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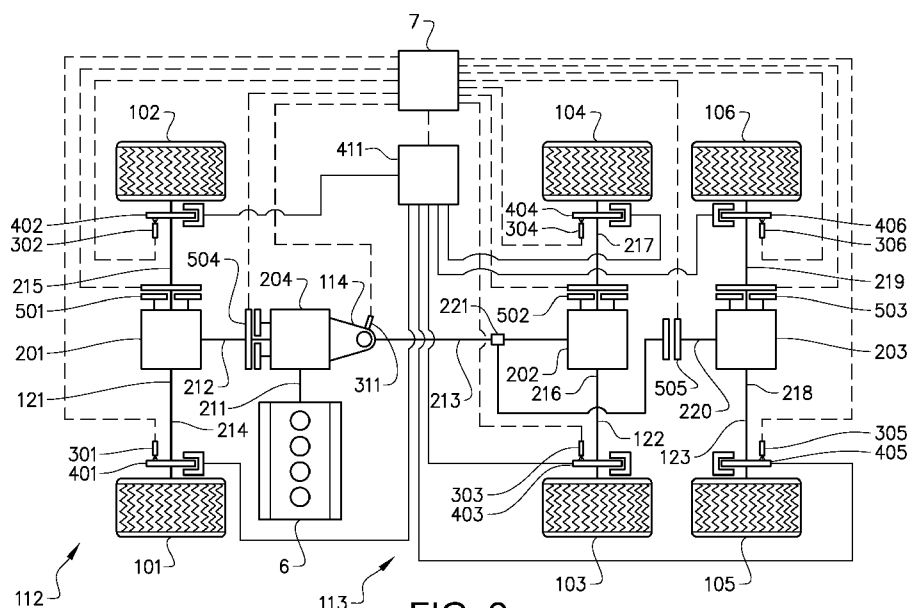


FIG. 2

(57) Abstract: The invention provides a method for engaging a clutch (501-505) of a vehicle (1) comprising a propulsion power source (6), the clutch (501-505) being arranged to selectively connect a first wheel (101-106) of the vehicle (1) with a second wheel (101-106) of the vehicle (1), the first wheel and the second wheel (101-106) being arranged to be driven by the power source (6), the method comprising - identifying (S3, S8) an indication that the first wheel (101-106) is slipping in relation to the ground, - controlling (S4, S9) a brake for the first wheel (101-106), which brake is controllable independently of a brake for the second wheel (101-106), for reducing the rotational speed difference between the first wheel and the second wheel (101-106), and - engaging (S6, S601) the clutch (501-505) when the rotational speed difference between the first wheel and the second wheel has been reduced as a result of the brake control.

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A METHOD FOR ENGAGING A CLUTCH OF A VEHICLE

TECHNICAL FIELD

5 The invention relates to a method for engaging a clutch of a vehicle comprising a propulsion power source, the clutch being arranged to selectively connect a first wheel of the vehicle with a second wheel of the vehicle, the first wheel and the second wheel being arranged to be driven by the power source. The invention also relates to a computer program, a computer readable medium, and a control unit.

10

The invention is applicable on vehicles in the form of working machines within the fields of industrial construction machines or construction equipment, in particular articulated haulers or wheel loaders. Although the invention will be described with respect to an articulated hauler, the invention is not restricted to this particular machine, but may also
15 be used in other working machines such as wheel loaders and backhoe loaders. The invention can also be applied in heavy-duty vehicles, such as trucks and buses. The invention may also be used in other vehicles such as cars.

BACKGROUND

20

Working machines such as articulated haulers, may be provided with multiple wheel axles with configurations such as 4x4, 6x4, 6x6, 8x4, 8x6 and so on. A working machine is typically articulated frame-steered and has a pair of hydraulic cylinders for turning or steering the working machine by pivoting a front frame and a rear frame of the working
25 machine relative to each other. The hydraulic system generally further comprises at least one hydraulic pump, which is arranged to supply hydraulic power, i.e. hydraulic flow and/or hydraulic pressure, to the hydraulic cylinders.

Working machines typically operate in rough, off-road terrain. Thereby, the wheels may
30 have differing grip from time to time due to different levels of friction and/or wheel load, or a varying load bearing capacity of the ground. This may cause a wheel to start slipping, and where a differential gear is provided on the wheel axle presenting the slipping wheel, the torque will be lost on all wheels of the axle, or even all wheels of the working machine depending on the working machine and the situation.

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JP05008649 describes a vehicle with a differential gear for distributing the torque from an engine to left and right wheels. A clutch in the form of a diff-lock device is provided and a control unit receives the rotational speed of the wheels. Once a difference in the rotational speed between the wheels has exceeded a set value, the control unit actuates the diff-
5 lock device to block the wheel differential generated by the differential gear. A problem with this solution is that once the diff-lock device is actuated, the rotational speed difference may be high enough to cause damage to the diff-lock device.

SUMMARY

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An object of the invention is to avoid damage of vehicle components, for example clutches, caused by clutch engagement for reducing wheel slippage in the vehicle.

The object is achieved by a method according to claim 1. Thus, the invention provides a
15 method for engaging a clutch of a vehicle comprising a propulsion power source, the clutch being arranged to selectively connect a first wheel of the vehicle and a second wheel of the vehicle with each other, said first wheel and said second wheel being arranged to be driven by the power source, the method comprising

- identifying an indication that the first wheel is slipping in relation to the ground,
- 20 - controlling a brake for the first wheel, which brake is controllable independently of a brake for the second wheel, for reducing the rotational speed difference between the first wheel and the second wheel, and
- engaging the clutch when the rotational speed difference between the first wheel and the second wheel has been reduced as a result of the brake control.

25

It is understood that the clutch may be arranged to selectively rotatably connect said wheels. The ground as understood herein may be any supporting element on which the vehicle is supported, including a structure such as a bridge. The first wheel is slipping means that the first wheel is losing traction. This may be due to the friction or the load on
30 the wheel having been reduced. In some situations the first wheel may even have, e.g. due to an uneven surface of the ground, lost contact with the ground. It is further understood that controlling the brake for reducing the rotational speed difference comprises controlling the brake so as to be actuated. The brake is controllable independently of the brake for the second wheel, and preferably the brake for the second
35 wheel is controllable independently of the brake for the first wheel.

By braking the first wheel for which an indication that it is slipping was identified, for reducing the rotational speed difference between said wheels, and engaging the clutch when the rotational speed difference has been reduced as a result of the brake control, it
5 may be ensured that the clutch is engaged without any excessive rotational speed difference. Thereby, damage of the clutch may be avoided. In addition, the comfort for a driver of the vehicle may be increased, since excessive noise and jerking, due to a clutch engagement at a high speed difference, may be avoided.

10 Where said wheels are arranged to be driven by the power source via a differential gear, the method advantageously comprises locking of the differential gear by means of the engagement of the clutch. Thus, invention may effectively provide a clutch engagement with a low risk of damage, for locking the differential gear for terminating a wheel slippage and provide for engine torque transfer to the wheels to be resumed. It should be noted
15 that the method may also be used for clutches without any differential gear, e.g. clutches arranged to selectively engage all wheels on a wheel axle to the power source.

Preferably, the clutch is engaged without any slip of the clutch. For this the clutch may be a positive clutch, such as a dog clutch. A positive clutch may present two parts, each with
20 teeth or jaws which may engage by a relative movement of the parts towards each other. Thus, the invention facilitates the use of a clutch type providing a strong and reliable torque transferring engagement, without any risk of slipping under high load. Further, the reduction of the rotational speed difference between said wheels reduces the risk of the positive clutch not being able to engage. This may increase the progress of the vehicle,
25 and hence the production of the vehicle.

Preferably the identifying step comprises measuring the rotational speeds of the first wheel and the second wheel. Thereby, the identifying of said indication may comprise comparing the measured rotational speed of the first wheel and the rotational speed of the
30 second wheel with each other. Thus, the identifying step may be carried out automatically. Thereby, a simple and reliable manner of establishing said indication may be provided.

The indication that the first wheel is slipping may be that the first wheel is rotating faster than the second wheel. In some embodiments, the indication that the first wheel is
35 slipping is that the rotational speed difference between the first wheel and at least one

other wheel of the vehicle, e.g. the second wheel, is higher than a slip speed threshold value. The use of such a slip speed threshold value may prevent unnecessary clutch engagements. In particular where the vehicle comprises a plurality of clutches as described above as differential locks for various respective wheel combinations, avoiding unnecessary clutch engagements is advantageous, since too many differential lock engagements may make a vehicle such as an articulated hauler difficult to steer. Further, differential lock engagements tend to increase tire wear and increase the fuel consumption of the vehicle; thus unnecessary clutch engagements may decrease tire wear and fuel consumption.

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Preferably the method comprises determining a steering angle of the vehicle, and determining the slip speed threshold value in dependence on the determined steering angle. This provides an adaption of the slip speed threshold value to the steering angle which makes it possible to take into account the difference of wheel rotational speeds of inner and outer wheels as the vehicle is turning. Thereby, unnecessary clutch engagements may be avoided.

Preferably the method comprises determining a speed of the vehicle, and determining the slip speed threshold value in dependence on the determined vehicle speed. This provides an adaption of the slip speed threshold value to the vehicle speed, which makes it possible to take into account that as the vehicle speed increases, the percentage of the wheel rotational speed which is caused by slippage will increase as well. Thereby, unnecessary clutch engagements may be avoided. In alternative embodiments, the slip speed threshold value may be predetermined, which provides a simplified control algorithm.

In some embodiments, the identifying step comprises determining an average rotational speed of at least some of the wheels of the vehicle and comparing the determined average rotational speed with the rotational speed of the first wheel. Thereby, the rotational speed of the wheel that is assumed to slip may be compared to the rotational speed of a plurality of other wheels of the vehicle, which may increase the level of certainty in the identification of said indication.

In some embodiments, the identifying step comprises determining the speed of the vehicle, determining a peripheral speed of the first wheel and comparing the determined peripheral speed of the first wheel with the determined vehicle speed. Thereby a direct indication of wheel slippage may be provided.

5

Preferably the method comprises, subsequently to controlling the brake for reducing the rotational speed difference between the first wheel and the second wheel, determining the rotational speed difference between the first wheel and the second wheel, and engaging the clutch in dependence on the determined rotational speed difference. The clutch may
10 be engaged in dependence on whether the determined rotational speed difference is lower than an engagement speed difference threshold value. Thereby, it may be secured that the clutch is not engaged until the rotational speed difference has been reduced to a level at which the risk of damage is avoided. However, the engagement speed difference threshold value also allows a controlled engagement with a remaining speed difference,
15 and this makes it possible to engage the clutch sooner than in the case of engagement at zero speed difference. Thereby a quicker response to the wheel slipping situation is provided, which makes the progress of the vehicle faster.

The engagement speed difference threshold value may be predetermined. The
20 engagement speed difference threshold value may be e.g. within 50-200 revolutions per minute. In some embodiments however the engagement speed difference threshold value may be zero. The engagement speed difference threshold value may be at least partly based on a torque delivered to the wheels, e.g. a maximum torque delivered to the wheels. Thereby the engagement speed difference threshold value may also
25 advantageously depend on the shape and size of the differential lock. Further, the engagement speed difference threshold value may be different depending on whether the clutch is arranged to connect wheels on the same wheel axle or to connect wheels on separate wheel axles. Thereby, it may be further secured that the clutch engagement does not cause or damage.

30

In some embodiments, the method comprises determining a torque of the power source, wherein the step of engaging the clutch is performed in dependence on the determined torque. Thereby, a decision whether to perform the step of engaging the clutch may be dependent on the determined torque. The step of engaging the clutch may be omitted if

the determined torque is below a torque threshold value. The determined torque may be, for example, the output torque of the power source, a requested torque of the power source, a torque delivered by a driveshaft connecting the power source to one or more wheels of the vehicle, etc. The torque threshold value may be predetermined.

5

Omitting the clutch engagement if the determined torque is below the torque threshold value may decrease unnecessary clutch engagements. E.g. at relatively low torque levels, the wheel slippage may be terminated solely by the brake control to reduce the wheel rotational speed difference. Thereby, the clutch engagement may be reserved for high torque situations, where it is required to terminate the wheel slippage. Thus, such
10 embodiments may combine a smooth, pure braking of the slipping wheel in low torque conditions with effective slippage terminating clutch engagement in high torque conditions.

15 In some embodiments, the method comprises determining a steering angle of the vehicle, wherein the step of engaging the clutch is performed in dependence on the determined steering angle. Thereby, a decision whether to perform the step of engaging the clutch may be dependent on the determined steering angle. The step of engaging the clutch may be omitted if the determined steering angle is above a steering angle threshold value.
20 Thus, a reduction of the steering capability of the vehicle, and a driver of the vehicle, caused by locking a differential gear with the clutch, may be avoided at relatively high steering angles. Such a steering angle dependence may advantageously be done by increasing the torque threshold value, discussed above, as the steering angle increases. However, alternatively, the steering angle threshold value may be predetermined.

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In some embodiments, the method comprises determining a speed of the vehicle, wherein the step of engaging the clutch is performed in dependence on the determined vehicle speed. Thereby, a decision whether to perform the step of engaging the clutch may be dependent on the determined vehicle speed. The step of engaging the clutch may be
30 omitted if the determined vehicle speed is above a vehicle speed threshold value. The vehicle speed threshold value may be predetermined. Such a vehicle speed dependence of the clutch engagement makes it possible to avoid unnecessary clutch engagements. More specifically, at relatively high vehicle speeds, a slippage of a wheel will likely be temporary, since the vehicle may despite a temporary reduction of propulsive torque

proceed due to its momentum past the cause of the slippage, which may be a ground unevenness or an ice patch.

The first wheel and the second wheel may be provided on the same wheel axle. In some
5 embodiments, the vehicle comprises a plurality of wheel axles, the method comprises, subsequently to the identifying step, and before engaging the clutch, engaging a further clutch arranged to selectively connect the first wheel and the second wheel with at least one wheel on another wheel axle. Thereby an advantageous sequence of clutch engagements may be provided, initially connecting wheels on separate wheel axles, and
10 subsequently, if the torque is not sufficient to remedy the situation, connecting wheels on the same wheel axle.

In some embodiments, where the first and the second wheel are provided on a wheel axle of the vehicle, and the vehicle comprises a third wheel and a fourth wheel provided on a
15 further wheel axle of the vehicle, the third and fourth wheels being arranged to be driven by the power source, the vehicle comprising a further clutch being arranged to selectively connect the third and fourth wheels, the method comprises

- identifying an indication that one of the third and fourth wheels is slipping in relation to the ground,
- 20 - controlling a brake for the one of the third and fourth wheels for which an indication that it is slipping was identified, which brake is controllable independently of a brake for the other of the third and fourth wheels, so as to be actuated for reducing the rotational speed difference between the third and fourth wheels, and
- 25 - engaging the further clutch when the rotational speed difference has been reduced as a result of the brake control.

Thus, multiple clutches of the vehicle may be engaged to terminate slip of any wheel of the vehicle. The clutches may be controlled independently of each other.

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Where the vehicle comprises a plurality of wheel axles, the first wheel and the second wheel may be provided on separate wheel axles. Thereby, the identifying step may comprise determining that the wheels on the wheel axle, on which the first wheel is provided, are on average rotating faster than the wheels on the wheel axle on which the
35 second wheel is provided. The method may thereby comprise engaging a further clutch

arranged to selectively connect the first wheel to another wheel on the same axle. The further clutch may be engaged after the engagement of the clutch arranged to selectively connect the first wheel and the second wheel on the separate wheel axles.

- 5 The object is also reached with a computer program according to claim 33, a computer readable medium according to claim 34, or a control unit according to claim 35.

The object is also reached with a control unit configured to control a clutch arranged to selectively connect a first wheel of a vehicle with a second wheel of the vehicle, the first
10 wheel and the second wheel being arranged to be driven by a propulsion power source of the vehicle, wherein the control unit is configured

- to identify an indication that the first wheel is slipping in relation to the ground,
- to control a brake for the first wheel, which brake is controllable independently of a brake for the second wheel, for reducing the rotational speed difference
15 between the first wheel and the second wheel, and
- to control the clutch so as to be engaged when the rotational speed difference has been reduced as a result of the brake control, so as to connect the first wheel and the second wheel.

- 20 Further advantages and advantageous features of the invention are disclosed in the following description and in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

- 25 With reference to the appended drawings, below follows a more detailed description of embodiments of the invention cited as examples.

In the drawings:

- 30 Fig. 1 is a perspective view of an articulated hauler.

Fig. 2 shows a driveline of the articulated hauler in fig. 1, and components to control the driveline.

- 35 Fig. 3 is a perspective view of a portion of the driveline in fig. 2.

Fig. 4 is a block diagram depicting steps in a method of controlling the driveline in fig. 2.

Fig. 5 is a block diagram depicting steps in an alternative method of controlling the
5 driveline in fig. 2.

Fig. 6 is a block diagram depicting steps in a further alternative method of controlling the driveline in fig. 2.

10 DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

Fig. 1 is an illustration of a vehicle in the form of a working machine, more specifically an articulated hauler 1. The articulated hauler comprises a frame with a front section 112 and a rear section 113. The front section 112 and the rear section 113 are mounted to each
15 other via a pivotable coupling 114. The front section 112 and the rear section 113 present two front wheels 101-102 and four rear wheels 103-106, respectively.

The pivotable coupling 114 is arranged to allow the front and rear sections to pivot in relation to each other around a pivot axis which is substantially vertical when the
20 articulated hauler 1 is supported on a horizontal support element. Thereby, an articulated steering capacity is provided to the working machine 1. Two steering hydraulic cylinders (not shown) are arranged on opposite sides of the articulated hauler 1 for turning the articulated hauler by means of relative movement of the front section 112 and the rear section 113. In other words, the articulated hauler 1 is articulated and frame steered by
25 means of the steering hydraulic cylinders. Also, the pivotable coupling 114 is arranged to allow the front and rear sections 112, 113 to twist in relation to each other, i.e. to assume different lateral attitudes. Such a pivotable coupling may be referred to as an oscillation joint.

30 The front section 112 of the articulated hauler 1 comprises an engine compartment 115 with a propulsion power source in the form of an internal combustion engine. It should be noted that the invention is applicable to vehicles having other types of propulsion power sources, such as an electric motor. In some embodiments, the propulsion power source may comprise two engines or motors, one in the front section 112 arranged to drive the

front wheels 101-102, and another in the rear section 113 the rear wheels 103-106. The front section 112 further comprises a driver compartment 116.

The rear section 113 comprises a dump truck body 117 for carrying payload, e.g. gravel, sand, rocks, etc. The dump truck body 117 is arranged to be tilted in the rearwards direction in relation to a frame 118 of the rear section 113, by means of two tilting hydraulic cylinders 119 distributed on opposite lateral sides of the dump truck body 117. It is understood that the dump truck body may be provided in a variety of ways, each adapted for particular types of operations.

10

Reference is made to fig. 2. The front wheels 101-102 are provided on a front wheel axle 121 and the rear wheels 103-106 are distributed on two rear wheel axles 122, 123. Each of the wheels 101-106 is arranged to be driven by the engine 6 via differential gears 201-204. The engine 6 is connected to a central differential gear 204 by means of an engine driveshaft 211. The central differential gear 204 is arranged to split the torque from the engine 6 between a front driveshaft 212 and a rear driveshaft 213.

A left front wheel 101 is mounted to a left front wheel shaft 214, and a right front wheel 102 is mounted to a right front wheel shaft 215. A front differential gear 201 is arranged to split the torque from the front driveshaft 212 between the left front wheel shaft 214 and the right front wheel shaft 215.

A left front rear wheel 103 is mounted to a left front rear wheel shaft 216, and a right front rear wheel 104 is mounted to a right front rear wheel shaft 217. A front rear differential gear 202 is provided between the left front rear wheel shaft 216 and the right front rear wheel shaft 217. A left rear rear wheel 105 is mounted to a left rear rear wheel shaft 218, and a right rear rear wheel 106 is mounted to a right rear rear wheel shaft 219. A rear rear differential gear 203 is provided between the left rear rear wheel shaft 218 and the right rear rear wheel shaft 219. A connecting driveshaft 220 is provided between a torque distributing gear arrangement 221 and the rear rear differential gear 203. Thus, the torque distributing gear arrangement 221 is arranged to distribute, e.g. divide, the torque transferred by the rear driveshaft 213 to the front rear differential gear 202 and the connecting driveshaft 220.

The rear driveshaft 213 is provided with a joint at the pivotable coupling 114. The front rear differential gear 202 is arranged to split the torque from the rear driveshaft 213 between the left front rear wheel shaft 216, and the right front rear wheel shaft 217. The rear rear differential gear 203 is arranged to split the torque from the connecting driveshaft 5 220 between the left rear rear wheel shaft 218 and the right rear rear wheel shaft 219.

The vehicle further comprises a control unit 7. At each of the wheels 101-106, a respective wheel speed sensor 301-306 is arranged and connected to the control unit 7, so as for the control unit 7 to determine based on signals from the respective wheel speed 10 sensor 301-306 a rotational speed of the respective wheel 101-106. The wheel speed sensors may be of any suitable type, e.g. of a type using a magnet and a Hall effect sensor, or a toothed wheel and an electromagnetic coil to generate a signal.

The vehicle 1 is further provided with a brake system comprising a respective brake 401- 15 406 at each of the wheels 101-106. A brake power unit 411 is arranged to provide hydraulic brake power for actuation of the brakes 401-406. The brake power unit 411 comprises a hydraulic pump (not shown) and a set of valves (not shown) to selectively and individually actuate the brakes 401-406 via respective conduits, e.g. in the form of tubes. The control unit 7 is arranged to control the brake power unit 411 so as to control 20 the brakes 401-406. Thus, the control unit 7 is arranged to control each brake 401-406 independently of any of the other brakes.

The vehicle is further provided with five clutches 501-505 arranged to selectively connect two of the wheels 101-106 or two sets of the wheels 101-106, as described closer below. 25 The clutches 501-505 are provided as positive clutch in the form of so called dog clutches. Thus each clutch is arranged to provide an engagement without any slip. However, it should be noted that the invention is also applicable to vehicles where one or more of the clutches are provided as friction clutches, each arranged to provide an engagement with slip. It should also be noted that the invention is applicable to vehicles have less or more 30 than five clutches.

One of the clutches, herein referred to as a front differential lock 501, is provided as a differential lock for the front differential gear 201. Another of the clutches, herein referred to as a front rear differential lock 502, is provided as a differential lock for the front rear 35 differential gear 202. A further of the clutches, herein referred to as a rear rear differential

lock 503, is provided as a differential lock for the rear rear differential gear 203. Yet another of the clutches, herein referred to as a central differential lock 504, is provided as a differential lock for the central differential gear 204.

- 5 An additional of the clutches, herein referred to as a connecting clutch 505, is provided on the connecting driveshaft 220, and is arranged to selectively connect the rear rear wheels 105, 106 to the engine 6. In this embodiment, the connecting clutch is during normal operation disconnected, so that the vehicle is in what could be referred to as a 6X4 mode. In certain operational circumstances, e.g. as exemplified below, the connecting clutch is
10 engaged, so that the vehicle enters what could be referred to as a 6X6 mode.

It should be noted that in alternative embodiments, a further differential gear may be arranged to split the torque from the rear driveshaft 213 between the front rear differential gear 202 and the rear rear differential gear 203. Thereby, the connecting clutch 505 may
15 work as a differential lock for such a further differential gear.

Each of the clutches 501-505 are provided with actuators which are controllable by the control unit 7. Thus, each of the clutches 501-505 is individually controllable by the control unit 7.

20

A steering angle sensor 311 is provided at the pivotable coupling 114. The control unit 7 is arranged to determine based on signals from the steering angle sensor 311 the steering angle of the vehicle. The control unit 7 is further arranged to receive real time information about the vehicle speed, e.g. from a suitable sensor at one of the driveshafts 212, 213, or
25 from a Global Position System (GPS) device, as is known per se. In addition, the control unit is arranged to determine the output torque of the engine 6, e.g. based on the air flow to the engine, the engine rotational speed and the fuel fed to the engine, as is known per se.

- 30 Fig. 3 shows the front rear differential gear 202 and the front rear differential lock 502. Also, the actuator 5021, by means of which the control unit 7 can control the front rear differential lock 502, can be seen. The other combinations of differential gears 201, 203, 204 and differential locks 401, 503, 504 are arranged in the same way.

Reference is made to fig. 4 depicting steps in a method to control the clutches 501-505. In an example, the vehicle is operated with all differential locks 501-504 disengaged, and the connection clutch 505 is disengaged.

- 5 By means of the steering angle sensor 311, the steering angle and the speed of the vehicle are determined S1. Based on the determined steering angle and the determined vehicle speed, a slip speed threshold value, used as described below, is determined or adjusted S2. It should be noted that in alternative embodiments, the slip speed threshold value may be predetermined.

10

- As the vehicle is moving along with propulsion from the engine 6, one of the wheels, e.g. the left front rear wheel 103, starts slipping or spinning, e.g. due to a loss of friction between the wheel tire and the supporting surface. As a result, due to the front rear differential gear 202, the torque provided by the engine 6 to the right front rear wheel 104 will be reduced or lost. By means of the wheel speed sensors 303, 304 at the front rear wheels 103, 104 the control unit 7 determines S3 that the left front rear wheel 103 is rotating faster than the right front rear wheel 104, and that the rotational speed difference is higher than the slip speed threshold value. The rotational speed difference above the slip speed threshold value is an indication that the left front rear wheel 103 is slipping in relation to a supporting element, e.g. the ground, on which the vehicle is supported. That the wheel 103 is slipping means that it is losing its traction. The wheel for which an indication is provided that it is slipping is herein also referred to as a first wheel.

- If the detected rotational speed difference that is not higher than the slip speed threshold value, the adjustment of the slip speed threshold value is repeated. The adaption of the slip speed threshold value to the vehicle speed makes it possible to take into account that as the vehicle speed increases, the percentage of the wheel rotational speed which is caused by slippage will increase as well. The adaption of the slip speed threshold value to the steering angle makes it possible to take into account the difference of wheel rotational speeds of inner and outer wheels as the vehicle is turning.

- In alternative embodiments, determining whether any of the wheels is slipping may comprise determining a peripheral speed of each wheel may and compared the peripheral speed with the determined vehicle speed. In some embodiments, the control unit may be arranged to determine an average rotational speed of some or all of the wheels of the

vehicle. Thereby, an indication that a wheel is slipping may comprise comparing the determined average rotational speed with the rotational speed of each wheel.

Upon detecting the wheel rotational speed difference above the slip speed threshold
5 value, the control unit 7 controls S4 the brake 403 for the left front rear wheel 103, for
reducing the rotational speed difference between the front rear wheels 103, 104. During
the brake actuation, the rotational speed difference between the left front rear wheel 103
and the right front rear wheel 104 is determined S5. If the rotational speed difference is
not lower than a predetermined engagement speed difference threshold value, e.g. within
10 50-200 revolutions per minute, the brake actuation is continued. When the control unit 7
determines S5 that the rotational speed difference has been reduced as a result of the
brake actuation, to be lower than the engagement speed difference threshold value, the
front rear differential lock 502 is engaged S6, thereby locking the front rear differential
gear 202. Thereby, torque provided by the engine 6 to the right front rear wheel 104 will
15 again increase. Upon engaging the front rear differential lock 502, the brake 403 for the
left front rear wheel 103 is released S7. The wheel to which the wheel, for which an
indication is provided that it is slipping, is connected is herein also referred to as a second
wheel.

20 It should be noted that the engagement speed difference threshold value may depend on
the shape and size of the differential lock 502. The engagement speed difference
threshold value may also depend on the maximum torque produced by the engine 6 or
transferred by the rear driveshaft 213. The engagement speed difference threshold value
may be different depending on whether the clutch is arranged to connect wheels on the
25 same wheel axle or to connect wheels on separate wheel axles.

In the example above, the wheels which the clutch connects, to prevent one of the wheels
slipping, are provided on the same wheel axle. As exemplified below, the wheels which
the clutch connects, to prevent one of the wheels slipping, may be provided on separate
30 wheel axles.

In another example, both wheels 103, 104 of the front rear wheel axle 122 starts slipping
as the vehicle is moving along under the propulsion of the engine 6. As a result, due to
the central differential gear 204, the torque provided by the engine 6 to the front wheels
35 101, 102 will be reduced or lost.

By means of the wheel speed sensors 301, 302, 303, 304 at the front wheels 101, 102 and the front rear wheels 103, 104, the control unit 7 determines that the front rear wheels 103, 104 are both rotating faster than the front wheels 101, 102. More specifically, the
5 control unit 7 determines the average rotational speed of the front wheels 101, 102 and compares this to each of the front rear wheel rotational speeds.

Upon detecting that each of the front rear wheels 103, 104 has a rotational speed which is higher than the average rotational speed of the front wheels 101, 102, the control unit 7
10 controls the brakes 403, 404 for the front rear wheels 103, 104 for reducing the rotational speed difference between the front wheels 101, 102 and the front rear wheels 103, 104. When the control unit 7 determines that the rotational speed difference has been reduced as a result of the brake actuation, the central differential lock 504 is engaged, thereby locking the central differential gear 204. Thereby, torque provided by the engine 6 to the
15 front wheels 101, 102 will increase.

With reference to fig. 5 an alternative embodiment of the method will be described. In an example, the control unit 7 determines S3, similarly to the example described with reference to fig. 4, that the left front rear wheel 103 is rotating faster than the right front
20 rear wheel 104, and that the rotational speed difference is higher than the slip speed threshold value. As a response to this detection, the control unit 7 controls S4 the brake 403 for the left front rear wheel 103, for reducing the rotational speed of the left front rear wheel 103.

25 During the brake actuation S4, it is determined S401 whether the connecting clutch 505 is engaged. If the connecting clutch 505 is not engaged, the rotational speed difference between the left front rear wheel 103 and the rear rear wheels 105, 106 is determined S501. If the rotational speed difference is not lower than a predetermined engagement speed difference threshold value, the brake actuation is continued. When the control unit
30 7 determines that the rotational speed difference has been reduced as a result of the brake actuation, to be lower than the engagement speed difference threshold value, the connecting clutch 505 is controlled so as to connect S601 the rear rear wheels 105, 106 to the engine 6.

Upon engaging the connecting clutch 505, the brake 403 for the left front rear wheel 103 is released S701. Subsequently, if it is determined S8 that once again that the left front rear wheel 103 is rotating faster than the right front rear wheel 104, and that the rotational speed difference is higher than the slip speed threshold value, the control unit 7 once again controls S9 the brake 403 for the left front rear wheel 103, for reducing the rotational speed difference between the front rear wheels 103, 104. When the control unit 7 determines S5 that the rotational speed difference has been reduced as a result of the brake actuation, to be lower than the engagement speed difference threshold value, the front rear differential lock 502 is engaged S6, thereby locking the front rear differential gear 202. Upon engaging the front rear differential lock 502, the brake 403 for the left front rear wheel 103 is released S7.

If it is determined S401 during the first brake actuation S2 that the connecting clutch 505 is engaged, the method proceeds directly to the steps of determining S5 whether the rotational speed difference is lower than the engagement speed difference threshold value, and if so engaging S6 the front rear differential lock 502 and releasing S7 the brake 403 for the left front rear wheel 103.

With reference to fig. 6 a further embodiment of the method will be described. As in the embodiments described above, the steering angle and the speed of the vehicle are determined S1. Based on the determined steering angle and the determined vehicle speed, the slip speed threshold value is adjusted S2. In addition, a torque threshold value, used as described below, is adjusted S201. The torque threshold value is increased as the as the steering angle increases, and vice versa. This correlation between the torque threshold value and the steering angle may be linear, non-linear or even non-continuous. In alternative embodiments, the torque threshold value may be predetermined.

Also, the output torque of the engine is repeatedly determined S202.

In an example, similarly to the one described with reference to fig. 4, the control unit 7 determines S3 that the left front rear wheel 103 is rotating faster than the right front rear wheel 104, and that the rotational speed difference is higher than the slip speed threshold value. Upon detecting S3 the wheel rotational speed difference above the slip speed threshold value, it is determined S301 whether the vehicle speed is above a predetermined vehicle speed threshold value. If the vehicle speed is below the

predetermined vehicle speed threshold value, the control unit 7 controls S4 the brake 403 for the left front rear wheel 103, for reducing the rotational speed difference between the front rear wheels 103, 104. If the vehicle speed is above the predetermined vehicle speed threshold value, the step of braking S4 the left front rear wheel 103, and the step
5 described below of engaging S6 differential lock 502, are omitted.

When braking S4 the left front rear wheel 103, it is determined S402 whether the torque is below the torque threshold value. If the torque is below the torque threshold value, the engagement S6 of the front rear differential lock 502, described below, is omitted S403.
10 Thereby, the slipping of the left front rear wheel 103 is stopped by the braking action only.

However, if S402 the torque is above the torque threshold value, the rotational speed difference between the left front rear wheel 103 and the right front rear wheel 104 is determined during the brake actuation. If the rotational speed difference is not lower than
15 a predetermined engagement speed difference threshold value the brake actuation S4 is continued. When the rotational speed difference is lower than the engagement speed difference threshold value, the front rear differential lock 502 is engaged S6. Upon engaging the front rear differential lock 502, the brake 403 for the left front rear wheel 103 is released S7.

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By increasing the torque threshold value as the steering angle increases, the step of engaging S6 differential lock 502 is performed in dependence on the determined steering angle. Alternatively, engaging S6 differential lock 502 may be omitted if the determined steering angle is above a predetermined steering angle threshold value.

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It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended claims.

30

CLAIMS

1. A method for engaging a clutch (501-505) of a vehicle (1) comprising a propulsion power source (6), the clutch (501-505) being arranged to selectively connect a first wheel (101-106) of the vehicle (1) and a second wheel (101-106) of the vehicle (1) with each other, said first wheel and said second wheel (101-106) being arranged to be driven by the power source (6), characterized by
 - identifying (S3, S8) an indication that the first wheel (101-106) is slipping in relation to the ground,
 - controlling (S4, S9) a brake for the first wheel (101-106), which brake is controllable independently of a brake for the second wheel (101-106), for reducing the rotational speed difference between the first wheel and the second wheel (101-106), and
 - engaging (S6, S601) the clutch (501-505) when the rotational speed difference between the first wheel and the second wheel has been reduced as a result of the brake control.
2. A method according to claim 1, where said wheels (101-106) are arranged to be driven by the power source (6) via a differential gear, characterized by locking (S6) of the differential gear by means of the engagement of the clutch.
3. A method according to any one of the preceding claims, characterized by engaging (S6, S601) the clutch (501-505) without any slip of the clutch (501-505).
4. A method according to any one of the preceding claims, characterized in that the clutch (501-505) is a positive clutch.
5. A method according to any one of the preceding claims, characterized in that the identifying step (S3, S8) comprises measuring the rotational speeds of the first wheel and the second wheel.
6. A method according to claim 5, characterized by comparing (S3, S8) the measured rotational speed of the first wheel and the rotational speed of the second wheel with each other.

7. A method according to any one of the preceding claims, characterized in that the indication that the first wheel (101-106) is slipping is that the first wheel (101-106) is rotating faster than the second wheel (101-106).
- 5 8. A method according to any one of the preceding claims, characterized in that the indication that the first wheel (101-106) is slipping is that the rotational speed difference between the first wheel (101-106) and at least one other wheel (101-106) of the vehicle is higher than a slip speed threshold value.
- 10 9. A method according to claim 8, characterized by determining (S1) a steering angle of the vehicle, and determining (S2) the slip speed threshold value in dependence on the determined steering angle.
- 15 10. A method according to any one of claims 8-9, characterized by determining (S1) a speed of the vehicle, and determining (S2) the slip speed threshold value in dependence on the determined vehicle speed.
- 20 11. A method according to claim 8, characterized in that the slip speed threshold value is predetermined.
- 25 12. A method according to any one of the preceding claims, characterized in that the identifying step (S3, S8) comprises determining an average rotational speed of at least some of the wheels of the vehicle and comparing the determined average rotational speed with the rotational speed of the first wheel (101-106).
- 30 13. A method according to any one of the preceding claims, characterized in that the identifying step (S3, S8) comprises determining the speed of the vehicle, determining a peripheral speed of the first wheel (101-106) and comparing the determined peripheral speed of the first wheel with the determined vehicle speed.
14. A method according to any one of the preceding claims, characterized by, subsequently to controlling (S4, S9) the brake for reducing the rotational speed difference between the first wheel and the second wheel (101-106), determining (S5, S501) the rotational speed difference between the first wheel and the second

wheel, and engaging (S6, S601) the clutch (501-505) in dependence on the determined rotational speed difference.

5 15. A method according to claim 14, characterized by engaging (S6, S601) the clutch (501-505) in dependence (S5, S501) on whether the determined rotational speed difference is lower than an engagement speed difference threshold value.

10 16. A method according to claim 15, characterized in that the engagement speed difference threshold value is predetermined.

17. A method according to any one of claims 15-16, characterized in that the engagement speed difference threshold value is within 50-200 revolutions per minute.

15 18. A method according to any one of claims 15-17, characterized in that the engagement speed difference threshold value is at least partly based on a torque delivered to the wheels.

20 19. A method according to any one of the preceding claims, characterized by determining a torque of the power source (6), wherein the step of engaging (S6, S601) the clutch (501-505) is performed in dependence on the determined torque.

25 20. A method according to claim 19, characterized in that the step of engaging (S6, S601) the clutch (501-505) is omitted if the determined torque is below a torque threshold value.

30 21. A method according to any one of the preceding claims, characterized by determining a steering angle of the vehicle, wherein the step of engaging (S6, S601) the clutch (501-505) is performed in dependence on the determined steering angle.

22. A method according to claim 20 and 21, characterized by increasing the torque threshold value as the steering angle increases.

23. A method according to any one of claims 21-22, characterized in that the step of engaging (S6, S601) the clutch (501-505) is omitted if the determined steering angle is above a steering angle threshold value.
- 5 24. A method according to any one of the preceding claims, characterized by determining a speed of the vehicle, wherein the step of engaging (S6, S601) the clutch (501-505) is performed in dependence on the determined vehicle speed.
- 10 25. A method according to claim 24, characterized in that the step of engaging (S6, S601) the clutch (501-505) is omitted if the determined vehicle speed is above a vehicle speed threshold value.
- 15 26. A method according to any one of the preceding claims, where the first wheel and the second wheel (101-106) are provided on the same wheel axle.
- 20 27. A method according to claim 26, where the vehicle (1) comprises a plurality of wheel axles, characterized by, subsequently to the identifying step (S3), and before engaging (S6) the clutch (501-505), engaging (S601) a further clutch arranged to selectively connect the first wheel and the second wheel (101-106) with at least one wheel on another wheel axle.
- 25 28. A method according to any one of the preceding claims, where the first and the second wheel (101-106) are provided on a wheel axle of the vehicle (1), and the vehicle (1) comprises a third wheel (101-106) and a fourth wheel (101-106) provided on a further wheel axle of the vehicle (1), the third and fourth wheels (101-106) being arranged to be driven by the power source (6), the vehicle (1) comprising a further clutch (501-505) being arranged to selectively connect the third and fourth wheels (101-106), characterized by
- 30 - identifying (S3, S8) an indication that one of the third and fourth wheels (101-106) is slipping in relation to the ground,
 - controlling (S4, S9) a brake for the one of the third and fourth wheels (101-106) for which an indication that it is slipping was identified, which brake is controllable independently of a brake for the other of the third and fourth wheels (101-106), for reducing the rotational speed difference between the
 - 35 third and fourth wheels (101-106), and

- engaging (S6, S601) the further clutch (501-505) when the rotational speed difference has been reduced as a result of the brake control.

- 5 29. A method according to any one of the preceding claims, where the vehicle (1) comprises a plurality of wheel axles, and the first wheel and the second wheel are provided on separate wheel axles.
- 10 30. A method according to claim 29, characterized in that the identifying step (S3, S8) comprises determining that the wheels (101-106) on the wheel axle, on which the first wheel (101-106) is provided, are on average rotating faster than the wheels (101-106) on the wheel axle on which the second wheel is provided.
- 15 31. A method according to any one of claims 29-30, characterized by engaging (S6) a further clutch (501-503) arranged to selectively connect the first wheel to another wheel on the same axle.
- 20 32. A method according to claim 31, characterized in that the further clutch is engaged after the engagement of the clutch (504-505) arranged to selectively connect the first wheel and the second wheel (101-106) on the separate wheel axles.
33. A computer program comprising program code means for performing the steps of any one of the preceding claims when said program is run on a computer.
- 25 34. A computer readable medium carrying a computer program comprising program code means for performing the steps of any one of claims 1-32 when said program product is run on a computer.
- 30 35. A control unit configured to perform the steps of the method according to any one of claims 1-32.
- 35 36. A control unit configured to control a clutch (501-505) arranged to selectively connect a first wheel (101-106) of a vehicle (1) with a second wheel (101-106) of the vehicle (1), the first wheel and the second wheel (101-106) being arranged to be driven by a propulsion power source (6) of the vehicle, characterized in that the control unit is configured

- to identify (S3, S8) an indication that the first wheel (101-106) is slipping in relation to the ground,
- to control (S4, S9) a brake for the first wheel (101-106), which brake is controllable independently of a brake for the second wheel (101-106), for reducing the rotational speed difference between the first wheel and the second wheel (101-106), and
- to control (S6, S601) the clutch (501-505) so as to be engaged when the rotational speed difference has been reduced as a result of the brake control, so as to connect the first wheel and the second wheel.

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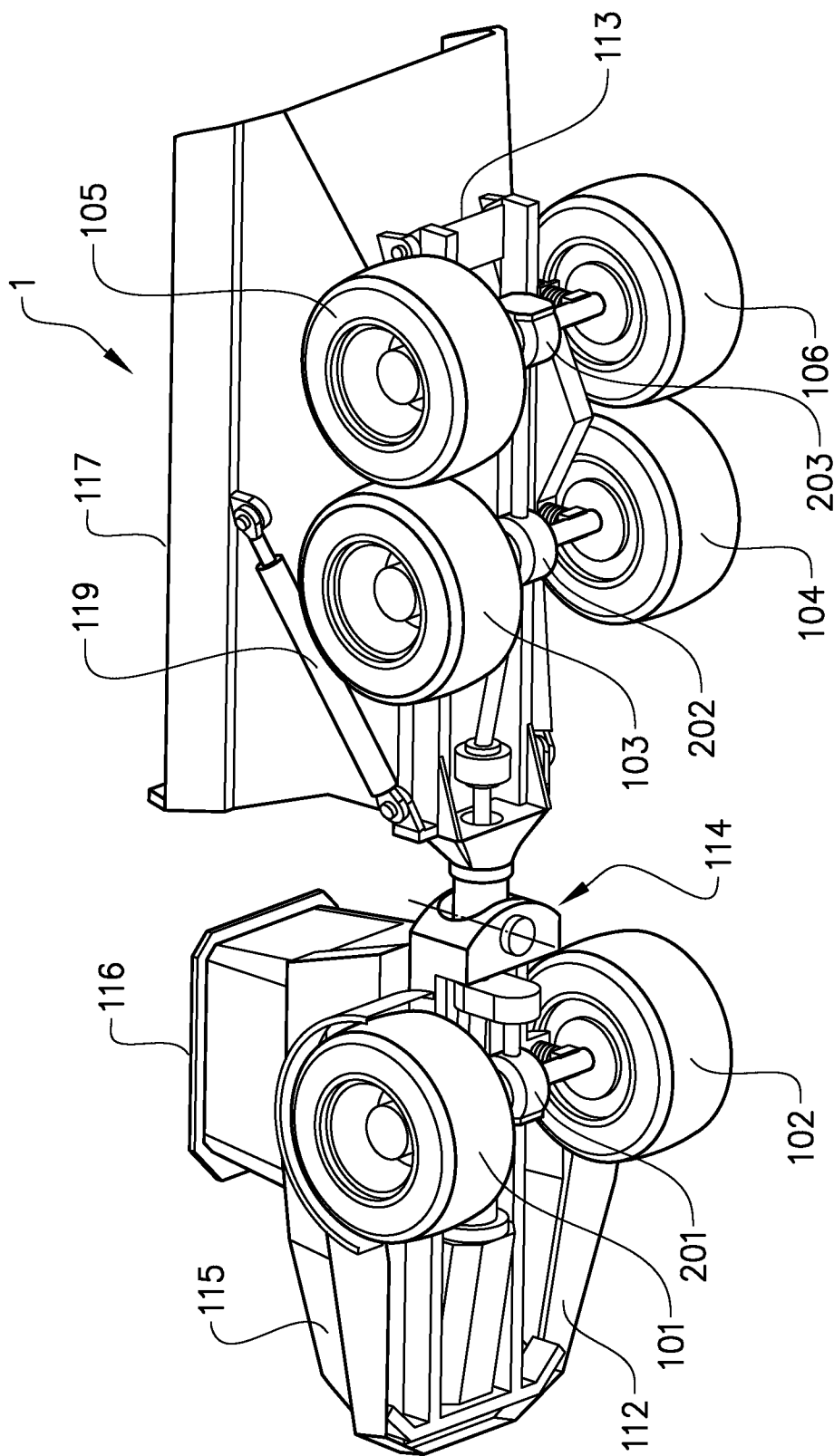
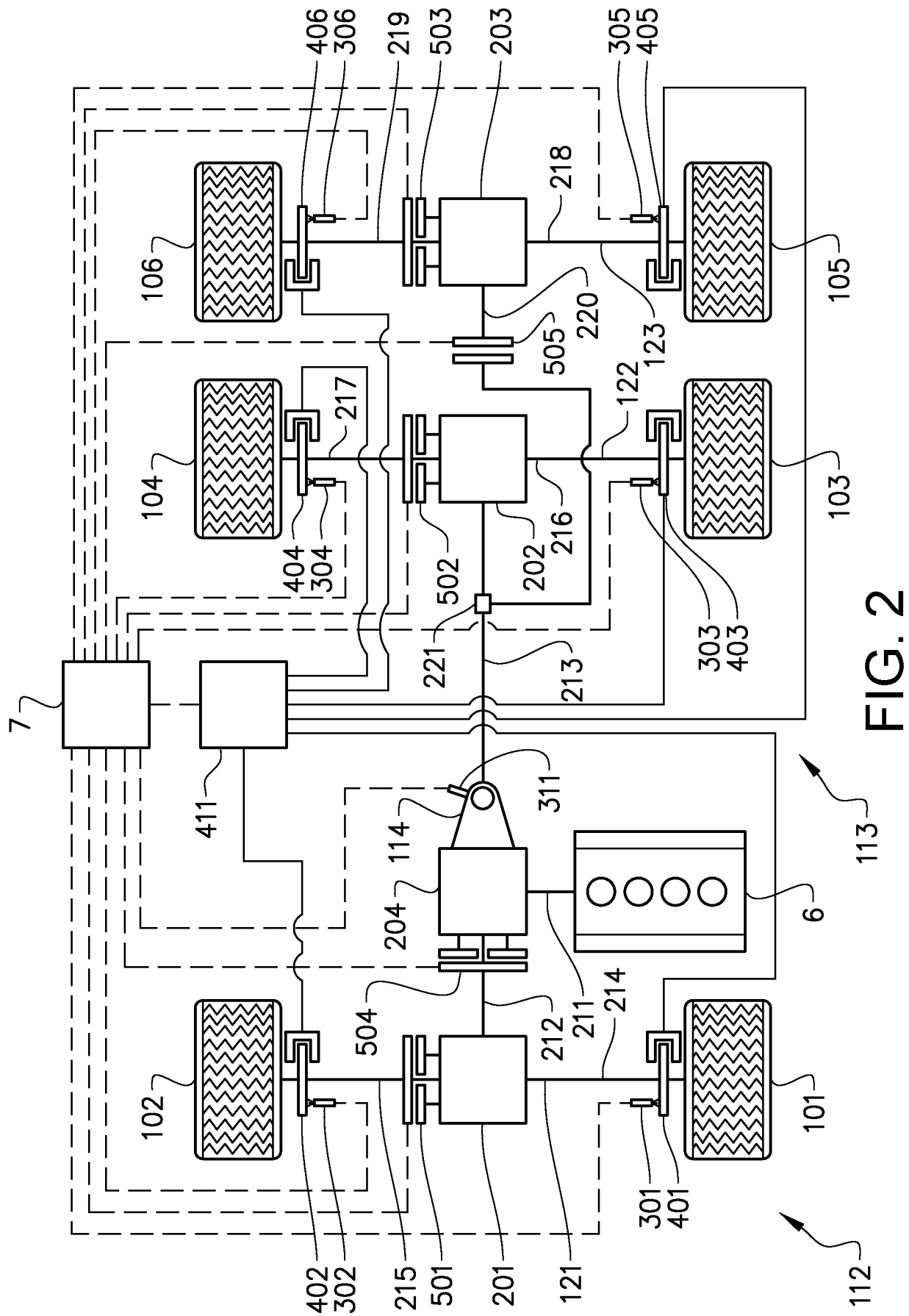


FIG. 1



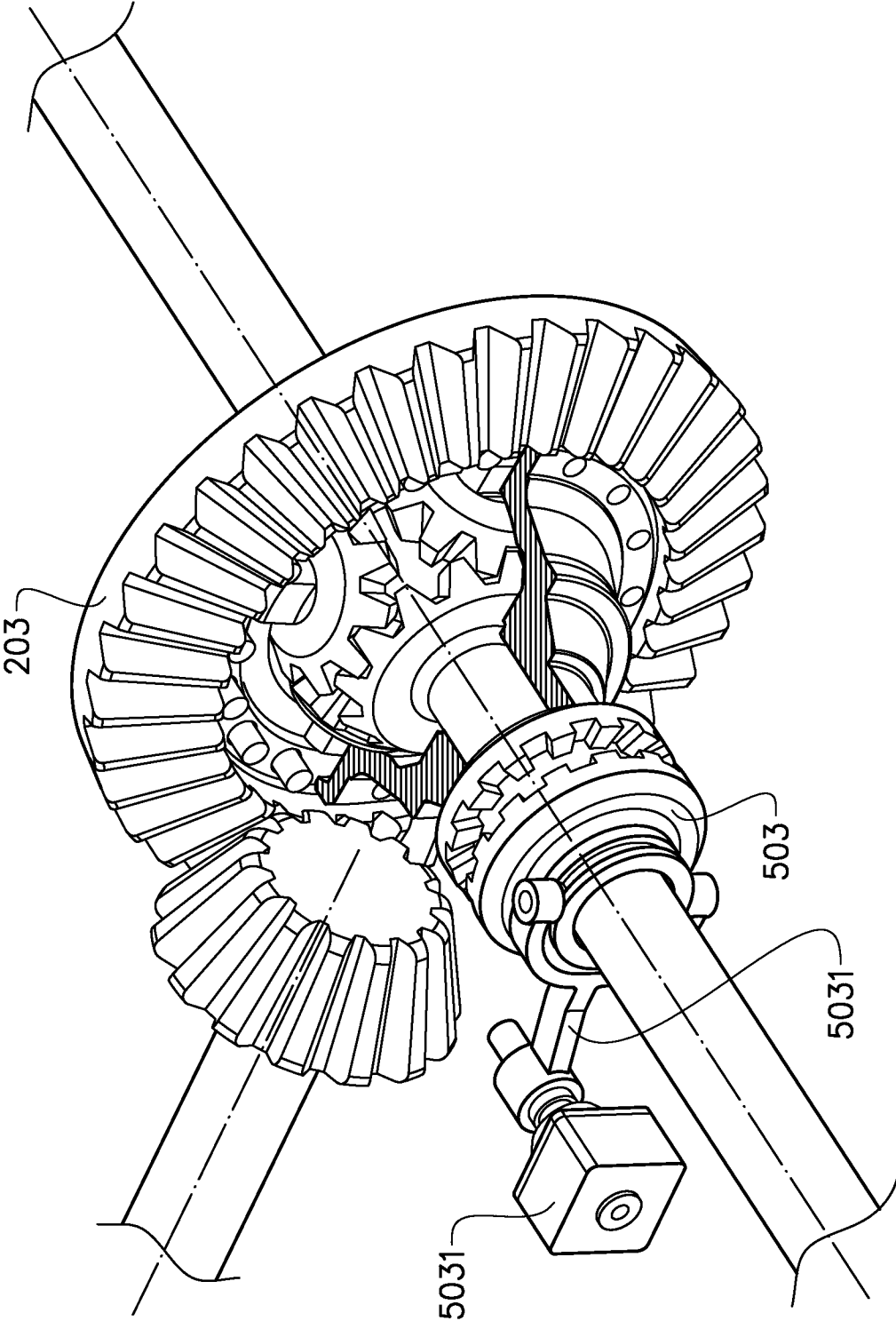


FIG. 3

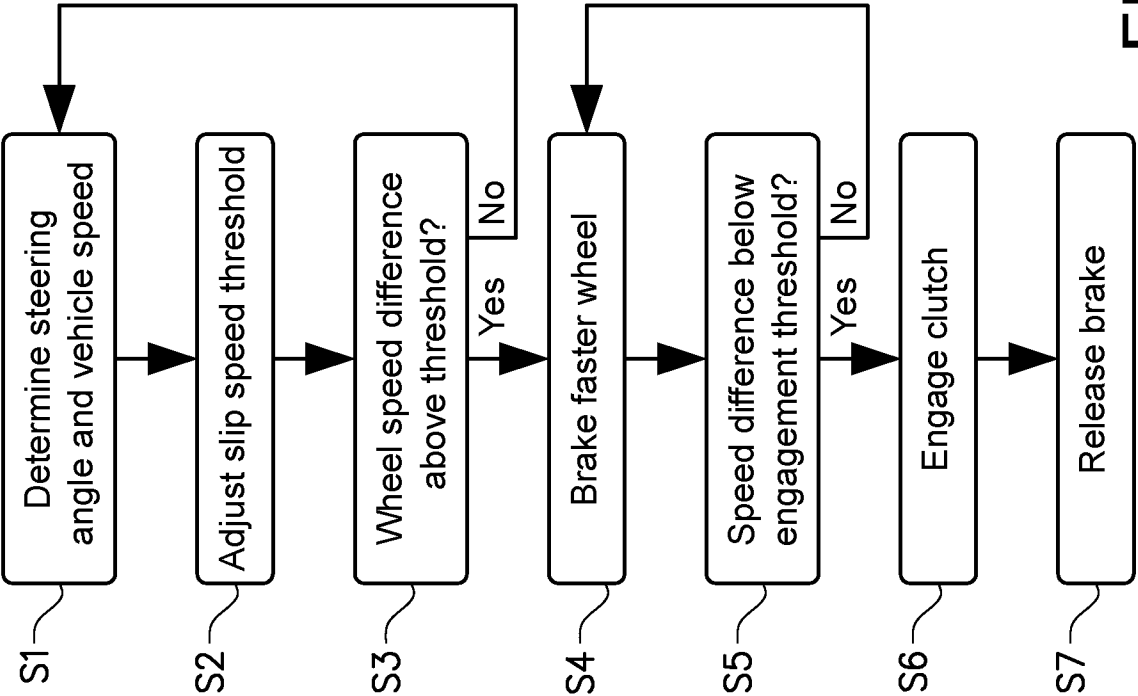


FIG. 4

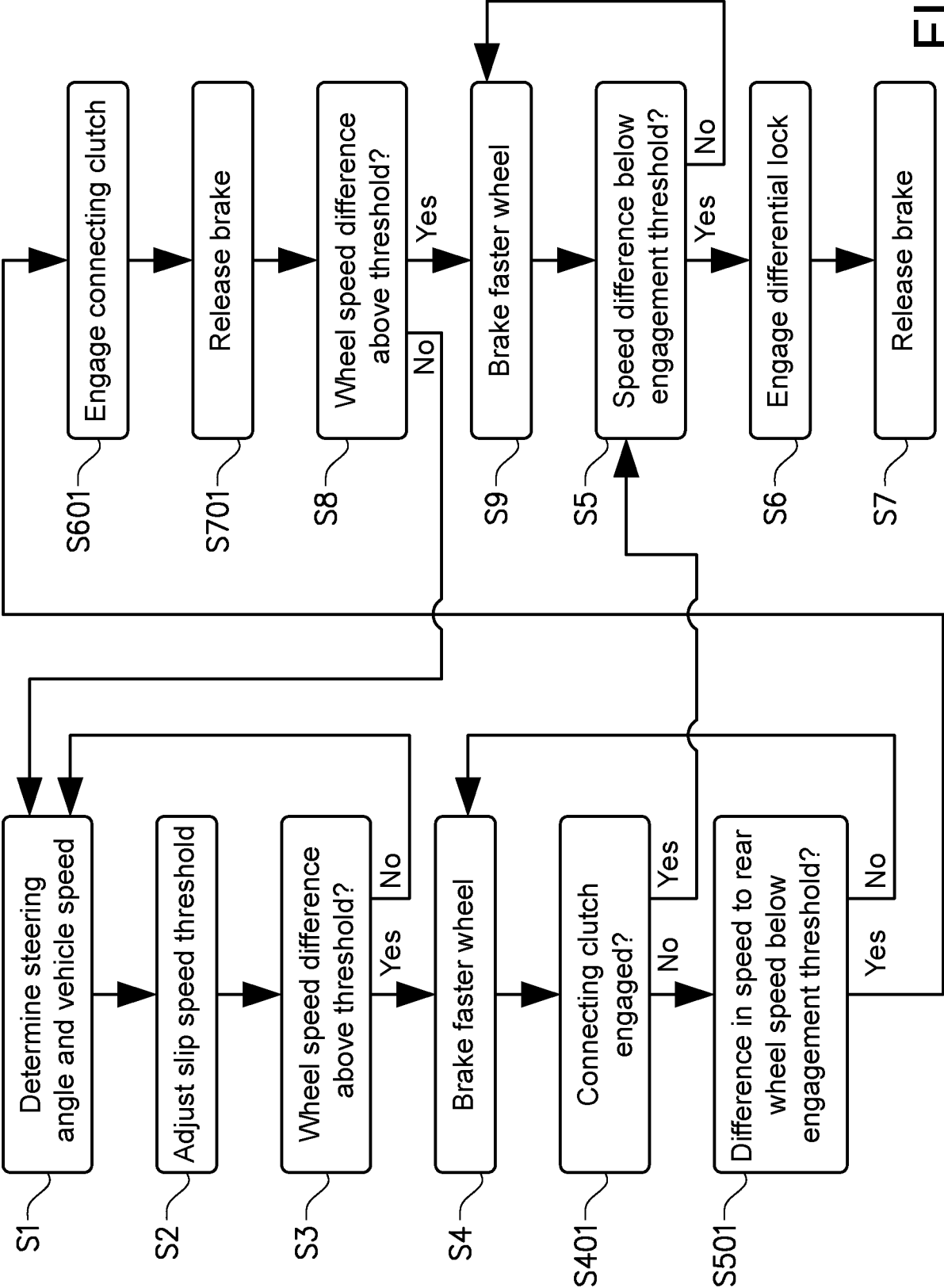


FIG. 5

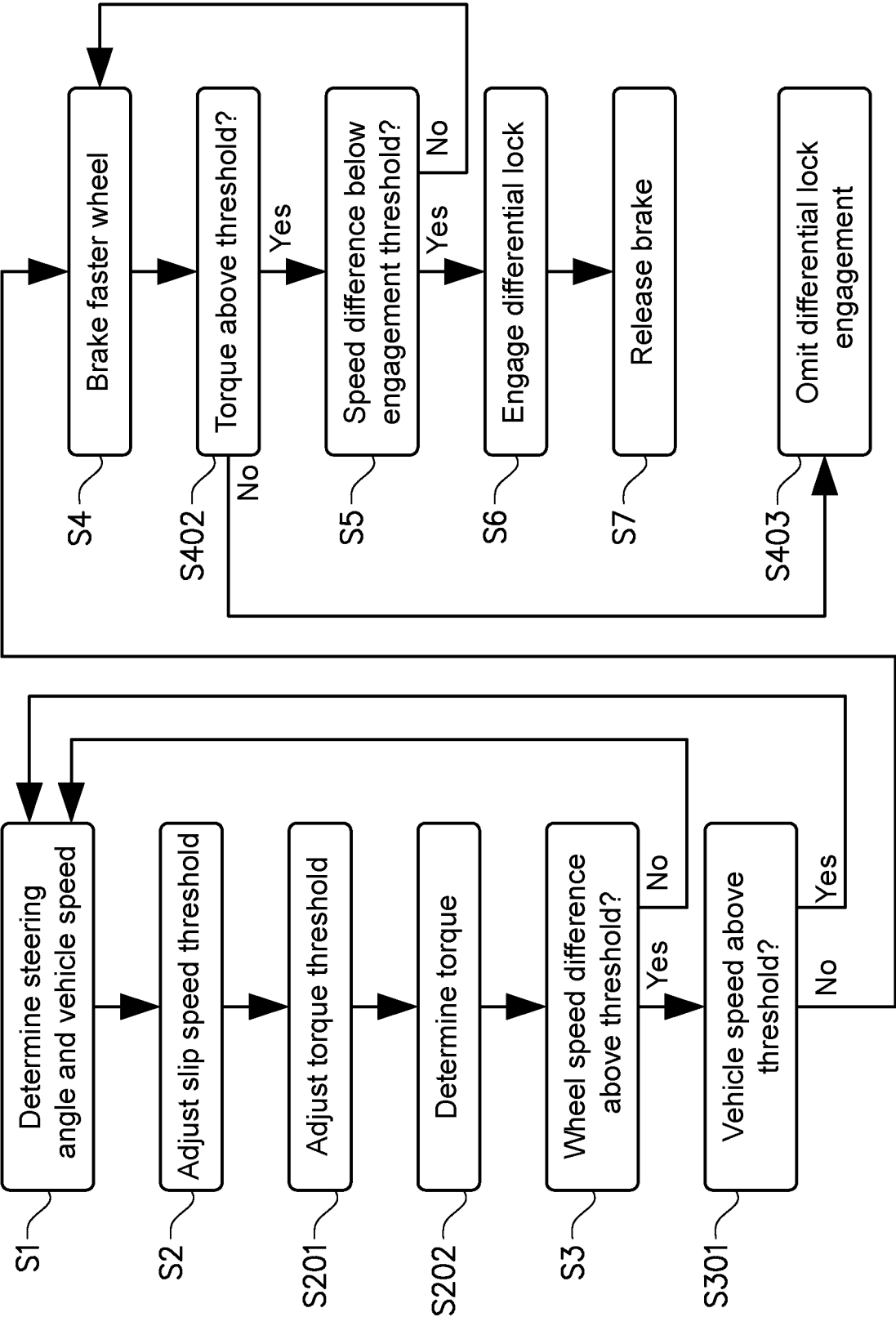


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2016/051279

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: B60K, B60W, F16D, F16H

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20160194001 A1 (KELLY JAMES), 7 July 2016 (2016-07-07); figures 1 and 6; paragraphs [0011], [0146]-[0158]; claim 1 --	1-36
A	GB 2129886 A (ROCKWELL INTERNATIONAL CORP), 23 May 1984 (1984-05-23); claim 1 --	1-36
A	US 5450919 A1 (SHITANI YUJI), 19 September 1995 (1995-09-19); figure 3; column 9, lines 23-54 -- -----	1-36

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:	"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
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"P" document published prior to the international filing date but later than the priority date claimed	

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Continuation of: second sheet

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B60K 28/16 (2006.01)

B60W 10/12 (2012.01)

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B60W 30/18 (2012.01)

F16H 48/24 (2006.01)

F16D 48/10 (2006.01)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SE2016/051279

US	20160194001 A1	07/07/2016	EP	3030445 A1	15/06/2016
			GB	2546920 A	02/08/2017
			GB	2516933 A	11/02/2015
			WO	2015018651 A1	12/02/2015
GB	2129886 A	23/05/1984	AU	6587080 A	30/07/1981
			AU	538955 B2	06/09/1984
			BE	887157 A2	14/05/1981
			BR	8100340 A	11/08/1981
			CA	1182886 A	19/02/1985
			CH	655280 A5	15/04/1986
			DE	3102173 A1	24/12/1981
			FR	2473964 A1	24/07/1981
			GB	2067685 A	30/07/1981
			GB	2130313 B	14/11/1984
			IT	1169018 B	20/05/1987
			JP	56108310 A	27/08/1981
			JP	0154212 B2	17/11/1989
			MX	6153 E	28/11/1984
			NL	8100021 A	17/08/1981
			SE	8100364 L	24/07/1981
			SE	453813 B	07/03/1988
US	5450919 A1	19/09/1995	CN	1093985 A	26/10/1994
			CN	1047558 C	22/12/1999
			DE	4400685 A1	14/07/1994