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- (54) Title:** A METHOD FOR CONTROLLING A WORKING MACHINE AND A WORKING MACHINE

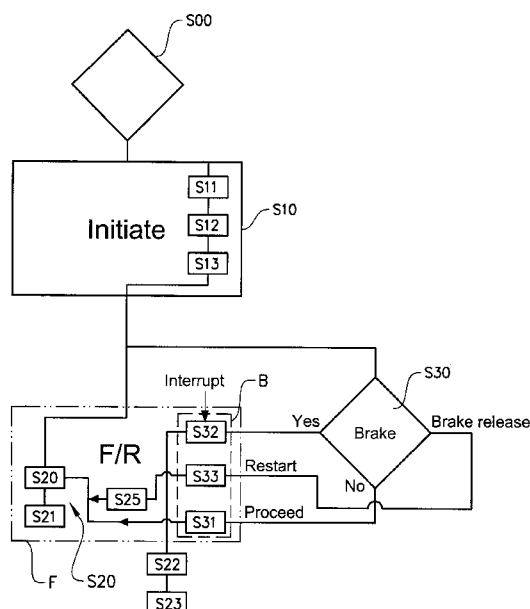


FIG. 4

- (57) Abstract:** A method for controlling a working machine (71) having a propulsion unit (2) for transmitting power to the driven wheels (12) of the working machine (71), the working machine (71) being provided with a shuttle shift function (3) enabling the travel direction of the working machine (12) to be changed automatically from forward to reverse and/or vice versa in accordance with a control sequence (S10,S20) without manually activating any means (70,72) for inhibiting transmission of power from the propulsion unit (2) to the driven wheels (12).



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A method for controlling a working machine and a working machine

TECHNICAL FIELD

The present invention relates to a method for controlling a working machine.

- 5 In particular the present invention relates to a method for controlling a working machine having an propulsion unit for transmitting power to the driven wheels of the working machine, the working machine being provided with a shuttle shift function enabling the travel direction of the working machine to be changed automatically from forward to reverse and/or vice versa in
- 10 accordance with a control sequence without manually activating any means for inhibiting transmission of power from the propulsion unit to the driven wheels. The shuttle shift is normally activated at an initial process step by selection of a driver, for instance by activating a switch.
- 15 The present invention furthermore relates to a working machine having an propulsion unit for transmitting power to the driven wheels of the working machine, the working machine being provided with a shuttle shift function enabling the travel direction of the working machine to be changed automatically from forward to reverse and/or vice versa said working machine
- 20 being controlled by an electronic control unit enabling a control sequence without manually activating any means for inhibiting transmission of power from the propulsion unit to the driven wheels.

TECHNICAL BACKGROUND

- 25 A working machine according to the invention includes a shuttle shift function, where during propagation of the working machine in one direction a command to change the direction is requested. This request will normally be made by the driver, for instance by activation of a switch, by pressing a button, clicking on a screen or by change of a lever position. After the command has been
- 30 made, no further activity of the driver is required to change the direction of propagation of the vehicle from an initial direction to the requested opposite direction. Instead the change of direction is controlled by a control sequence

which automatically controls the working machine from propagation of the working machine in one direction at an initial speed toward propagation of the working machine at an opposite direction at a final speed.

- 5 During shuttle shift, the initial and final speeds may be the same or not depending on the selected gear ratios for the initial and opposite direction and whether an input to an accelerator pedal or other control means for the engine has been changed or not during the control sequence. The shuttle shift function enables automatic change of the direction with a single request
10 made by the driver without any requirement of further manual intervention by the driver, such as disengagement of clutches.

- A shuttle shift function enables a driver to focus on the working task while a change of direction occurs. This is suitable for machines performing a working
15 task a plurality of times in opposite propagation directions, such as operations performed by a motor grader, a compactor. The invention is also suitable for any other working machine lacking a torque converter and at which acceleration from start takes place by use a frictional clutch.

- 20 With varying gradients of ground surface and varying initial velocities of the working machine as well as varying weight of the working machine, the distance to perform a shift in direction of travel from one direction to the other will vary. A problem with known shuttle shift functions for working machines is that it is difficult for a driver to foresee the appropriate timing for activation of
25 the shuttle shift function in order to decide the position at which the working machine is at standstill and ready to proceed in the opposite direction.

An object of the invention is to improve a shuttle shift function by increasing the flexibility of its use.

30

SUMMARY OF THE INVENTION

This object is achieved by a method according to claim 1. The invention contemplates a method for controlling a working machine having a propulsion

unit for transmitting power to the driven wheels of the working machine. The working machine is provided with a shuttle shift function enabling the travel direction of the working machine to be changed automatically from forward to reverse and/or vice versa in accordance with a control sequence without manually activating any means for inhibiting transmission of power from the propulsion unit to the driven wheels. The working machine is thus provided with a shuttle shift function enabling change of direction without further manual engagement in the process once the process has been initiated. The shuttle shift is normally activated at an initial process step by selection of a driver, for instance by activating a switch.

According to the invention the power transmitted to the driven wheels is automatically decreased in the event a service brake torque is applied by means of a service brake during the control sequence performing the shuttle shift operation. Further the control sequence performing the shuttle shift operation is interrupted once the service brake has been applied.

During the control sequence for performing shuttle shift function a torque applied to the driven wheels is reversed. The interruption of the control sequence results in that the brake command takes over such that a conflict between torque applied by the engine and the service brake torque is essentially resolved. Hence, in the event the shuttle shift function is in an acceleration phase after standstill, torque acting against the service brake is interrupted. In the event the shuttle shift function is in the retardation phase, the torque transmitted from the engine is at least interrupted once the brake has stopped the working machine. In one embodiment the conflict is resolved by interrupting the shuttle shift function once the applied brake pressure exceeds a threshold limit.

This means that the service brake can be used as an effective control of the movement of the working machine during shuttle shift operation. The retardation of the working machine may be additionally controlled by the service brake so as to more precisely adapt the movement of the working

machine to varying gradients of ground surface, varying initial velocities of the working machine and possibly varying weight of the working machine. Hence, an adaptation of the distance to perform a shift in direction of travel from one direction to the other is made possible. The driver can thus easily control the distance by the use of the service brake.

Optionally the control sequence may be restarted in the event the braking torque ceases and/or an increased propulsion unit power is demanded. This enables an operation of the working machine, where an operator uses the service brake to control the deceleration of the working machine, possibly to standstill of the working machine, and desires the shuttle shift control sequence to proceed to reverse the direction of movement of the working machine once the brake has been released. This may be useful for instance during operation of a grader, when the driver wants to adjust the blade at standstill before continuing in the opposite direction compared to an initial direction of movement.

In an embodiment of the invention, the automatic decrease of the power transmitted to the driven wheels is performed by releasing a clutch arranged between the propulsion unit and the driven wheels. In this embodiment, the engine will not be subjected to a load from transmitting a torque over the transmission to driven wheels braked or locked by the service brakes. Hence, unnecessary load on the transmission components resulting in wear of the components and heat dissipation will be avoided. In the event a transmission without torque converters is used, which is common in transmissions for motor graders, engine failure due to loss of engine speed under a critical engine speed may be avoided by automatic release of the coupling after or during application of the service brake.

Optionally the engine speed may be controlled to be at or below a predetermined engine speed threshold at initiation of the shuttle shift control sequence. This enables control of the engine such that the engine speed is not inappropriate for a shuttle shift function. As a next step a clutch in an

initial direction may be disengaged once the engine speed is controlled to be at or below said engine speed threshold. This removes a driving torque in the initial direction and prepares for an opposite of direction of the movement of the working machine. After initiation of said control sequence an applied
5 torque to the driven wheels is reversed. This may be performed by ramping up an applied torque to the driven wheels in the reversed direction during operation of said shuttle shift control sequence. The ramping up of the torque may be performed by controlled automatic application of a clutch. Reduction of the engine speed is performed in order to reduce heat dissipated during the
10 shuttle shift operation.

Optionally the method may be used in a working machine including a transmission having a first direction transmission path with a first clutch, an opposite direction transmission path with a second clutch, said clutches
15 allowing control of torque transmission in said first and opposite transmission paths.

A shuttle shift process for a machine having two clutches may be initiated with the transmission being operated with the first clutch engaged and torque is
20 transmitted over the first direction transmission path. A shuttle shift process includes the steps of:

- receiving a control signal to selectively switch to operating said transmission with said second clutch engaged and torque is transmitted over the opposite direction transmission path; and
- 25 - initiating a shuttle shift control sequence in which said first clutch is controlled to be released in order not to transmit any torque via said first transmission path. The control of the engagement process of the second clutch is performed by a subprocess of the shuttle shift control sequence. In this subprocess a clutch pressure is controlled at the second clutch to allow
30 synchronization between an input and output of said second clutch and engagement of the second clutch. The clutch pressure may be increased by following ramps or by applying a constant pressure. By increase of the clutch pressure at the second clutch torque may be transmitted to the driven wheels

in the opposite direction in relation to the directed transmitted via the first transmission path. The control of pressure is selected to achieve a desired retardation and acceleration during the shuttle shift.

- 5 In the event a braking torque from the service brake is applied during the shuttle shift control sequence, the shuttle shift control sequence is interrupted. This may be performed by reducing the pressure at the second clutch in order to remove or substantially remove the torque transmitted over the coupling, for instance by interrupting the increase of clutch pressure at the second
10 clutch.

- During the subprocess of shuttle shift control sequence, the clutch pressure at the second clutch is controlled to follow a pressure curve from a low pressure
15 corresponding to an unengaged state of said clutch to a high pressure corresponding to an engaged state of said clutch. At the unengaged state, no or an insubstantial torque is transmitted via the clutch, at the engaged state, the clutch will be fully engaged with no or essentially no slip in the clutch.

- 20 In the event a braking torque is applied to the driven wheels, the pressure curve will be controlled to drop to a low level.

- The low level corresponds to a pressure where no or an insubstantial torque is transmitted via the torque.
25

- The pressure curve will be set to assume a maximum value at detection of synchronism of said input and output of said second clutch, in order to maintain safe engagement of the second clutch at synchronism.

- 30 The shuttle shift control sequence is set to elapse during a time window. The pressure curve will be set to assume a maximum value at the end of said time window regardless of whether synchronism of said input and output of said second clutch is detected or not. This safeguards against too much heat

dissipation in the clutch, an ensures engagement of the second clutch once the time window has elapsed.

5 The time window may be extended as a function of the time the braking torque is applied. This ensures that the application of the service brake for a time period will not shorten the period the time window for performing the reversal of the travel direction of the working machine substantially. Optionally the time window is prolonged by the time the vehicle is kept at standstill. A more complex function may be used where the impact of the retardation of
10 the working machine by the service brake in comparison to the retardation that would have been made by the shuttle shift control sequence without application of the service brake is assessed and accounted for.

15 Optionally the increase of clutch pressure is resumed once the braking torque is released during said shuttle shift control sequence. This ensures that the shuttle shift control sequence can be completed after release of the service brake such that the working machine may start or continue to propagate in the opposite direction.

20 Generally the pressure in the clutch is controlled to provide a desired torque transmitted to the driving wheels to generate a desired deceleration and acceleration during the shuttle shift. Optionally, the clutch pressure is controlled to be increased to a target pressure after resuming the shuttle shift control sequence. The target pressure may be dependent on the pressure
25 before interruption of the pressure increase due to application of the braking torque, and optionally dependent on the difference of rotational speeds of the input and output of said second clutch at the release of the braking torque. The increase in pressure may follow a sharp ramp up to the target pressure, where after the pressure will follow the pressure curve corresponding to an
30 uninterrupted shuttle shift control sequence.

Optionally, the shuttle shift control sequence includes a pre shift stage at which said first clutch is released and the second clutch is filled. Optionally,

the engine speed is kept constant or set to assume a limited engine speed in the event the engine speed is above said limited engine speed during said pre shift stage. During the pre shift stage, torque is not transmitted over the clutch.

5

The shuttle shift control sequence may include an inertia stage at which torque is transmitted to the driving wheels. The torque is determined by control of the pressure to follow a pressure curve such that a desired torque is transmitted to the driving wheels. In one embodiment, the pressure curve may follow a first sharp ramp during an initial stage said pre shift stage whereafter the pressure follows a second ramp having a slower rate of increase of the pressure than said first ramp.

Optionally, the engine speed may be ramped up from a set engine speed to a requested engine speed during said inertia stage. The set engine speed may be set to an engine speed adapted to the shuttle shift process, while the requested engine speed is the engine speed requested by the driver.

The invention furthermore relates to a working machine having an propulsion unit for transmitting power to the driven wheels of the working machine, the working machine being provided with a shuttle shift function enabling the travel direction of the working machine to be changed automatically from forward to reverse and/or vice versa by a shuttle shift control sequence without manually activating any means for inhibiting transmission of power from the propulsion unit to the driven wheels.

According to the invention, the electronic control unit is arranged to automatically decrease the power transmitted to the driven wheels and interrupt such a shuttle shift control sequence in the event a braking torque is applied by means of a service brake of the working machine.

Optionally, electronic control unit may be arranged to automatically decrease the power transmitted to the driven wheels by releasing a clutch arranged between the propulsion unit and the driven wheels.

- 5 Optionally, electronic control unit may be arranged to restart the control sequence in the event the braking torque ceases and/or an increased propulsion unit power is demanded.

- 10 Optionally, the working machine may include a transmission arrangement with a first direction transmission path with a first clutch, an opposite direction transmission path with a second clutch, said clutches allowing control of torque transmission in said first and opposite transmission paths. Further the working machine may include a controller arranged to receive a control signal to selectively switch from operating said transmission with said first
- 15 clutch engaged and torque is transmitted over the first direction transmission path to operating said transmission with said second clutch engaged and torque is transmitted over the opposite direction transmission path. The controller is furthermore arranged to initiate and run a shuttle shift control sequence in which said first clutch is controlled to be released in order not to
- 20 transmit any torque via said first transmission path and a clutch pressure is increased at said second clutch to allow synchronization between an input and output of said second clutch and engagement of the second clutch. According to this embodiment the controller is arranged to interrupt the increase of clutch pressure in the event a braking torque is applied during
- 25 said shuttle shift control sequence.

- 30 Optionally, the controller may include a pressure curve control block defining a pressure curve having a pre shift state with a pressure following a first flank, a inertia state at which a pressure is increased along a second flank having a smaller differential than said first flank, and a hold state at which a braking torque is applied and at which the pressure curve assumes a low pressure transmitting no or an insignificant torque over the second clutch.

Optionally, the controller may include further control blocks ensuring the operation of the methods or method steps proposed in the methods or method steps described above.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Embodiment(s) of the invention will be described in further detail below, with reference to appended drawings, where

Fig. 1 shows a lay out of a transmission in which the present invention may
10 be operated,

Fig. 2 shows a schematic drawing of a gear box at which the present invention may be operated,

15 Fig. 3 shows a schematic drawing of a grader,

Fig. 4 shows a schematic process for shuttle shift,

Fig. 5 shows different steps of the control sequence present in a shuttle shift
20 process,

Fig. 6 shows a diagram of the engine speed and torque transmitted to the drive wheels as a function of time, and

25 Fig. 7 shows a schematic drawing of a transmission including a first and a second transmission paths.

30

DETAILED DESCRIPTION

In figure 1 is shown a schematic drawing of a transmission 1 at which the present invention may be used. The transmission 1 includes a propulsion unit

2, which suitably is a combustion engine. The propulsion unit 2 is connected to a gear box 4. The gear box 4 includes an input shaft 6 and an output shaft 8. The input shaft 6 may be mechanically connected to a power output of the propulsion unit, 2 such as a crank shaft 10. The working machine includes a function 3 enabling the travel direction of the working machine to be changed automatically from forward to reverse and/or vice versa. The function 3 may be performed by an electronic control unit 5 having a functional block 7 running the method according to the invention, which method is described in more detail below. The functional block 7 includes a control block

5 Suitably change of the travel direction of the working machine is performed under control of clutches (not shown) whose engagement and disengagement may be controlled by valves 9 controlling the pressure as a function of the flow of oil in an hydraulic circuit 11 including an oil pump 13. The valves 9 are controlled by the electronic unit 5. The connection between the input shaft 6

10 and the power output may be direct, or via intermediate transmission elements such as a set of gear wheels 12. Optionally a torque converter may be positioned between the power output and the input shaft 6. However, for some working machine applications, such as in some motor graders, a torque converter will not be present. In this case the propulsion unit 2 is mechanically

15 connected to the input shaft 6. Optionally a master clutch may be positioned in between the propulsion unit 2 and the gear box 4. However, clutches may be embedded as is shown in figure 2. The output shaft 8 of the gear box 4 is connected to ground engagement elements 12, for instance wheels via a transmission part which may include a differential 14 and optionally a hub

20 reduction unit. The figure schematically indicates a brake unit 15 including a service brake 17 and a brake actuator 19 for control of the service brake. The brake unit will apply a braking torque to the wheels 12 of the working machine.

25

30 In figure 2 an example of a gear box 4 which suitably may be used in connection with operating the invention is shown. The gear box 4 is of countershaft type and includes an input shaft 6, an output shaft 8 and a first intermediate shaft 16 and a second intermediate shaft 18. The input shaft

includes a first and a second gear wheel 20, 22 engaging with a respective third and fourth gear wheel 24, 26 on the first intermediate shaft 16. A first and a second clutch 28, 30 are provided for releasing respective engaging the connection between the first and third gear wheels 20, 24 and the second and fourth gear wheels 22, 26 respectively. The first intermediate shaft 16 includes a fifth and a sixth gear wheel 32, 34. The fourth, fifth and sixth gear wheels 26, 32, 34 of the first intermediate shaft 16 engage with seventh, eighth and ninth gear wheel 36, 38, 40 of the second intermediate shaft 18. A set of clutches 42, 44, 46 are provided for releasing respective engaging the connection between the fifth and seventh gear wheels 32, 36, the sixth and eighth gear wheels 34, 38 and the fourth and ninth gear wheels 26, 40 respectively. The second intermediate shaft 18 is provided with a tenth and an eleventh gear wheel 48, 50 being in engagement with a twelfth and a thirteenth gear 52, 54 when provided on the output shaft 8. A set of clutches 56, 58 are provided for releasing respective engaging the connection between the tenth and twelfth gear wheels 48, 52 and the eleventh and thirteenth gear wheels 50, 54 respectively. A reverse shaft 60 is provided. The reverse shaft carries a reverse gear wheel 64 being in engagement with the fifth gear wheel 32 arranged on the first mid shaft 16. A first reverse clutch 70 is provided for releasing respective engaging the connection between the reverse gear wheel 64 and the input shaft 6.

The gear box disclosed in figure 2 is quite complex and allows for operation in 12 forward gears and 12 reverse gears. The invention is operable in far less complex transmissions including a first direction transmission path with a first clutch, an opposite direction transmission path with a second clutch, said clutches allowing control of torque transmission in said first and opposite transmission paths, wherein said transmission is operated with said first clutch engaged and torque is transmitted over the first direction transmission path. The shuttle shift function may be controlled by forward/reverse clutches embedded in the gearbox. However, the shuttle shift function may also be controlled by a master clutch separate from the gear box clutches. The

master clutch will then be designed to sustain slip, while the clutches in the gear box may have a less robust design.

5 In the gear box 4 shown in figure 2 any forward gear connection provided over the gear box may constitute a first direction transmission path, and any reverse gear connection may constitute an opposite direction transmission path, or vice versa. The first transmission path includes at least one clutch and the second transmission path includes at least one clutch.

10 The operation of the clutches under shuttle shift will be explained in detail below.

In figure 3 shows a schematic drawing of a working machine constituted by a motor grader. The motor grader 72, includes a blade high lift arrangement 75 generally located at the free end of the draw bar 73 which is universally
15 mounted at the nose of the motor grader. The motor grader has a forwardly extending frame 74 which supports the steerable and tiltable front wheels 90. The blade high lift arrangement 75 includes a slidable blade 77 which is also tiltable by means of the blade tilt arrangement 78 and is movable to various angled positions in the vertical plane by adjustment of opposed high lift
20 cylinders 80. The ring gear 82 is rotatable beneath the draw bar 73 and thus, the attack angle of the blade can be adjusted. In addition, there is a side shift cylinder 84 for moving the ring gear either side or directly beneath the forward extending frame 74.

25 The motor grader includes a cab 85 located forward of a propulsion unit 86. A pivot point 88 connects the forwardly extending frame 74 to the propulsion unit 86. This arrangement allows articulation of the forwardly extending frame 74 relative to the propulsion unit 86. The propulsion unit 86 includes the propulsion unit 2. A transmission, for example a transmission as disclosed in
30 figures 1 and 2 connects the propulsion unit with the ground engaging elements 12. The rear wheels 12a, 12b may all be connected to the propulsion unit in a conventional four wheel tandem drive arrangement. Suitably the front wheels may be hydraulically operated by an axial piston

pump arranged in connection with the front wheels 12c. The transmission of the grader directly connects the propulsion unit to the driven wheels without any torque converter positioned in between propulsion unit and driven wheels.

5

Figure 4 shows a schematic drawing of a shuttle shift process. The shuttle shift process is initiated at in initial process step S00 by a control input of an operator to selectively switch the travel direction of the working machine to be changed automatically from forward to reverse and/or vice versa. The control
10 input can be activated by any type of input including pressing a control knob, activating a switch. The shuttle shift process thus includes the initial process step S00 and the shuttle shift control sequence S10,S20

On the reception of the control input, the shuttle shift control sequence
15 performing the automatic change of direction from forward to reverse and/or vice versa starts running at a first process step S10 of the shuttle shift control sequence. The process step S10 may optionally include the step S11 of controlling an engine speed n to be at or below a predetermined engine speed threshold n_{th} at initiation of a shuttle shift process.

20

Further, the process step S10 may include a step S12 of disengaging a clutch in an initial direction. Optionally the control of the engine speed to be at or below said engine speed threshold may be triggered by the disengagement of the clutch.

25

After having been initiated at the first process step S10 the control sequence continues in a subprocess S20 at which the change of direction from forward to reverse is performed in a process frame F. During the subprocess S20 is performed a brake application monitoring routine S30 is performed. The brake
30 monitoring routine S30 explores whether a brake torque is applied while the subprocess S20 is being run. The brake monitoring routine S30 generates a proceed state S31, which indicates that a brake condition indicating that a shuttle shift should not be interrupted and that thus interrupting the shuttle

shift control sequence should not be performed. In the event a brake condition is detected, the brake monitoring routine S30 generates an interrupt state S32, where the control sequence is interrupted. The brake condition may be that a brake pressure is applied. A more complex brake condition
5 may be applied, where it is accounted for whether the working machine have assumed a low threshold velocity, which may be zero, or not. In this event interruption of the control sequence may be initiated once the working machine has been retarded to the threshold velocity. The brake condition may also represent a threshold retardation velocity such that interruption of the
10 control sequence may be initiated once the working machine decelerates more than a certain threshold value or that a braking torque exceeds a threshold value.

In the event a proceed state S31 is present, the control sequence performing
15 the reversal of direction will continue. This may be done by continuing increase of the pressure applied at a clutch until the clutch is engaged. The pressure at the clutch may follow a curve as indicated by ramp 1, ramp 2, optionally ramp 3 and a final engagement at a static torque level as indicated by the solid line with its two connected branches shown in figure 5.

20

Further a resume state S33 may be generated at which the control sequence is restarted by resuming the subprocess S20. The resume state is generated once a resume condition is detected. The restart condition is generally that
25 the brake condition is no longer present and may be that a brake pressure is no longer applied.

At the subprocess S20 of the shuttle shift control sequence the power transmitted to the driven wheels during the shuttle shift process is controlled.
30 This may optionally be performed by controlling the pressure in a clutch. The control of the power transmitted to the driven wheels during the shuttle shift process performed under subprocess S20 may be constituted by ramping up the torque transmitted to the driven wheels. In one embodiment of the

invention, the control sequence includes the ramping up the pressure in a clutch transmitting torque to the wheels of the working machine in a direction which is opposite to the direction of the torque transmitted to the wheels prior to initiation of the shuttle shift process. While the ramping up of the pressure is performed under subprocess S20, the brake monitoring routine is performed and generates a proceed state S31, or an interrupt state S32 or optionally a resume state S33.

The momentarily present state is denoted in a functional block B which controls the subprocess S20 under which the power transmitted to the driven wheels during the shuttle shift process is controlled.

In the event an interrupt state S32 is detected, the shuttle shift control sequence S10, S20 is interrupted in a step S22 and power transmitted to the driven wheels will be decreased in a step S23. This may be done by reducing the pressure applied at the clutch, preferably to such a level where no or an insignificant torque is transmitted over the clutch. Once the control sequence is interrupted at step S22, the shuttle shift process of reversing direction is put on hold and the low pressure applied under step S23 is maintained.

Optionally a resume state S33 may be generated in the event a brake condition no longer applies. In one embodiment, the brake condition merely resides in whether the service brake is applied or not. In the event the service brake is applied a brake condition is present and the interrupt state will be generated. In the event the service brake is released the resume state may optionally be generated in the event an increased propulsion unit power is demanded. On detection of the resume state S33, the control of torque transmitted to the driven wheels is restarted in a step S25 by continuing the subprocess S20 for controlling the power transmitted to the driven wheels by ramping up the torque transmitted to the driven wheels.

In one embodiment, however the resume state may not be available and interruption of the control sequence will generate a termination of the shuttle shift process.

- 5 Fig. 5 shows different steps of function for performing a change of the travel direction of the working machine. The figure shows engine rpm control, output torque control and rotational speed of clutch as a function of time t . Different steps of the shuttle shift control sequence are indicated along the time line.
- 10 The engine speed may be controlled as follows.
At instant A the initial process step S00 may start the shuttle shift control sequence with the first process step S10 with execution of the step S11 of controlling the engine speed and by disengagement of the clutch at step S12. The disengagement of the clutch may take place instantaneously on request
15 or when the engine speed has been reduced.
- At the first process step S10 before entering subprocess S20 has been started, the engine rpm may be controlled to assume an engine speed threshold value n_{th} . During the subprocess S20, the engine speed may be
20 ramped up to a rotational speed n_{exit} . The rotational speed n_{exit} may preferably correspond to an engine speed requested by the driver.
The engine speed control is not necessary for the invention but may be useful to limit the power dissipated in the clutch during shuttle shift operation.
- 25 In order to achieve a fixed retardation it would be possible to have a constant pressure applied once the clutch is applied. However, in order to ascertain that the vehicle is reversed even if the vehicle is operated in downhill, it is preferred that the pressure is increased until completion of shuttle shift.
However, in order to limit the pressure at which the clutch is engaged, some
30 embodiments propose to limit the increase of the pressure by using a plurality of ramps with decreasing gradients. Alternatively it would be possible to include a regulator regulating the pressure to achieve a desired retardation and acceleration of the vehicle during shuttle shift.

Further a diagram for output torque control is shown in figure 6. The torque applied to the driven wheels before disengagement of a clutch at process step S12 is indicated at the left of the figure. The output torque is here the torque transmitted to the driven wheels via a clutch transmitting torque in an initial direction. By disengagement of the clutch at instant B by process step S12, the torque transmitted to the driven wheels will fall from the output torque to a low level. A reversal of the torque applied to the driven wheels is performed by disengagement of the clutch at step S12 and by increase of the torque transmitted to the driven wheels during the subprocess S20 controlling the power transmitted to the driven wheels. At instant C, the torque is increased via a first initial ramp R1 which generates a rapid increase out transmitted torque. In the exemplary embodiment, the torque is increased to approximately 30% of static torque output level in less than 1/6 of the time span for forced end of the engagement process. At instant D, a second ramp R2 with a slower increase rate of the torque will follow after the first ramp R1. In the exemplary embodiment, the second ramp increases to about 60% of static torque until about 2/3 of the time span for forced end of the engagement process has elapsed.

20

Once a speed difference over a clutch transmitting torque in said initial direction is less than a threshold value, it may optionally be determined that complete engagement should quickly take place, in order to reduce the amount of heat dissipated in the clutch. This may be done by sharply increasing the torque level to the static torque level at a process step S21. In the event the speed difference over the clutch does not reach the desired value for end of the engagement process, the increase of the output torque may optionally follow a third ramp, which has an even smaller increase rate than the second ramp. The third ramp preferably starts once the limitation of the engine speed no longer applies and that the engine speed is controlled by the driver.

30

If too long time has expired and the engagement is still not completed, the torque will be rapidly increased to a static torque level at the end of the time span for forced engagement. The rapid increase of the torque take place after a time window W has elapsed. Suitably the time window is extended by the
5 time Δ the shuttle shift process is put on hold in the event of application of the service brake. In figure 5, an extended time window $W + \Delta$.

Finally the rotational speed of the clutch to be engaged is denoted. At the start of the process, the incoming and outgoing parts of the clutch will rotate
10 in opposite directions, while at the end of the process they will rotate with the same speed and same direction, i.e. transmission is synchronized, due to engagement of the clutch.

It is further shown in figure 5 an interruption and a resumption of the control
15 sequence. At the instant E the operator will apply the service brake and thereby a brake condition is acknowledged. An interrupt state $S32$ is thus generated and the shuttle shift control sequence $S10$, $S20$ is interrupted in a step $S22$ and power transmitted to the driven wheels will be decreased in a step $S23$. The output torque control will reduce the torque transmitted to the
20 driven wheels such that the output power is reduced. As is seen in the figure, the output torque is preferably reduced to a level where no or an insubstantial torque is transmitted to the driven wheels. At instant F the operator releases the service brake. This leads to that a resume state $S33$ is generated and the control of torque transmitted to the driven wheels is restarted in a step $S25$ by
25 continuing the subprocess $S20$ for controlling the power transmitted to the driven wheels by ramping up the torque transmitted to the driven wheels.

The output torque is thereby quickly increased along a first ramp. The first ramp at the resumption process may be the same as the first ramp used at
30 initiation of the control sequence. The ramp may optionally continue with the same increase rate all the way up till the output torque generated at the interruption of the control sequence. In figure 5, the shift to a ramp with a slower increase rate takes place at instant G . Alternatively, the resumption of

the control sequence may be made by using the same ramps as at the start of the control sequence before interruption of the process.

It is evident that the time span for forced engagement will be extended due to the interruption of the control sequence. Such forced engagement will take
5 place at instant H1 or H2, in the event an engagement has not yet occurred.

Fig. 6 shows a diagram of the engine speed and torque transmitted to the drive wheels as a function of time. In the event the torque is controlled by a clutch, the curve showing the torque transmitted will correspond to a pressure
10 curve P having the same appearance. The process starts at time $t=0$ where a working machine is driven in a first initial direction. At instant A an operator generates a control signal indicating a desire to change direction from the first initial direction to an opposite direction. This may appropriately be done by activating a switch, for example.

15

At this instant a clutch in the initial direction may be disengaged at a process step S12 and the engine will be controlled so as to reach an engine speed threshold value during a process step S11, in the event the engine speed is above the engine speed threshold value. Disengagement of the clutch takes
20 place at instant B in figure 6. After the clutch in the initial direction has been disengaged, the control sequence continues to start applying a torque in the opposite direction. Initially, a clutch in the opposite direction is being filled to achieve contact for transfer of torque. This initial filling process is performed under step S13 and takes some time until instant C. At instant C the pressure
25 in the clutch starts to rise and the amount of torque transmitted via the clutch to the driven wheels in the opposite direction is increased along the ramp R1. The torque transmitted to the driven wheels is thus reversed under process step S12 and subprocess S20. during the subprocess S20 the torque is ramped up at a first ramp R1. The torque increases until a torque limit T_{L1} has
30 been reached, whereafter a less steep ramp R2 is applied. This takes place at instant D. The ramp R2 may continue to rise until engagement is complete or until an engine speed has reached a final threshold value set for the control

sequence. Thereafter the torque may follow a third ramp, which has a somewhat smaller increase rate.

At an instant E the operator applies the service brake and generates a brake
5 condition. The proceed state S31 is changed to an interrupt state S32. The torque transmitted to the driven wheel is thereby reduced to zero or an insignificant value. The service brake is applied until instant F. Here the brake condition is terminated. Between the instances E and F, the engine will be controlled to assume an engine speed set value.
10
A resume state S33 will be assumed at instant F. The torque transmitted to the wheels will be increased along the ramp R4. The ramp R4 may be the same as ramp R1 or be allowed to rise to a value which was applied at the interruption or to a value dependent on the torque transmitted at the
15 interruption, and possibly the time span between E and F.
At instant G the torque transmitted to the driven wheels will follow a ramp with a smaller increase rate, in the same manner as in instant D. After instant G the control sequence will continue as normally with the possibility of termination by acknowledging synchronism or near synchronism at the clutch
20 or that a time out of the process must occur for avoiding too much heat dissipation in the clutch.

It is apparent that the interrupt state can occur at any time during the process from initiation to the end by engagement of the clutch. Optionally, the resume
25 state will not be possible if too long time has passed since the interrupt state was assumed.

Fig. 7 shows a schematic drawing of a transmission. The transmission is in this example a part of a parallel axle transmission having an input shaft 6 and
30 an output shaft 8. A reverse shaft 60 is provided. The reverse shaft carries a first and a second reverse gear wheel 62, 64 being in engagement with a third and a fourth reverse gear wheels 66, 68 being arranged on the input shaft. A first and a second reverse clutch 70, 72 are provided for releasing respective

engaging the connection between the first and third reverse gear wheels 62, 66 and the second and fourth reverse gear wheels 64, 68 respectively. Naturally, further gear stages and axles may be present between the input axle and the output axle. For the principle of operation of the invention it is
5 sufficient that the gearbox provides for a first transmission path transmitting torque from the input shaft to the output shaft in one direction and a second transmission path transmitting torque from the input shaft to the output shaft in an opposite direction. In the drawing the first transmission path is indicated with an arrow 74 and the second transmission path is indicated with an arrow
10 76.

The gearbox operates in a known manner and depending on which of the clutches 70, 72 currently is engaged one of the first and second transmission paths 74, 76 will be selected for transmitting torque from the propulsion unit to
15 the driven wheels.

The transmission thus has a first direction transmission path with a first clutch, and an opposite direction transmission path with a second clutch. It is immaterial which of the first and second transmissions paths 74, 76
20 constitutes the first direction transmission path and which constitutes the opposite direction transmission path. It is however important that the respective first and second transmission paths transmit torque in opposite directions. The clutches 70, 72 allow control of torque transmission in said first and opposite transmission paths.

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The shuttle shift process is operable in both directions, from forward to reverse and vice versa.

When performing shuttle shift process according to this embodiment of the
30 invention, the transmission is initially operated with a first clutch engaged and torque is transmitted over the first direction transmission path. This may be with clutch 70 disengaged and clutch 72 engaged to drive the working

machine in the forward direction or with clutch 72 disengaged and clutch 70 engaged to drive the working machine in the rearward direction.

The shuttle shift process includes the steps of:

- 5 - to receive an input at a process step S00 indicating a desire switch to operating said transmission with said second clutch engaged and torque is transmitted over the opposite direction transmission path; and
- initiating a shuttle shift control sequence S10, S20 in which said first clutch is controlled to be released S12 in order not to transmit any torque via said
- 10 first transmission path S10 and a clutch pressure is increased during the subprocess S20 at said second clutch to allow synchronization between an input and output of said second clutch and engagement of the second clutch S20.
- 15 The control sequence is interrupted at a step S22 in the event a braking torque is applied during said shuttle shift control sequence by interrupting an increase of clutch pressure at the second clutch.

20 The clutch pressure at said second clutch may be controlled to follow a pressure curve from a low pressure corresponding to an unengaged state to a high pressure corresponding to an engaged state during the subprocess S20 of said shuttle shift control sequence.

25 The pressure curve may be allowed to drop to a low level at detection of an applied braking torque at a step S23. The low level corresponds to a pressure where no or an insubstantial torque is transmitted via the torque.

30 The pressure curve may be set to assume a maximum value at detection of synchronism of said input and output of said second clutch.

The shuttle shift control sequence be set to elapse during a time window and that said pressure curve will be set to assume a maximum value at the end of said time window regardless of whether synchronism of said input and output

of said second clutch is detected or not.

The time window may be extended as a function of the time the braking torque is applied.

5

The increase of clutch pressure may be resumed once the braking torque is released during said shuttle shift control sequence. Resumption of the shuttle shift control sequence is performed by restarting subprocess S20 of controlling the power transmitted to the driven wheels.

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The clutch pressure may be increased to a target pressure, which target pressure is dependent on the pressure before interruption of the pressure increase due to application of the braking torque, and optionally dependent on the difference of rotational speeds of the input and output of said second clutch at the release of the braking torque.

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The shuttle shift control sequence may include a pre shift stage at which said first clutch is released and the second clutch is filled.

20 The engine speed may be kept constant or set to assume a limited engine speed in the event the engine speed is above said limited engine speed during said pre shift stage.

25

The pressure curve may follow a first sharp ramp during said pre shift stage.

The shuttle shift control sequence may include an inertia stage at which said pressure curve follows a second ramp having a slower rate of increase of the pressure than said first ramp.

30 The engine speed may be ramped up during said inertia stage.

CLAIMS

- 1) A method for controlling a working machine (71) having a propulsion unit (2) for transmitting power to the driven wheels (12) of the working machine (71), the working machine (71) being provided with a shuttle shift function (3) enabling the travel direction of the working machine (12) to be changed automatically from forward to reverse and/or vice versa in accordance with a control sequence (S10,S20) without manually activating any means (70,72) for inhibiting transmission of power from the propulsion unit (2) to the driven wheels (12),
characterized by automatically decreasing (S23) the power transmitted to the driven wheels (12) and interrupting (S22) such a control sequence (S10,S20) in the event a braking torque is applied by means of a brake (15) of the working machine (71).
- 2) A method according to claim 1, **characterized by** restarting (S25) the control sequence (S20) in the event the braking torque ceases and/or an increased propulsion unit power is demanded.
- 3) A method according to claim 1 or 2, **characterized by** automatically decreasing (S23) the power transmitted to the driven wheels by releasing a clutch (70,72) arranged between the propulsion unit (2) and the driven wheels (12).
- 4) A method according to any of claims 1 – 3, **characterized by** controlling (S11) an engine speed (n) to be at or below a predetermined engine speed threshold (n_{th}) at initiation (S10) of said control sequence.
- 5) A method according to claim 4, **characterized by** disengaging a clutch (70,72) in an initial direction once the engine speed (n) is controlled (S11) to be at or below said engine speed threshold (n_{th}).

- 6) A method according to any of the preceding claims, **characterized by** reversing (S12, S20) an applied torque to the driven wheels (12) after initiation (S10) of said control sequence.
- 5 7) A method according to any of claims 4 – 6, **characterized by** ramping up (S20) an applied torque to the driven wheels (12) in the reversed direction during operation of said control sequence (S10,S20).
- 10 8) A method according to any of the preceding claims, wherein said working machine (71) includes a transmission (1) having a first direction transmission path (74) with a first clutch (72), an opposite direction transmission path (76) with a second clutch (70), said clutches (70,72) allowing control of torque transmission in said first and opposite transmission paths (74,76), wherein said transmission (1) is operated with said first clutch engaged (72) and torque is transmitted over the first direction transmission path (74), and wherein said control sequence includes the steps of:
- 15 - to receive an input at a process step (S00) indicating a desire switch to operating said transmission (1) with said second clutch (70) engaged and torque is transmitted over the opposite direction transmission path (76); and
- 20 - initiating (S10) a shuttle shift control sequence in which said first clutch (72) is controlled to be released (S12) in order not to transmit any torque via said first transmission path (74) and a clutch pressure is increased at said second clutch (70) to allow synchronization between an input and output (71, 73) of said second clutch (72) and engagement of the second clutch (72), characterized in that said control sequence (S10,S20) is interrupted (S22) in the event a braking torque is applied during said shuttle shift control sequence (S10,S20) by interrupting an increase of clutch pressure at the second clutch.
- 25 9) Method according to claim 8 characterized in that said clutch pressure at said second clutch (S72) is controlled (S20) to follow a pressure
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curve (P) from a low pressure corresponding to an unengaged state to a high pressure corresponding to an engaged state during said shuttle shift control sequence (S10,S20).

- 5 10) Method according to claim 9, characterized in that the pressure curve (P) will drop to a low level at detection of an applied braking torque.
- 10 11) Method according to claim 10, characterized in that said low level corresponds to a pressure where no or an insubstantial torque is transmitted via the torque.
- 15 12) Method according to any of claims 8 - 11, characterized in that said pressure curve (P) will be set to assume a maximum value at detection of synchronism of an input and output of said second clutch.
- 20 13) Method according to any of claims 8 - 12, characterized in that said shuttle shift control sequence (S10,S20) is set to elapse during a time window (W) and that said pressure curve (P) will be set to assume a maximum value at the end of said time window regardless of whether synchronism of said input and output of said second clutch is detected or not.
- 25 14) Method according to claim 13, characterized in that said time window (W) is extended as a function of the time Δ the braking torque is applied.
- 30 15) Method according to any of claims 8 - 17, characterized in that said increase of clutch pressure is resumed (S25) once the braking torque is released.
- 16) Method according to claim 15, characterized in that said clutch pressure is increased to a target pressure, which target pressure is dependent on the pressure before interruption of the pressure increase due to

application of the braking torque, and optionally dependent on the difference of rotational speeds of the input and output of said second clutch at the release of the braking torque.

- 5 17) Method according to any of claims 8 - 16, characterized in that said shuttle shift control sequence includes a pre shift stage (S10) at which said first clutch is released (S12) and the second clutch is filled (S13).
- 10 18) Method according to claim 17, characterized in that the engine speed is kept constant or set to assume a limited engine speed in the event the engine speed is above said limited engine speed during said pre shift stage (S10).
- 15 19) Method according to claim 18, characterized in that said pressure curve (P) follows a first sharp ramp during said pre shift stage.
- 20 20) Method according to any of claims 17 – 19, characterized in that said shuttle shift control sequence includes an inertia stage (S20) at which said pressure curve follows a second ramp having a slower rate of increase of the pressure than said first ramp.
- 25 21) Method according to claim 20, characterized in that the engine speed is ramped up during said inertia stage.
- 30 22) A working machine (72) having an propulsion unit (2) for transmitting power to the driven wheels (12) of the working machine (72), the working machine (72) being provided with a function (3) enabling the travel direction of the working machine (72) to be changed automatically from forward to reverse and/or vice versa said working machine (72) being controlled by an electronic control unit (5) enabling a control sequence (S10, S20) performing said function without manually activating any means (70, 72) for inhibiting transmission of power from the propulsion unit to the driven wheels (S12),

characterized in that said electronic control unit (S5) is arranged to automatically decrease the power transmitted to the driven wheels (S12) and interrupt such a control sequence in the event a braking torque is applied by means of a brake (17) of the working machine.

5

23) A working machine according to claim 22, **characterized in that** said electronic control unit (5) is arranged to automatically decrease the power transmitted to the driven wheels (12) by releasing (S12) a clutch (70,72) arranged between the propulsion unit and the driven wheels.

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24) A working machine according to claim 22 or 23, **characterized in that** said electronic control unit is arranged to restart (S25) the control sequence (S10,S20) in the event the braking torque ceases and/or an increased propulsion unit power is demanded.

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25) A working machine according to claim 22, 23 or 24, **characterized in that** said working machine (72) includes a transmission including a first direction transmission path (74) with a first clutch (72), an opposite direction transmission path (76) with a second clutch (70), said clutches (70,72) allowing control of torque transmission in said first and opposite transmission paths (74,76), and a controller (5) arranged to receive a control signal to selectively switch from operating said transmission with said first clutch (72) engaged and torque is transmitted over the first direction transmission path (74) to operating said transmission with said second clutch (70) engaged and torque is transmitted over the opposite direction transmission path (76), and initiate (S00) a shuttle shift control sequence (S10,S20) in which said first clutch (72) is controlled to be released (S12) in order not to transmit any torque via said first transmission path (74) and a clutch pressure is increased at said second clutch (70) to allow synchronization between an input and output of said second clutch (70) and engagement of the second clutch (70), **characterized in that** said controller (5) is arranged to interrupt (S22) said increase of clutch pressure in the event a braking torque is

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applied.

- 5 26) A working machine according to claim 25, characterized in that said controller (5) includes a pressure curve control block (7a) defining a pressure curve (P) having a pre shift state with a pressure following a first flank, a inertia state at which a pressure is increased along a second flank having a smaller differential than said first flank, and a hold state at which a braking torque is applied and at which the pressure curve assumes a low pressure transmitting no or an
- 10 insignificant torque over the second clutch.
- 27) A working machine to any of claims 22 – 26, characterized in that said controller includes functional blocks for performing the methods according to any of claims 4 – 21.

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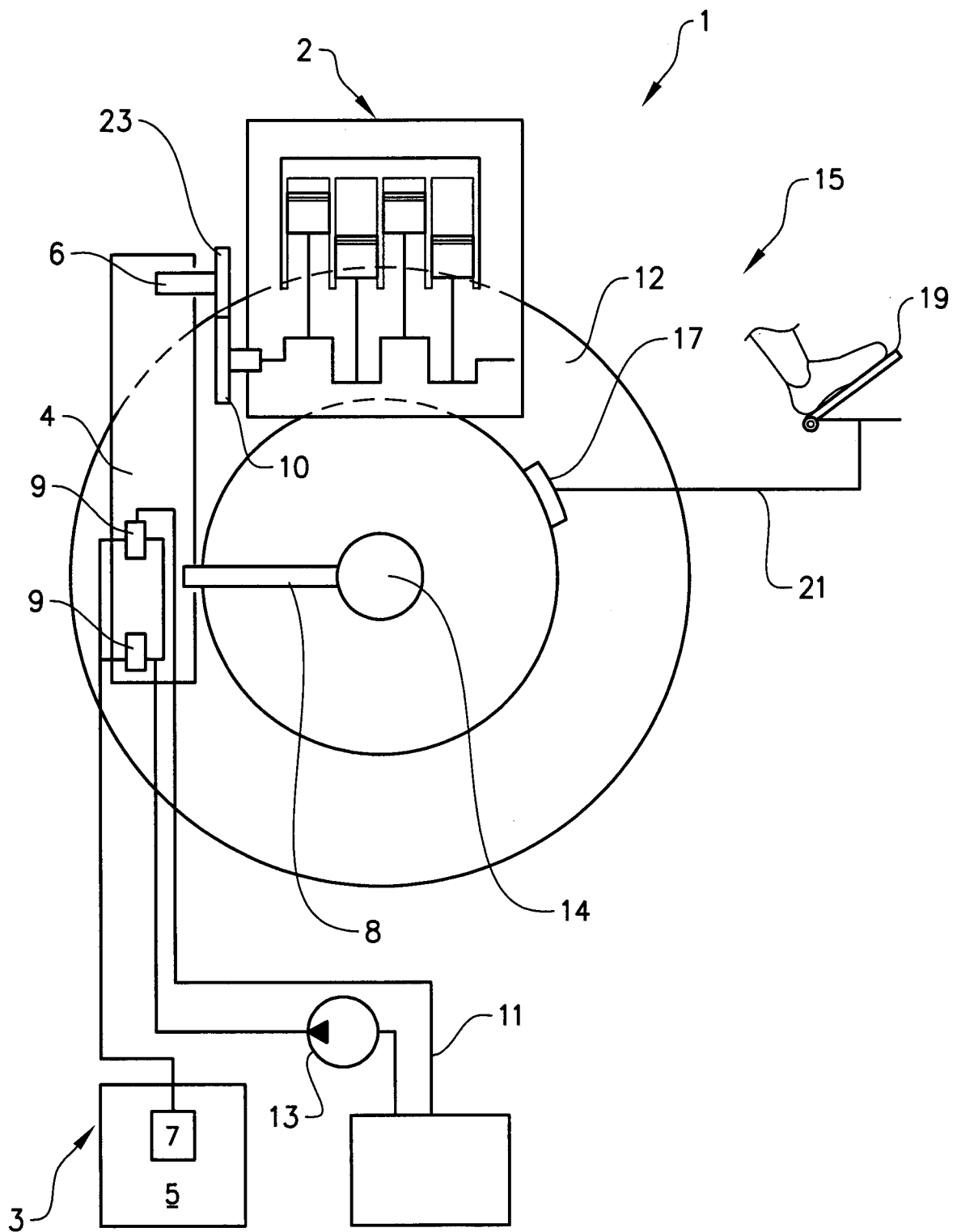


FIG. 1

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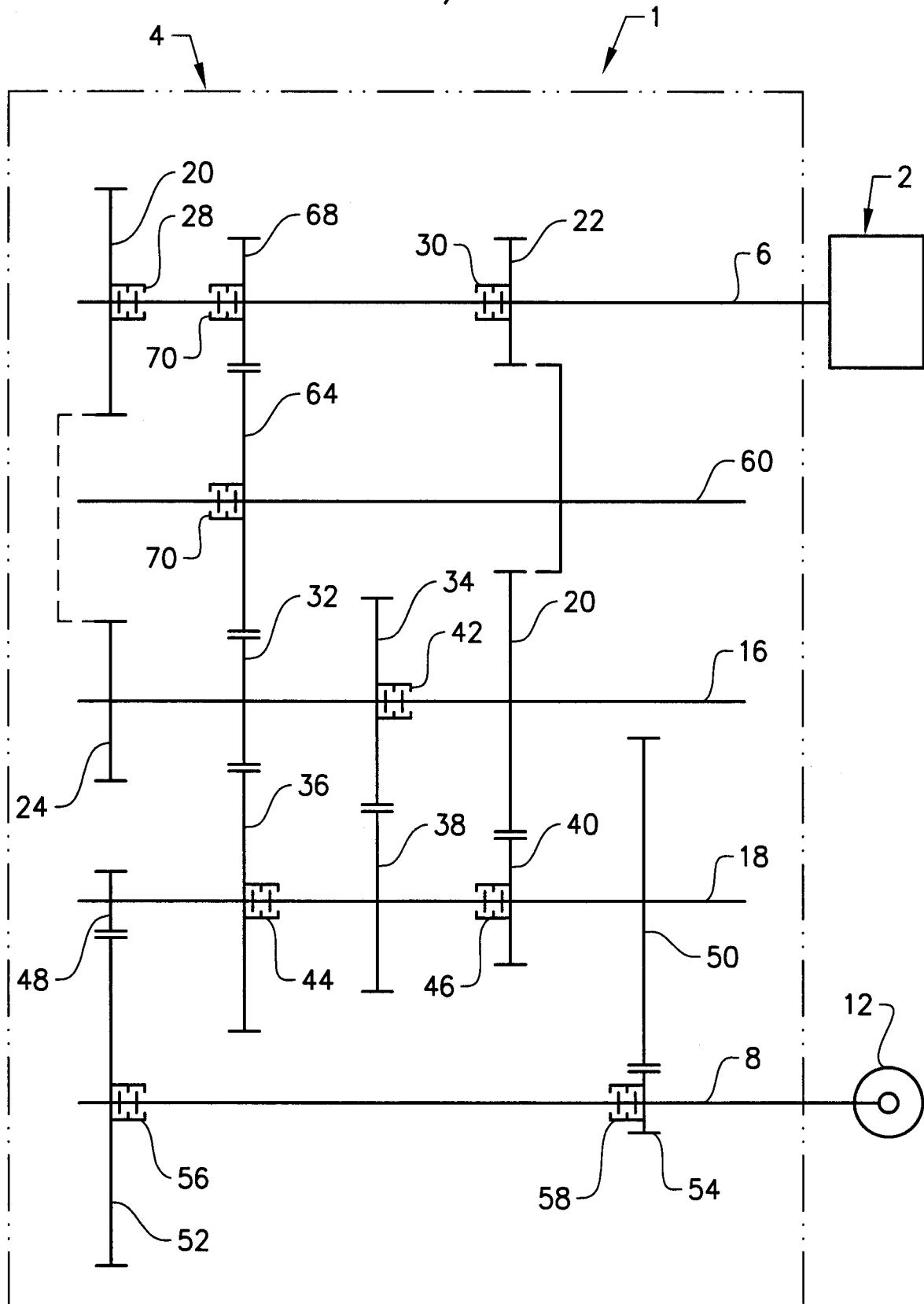


FIG. 2

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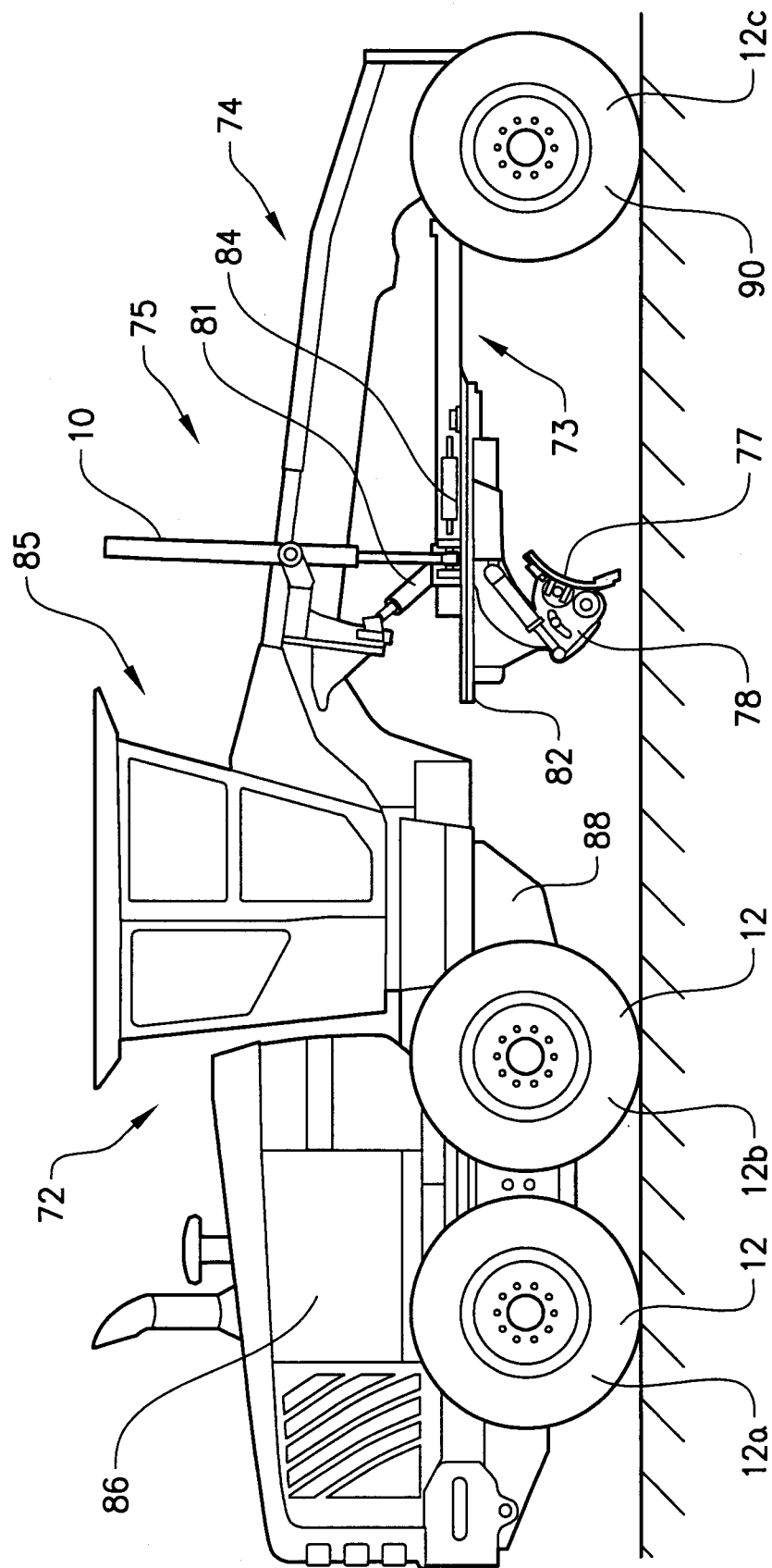


Fig. 3

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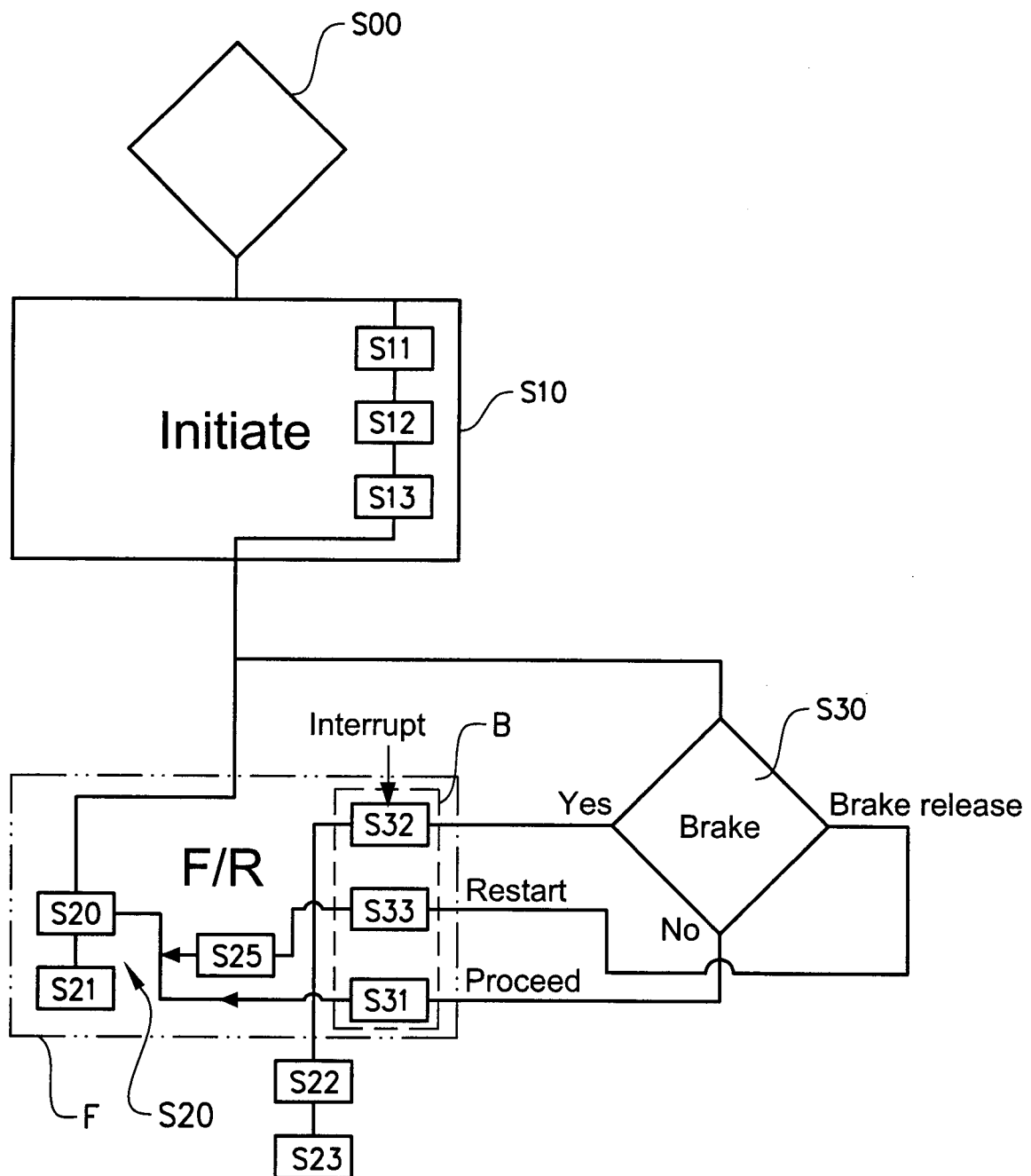


FIG. 4

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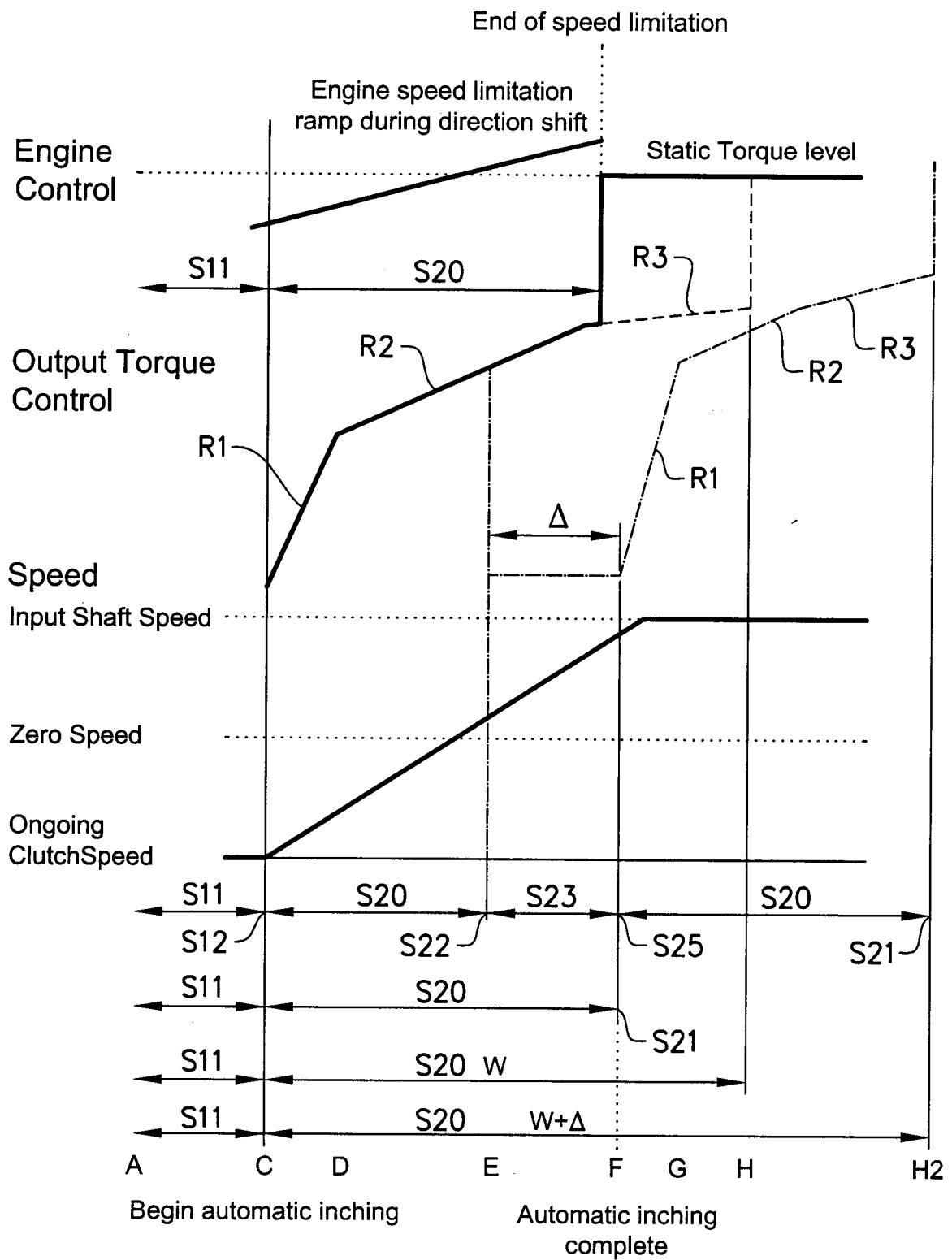


FIG. 5

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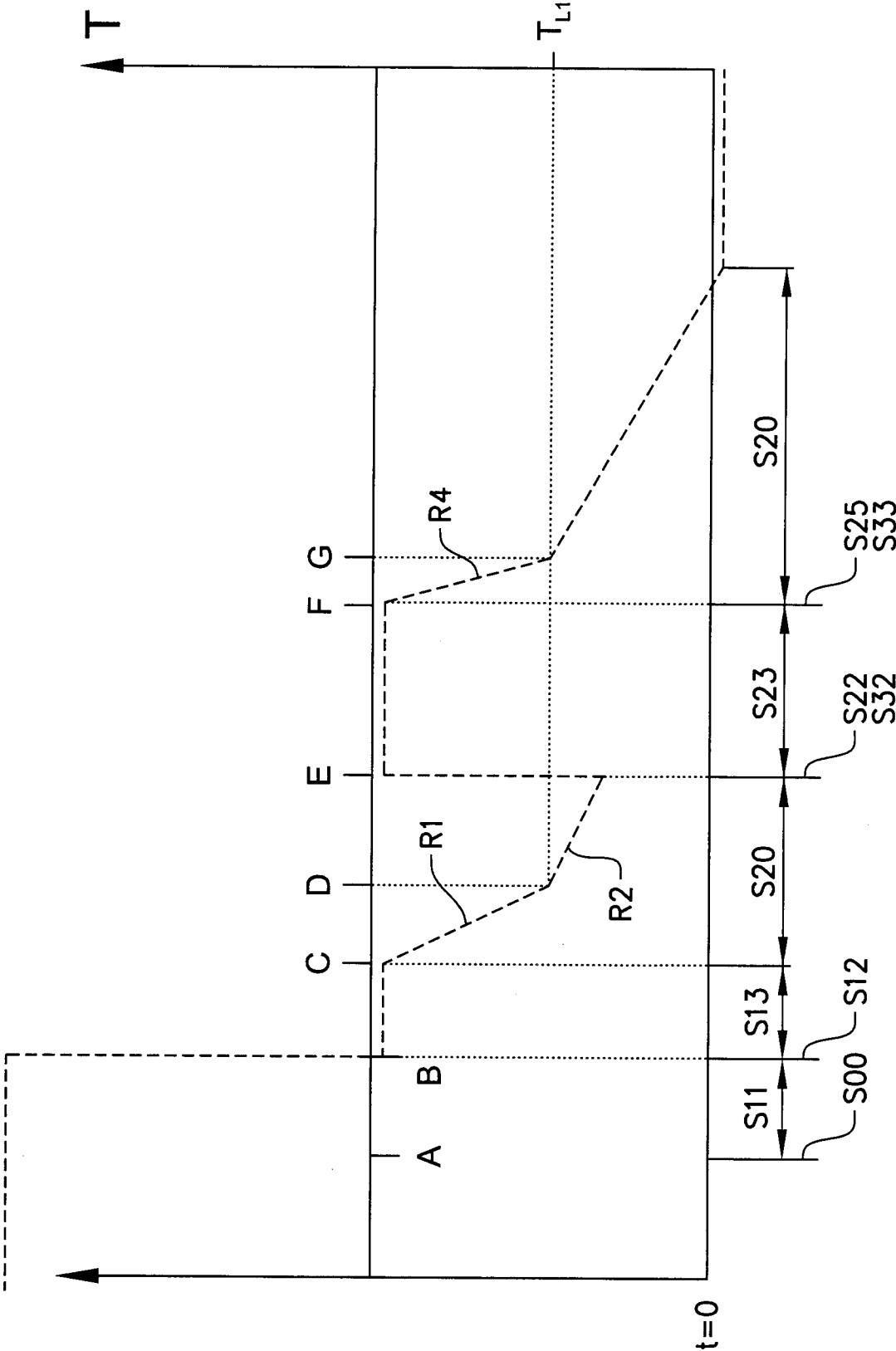


FIG. 6

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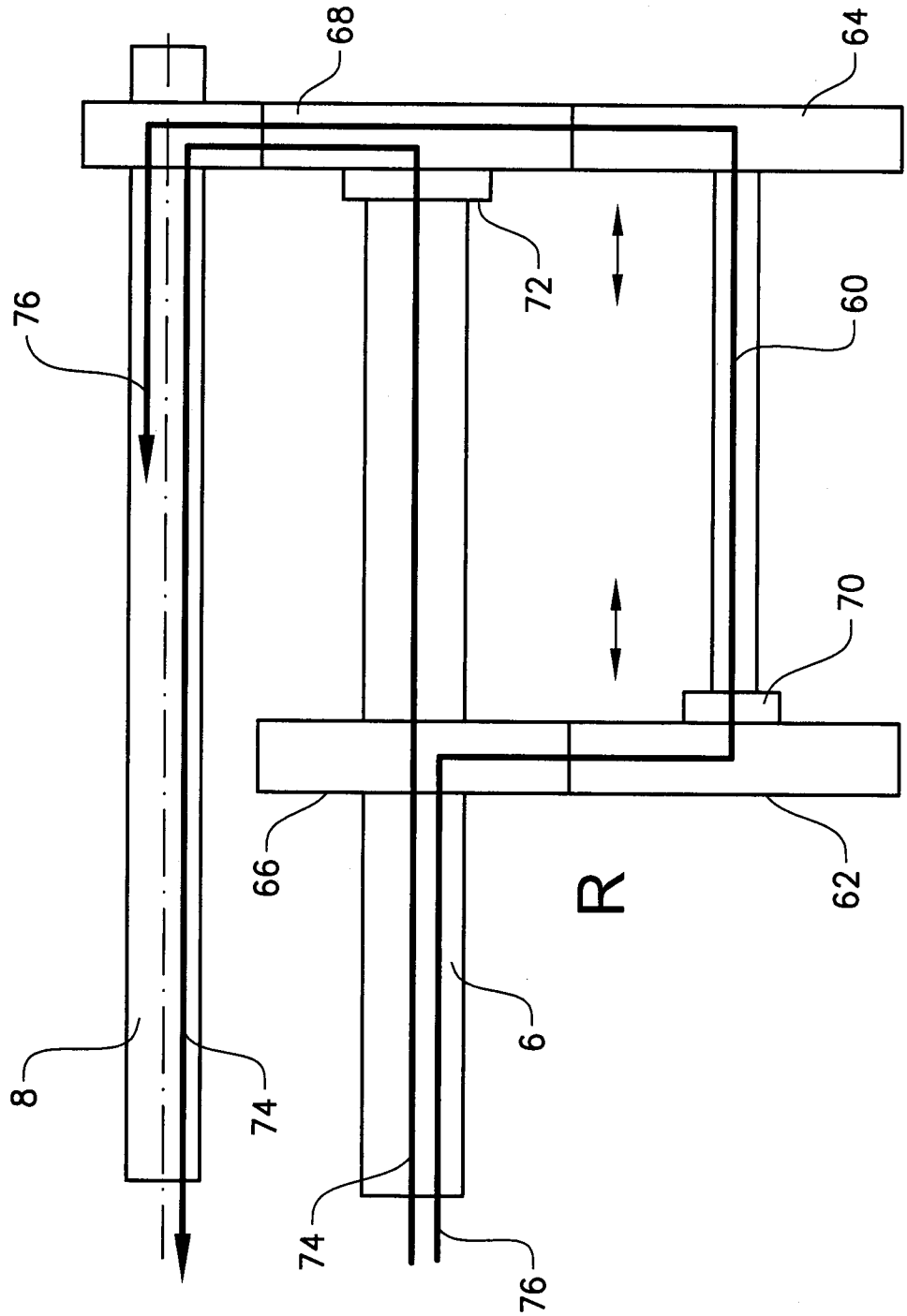


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2011/000074

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: B60T, B60W, E02F, 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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	GB 1500883 A (CATERPILLAR TRACTOR CO), 15 February 1978 (1978-02-15); page 1, line 27 - page 2, line 2 --	1-27

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

☒ See patent family annex.

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Date of the actual completion of the international search

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Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2011/000074

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Continuation of: second sheet

International Patent Classification (IPC)

F16H 59/08 (2006.01)

F16H 59/54 (2006.01)

B60W 30/18 (2006.01)

E02F 9/20 (2006.01)

F16H 61/02 (2006.01)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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