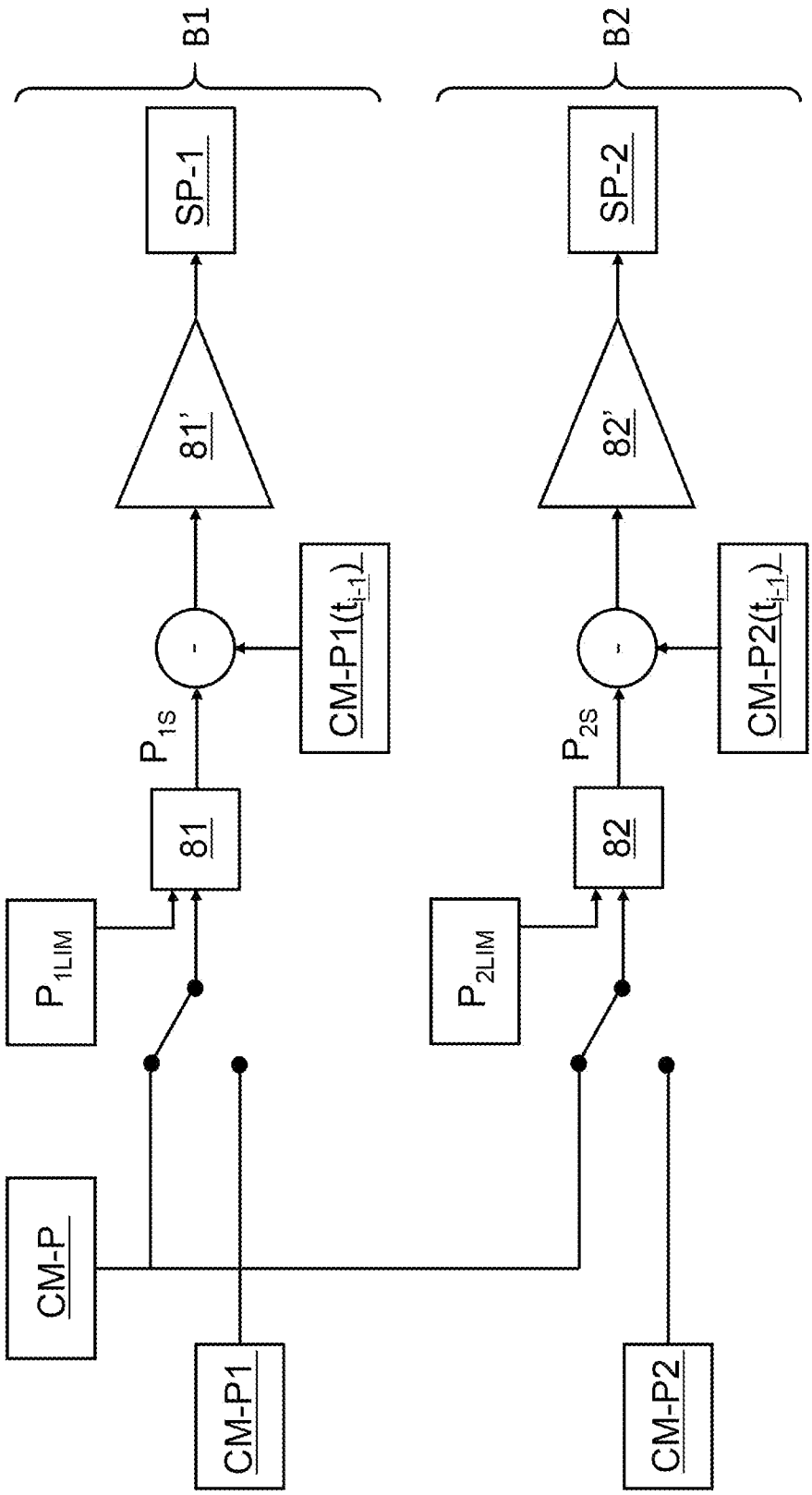

B1
B2
SP-1
SP-2
81'
82'
-
-
CM-P1(t_i-1)
CM-P2(t_i-1)
P_1S
P_2S
81
82
P_1LIM
P_2LIM
CM-P
CM-P1
CM-P2

Fig. 8

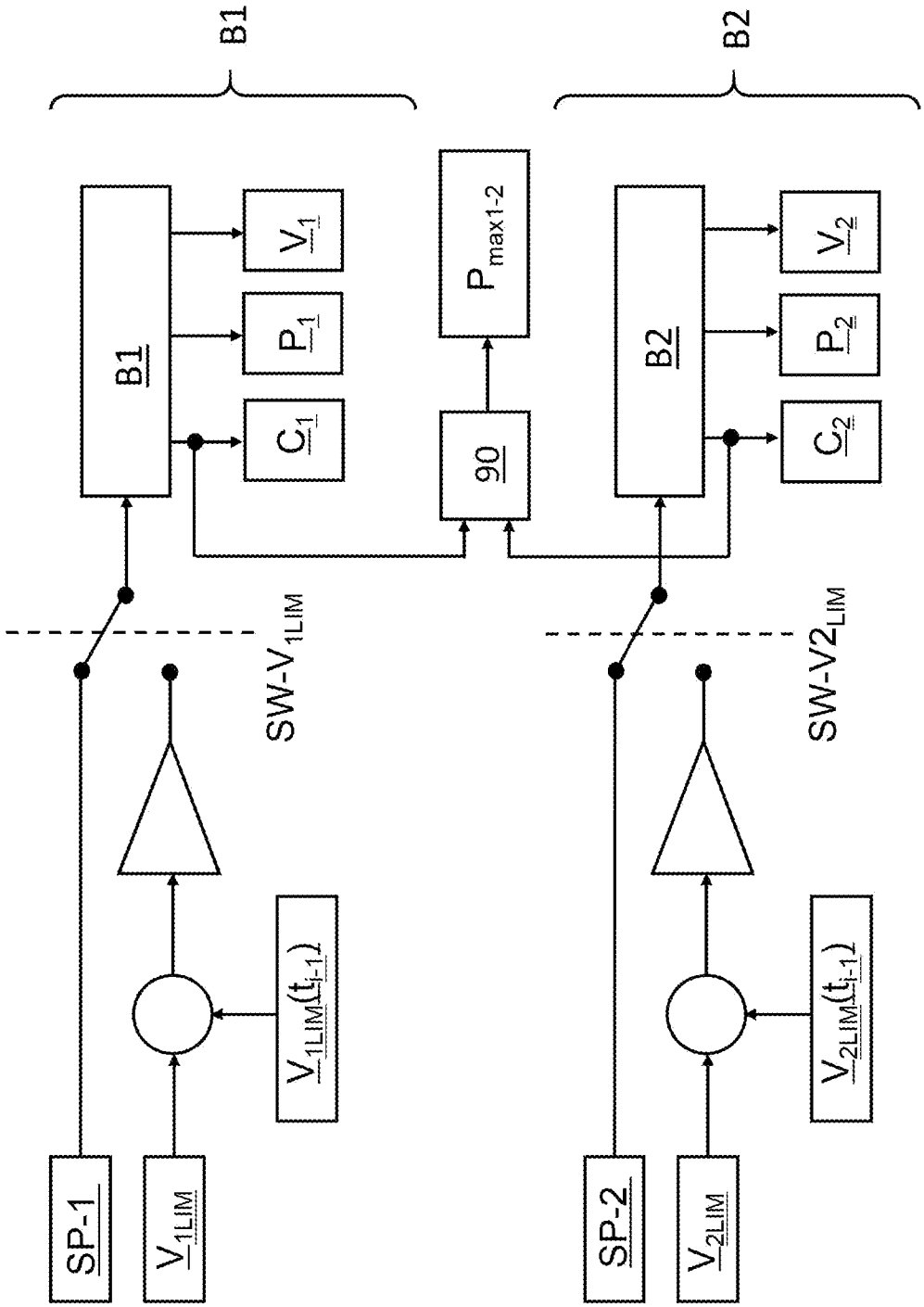

B1
B2
B1
B2
V_1
P_1
C_1
V_2
P_2
C_2
P_{max1-2}
90
SW-V_{1LIM}
SW-$V2_{LIM}$
$V_{1LIM}(t_{i-1})$
$V_{2LIM}(t_{i-1})$
SP-1
V_{1LIM}
SP-2
V_{2LIM}

Fig. 9

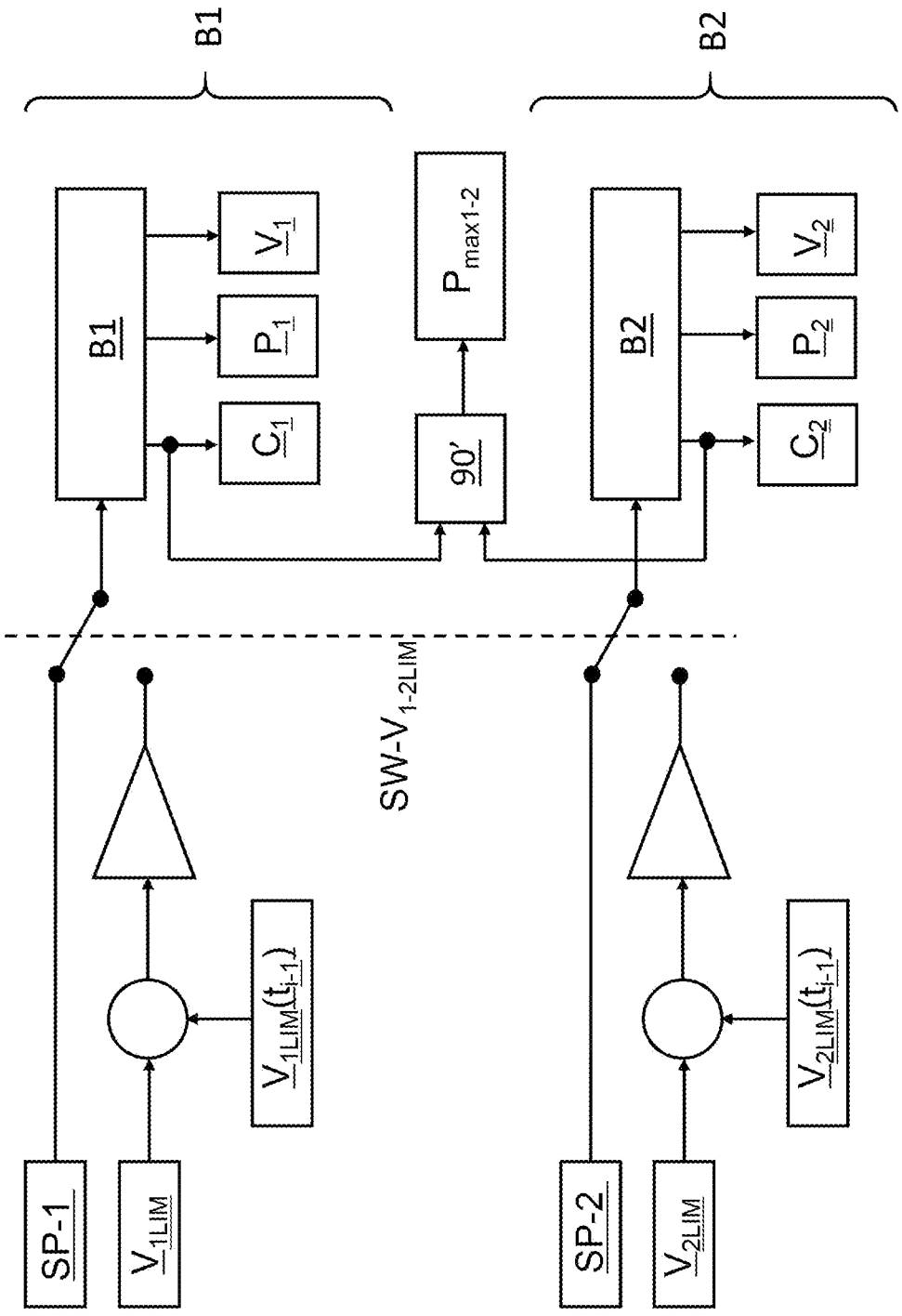

B1
B2
B1
V1
P1
C1
Pmax1-2
90'
B2
V2
P2
C2
SW-V1-2LIM
SP-1
V1LIM
V1LIM(ti-1)
SP-2
V2LIM
V2LIM(ti-1)

Fig. 10



Fig. 11

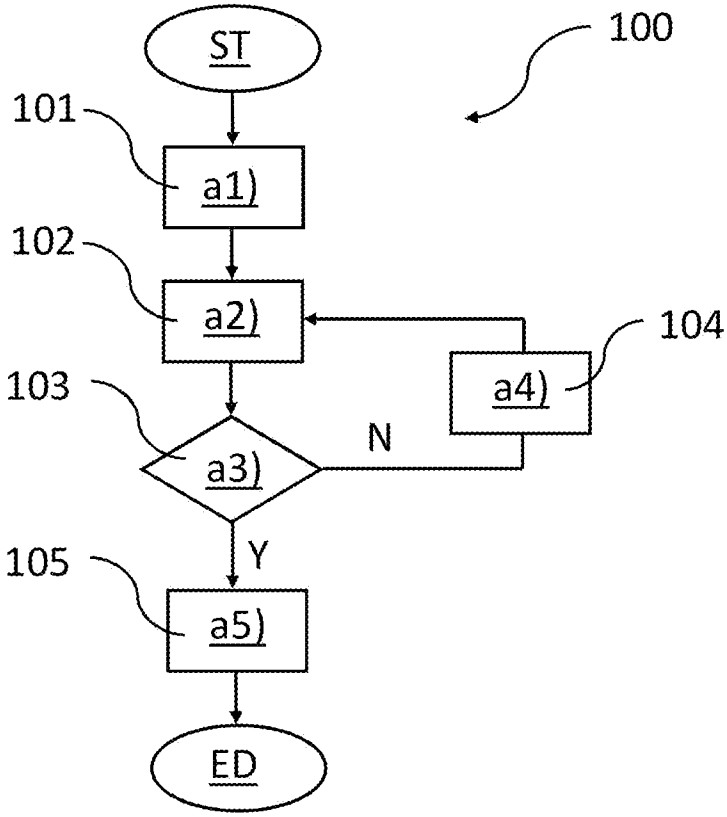


Fig. 12

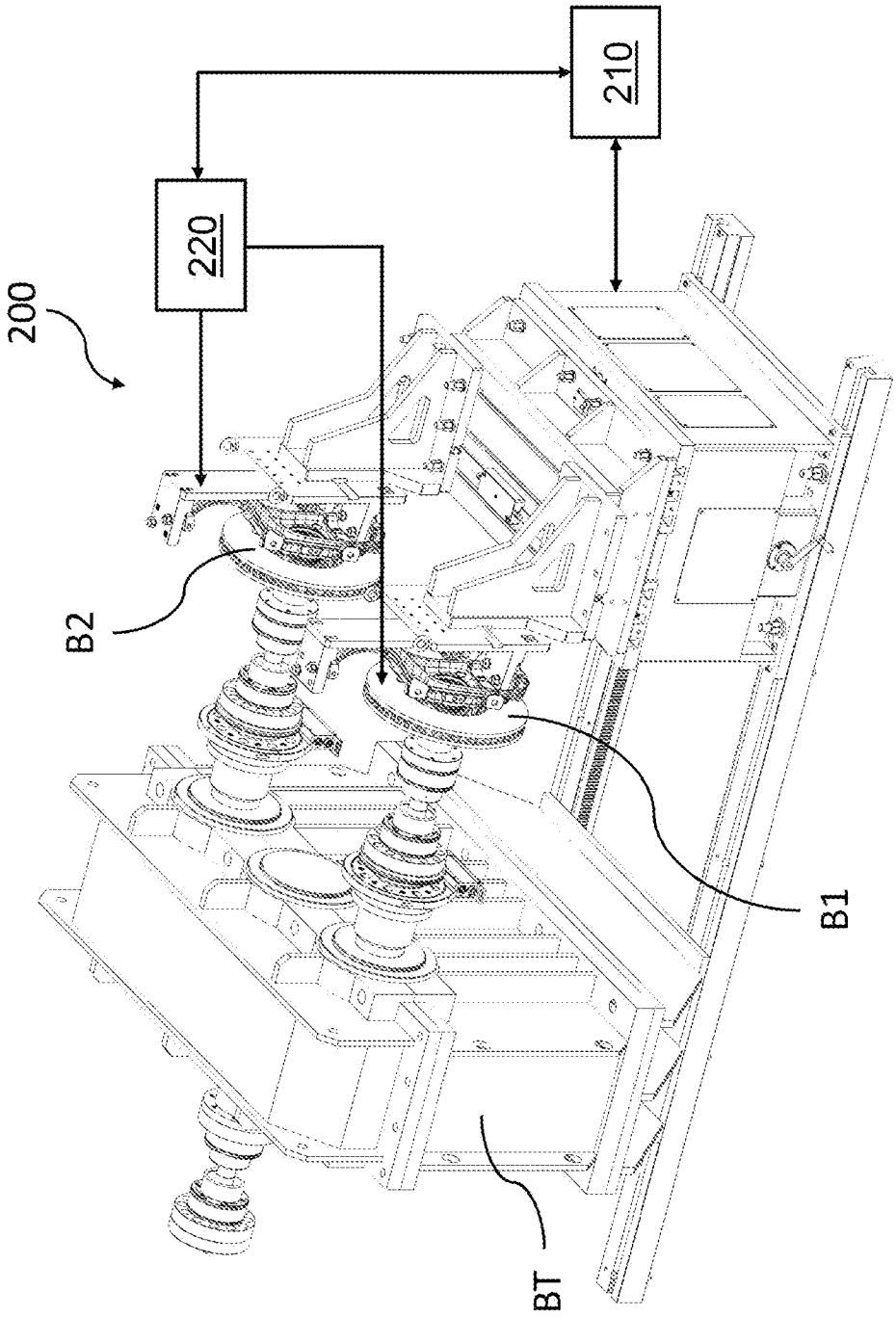


Fig. 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/062424

A. CLASSIFICATION OF SUBJECT MATTER

INV. B60T8/88 B60T17/22 G01M17/00 G01M17/007 G01L5/28
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B60T G01M G01L

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 91/19176 A1 (HUNTER ENG CO [US]) 12 December 1991 (1991-12-12)	1,20-29
Y	page 14, paragraph 4 - page 17, paragraph 1	20,22
A	figures 1,2,7-9	2-19
Y	CN 113 895 416 A (XIAN AVIATION BRAKE TECH CO LTD) 7 January 2022 (2022-01-07) paragraphs [0052], [0053]	20,22
A	DE 28 41 211 A1 (BOSCH GMBH ROBERT) 3 April 1980 (1980-04-03) page 6, line 14 - line 20 claim 10	1,24

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 March 2025	21/03/2025

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Colonna, Massimo

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2024/062424

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9119176 A1	12-12-1991	US 5083456 A	28-01-1992
		WO 9119176 A1	12-12-1991
CN 113895416 A	07-01-2022	NONE	
DE 2841211 A1	03-04-1980	NONE	