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(54) METHODS FOR CONTROLLING JERK AFTER GEAR SHIFTING IN VEHICLES, AND RELATED VEHICLES

VERFAHREN ZUR RUCKELSTEUERUNG NACH DEM SCHALTEN IN FAHRZEUGEN UND ENTSPRECHENDE FAHRZEUGE

PROCÉDÉS DE CONTRÔLE DE SECOUSSES APRÈS UN CHANGEMENT DE VITESSE DANS DES VÉHICULES ET VÉHICULES ASSOCIÉS

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Description

[0001] The present invention relates to methods for controlling in a closed loop vehicles, and related vehicles.

[0002] As known, a vehicle whose motion is controlled by an operator through input commands has a dynamic response that is influenced by jerk. As it is known, jerk is defined as the second derivative of the velocity or as the first derivative of the acceleration.

[0003] Therefore, the input commands of the operator cause a movement in the vehicle with a delay that depends on the jerk of the vehicle. In particular, an high jerk value provides an aggressive machine response, but it can cause the operator to lose control of the vehicle due to its rapid movement. On the other hand, a low jerk value allows an improved control of the vehicle by the operator, although the operation can be rather slow and performed tardy.

[0004] Moreover, in construction equipment vehicles (such as tractors, excavators, or bulldozers), powershift transmissions need control systems and procedures to preserve their integrity and avoid energy dissipation on clutches, in particular during gear shifting and shuttling (i.e., respectively, when switching gears in a transmission system and when changing vehicle direction). In fact, the clutches are severely affected by thermal heating and mechanical stress caused by gear switching when an engine shaft of the vehicle is rotating at high frequencies. In other words, when the "revolutions per minute" (RPM) of the engine are above a certain threshold (for example, above 1700rpm), gear shifting can pose serious risks to the integrity of clutches, thus resulting in an high probability of the vehicle malfunction.

[0005] Different solutions are available on the market to solve this problem. Generally, the engine speed (i.e., the engine RPM) is firstly reduced during gear shifting or shuttling, and then increased again as soon as the clutches safely close after the gear switching. The construction equipment vehicles possess an hydraulic power that allows them to perform operations such as weight lifting, trenches digging or materials shifting. Since the hydraulic power depends on the engine speed, it cannot be arbitrarily lowered. In fact, decreasing the engine speed makes the hydraulic power insufficient for carrying out the desired operations (e.g., a standard high idle of construction equipment vehicles is 2400rpm, and the reduction to 1700rpm during gear shuttling causes a decrease of about 40% of hydraulic power delivery, thus affecting the controllability of the machine and the speed of vehicle operations). In order to avoid this problem, an operator of construction equipment vehicles performs gear shifting with throttle pedal fully pressed (i.e., at max engine speed) while performing standard procedures (e.g., pick and place cycles, Y cycles, etc.), thus disregarding the clutches integrity and the feelings of the operator, that experiences high accelerations and jerks especially at low gears (i.e., when shuttling between gears having high torques, such as the first and second gears forward/reverse). This is achieved through common control systems based on open loop techniques.

[0006] US 5 233 530 relates to an engine controlling system for a vehicle which is suitable for use with an automobile.

[0007] EP 3 379 111 relates to a work vehicle exemplified by an agricultural tractor for towing a ground work machine, such as a tilling work machine or a seeding work machine, or a wheel loader for construction work.The aim of the present invention is to provide methods for controlling in a closed loop vehicles, and related vehicles that overcome the issues mentioned above.

[0008] According to the present invention, methods for controlling in a closed loop vehicles and related vehicles are provided, as defined in the annexed claims.

[0009] For a better understanding of the present invention, preferred embodiments thereof are now described in a triaxial Cartesian space defined by the reference axes X, Y and Z, purely by way of non-limiting example and with reference to the attached drawings, wherein:

- Figure 1 shows a schematic drawing of a construction equipment vehicle, according to an embodiment of the present invention;
- Figure 2 is a block diagram representing a system for shifting management, according to an embodiment of the present invention;
- Figure 3 is a functional state diagram representing the working of the system for shifting management of Figure 2, according to an embodiment of the present invention
- Figure 4 is a block diagram representing a detail of the system for shifting management of Figure 2, according to an embodiment of the present invention;
- Figure 5 is a block diagram representing a further detail of the system for shifting management of Figure 2, according to an embodiment of the present invention;
- Figure 6 is a block diagram representing a different embodiment of the detail of Figure 4;
- Figure 7 is a block diagram representing a detail of a different embodiment of the system for shifting management.

[0010] With reference to Figure 1, a construction equipment vehicle 1 (also known in the following as vehicle 1) is shown schematically, according to an embodiment of the present invention.

[0011] In the exemplarily described embodiment, the vehicle 1 includes an engine 3 operatively coupled to advancing elements 7 (such as wheels, tracks, skates or articulated supports) through a transmission 9 of known kind receiving input torque from an output shaft 4 of the engine 3. The transmission 9 includes clutches (not shown) and a plurality of gears (not shown), and is adapted to operatively couple the output shaft 4 of the engine 3 with the advancing elements 7. The transmission 9 allows gear shifting and shuttling via the clutches in order to modify the speed and the direction of the vehicle 1, according to per se known techniques. The vehicle 1 further includes: an electronic control unit 6 (which is an embedded system, such as a controller, a microcontroller or a CPU); an engine control unit 8 ("ECU", also known as engine control module), such as a controller, a microcontroller or a CPU, electrically coupled to the engine 3; and a transmission control unit 13 ("TCU"), such as a controller, a microcontroller or a CPU, electrically coupled to the transmission 9. The electronic control unit 6 and the engine control unit 8 are electrically coupled between each other, and the electronic control unit 6 is operatively coupled to the engine 3 through the engine control unit 8. The transmission control unit 13 and the electronic control unit 6 are electrically coupled between each other, and the electronic control unit 6 is operatively coupled to the transmission 9 through the transmission control unit 13. During the use of the vehicle 1, the engine control unit 8 controls the working of the engine 3 to ensure optimal engine performances, according to per se known techniques. In particular, the engine control unit 8 controls the operations of the engine 3 (e.g., injection, fumes map, exhaust temperature, etc.) based on a set-point input command (in the following, also indicated as engine rotation command ω_{eng}), according to per se known techniques. As an example, at each instant of time the engine revolutions per minute (RPM) are directly proportional to the set-point input command. On the other hand, the electronic control unit 6 (in the following, also referred to as vehicle control unit 6) acquires, during the use of the vehicle 1, measurements from a plurality of sensors coupled to the engine 3, to the output shaft 4 and/or to the transmission 9, and generates, according to the present invention, the set-point input command. In particular, the electronic control unit 6 is coupled to the transmission control unit 13 to retrieve from it the status of internal clutches present in the transmission 9, to understand when a gear shifting is completed. In fact, the transmission control unit 13 implements, in a per se known way, either an open loop or a closed loop algorithm to control the clutches position: if the current of clutches actuators is equal to, or grater than, a given value (for example 700mA), the clutches are considered fully closed, while if the current of the clutches actuators is lower than such value the clutches are considered open.

[0012] The vehicle 1 further includes at least one speed sensor 5. In the presently described embodiment, the speed sensor 5 is operatively coupled to the vehicle control unit 6 and to the transmission 9, to acquire a rotation (in details, axial rotation) of an output shaft (not shown, in the following also referred to as transmission output shaft) of the transmission 9, indicative of a vehicle ground speed v_{ground}. Considering the vehicle 1 moving on a ground, the vehicle ground speed v_{ground} is an horizontal speed (i.e., indicative of a vehicle displacement in a XY plane defined by the X axis and Y axis, thus without any vertical components of the vehicle displacement along the Z axis) of the vehicle 1 relative to the ground. According to an embodiment of the present invention, the vehicle control unit 6 calculates, during use, the vehicle ground speed v_{ground} by measuring, through the speed sensor 5, the rotation of the transmission output shaft (in the following, transmission output shaft rotation ω_{shaft}, not shown) and by processing the measured transmission output shaft rotation ω_{shaft} according to per se known techniques. According to an embodiment of the present invention, the vehicle ground speed v_{ground} is calculated according to the following expression:

$$v_{ground} = K \cdot \frac{\omega_{shaft}}{\frac{1000}{2\pi \cdot R_{dyn}} \cdot T}$$

wherein R_{dyn} is a dynamic radius of a tyre of the advancing elements 7 of the vehicle 1 (it is considered per se known to the person skilled in the art the modifications to the above expression required in case the vehicle has no tyre, e.g. for vehicles on tracks), T is an axle transmission ratio and K is a constant value (for example, depending on a number of teeth of a phonic wheel physically coupled to the speed sensor 5, and/or on a multiplication factor for correcting the vehicle ground speed v_{ground} in order to comply with safety requirements).

[0013] Moreover, the vehicle 1 comprises a throttle input device 10 (in the presently described embodiment, a throttle pedal 10) and a selector device 12, both electrically coupled to the vehicle control unit 6 and operable by an operator during the use of the vehicle 1.

[0014] As known, the throttle pedal 10 controls the vehicle ground speed based on its displacement with respect to a resting position. In particular, the vehicle control unit 6 calculates in a per se known way, based on the position of the throttle pedal 10 (throttle pedal input 24 in Figure 2), a respective throttle RPM value $\omega_{throttle}$. The throttle RPM value $\omega_{throttle}$ represents a desired value of engine RPM that is dependent on the position of the throttle pedal 10. As an example, the throttle RPM value $\omega_{throttle}$ has an amplitude that is linearly dependent with the displacement of the throttle pedal 10 with respect to its resting position.

[0015] Moreover, the selector device 12 allows the operator to select an acceleration profile (a desired acceleration target). In particular, the acceleration profile is the evolution in a time interval of the acceleration (i.e., first time derivative of the vehicle ground speed v_{ground}) of the vehicle 1. By selecting the acceleration profile, a jerk (i.e., the first time derivative of the acceleration) of the vehicle 1 is selected and defined. According to an embodiment of the present invention, the acceleration profile is a constant value in a time scale. In other words, in a biaxial Cartesian reference system having time as independent variable and acceleration as dependent variable, the acceleration profile shows a constant value of acceleration (thus having a null jerk). By selecting a value of the jerk equal to zero, the operator's driving experience is optimized and any abrupt change in the vehicle's speed is prevented. In particular, the constant value of acceleration is selected by the operator though the selector device 12 to have a minimum value (e.g., 0%), a maximum value (e.g., 100%) or, alternatively, an intermediate value (e.g., greater than 0% and lower than 100%). The intermediate value of acceleration is chosen by the operator either among a number of discrete intermediate values (for example, the value is 25%, 50% or 750) or from a continuum spectrum (where continuum spectrum has to be interpreted in the sense of a range having immediately consecutive discrete values with a small spacing, e.g., with a spacing equal to, or lower than, 1%).

[0016] According to an embodiment of the present invention, the selector device 12 is a display, such as a pen display, a touch display, an interactive display or a display operatively coupled to a keyboard, a mouse, buttons or similar devices adapted to receive input commands by the operator. During a configuration phase precedent to the use, the operator either selects the acceleration profile among a plurality of acceleration profiles stored and memorized in the display (in details, in a selector device memory included in, and/or operatively coupled to, the selector device 12, such as a nonvolatile memory) or generates the desired acceleration profile by drawing it onto the display. Optionally, the acceleration profile is selected among the plurality of stored acceleration profiles and is modified (e.g., its amplitude is decreased or increased) through the selector device 12. The operator performs the drawing of the desired acceleration profile either through a drawing element (for example, a touch pen) or manually (for example, using a finger).

[0017] According to a different embodiment of the present invention, the selector device 12 is a knob or a button, used by the operator to select the acceleration profile among a plurality of acceleration profiles stored and memorized in the selector device memory.

[0018] Moreover, the vehicle 1 comprises a direction input device (not shown). According to an embodiment of the present invention, the direction input device comprises a shuttle lever behind the steering wheel, operable by the operator to be in a first position (forward position), in a second position (neutral position) or, alternatively, in a third position (reverse position). According to another embodiment of the present invention, the direction input device comprises three pushbuttons on the joystick (to command, respectively, forward direction, neutral or reverse direction). In particular, when the direction input device is set in the first or third position, the clutches of the vehicle 1 are closed and no gear shifting occurs; when the direction input device is in second position, the clutches are opened and no gear shifting occurs; when the direction input device is shifted from one of such positions to a different one (for example, when it is moved from the second position to the first position), the clutches of the vehicle 1 are opened and the gear shifting is carried out. The transmission control unit 9 generates a clutch signal A_{clutch} whose value is dependent on the state of the direction input device; such clutch signal A_{clutch} is then acquired by the vehicle control unit 6. According to an embodiment of the present invention, the clutch signal A_{clutch} is an activation signal (digital signal) having: a high value (e.g., equal to 1) when the direction input device is shifted from one position to a different one; or a low value (e.g., equal to 0) when the clutch input device 13 is in the first, the second or the third position. Therefore, the clutch signal A_{clutch} is indicative of the state of the gear shifting.

[0019] During use, the vehicle control unit 6 computes the set-point input command (i.e., the desired operating point of the engine 3) according to an iterative and closed-loop procedure (method) implemented through a system for shifting management 20, as shown in Figure 2.

[0020] In particular, a functional state diagram of the working of the system for shifting management 20 is shown in Figure 3.

[0021] In details, during the use of the vehicle 1, the direction input device is in a given position (i.e., low value of the clutch signal A_{clutch}) and the vehicle control unit 6 is in a normal mode state S0. In the normal mode state S0, the working of the engine 3 depends on a manual request of the operator acquired through the throttle pedal 10, in a per se known way (e.g., the vehicle control unit 6 converts the throttle pedal position in a RPM command and sends it to the engine controller 8) .

[0022] When the direction input device is set by the operator from a certain position to a different position ("shifting request" in Figure 3, i.e. low value to high value of the clutch signal A_{clutch}), the vehicle control unit 6 switches in a shifting in progress state S1, wherein the clutches of the vehicle 1 are opened and the gear shifting is carried out. In the shifting in progress state S1, the working of the engine 3 is controlled by the engine control unit 8 and the vehicle control unit 6 according to techniques per se known to the skilled person. In particular, the transmission output shaft rotation ω_{shaft} depends on an automatic setpoint rotation $\omega_{automatic}$, which is a setpoint of engine RPM values automatically generated by vehicle control unit 6 in order to ensure transmission integrity according to per se known techniques. In details, the vehicle control unit 6 decreases the automatic setpoint rotation $\omega_{automatic}$ (for example, in a range of about 1700rpm to about 1750rpm), so that the transmission output shaft rotation ω_{shaft} will follow it reaching a shifting RPM value during a shifting time period, in order to safely perform the gear shifting or shuttling. In fact, shifting the gears when the transmission output shaft rotation ω_{shaft} is at the shifting RPM value ensures the clutches integrity, since the energy dissipation on the clutches is reduced and does not cause their overheating.

[0023] When the transmission control unit 13 gives the signal of clutches fully closed (i.e., high value to low value of the clutch signal A_{clutch}), the vehicle control unit 6 either switches in a shifting completed state S2 when a shifting completed condition is verified, or comes back again to the normal mode state S0 when a first normal mode condition is verified.

[0024] In the presently described embodiment, the first normal mode condition is verified if either the vehicle ground speed v_{ground} is greater than, or equal to, a ground speed threshold (e.g., equal to 20 kph) or an actual engine speed ω_{actual} (measured in RPM in a per se known way) is greater than, or equal to, the throttle RPM value $\omega_{throttle}$.

[0025] In the presently described embodiment, the shifting completed condition is verified if the clutch signal A_{clutch} moves from high to low value and the first normal mode condition is not verified (i.e., the vehicle groud speed v_{ground} is lower than the ground speed threshold and the actual engine speed ω_{actual} is lower than throttle RPM value $\omega_{throttle}$).

[0026] In the shifting completed state S2, the vehicle control unit 6 computes the set-point input command based on the selected acceleration profile, according to the system for shifting management 20 shown in Figure 2, as better described in the following.

[0027] When a second normal mode condition is verified, the vehicle control unit 6 switches from the shifting completed state S2 to the normal mode state S0. In the presently described embodiment, the second normal mode condition is verified if either the vehicle ground speed v_{ground} is greater than, or equal to, the ground speed threshold (e.g., equal to 20 kph) or the actual engine speed ω_{actual} is greater than, or equal to, the throttle RPM value $\omega_{throttle}$.

[0028] With reference to Figure 2, the system for shifting management 20 and method thereof are described.

[0029] During the real-time use of the vehicle 1 (i.e., when it is started and operating), at each iteration (e.g., iteration N) the vehicle control unit 6 acquires the throttle pedal input 24 and calculates (block 28) the throttle RPM value $\omega_{throttle}$ as previously described.

[0030] Moreover, the vehicle control unit 6 acquires the acceleration profile (also indicated in Figure 2 as acceleration profile input 22) through the selector device 12. Furthermore, the vehicle control unit 6 calculates (block 29) the vehicle ground speed v_{ground} by acquiring, through the speed sensor 5, the transmission output shaft rotation ω_{shaft}, as previously described.

[0031] The vehicle control unit 6 calculates an acceleration profile rotation $\omega_{profile}$ based on both the vehicle ground speed v_{ground} (output of the block 29) and the acceleration profile input 22. In particular, a comparing block 30 (included in, and/or implemented by, the vehicle control unit 6) receives as inputs at least both the acceleration profile input 22 ("In1" of the comparing block 30) and the ground speed v_{ground} ("In2" of the comparing block 30), and generates as an output the acceleration profile rotation $\omega_{profile}$, as better described in the following. The acceleration profile rotation $\omega_{profile}$ is a value of engine RPM dependent on, and indicative of, the acceleration profile input 22.

[0032] Moreover, the vehicle control unit 6 selects said engine rotation command ω_{eng} (i.e., the set-point input command) based on both the acceleration profile rotation $\omega_{profile}$ (output of the comparing block 30) and the throttle RPM value $\omega_{throttle}$ (output of the block 28). In particular, a command gateway 32 (included in, and/or implemented by, the vehicle control unit 6) receives as inputs at least both the throttle RPM value $\omega_{throttle}$ ("In1" of the command gateway 32) and the acceleration profile rotation $\omega_{profile}$ ("In2" of the command gateway 32), and generates as an output the engine rotation command ω_{eng} by selecting among at least the acceleration profile rotation $\omega_{profile}$ and the throttle RPM value $\omega_{throttle}$, as better described in the following.

[0033] The engine control unit 8 acquires the engine rotation command ω_{eng} from the vehicle control unit 6 and controls (block 34) the engine 3 (in particular, the engine RPM) according to per se known techniques. In detail, the engine controller 8 modifies the actual engine speed ω_{actual} according to the engine rotation command ω_{eng} (e.g., accelerating or decelerating the engine speed RPM), thereby generating an updated ground speed v_{new} of the vehicle 1.

[0034] A new iteration (e.g., iteration N+1) is therefore started, wherein the transmission output shaft rotation ω_{shaft} at iteration N+1 depends on (e.g., is equal to) the engine rotation command ω_{eng} at iteration N, and the vehicle ground speed v_{ground} at iteration N+1 depends on (e.g., is equal to) the updated ground speed v_{new} at iteration N.

[0035] In particular, the vehicle control unit 6 acquires, through the speed sensor 5, the updated ground speed v_{new} at the iteration N and provides it as a feedback signal at the iteration N+1 to the comparing block 30 (as vehicle ground speed v_{ground}, at "In2" of the comparing block 30), thus allowing to control the working of the engine 3 in a closed-loop way and starting the new iteration (iteration N+1) of the system for shifting management 20.

[0036] Figure 4 shows in further detail the comparing block 30 and its actions, implemented through the vehicle control unit 6.

[0037] In particular, the comparing block 30 receives as inputs the acceleration profile input 22, the vehicle ground speed v_{ground} and the clutch signal A_{clutch}.

[0038] The acceleration profile input 22 is set as an input to a setpoint generation block 26, which generates as an output an acceleration setpoint a_{set}. The acceleration setpoint a_{set} is a desired target acceleration value of the vehicle 1, selected from the acceleration profile input 22. According to an embodiment of the present invention, the acceleration setpoint a_{set} is selected by sampling the acceleration profile input 22 at a certain time instant (corresponding to the iteration N at issue). According to a different embodiment of the present invention, acceleration setpoint a_{set} is selected by interpolating the acceleration profile input 22 (i.e., by interpolating the values of the acceleration profile input 22) to generate an interpolated acceleration profile function, and by sampling the interpolated acceleration profile function at a certain time instant (corresponding to the iteration N at issue).

[0039] An integrator block 38 calculates as an output a speed setpoint v_{set}, by integrating the acceleration setpoint a_{set} (output of the setpoint generation block 26). In particular, a reset signal A_{reset} resets the integrator block 38 (i.e., to set the speed setpoint v_{set} to zero) when a reset condition is verified. In the presently described embodiment, the reset signal A_{reset} is a digital signal having opposite value with respect to the clutch signal A_{clutch} (i.e., the reset signal A_{reset} has an high value when the clutch signal A_{clutch} has a low value, and the reset signal A_{reset} has an low value when the clutch signal A_{clutch} has a high value) . In other words, the reset signal A_{reset} is generated as an output of a NOT gate 40, which receives as an input the clutch signal A_{clutch}. The reset condition is verified when the reset signal A_{reset} has a low value (i.e., when the direction input device is in the second position and the gear shifting is occurring). Therefore, the reset condition is verified whenever the vehicle control unit 6 is in the shifting in progress state S1, in order to reset the integrator block 38 when the gear shifting is occurring and is not yet completed.

[0040] Moreover, both the clutch signal A_{clutch} and the vehicle ground speed v_{ground} are set as inputs to a speed latching block 42, which generates as an output a stored vehicle ground speed v_{stored} when the clutch signal A_{clutch} has a low value. In detail, whenever the reset condition passes from a verification state to a non-verification state (i.e., when the clutch signal A_{clutch} passes from a high value to a low value, and the vehicle control unit 6 passes from the shifting in progress state S1 to either the normal mode state S0 or the shifting completed state S2), the vehicle ground speed v_{ground} at that time instant (i.e., at such iteration) is stored and memorized as the stored vehicle ground speed v_{stored}. As an example, the stored vehicle ground speed v_{stored} is stored in a vehicle memory (not shown, of a known type such as a RAM memory) operatively coupled to the vehicle control unit 6. Therefore, between two consecutive gear shifts (i.e., between a first shifting request and a second shifting request, the first shifting request being immediately successive to the second shifting request, where the wording "immediately successive" has to be interpreted in the sense that no further shifting request is present between the first shifting request and the second shifting request), the stored vehicle ground speed v_{stored} is the lastly stored vehicle ground speed v_{ground} (i.e., the one corresponding to the first shifting request). On the other hand, when the clutch signal A_{clutch} has a high value, the speed latching block 42 generates as an output a quantity having zero value (i.e., the stored vehicle ground speed v_{stored} equal to zero).

[0041] Both the stored vehicle ground speed v_{stored} (output of the speed latching block 42) and the speed setpoint v_{set} (output of the integrator block 38) are summed (block 44) between each other to generate a first summed speed v_{sum1}. Therefore, the stored vehicle ground speed v_{stored} is considered as an offset value of speed of the vehicle 1 that is added to the speed setpoint v_{set} (which, being the output of the integrator block 38, is periodically reset to a zero value).

[0042] The first summed speed v_{sum1} is filtered (filtering block 46) to generate a second summed speed v_{sum2}, according to per se known techniques. In particular, a low-pass filter (for example, a first order low-pass filter) is applied to the first summed speed v_{sum1} to smooth a first derivative of such speed, thus optimizing the related jerk and the operator's driving experience. In further details, the low-pass filter allows to compensate and control the effects of transitory conditions during the gear shifting and shuttling, due to the filter's exponential behaviour (i.e., having continuous derivative at each order of derivation). In the presently described embodiment, the low-pass filter of the filtering block 46 is implemented through a feedback circuit: the first summed speed v_{sum1} (input of the filtering block 46) is amplified, integrated and both set as the output of the filtering block 46 (the second summed speed v_{sum2}) and subtracted to the first summed speed v_{sum1} as a further input of the filtering block 46 (thus realizing a closed-loop with negative feedback).

[0043] The vehicle ground speed v_{ground} is subtracted (block 48) to the second summed speed v_{sum2} (output of the filtering block 46) to calculate a following error e_{follow}. The following error e_{follow} is therefore the difference (the error) between the second summed speed v_{sum2} and the vehicle ground speed v_{ground}.

[0044] The following error e_{follow} (an error in speed) is processed (error compensator block 50) according to per se known error compensation techniques, to calculate an engine RPM error e_{engine} (an error in engine rotation). The processing of the error compensator block 50 allows to generate the engine RPM error e_{engine} based on both the following error e_{follow} and a set of further information. Such set of further information (being, for example, outputs of a number of sensors further coupled to the engine control unit 8 and adapted to acquire quantities indicative of a state of the vehicle 1) allows to take into account the state of the vehicle 1 (such as the vehicle 1 performing an uphill or a downhill, carrying a load or travelling on a steep terrain), and to influence the working of the engine 3 accordingly.

[0045] Moreover, the second summed speed v_{sum2} is feed-forwarded (feed-forward block 52) to associate, according to per se known techniques, to the second summed speed v_{sum2} a respective value of engine RPM rotation (in the following, feed-forward engine rotation command $\omega_{feedforward}$), which is set as an output of the feed-forward block 52. According to an embodiment of the present invention, the block 52 is a tridimensional lookup table adapted to generate as an output a desired value of RPM (the feed-forward engine rotation command $\omega_{feedforward}$) according to the actual vehicle speed setpoint and the actual engaged gear (i.e., the actual transmission ratio), according to per se known techniques. According to another embodiment, the block 52 implements an experimental mathematical expression to compute the feed-forward engine rotation command $\omega_{feedforward}$ according to actual vehicle operating conditions (such as gear ratio, vehicle speed setpoint, engine torque, etc.), according to per se known techniques.

[0046] The feed-forward engine rotation command $\omega_{feedforward}$ is summed (block 54) to the engine RPM error e_{engine} (output of the error compensator block 50) to calculate a summed engine rotation command ω_{sum}, which is set as an output of the block 54. As an instance, the error compensator block 50 is implemented by a proportional-integrative-derivative controller (PID) of per se known type.

[0047] The summed engine rotation command ω_{sum} (output of the block 54) is further processed (saturation block 56) to calculate the acceleration profile rotation $\omega_{profile}$. In particular, the acceleration profile rotation $\omega_{profile}$ is calculated by saturating the summed engine rotation command ω_{sum} to pre-defined engine rotation values, in a per se known way. In details, different ranges of summed engine rotation command ω_{sum} are associated to different values of acceleration profile rotation $\omega_{profile.}$

[0048] Figure 5 shows in further detail the command gateway 32 and its actions (implemented through the vehicle control unit 6) according to an embodiment of the present invention.

[0049] In particular, the command gateway 32 receives as inputs the clutch signal A_{clutch}, the throttle RPM value $\omega_{throttle}$, the actual engine speed ω_{actual}, the vehicle ground speed v_{ground}, the automatic setpoint rotation $\omega_{automatic}$ and the acceleration profile rotation $\omega_{profile}$, and generates as an output the engine rotation command ω_{eng} (to be set as input to the engine controller 8). Optionally, the command gateway 32 receives as a further input a threshold ground speed $v_{groundth}$ from the vehicle memory.

[0050] A command selector block 60 (included in the command gateway 32) receives as inputs the clutch signal A_{clutch}, the throttle RPM value $\omega_{throttle}$, the actual engine speed ω_{actual} and, optionally, the vehicle ground speed v_{ground} and the threshold ground speed $v_{groundth}$, and generates a gateway signal $A_{gateway}$ based on said received inputs. In particular, when the direction input device is in one of the abovementioned positions (i.e., low value of the clutch signal A_{clutch}), the gateway signal $A_{gateway}$ has a first value and the vehicle control unit 6 is set in the normal mode state S0. When the direction input device is set by the operator in a different position ("shifting request" in Figure 3, i.e. low value to high value of the clutch signal A_{clutch}), the gateway signal $A_{gateway}$ has a second value and the vehicle control unit 6 is set in the shifting in progress state S1. When the transmission control unit 13 recognises the clutches as fully closed (i.e., high value to low value of the clutch signal A_{clutch}) and the shifting completed condition is verified, the gateway signal $A_{gateway}$ has a third value and the vehicle control unit 6 is set in the shifting completed state S2. When the transmission control unit 13 recognises the clutches as fully closed (i.e., high value to low value of the clutch signal A_{clutch}) and the first normal mode condition is verified, the gateway signal $A_{gateway}$ has the first value and the vehicle control unit 6 is set in the normal mode state S0.

[0051] Moreover, the threshold ground speed $v_{groundth}$ is a threshold value of the vehicle ground speed v_{ground}, used as a calibration value to trigger an escape condition (e.g., $v_{ground} > v_{groundth}$) which sets the vehicle control unit 6 back to normal mode S0.

[0052] A gateway multiplexer 62 receives as inputs the throttle RPM value $\omega_{throttle}$, the automatic setpoint rotation $\omega_{automatic}$ and the acceleration profile rotation $\omega_{profile}$, and generates as an output the engine rotation command ω_{eng}. In particular, the gateway multiplexer 62 further receives as input command the gateway signal $A_{gateway}$, and sets the engine rotation command ω_{eng} equal to: the throttle RPM value $\omega_{throttle}$ when the gateway signal $A_{gateway}$ has the first value (P0 in Figure 5); the automatic setpoint rotation $\omega_{automatic}$ when the gateway signal $A_{gateway}$ has the second value (P1 in Figure 5); the acceleration profile rotation $\omega_{profile}$ when the gateway signal $A_{gateway}$ has the third value (P2 in Figure 5). Optionally, the gateway multiplexer 62 sets the engine rotation command ω_{eng} equal to the throttle RPM value $\omega_{throttle}$ when the value of the gateway signal $A_{gateway}$ is different from the first, the second or the third value (P3 in Figure 5).

[0053] From what has been described and illustrated previously, the advantages of the present invention are evident.

[0054] The system for shifting management 20 allows to improve the operator's feelings by controlling, in closed loop, the shape of the vehicle ground acceleration during gear shifting. In particular, the operator can manually set a preferred jerk, so that the ramping up phase of the engine 3 after gear shifting is smoother and less abrupt than in the vehicles actually on the market. Moreover, the operator can either choose the preferred acceleration profile among a plurality of memorized acceleration profiles or draw it manually, so that a full customization of the aggressiveness of the acceleration profile is achieved. Furthermore, the operator can change the behaviour of the vehicle 1 in run-time to accomplish different tasks (such as y cycles, road traveling, material handling, silaging, rough transportation and pick and place).

[0055] The system for shifting management 20 allows to perform repeatable operations and to reduce the energy dissipation on clutches, in order to increase the longevity of both the transmission 9 and the output shaft 4 of the engine 3. Moreover, it allows the possibility to minimize the impact of wear (e.g., clutches wear) upon machine performance and operator feeling because of its closed loop algorithm. In fact, it adapts the engine rpm request in order to perform always the same manoeuvres despite of hardware variability of the transmission 9. Furthermore, it allows to minimize the impact of environmental condition on machine performances and operator comfort. As instance, the low temperature makes the transmission system slower: the vehicle control unit 6 adapts the rpm command according actual transmission response (i.e., it increases the rpm command to speed up the response, or it decreases the rpm command to slow it down).

[0056] The acceleration profile is continuously interpolated in the setpoint generation block 26, to ensure a full continuous signal and a full continuous first derivative of such signal. This allows to continuously control the jerk of the vehicle 1.

[0057] Finally, it is clear that modifications and variations may be made to what has been described and illustrated herein, without thereby departing from the scope of the present invention, as defined in the annexed claims.

[0058] In particular, if a mechanical engine is installed on the vehicle 1, a further speed sensor is additionally coupled to the transmission output shaft to measure its rotation. This solution allows therefore to consider and treat the overall mechanical system as a fully electronic system, as the one previously described.

[0059] Figure 6 and Figure 7 show respective further embodiments of the comparing block 30 (comparing block 130 in Figure 6, and comparing block 230 in Figure 7). In the following, blocks and elements already described with reference to the previous Figures are indicated with the same reference numerals and they are not further described, while new blocks and elements related to what previously described are indicated either with the respective reference numeral increased of 100 unities or with superscripts.

[0060] With reference to Figure 6, the comparing block 130 implements a control in acceleration (not part of the present invention), rather than in velocity as shown in Figure 4.

[0061] In particular, an accelerometer (not shown in Figure 1) is operatively coupled to the vehicle control unit 6 and to the transmission 9 to acquire, according to per se known techniques, the transmission output shaft rotation ω_{shaft} indicative of a vehicle ground acceleration a_{ground} (first time derivative of the vehicle ground speed v_{ground}; indicated in Figure 2 as an alternative embodiment to the vehicle ground speed v_{ground}) .

[0062] The vehicle ground acceleration a_{ground} is subtracted (block 148) to the acceleration setpoint a_{set} (output of the setpoint generation block 26) to calculate the following error e'_{follow}.

[0063] The following error e'_{follow} (an error in acceleration) is processed (error compensator block 150) according to per se known error compensation techniques, to calculate the engine RPM error e'_{engine} (an error in engine rotation) based on both the following error e'_{follow} and the set of further information. In details, the error compensator block 150 is activated by the clutch signal A_{clutch} (in particular, when the clutch signal A_{clutch} has high value.

[0064] Moreover, the acceleration setpoint a_{set} (output of the setpoint generation block 26) is feed-forwarded (feed-forward block 152) to associate, according to per se known techniques, the feed-forward engine rotation command $\omega'_{feedforward}$ to the acceleration setpoint a_{set}.

[0065] The feed-forward engine rotation command $\omega'_{feedforward}$ is summed (block 154) to the engine RPM error e'_{engine} (output of the error compensator block 150) to calculate the summed engine rotation command ω'_{sum}, which is set as an output of the block 154.

[0066] The summed engine rotation command ω'_{sum} (output of the block 154) is further processed (saturation block 156) to calculate the acceleration profile rotation $\omega'_{profile}$, by saturating the summed engine rotation command ω'_{sum} to pre-defined engine rotation values, in a per se known way.

[0067] With reference to Figure 7, the comparing block 230 implements an open-loop control (not part of present invention). In fact, no feedback control in vehicle ground speed v_{ground} (or in vehicle ground acceleration a_{ground}) is carried out.

[0068] In particular, the transmission output shaft rotation ω_{shaft} is acquired either through a direct measure performed by the speed sensor 5, or in an indirect way (e.g., using an accelerometer or an Inertial Mass Unit, IMU, upon the vehicle frame) according to per se known techniques.

[0069] Both the clutch signal A_{clutch} and the transmission output shaft rotation ω_{shaft} are set as inputs to a rotation latching block 242, which generates as an output a stored rotation ω''_{stored} when the clutch signal A_{clutch} has a low value. In detail, when the clutch signal A_{clutch} passes from a high value to a low value and the engine 3 passes from the shifting in progress state S1 to either the normal mode state S0 or the shifting completed state S2, the transmission output shaft rotation ω_{shaft} at that time instant (i.e., at such iteration) is stored and memorized as the stored rotation ω''_{stored} in the vehicle memory. On the other hand, when the clutch signal A_{clutch} has a high value, the rotation latching block 242 generates as an output a quantity having zero value (i.e., the stored rotation ω''_{stored} is equal to zero).

[0070] The speed setpoint v_{set} (output of the integrator block 38) is processed (block 265) to associate to such value, according to per se known techniques, a respective rotation setpoint ω''_{set} (as already described with reference to the feed-forward engine rotation command $\omega_{feedforward}$).

[0071] Both the stored rotation ω''_{stored} (output of the rotation latching block 242) and the rotation setpoint ω''_{set} (output of the block 265) are summed (block 254) between each other to calculate the summed engine rotation command ω''_{sum}, which is set as an output of the block 254.

[0072] The summed engine rotation command ω''_{sum} (output of the block 254) is further processed (saturation block 256) to calculate the acceleration profile rotation $\omega''_{profile}$, by saturating the summed engine rotation command ω''_{sum} to pre-defined engine rotation values, in a per se known way.

[0073] Furthermore, the operator can select one acceleration profile per each gear of the transmission 9, to further customize the reaction of the vehicle 1 to gear shifting.

[0074] According to a variant of the present invention, the system for shifting management 20 is implemented through a dedicated control unit electrically coupled to the engine 3 to control it.

[0075] According to a further variant of the present invention, the setpoint generation block 26 (and, when present, the integrator block 38 and the NOT gate 40) is not comprised in the comparing block 30 (nor, analogously, in the comparing block 130 or in the comparing block 230). The comparing block 30 is therefore modified accordingly in a per se known way to the person skilled in the art (in particular, the comparing blocks 30, 130, 230 receive as an input the speed setpoint v_{set}).

[0076] According to an embodiment of the present invention, the vehicle control unit 6 and the engine control unit 8 are comprised in a unique control unit (not shown).

[0077] Moreover, according to the present invention, the vehicle 1 is a work vehicle (such as a tractor).

Claims

1. Method (20) for controlling in a closed loop a work vehicle (1) operable by an operator, the work vehicle (1) including:

an engine (3) having an output shaft (4) operatively coupled through a transmission (9) to wheels or tracks (7) of the work vehicle (1),
a control unit (6) operatively coupled to the engine (3),
a sensor (5) operatively coupled to the control unit (6),
a selector device (12) electrically coupled to the control unit (6) and configured to permit the operator to select or define an acceleration profile (22), and
a throttle input device (10) coupled to the control unit (6) and operable by the operator during use of the work vehicle (1),
the method comprising the steps of:

- acquiring, by the control unit (6), a ground speed (v_{ground}) of the work vehicle (1) through the sensor (5);
- generating (28), by the control unit (6), a throttle engine rotation command ($\omega_{throttle}$) indicative of a desired value of engine revolutions per minute, RPM, that depends on a position of the throttle input device (10);
- acquiring, by the control unit (6), the acceleration profile (22) through the selector device (12);
- generating (26, 38), by the control unit (6), a setpoint quantity (v_{set}) based on the acceleration profile (22);
- generating (30), by the control unit (6), a profile engine rotation command ($\omega_{profile}$) based on both the setpoint quantity (v_{set}) and the ground speed (v_{ground})
- generating (32), by the control unit (6), an engine rotation command (ω_{eng}) by selecting among at least the profile engine rotation command ($\omega_{profile}$) and the throttle engine rotation command ($\omega_{throttle}$); and
- controlling the engine (3) based on the generated engine rotation command (ω_{eng}), thereby updating the ground speed (v_{ground}) of the work vehicle (1),

wherein the step of generating (26, 38) the setpoint quantity (v_{set}) comprises the steps of:

sampling (26) the acceleration profile (22) at a certain time instant to generate an acceleration setpoint; and
generating (38) a speed setpoint by integrating the acceleration setpoint, the speed setpoint being the setpoint quantity (v_{set}).

2. Method according to claim 1, wherein the step of generating (30) the profile engine rotation command ($\omega_{profile}$) comprises the steps of:

calculating (44, 46) a summed speed (v_{sum2}) by summing the setpoint quantity (v_{set}) and an offset speed (v_{stored});
associating (52) to the summed speed (v_{sum2}) a respective feedforward engine rotation command ($\omega_{feedforward}$);
calculating (48, 50) an engine rotation error command (e_{engine}) based on both the ground speed (v_{ground}) and the summed speed (v_{sum2}) ; and
generating (54, 56) the profile engine rotation command ($\omega_{profile}$) by modifying the feedforward engine rotation command ($\omega_{feedforward}$) based on the engine rotation error command (e_{engine}) .

3. Method according to claim 2, wherein the step of calculating (44, 46) the summed speed (v_{sum2}) comprises the steps of:

summing (44) the setpoint quantity (v_{set}) and the offset speed (v_{stored}) to generate a first summed speed (v_{sum1}); and
generating (46) the summed speed (v_{sum2}) by filtering the first summed speed (v_{sum1}).

4. Method according to anyone of claims 2-3, wherein the step of calculating (48, 50) the engine rotation error command (e_{engine}) comprises the steps of:

comparing (48) the ground speed (v_{ground}) with the summed speed (v_{sum2}) to calculate a following rotation error command (e_{follow}); and associating (50) to the following rotation error command (e_{follow}) the engine rotation error command (e_{engine}) .

5. Method according to anyone of claim 2-4, wherein the step of generating (54, 56) the profile engine rotation command ($\omega_{profile}$) comprises the steps of:

generating (54) a summed engine rotation command (ω_{sum}) by summing the feedforward engine rotation command ($\omega_{feedforward}$) and the engine rotation error command (e_{engine}); and saturating (56) the summed engine rotation command (ω_{sum}) to generate the profile engine rotation command ($\omega_{profile}$).

6. Method according to anyone of claim 2-5, further comprising the step of storing (42) the ground speed (v_{ground}) when a gear shifting occurs, the offset speed (v_{stored}) being the last stored ground speed (v_{ground}) between two consecutive gear shiftings.

7. Method according to anyone of the preceding claims, wherein the step of generating (32) the engine rotation command (ω_{eng}) comprises the steps of: generating (60) a gateway command ($A_{gateway}$) based on the throttle engine rotation command ($\omega_{throttle}$), an actual engine speed (ω_{actual}), and a clutch signal (A_{clutch}) indicative of gear shifting, wherein the gateway command ($A_{gateway}$) has:

- a first value (P0) when the clutch signal (A_{clutch}) has a first value, or when the clutch signal (A_{clutch}) passes from a second value to the first value and a first normal mode condition is verified, the first normal mode condition being verified if either the ground speed (v_{ground}) is greater than, or equal to, a ground speed threshold or the actual engine speed (ω_{actual}) is greater than, or equal to, the throttle engine rotation command ($\omega_{throttle}$);
- a second value (P1) when the clutch signal (A_{clutch}) passes from the first value to the second value;
- a third value (P2) when the clutch signal (A_{clutch}) passes from the second value to the first value and a shifting completed condition is verified, the shifting completed condition being verified if the clutch signal (A_{clutch}) passes from the second value to the first value and the first normal mode condition is not verified; and selecting (62) as the engine rotation command (ω_{eng}), based on the gateway command ($A_{gateway}$), one among the throttle engine rotation command ($\omega_{throttle}$), the profile engine rotation command ($\omega_{profile}$) and an automatic shifting engine rotation command ($\omega_{automatic}$), wherein the engine rotation command (ω_{eng}) is equal to:
- the throttle engine rotation command ($\omega_{throttle}$) when the gateway command ($A_{gateway}$) has the first value (P0);
- the automatic shifting engine rotation command ($\omega_{automatic}$) when the gateway command ($A_{gateway}$) has the second value (P1);
- the profile engine rotation command ($\omega_{profile}$) when the gateway command ($A_{gateway}$) has the third value (P2) .

8. Method according to anyone of the preceding claims, wherein the step of acquiring the acceleration profile comprises either the step of generating, through a display (12), the acceleration profile, or the step of selecting, through the display (12) operatively coupled to a memory, one acceleration profile among a plurality of acceleration profiles stored in the memory.

9. Method according to anyone of claims 1-7, wherein the step of acquiring the acceleration profile comprises the step of selecting, through a knob or a button (12), one acceleration profile among a plurality of acceleration profiles stored in the memory.

10. Work vehicle (1) operable by an operator and including:

an engine (3) having an output shaft (4) operatively coupled trough a transmission (9) to wheels or tracks (7) of the work vehicle (1),
a control unit (6) and an engine control unit (8), operatively coupled one another and to the engine (3), and configured to control the work vehicle (1) in a closed loop,
a sensor (5) operatively coupled to the control unit (6) and configured to acquire a ground speed (v_{ground}) of the work vehicle (1),
a throttle input device (10) electrically coupled to the control unit (6) and operable by the operator during use of the work vehicle (1), and
a selector device (12) electrically coupled to the control unit (6) and configured to permit the operator to select or define an acceleration profile (22),
wherein the control unit (6) is configured to:

- acquire the ground speed (v_{ground}) of the work vehicle (1) through the sensor (5);
- generate (28) a throttle engine rotation command ($\omega_{throttle}$) indicative of a desired value of engine revolutions per minute, RPM, that depends on a position of the

throttle input device (10);
- acquire the acceleration profile (22) through the selector device (12);
- generate (26, 38) a setpoint quantity (v_{set}) based on the acceleration profile (22);
- generate (30) a profile engine rotation command ($\omega_{profile}$) based on both the setpoint quantity (v_{set}) and either the ground speed (v_{ground}); and
- generate (32) an engine rotation command (ω_{eng}) by selecting among at least the profile engine rotation command ($\omega_{profile}$) and the throttle engine rotation command ($\omega_{throttle}$), and

wherein the engine control unit (8) is configured to control the engine (3) based on the generated engine rotation command (ω_{eng}), thereby updating the ground speed (v_{ground}) of the work vehicle (1),
wherein generating (26, 38) the setpoint quantity (v_{set}) comprises:

sampling (26) the acceleration profile (22) at a certain time instant to generate an acceleration setpoint; and
generating (38) a speed setpoint by integrating the acceleration setpoint, the speed setpoint being the setpoint quantity (v_{set}).

Patentansprüche

1. Verfahren (20) zum Steuern eines Arbeitsfahrzeugs (1) mittels eines geschlossenen Regelkreises, das von einem Benutzer bedienbar ist, wobei das Arbeitsfahrzeug (1) umfasst:

einen Motor (3) mit einer Ausgangswelle (4), die wirkend über ein Getriebe (9) mit Rädern oder Ketten (7) des Arbeitsfahrzeugs (1) verbunden ist,
eine Steuereinheit (6), die wirkend mit dem Motor (3) gekoppelt ist,
einen Sensor (5), der wirkend mit der Steuereinheit (6) gekoppelt ist,
eine Wähleinrichtung (12), die elektrisch mit der Steuereinheit (6) gekoppelt ist und die dazu eingerichtet ist, dem Benutzer zu ermöglichen, ein Beschleunigungsprofil (22) auszuwählen oder zu definieren, und
eine Fahrhebeleingabevorrichtung (10), die mit der Steuereinheit (6) gekoppelt und die von dem Benutzer während der Benutzung des Arbeitsfahrzeugs (1) bedienbar ist,
wobei das Verfahren des Weiteren folgende Schritte aufweist:

- Erfassen einer Bodengeschwindigkeit (v_{ground}) des Arbeitsfahrzeugs (1) durch den Sensor (5) mittels der Steuereinheit (6);
- Erzeugen (28) eines Fahrhebel-Motorrotationsbefehls ($\omega_{throttle}$), der kennzeichnend für einen Sollwert an Motorumdrehungen pro Minute, U/MIN, und der abhängig von einer Position der Fahrhebeleingabevorrichtung (10) ist, mittels der Steuereinheit (6);
- Erfassen des Beschleunigungsprofils (22) über die Wähleinrichtung (12) mittels der Steuereinheit (6);
- Erzeugen (26, 38) einer Sollwertgröße (v_{set}) basierend auf dem Beschleunigungsprofil (22) mittels der Steuereinheit (6);
- Erzeugen (30) eines Profil-Motorrotationsbefehls ($\omega_{profile}$) basierend auf beiden aus der Sollwertgröße (v_{set}) und der Bodengeschwindigkeit (v_{ground}) mittels der Steuereinheit (6);
- Erzeugen (32) eines Motorrotationsbefehls (ω_{eng}) durch Auswählen zumindest des Profil-Motorrotationsbefehls ($\omega_{profile}$) und des Fahrhebel-Motorrotationsbefehls ($\omega_{throttle}$) mittels der Steuereinheit (6); und
- Steuern des Motors (3) basierend auf dem erzeugten Motorrotationsbefehl (ω_{eng}), wodurch die Bodengeschwindigkeit (v_{ground}) des Arbeitsfahrzeugs (1) aktualisiert wird,

wobei der Schritt des Erzeugens (26, 38) der Sollwertgröße (v_{set}) die Schritte aufweist:

Abtasten (26) des Beschleunigungsprofils (22) zu einem bestimmten Zeitpunkt, um einen Beschleunigungssollwert zu erzeugen; und
Erzeugen (38) eines Geschwindigkeitssollwerts durch Integrieren des Beschleunigungssollwerts, wobei der Geschwindigkeitssollwert die Sollwertgröße (v_{set}) ist.

2. Verfahren nach Anspruch 1, wobei der Schritt des Erzeugens (30) des Profil-Motorrotationsbefehls ($\omega_{profile}$) folgende Schritte aufweist:

Berechnen (44, 46) einer summierten Geschwindigkeit (v_{sum2}) durch Aufsummieren der Sollwertgröße (v_{set}) und einer Kompensationsgeschwindigkeit (v_{stored});
Zuordnen (52) eines entsprechenden Vorwärts-Motorrotationsbefehls ($\omega_{feedfor\text{-}ward}$) zu der summierten Geschwindigkeit (v_{sum2});
Berechnen (48, 50) eines Motorrotationsdifferenzbefehls (e_{engine}) basierend sowohl auf der Bodengeschwindigkeit (v_{ground}) als auch auf der summierten Geschwindigkeit (v_{sum2}); und

Erzeugen (54, 56) des Profil-Motorrotationsbefehls ($\omega_{profile}$) durch Anpassen des Vorwärts-Motorrotationsbefehls ($\omega_{feedforward}$) basierend auf dem Motorrotationsdifferenzbefehl (e_{engine}).

3. Verfahren nach Anspruch 2, wobei der Schritt des Berechnens (44, 46) der summierten Geschwindigkeit (v_{sum2}) folgende Schritte aufweist:

Summieren (44) der Sollwertgröße (v_{set}) und der Kompensationsgeschwindigkeit (v_{stored}), um eine erste summierte Geschwindigkeit (v_{sum1}) zu erzeugen; und
Erzeugen (46) der summierten Geschwindigkeit (v_{sum2}) durch Filtern der ersten summierten Geschwindigkeit (v_{sum1}).

4. Verfahren nach einem der Ansprüche 2 bis 3, wobei der Schritt des Berechnens (48, 50) des Motorrotationsdifferenzbefehls (e_{engine}) folgende Schritte aufweist:

Vergleichen (48) der Bodengeschwindigkeit (v_{ground}) mit der summierten Geschwindigkeit (v_{sum2}), um einen nachfolgenden Rotationsdifferenzbefehl (e_{follow}) zu berechnen; und
Zuordnen (50) des Motorrotationsdifferenzbefehls (e_{engine}) zu dem nachfolgenden Rotationsdifferenzbefehls (e_{follow}).

5. Verfahren nach einem der Ansprüche 2 bis 4, wobei der Schritt des Erzeugens (54, 56) des Profil-Motorrotationsbefehls ($\omega_{profile}$) folgende Schritte aufweist:

Erzeugen (54) eines summierten Motorrotationsbefehls (ω_{sum}) durch Aufsummieren des Vorwärts-Motorroationsbefehls ($\omega_{feedforward}$) und des Motorrotationsdifferenzbefehls (e_{engine}); und
Nachregeln (56) des summierten Motorrotationsbefehls (ω_{sum}), um den Profil-Motorrotationsbefehl ($\omega_{profile}$) zu erzeugen.

6. Verfahren nach einem der Ansprüche 2 bis 5, das des Weiteren den Schritt des Speicherns (42) der Bodengeschwindigkeit (v_{ground}) aufweist, wenn ein Gangwechsel erfolgt, wobei die Kompensationsgeschwindigkeit (v_{stored}) die zuletzt gespeicherte Bodengeschwindigkeit (v_{ground}) zwischen zwei aufeinanderfolgenden Gangwechseln ist.

7. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Schritt des Erzeugens (32) des Motorrotationsbefehls (ω_{eng}) folgende Schritte aufweist:

Erzeugen (60) eines Schnittstellenbefehls ($A_{gateway}$) basierend auf dem Fahrhebel-Motorrotationsbefehl ($\omega_{throttle}$), einer aktuellen Motorgeschwindigkeit (ω_{actual}) und einem Kupplungssignal (A_{clutch}), das kennzeichnend für einen Gangwechsel ist, wobei der Schnittstellenbefehl ($A_{gateway}$) aufweist:

- einen ersten Wert (P0), wenn das Kupplungssignal (A_{clutch}) einen ersten Wert aufweist, oder wenn das Kupplungssignal (A_{clutch}) von einem zweiten Wert in den ersten Wert übergeht und wobei ein erster Normalmoduszustand verifiziert wird, wobei der erste Normalmoduszustand verifiziert ist, wenn entweder die Bodengeschwindigkeit (v_{ground}) größer als oder gleich einem Bodengeschwindigkeitsgrenzwert ist oder die aktuelle Motorgeschwindigkeit (ω_{actual}) größer als oder gleich dem Fahrhebel-Motorrotationsbefehl ($\omega_{throttle}$) ist;
- einen zweiten Wert (P1), wenn das Kupplungssignal (A_{clutch}) von dem ersten Wert in den zweiten Wert übergeht;
- einen dritten Wert (P2), wenn das Kupplungssignal (A_{clutch}) von dem zweiten Wert in den ersten Wert übergeht und ein Gangwechsel-Abgeschlossen-Zustand verifiziert wird, wobei der Gangwechsel-Abgeschlossen-Zustand verifiziert ist, wenn das Kupplungssignal (A_{clutch}) von dem zweiten Wert in den ersten Wert übergeht und der erste Normalmoduszustand nicht verifiziert ist; und

Auswählen (62) als Motorrotationsbefehl (ω_{eng}), basierend auf dem Schnittstellenbefehl ($A_{gateway}$), einen Befehl aus dem Fahrhebel-Motorrotationsbefehl ($\omega_{throttle}$), dem Profil-Motorrotationsbefehl ($\omega_{profile}$) und einem automatischen Schalt-Motorrotationsbefehl ($\omega_{automatic}$), wobei der Motorrotationsbefehl (ω_{eng}) gleich ist mit:

- dem Fahrhebel-Motorrotationsbefehl ($\omega_{throttle}$), wenn der Schnittstellenbefehl ($A_{gateway}$) den ersten Wert (P0) aufweist;
- dem automatischen Schalt-Motorrotationsbefehl ($\omega_{automatic}$), wenn der Schnittstellenbefehl ($A_{gateway}$) den zweiten Wert (P1) aufweist;
- dem Profil-Motorrotationsbefehl ($\omega_{profile}$), wenn der Schnittstellenbefehl ($A_{ga\text{-}teway}$) den dritten Wert (P2) aufweist.

8. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Schritt des Erfassens des Beschleunigungsprofils entweder den Schritt eines Erzeugens des Beschleunigungsprofils mittels einer Ausgabevorrichtung (12) oder den Schritt eines Auswählens mittels der Ausgabevorrichtung (12), die wirkend mit einem Speicher verbunden ist, eines Beschleunigungsprofils aus einer Mehrzahl von Beschleunigungsprofilen, die in dem Speicher gespeichert sind.

9. Verfahren nach einem der Ansprüche 1 bis 7, wobei der Schritt des Erfassens des Beschleunigungsprofils den Schritt eines Auswählens mittels eines Drehschalters oder eines Knopfs (12) eines Beschleunigungsprofils aus einer Mehrzahl von Beschleunigungsprofilen aufweist, die in dem Speicher gespeichert sind.

10. Arbeitsfahrzeug (1), das von einem Benutzer bedienbar ist und das umfasst:

einen Motor (3), der eine Ausgangswelle (4) aufweist, die wirkend über ein Getriebe (9) mit Rädern oder Ketten (7) des Arbeitsfahrzeugs (1) verbunden ist,
eine Steuereinheit (6) und eine Motorsteuereinheit (8), die wirkend miteinander und dem Motor (3) verbunden sind, und dazu eingerichtet sind, das Arbeitsfahrzeug (1) mittels eines geschlossenen Regelkreises zu steuern,
einen Sensor (5), der wirkend mit der Steuereinheit (6) verbunden und der dazu eingerichtet ist, eine Bodengeschwindigkeit (v_{ground}) des Arbeitsfahrzeugs (1) zu erfassen,
eine Fahrhebeleingabevorrichtung (10), die elektrisch mit der Steuereinheit (6) gekoppelt und von dem Benutzer während der Benutzung des Arbeitsfahrzeugs (1) betätigbar ist, und
eine Wähleinrichtung (12), die elektrisch mit der Steuereinheit (6) gekoppelt und
die dazu eingerichtet ist, dem Benutzer zu ermöglichen, ein Beschleunigungsprofil (22) auszuwählen oder zu definieren,
wobei die Steuereinheit (6) eingerichtet ist zum:

- Erfassen einer Bodengeschwindigkeit (v_{ground}) des Arbeitsfahrzeugs (1) durch den Sensor (5);
- Erzeugen (28) eines Fahrhebel-Motorrotationsbefehls ($\omega_{throttle}$), der kennzeichnend für einen Sollwert an Motorumdrehungen pro Minute, U/MIN, und der abhängig von einer Position der Fahrhebel-Eingabevorrichtung (10) ist;
- Erfassen des Beschleunigungsprofils (22) durch die Wähleinrichtung (12);
- Erzeugen (26, 38) einer Sollwertgröße (v_{set}) basierend auf dem Beschleunigungsprofil (22);
- Erzeugen (30) eines Profil-Motorrotationsbefehls ($\omega_{profile}$) basierend auf beiden aus der Sollwertgröße (v_{set}) und wahlweise der Bodengeschwindigkeit (v_{ground}); und
- Erzeugen (32) eines Motorrotationsbefehls (ω_{eng}) durch Auswählen zumindest des Profil-Motorrotationsbefehls ($\omega_{profile}$) und des Fahrhebel-Motorrotationsbefehls ($\omega_{throttle}$), und

wobei die Motorsteuereinheit (8) dazu eingerichtet ist, den Motor (3) auf der Grundlage des erzeugten Motorrotationsbefehls (ω_{eng}) zu steuern, wodurch die Bodengeschwindigkeit (v_{ground}) des Arbeitsfahrzeugs (1) aktualisiert wird,
wobei das Erzeugen (26, 38) der Sollwertgröße (v_{set}) aufweist:

Abtasten (26) des Beschleunigungsprofils (22) in einem bestimmten Zeitpunkt, um einen Beschleunigungssollwert zu erzeugen; und
Erzeugen (38) eines Geschwindigkeitssollwerts durch Integrieren des Beschleunigungssollwerts, wobei der Geschwindigkeitssollwert die Sollwertgröße (v_{set}) ist.

Revendications

1. Procédé (20) de commande en boucle fermée d'un véhicule de travail (1) actionnable par un opérateur, le véhicule de travail (1) comprenant :

un moteur (3) possédant un arbre de sortie (4) couplé fonctionnellement par le biais d'une transmission (9) aux roues ou chenilles (7) du véhicule de travail (1),
une unité de commande (6) fonctionnellement couplée au moteur (3),
un capteur (5) fonctionnellement couplé à l'unité de commande (6),
un dispositif sélecteur (12) couplé électriquement à l'unité de commande (6) et configuré pour permettre à l'opérateur de sélectionner ou de définir un profil d'accélération (22), et
un dispositif d'entrée d'accélérateur (10) couplé à l'unité de commande (6) et utilisable par l'opérateur pendant l'utilisation du véhicule de travail (1),

le procédé comprenant les étapes consistant à :

- acquérir, par l'unité de commande (6), une vitesse d'avancement (V_{ground}) du véhicule de travail (1) par l'intermédiaire du capteur (5) ;
- générer (28), par l'unité de commande (6), une commande de rotation du moteur à papillon ($\omega_{throttle}$) indicative d'une valeur souhaitée de tours de moteur par minute, tr/min, qui dépend

d'une position du dispositif d'entrée d'accélérateur (10) ;
- acquérir, par l'unité de commande (6), le profil d'accélération (22) par le biais du dispositif sélecteur (12) ;
- générer (26, 38), par le biais de l'unité de commande (6), une quantité de points de consigne (V_{set}) basée sur le profil d'accélération (22) ; générer (30), par le biais de l'unité de commande (6), une commande de rotation du moteur de profil ($\omega_{profile}$) basée à la fois sur la quantité de points de consigne (V_{set}) et sur la vitesse d'avancement (V_{ground}) ;
- générer (32), par le biais de l'unité de commande (6), une commande de rotation de moteur (ω_{eng}) en sélectionnant parmi au moins la commande de rotation du moteur de profil ($\omega_{profile}$) et la commande de rotation du moteur à papillon ($\omega_{throttle}$) ; et
- contrôler le moteur (3) en fonction de la commande de rotation du moteur générée (ω_{eng}), mettant ainsi à jour la vitesse d'avancement (V_{ground}) du véhicule de travail (1),

dans lequel l'étape de génération (26, 38) de la quantité de points de consigne (V_{set}) comprend les étapes consistant à :

échantillonner (26) le profil d'accélération (22) à un certain instant pour générer un point de consigne d'accélération ; et
générer (38) un point de consigne de vitesse en intégrant le point de consigne d'accélération, le point de consigne de vitesse correspondant à la quantité de points de consigne (V_{set}).

2. Procédé selon la revendication 1, dans lequel l'étape de génération (30) de la commande de rotation du moteur de profil ($\omega_{profile}$) comprend les étapes consistant à :

calculer (44, 46) une vitesse calculée (V_{sum2}) en additionnant la quantité de points de consigne (V_{set}) et une vitesse compensée (V_{stored}) ;
associer (52) à la vitesse calculée (V_{sum2}) une commande prédictive de rotation du moteur respective ($\omega_{feedforward}$) ;
calculer (48, 50) une commande d'erreur de rotation du moteur (e_{engine}) sur la base à la fois de la vitesse d'avancement (V_{ground}) et de la vitesse calculée (V_{sum2}) ; et
générer (54, 56) la commande de rotation du moteur de profil ($\omega_{profile}$) en modifiant la commande prédictive de rotation du moteur ($\omega_{feedforward}$) en se basant sur la commande d'erreur de rotation du moteur (e_{engine}).

3. Procédé selon la revendication 2, dans lequel l'étape de calcul (44, 46) de la vitesse calculée (V_{sum2}) comprend les étapes consistant à :

Additionner (44) la quantité des points de consigne (V_{set}) et la vitesse compensée (V_{stored}) pour générer une première vitesse calculée (V_{sum1}) ; et
Générer (46) la vitesse calculée (V_{sum2}) en filtrant la première vitesse calculée (Vsum1).

4. Procédé selon l'une quelconque des revendications 2 et 3, dans lequel l'étape de calcul (48, 50) de la commande d'erreur de rotation du moteur (e_{engine}) comprend les étapes consistant à :

comparer (48) la vitesse d'avancement (V_{ground}) avec la vitesse calculée (V_{sum2}) pour calculer une commande d'erreur de rotation suivante (e_{follow}) ; et
associer (50) à la commande d'erreur de rotation suivante (e_{follow}) la commande d'erreur de rotation du moteur (e_{engine}).

5. Procédé selon l'une quelconque des revendications 2 à 4, dans lequel l'étape de génération (54, 56) de la commande de rotation du moteur de profil ($\omega_{profile}$) comprend les étapes consistant à :

générer (54) une commande de rotation du moteur totale (ω_{sum}) en additionnant la commande prédictive de rotation du moteur ($\omega_{feedforward}$) et la commande d'erreur de rotation du moteur (e_{engine}) ; et
saturer (56) la commande de rotation du moteur totale (ω_{sum}) pour générer la commande de rotation du moteur de profil ($\omega_{profile}$).

6. Procédé selon l'une quelconque des revendications 2 à 5, comprenant en outre l'étape consistant à stocker (42) la vitesse d'avancement (V_{ground}) lorsqu'un changement de vitesse se produit, la vitesse compensée (V_{stored}) étant la dernière vitesse d'avancement stockée (V_{ground}) entre deux changements de vitesse consécutifs.

7. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'étape de génération (32) de la commande de rotation du moteur (ω_{eng}) comprend les étapes consistant à :
générer (60) une commande passerelle ($A_{gateway}$) en fonction de la commande de rotation du moteur à papillon ($\omega_{throttle}$), un régime moteur réel (ω_{actual}) et un signal d'embrayage (A_{clutch}) indiquant un changement de vitesse, la commande passerelle ($A_{gateway}$) comportant :

- une première valeur (PO) lorsque le signal d'embrayage (A_{clutch}) a une première valeur, ou

lorsque le signal d'embrayage (Aclutch) passe d'une deuxième valeur à la première valeur et qu'une première condition de mode normal est vérifiée, la première condition de mode normal étant vérifiée si la vitesse d'avancement (V_{ground}) est supérieure ou égale à un seuil de vitesse d'avancement ou si le régime moteur réel (ω_{actual}) est supérieur ou égal à la commande de rotation du moteur à papillon ($\omega_{throttle}$) ;
- une deuxième valeur (P1) lorsque le signal d'embrayage (A_{clutch}) passe de la première valeur à la deuxième valeur ;
- une troisième valeur (P2) lorsque le signal d'embrayage (A_{clutch}) passe de la deuxième valeur à la première valeur et qu'une condition d'achèvement de changement de vitesse est vérifiée, la condition d'achèvement de changement de vitesse étant vérifiée si le signal d'embrayage (Aclutch) passe de la deuxième valeur à la première valeur et la première condition de mode normal n'est pas vérifiée ; et sélectionner (62) comme commande de rotation du moteur (ω_{eng}), basé sur la commande passerelle ($A_{gateway}$), une parmi les commandes de rotation du moteur à papillon ($\omega_{throttle}$), la commande de rotation du moteur à papillon ($\omega_{profile}$) et une commande de rotation du moteur à changement automatique de vitesse ($\omega_{automatic}$), dans lequel la commande de rotation du moteur (ω_{eng}) est égale à :
- la commande de rotation du moteur à papillon ($\omega_{throttle}$) lorsque la commande passerelle ($A_{gateway}$) correspond à la première valeur (PO) ;
- la commande de rotation du moteur à changement automatique de vitesse ($\omega_{automatic}$) lorsque la commande passerelle ($A_{gateway}$) correspond à la deuxième valeur (PI) ;
- la commande de rotation du moteur de profil ($\omega_{profile}$) lorsque la commande passerelle ($A_{gateway}$) correspond à la troisième valeur (P2) ;

8. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'étape d'acquisition du profil d'accélération comprend soit l'étape de génération, par le biais d'un affichage (12), du profil d'accélération, soit l'étape de sélection, par le biais de l'affichage (12) fonctionnellement couplé à une mémoire, d'un profil d'accélération parmi une pluralité de profils d'accélération stockés dans la mémoire.

9. Procédé selon l'une quelconque des revendications 1 à 7, dans lequel l'étape d'acquisition du profil d'accélération comprend l'étape de sélection, au moyen d'une manette ou d'un bouton (12), d'un profil d'accélération parmi une pluralité de profils d'accélération stockés dans la mémoire.

10. Véhicule de travail (1) utilisable par un opérateur et comprenant :

un moteur (3) possédant un arbre de sortie (4) couplé fonctionnellement par le biais d'une transmission (9) aux roues ou chenilles (7) du véhicule de travail (1),
une unité de commande (6) et une unité de commande de moteur (8), couplées fonctionnellement l'une à l'autre et au moteur (3), et configurées pour commander le véhicule de travail (1) en boucle fermée,
un capteur (5) fonctionnellement couplé à l'unité de commande (6) et configuré pour acquérir une vitesse d'avancement (V_{ground}) du véhicule de travail (1),
un dispositif d'entrée d'accélérateur (10) couplé électriquement à l'unité de commande (6) et utilisable par l'opérateur pendant l'utilisation du véhicule de travail (1), et
un dispositif sélecteur (12) couplé électriquement à l'unité de commande (6) et configuré pour permettre à l'opérateur de sélectionner ou de définir un profil d'accélération (22),
dans lequel l'unité de commande (6) est configurée pour :

- acquérir la vitesse d'avancement (V_{ground}) du véhicule de travail (1) par l'intermédiaire du capteur (5) ;
- générer (28) une commande de rotation du moteur à papillon ($\omega_{throttle}$) indicative d'une valeur souhaitée de tours de moteur par minute, tr/min, qui dépend d'une position du dispositif d'entrée d'accélérateur (10) ;
- acquérir le profil d'accélération (22) par le biais du dispositif sélecteur (12) ;
- générer (26, 38) une quantité de points de consigne (V_{set}) sur la base du profil d'accélération (22) ;
- générer (30) une commande de rotation du moteur de profil ($\omega_{profile}$) à la fois en fonction de la quantité de points de consigne (V_{set}) et en fonction de la vitesse d'avancement (V_{ground}) et
- générer (32) une commande de rotation de moteur (ω_{eng}) en sélectionnant parmi au moins la commande de rotation du moteur de profil ($\omega_{profile}$) et la commande de rotation du moteur à papillon ($\omega_{throttle}$), et

dans lequel l'unité de commande du moteur (8) est configurée pour contrôler le moteur (3) en fonction de la commande de rotation du moteur générée (ω_{eng}), mettant ainsi à jour la vitesse d'avancement (V_{ground}) du véhicule de

travail (1),
dans lequel la génération (26, 38) de la quantité de points de consigne (V_{set}) comprend les étapes consistant à :

échantillonner (26) le profil d'accélération (22) à un certain instant pour générer un point de consigne d'accélération ; et
générer (38) un point de consigne de vitesse en intégrant le point de consigne d'accélération, le point de consigne de vitesse correspondant à la quantité de points de consigne (V_{set}).

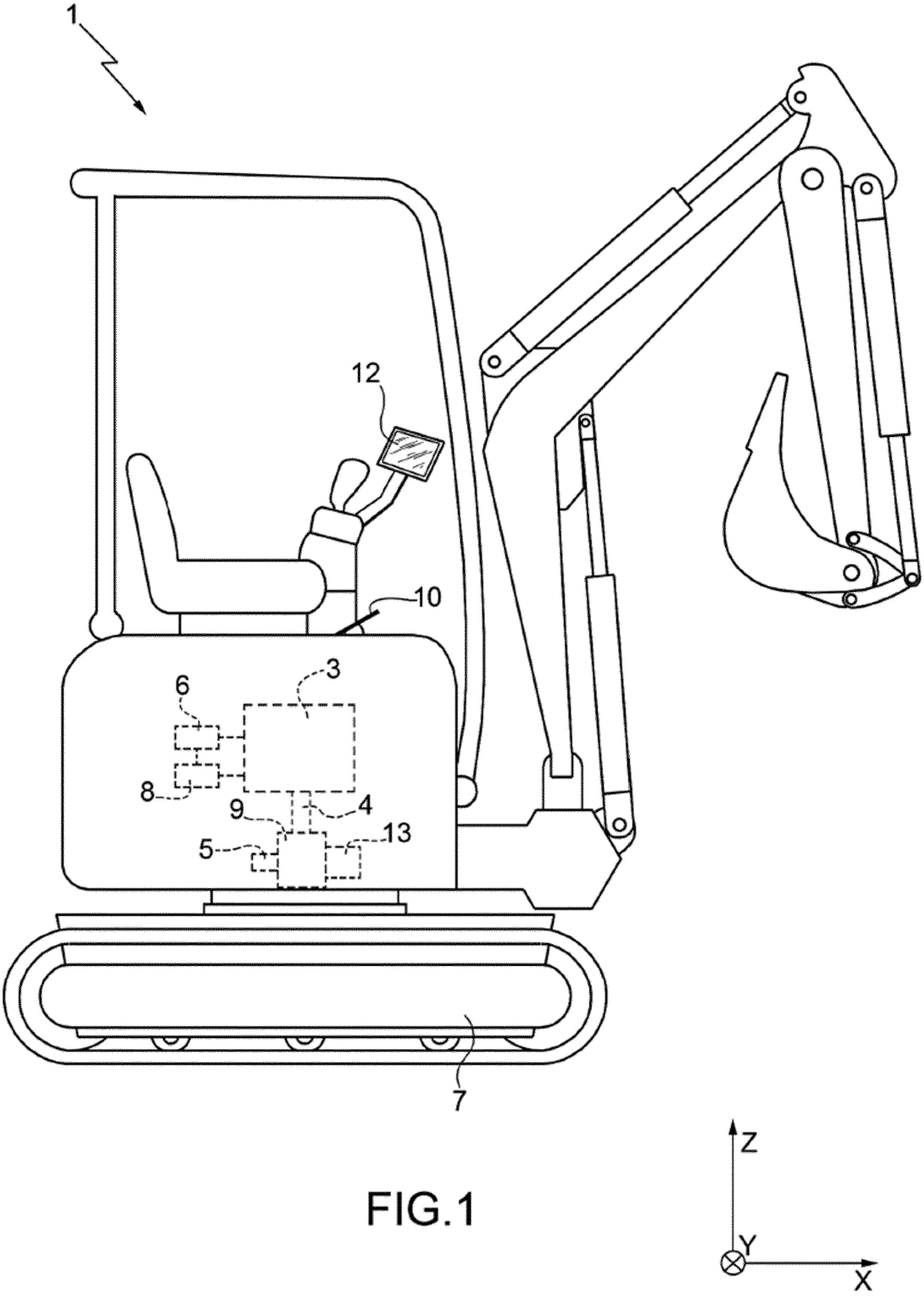
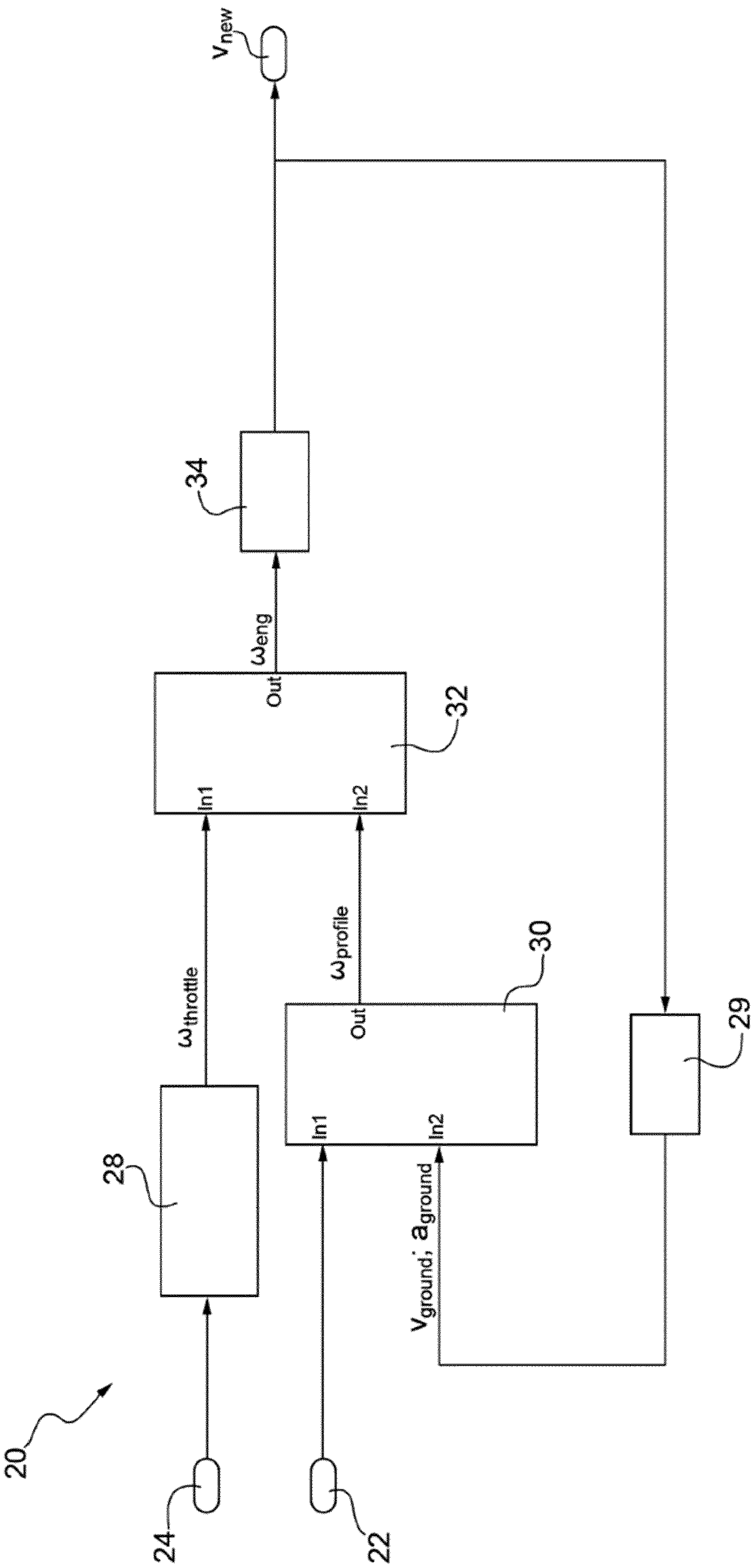


FIG.1



v_{new}
34
ω_{eng}
Out
32
In1
In2
$\omega_{throttle}$
$\omega_{profile}$
30
Out
In1
In2
28
29
v_{ground}, a_{ground}
20
24
22

FIG.2

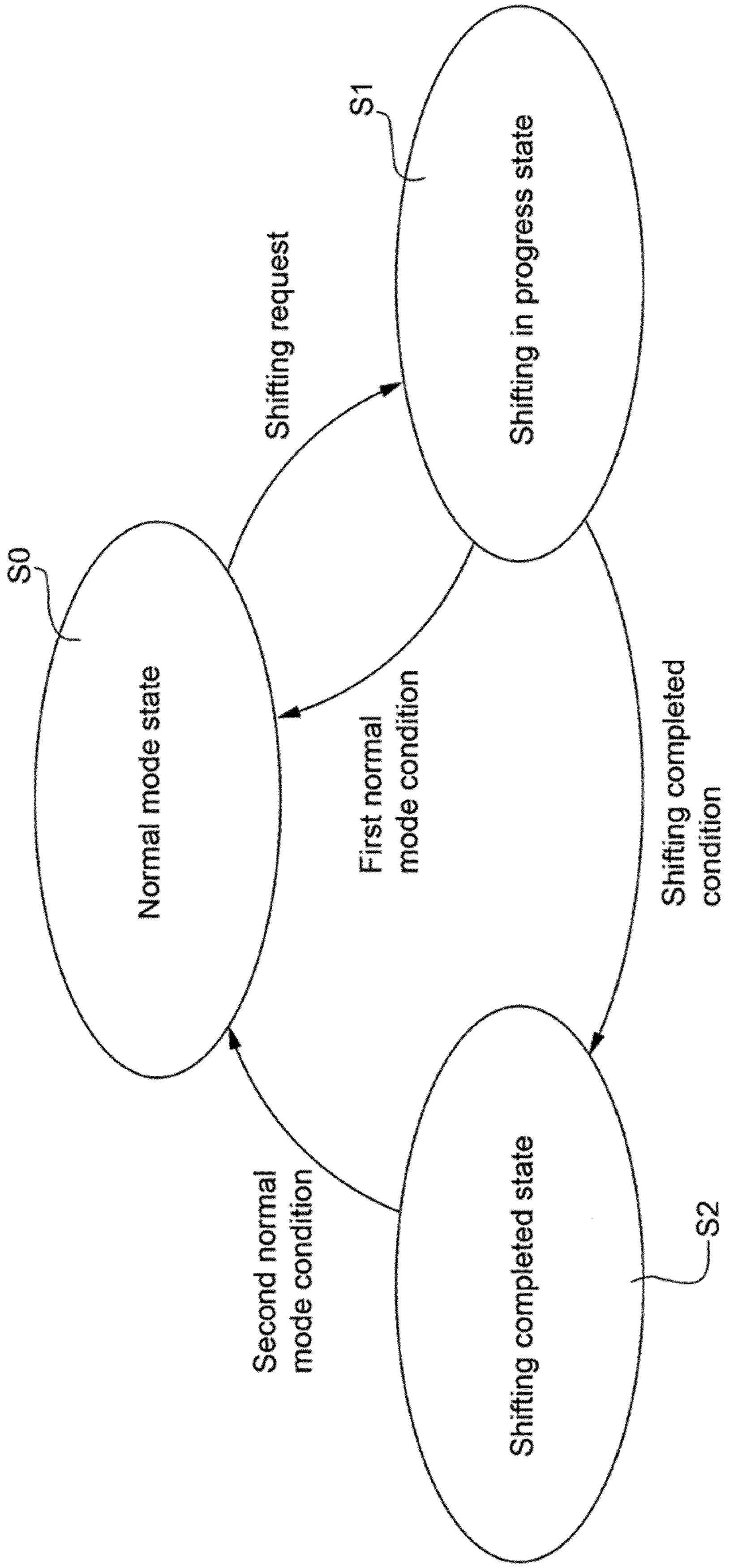

S0
Normal mode state
S1
Shifting in progress state
S2
Shifting completed state
Shifting request
First normal mode condition
Shifting completed condition
Second normal mode condition

FIG.3

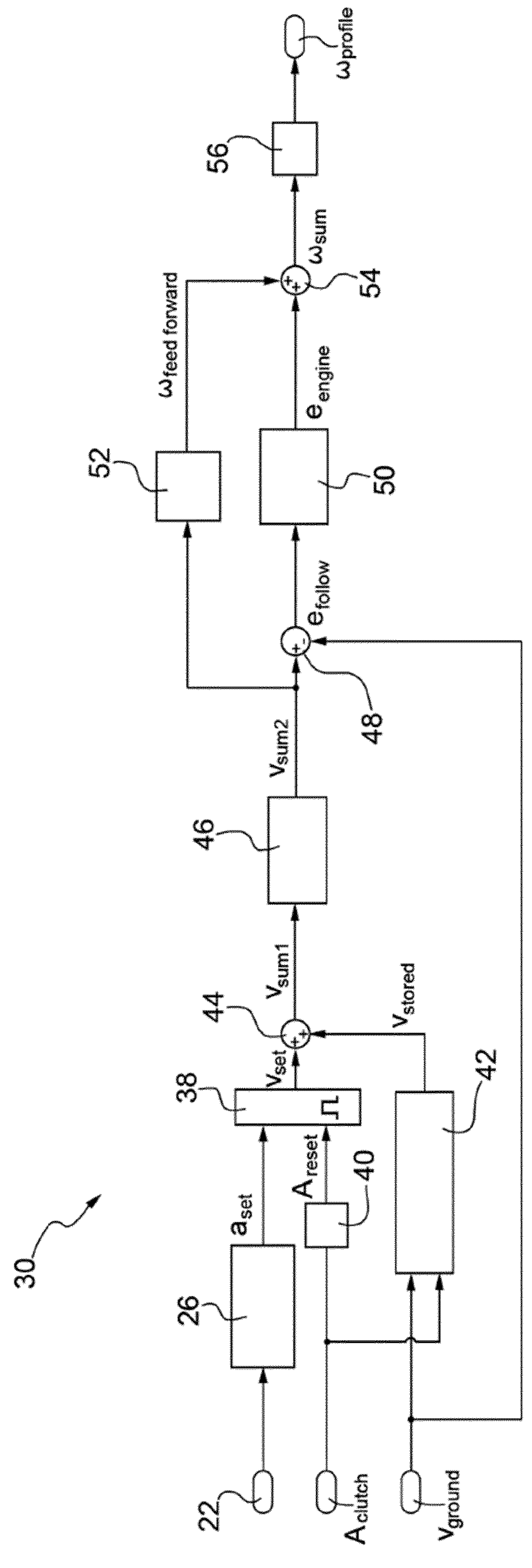
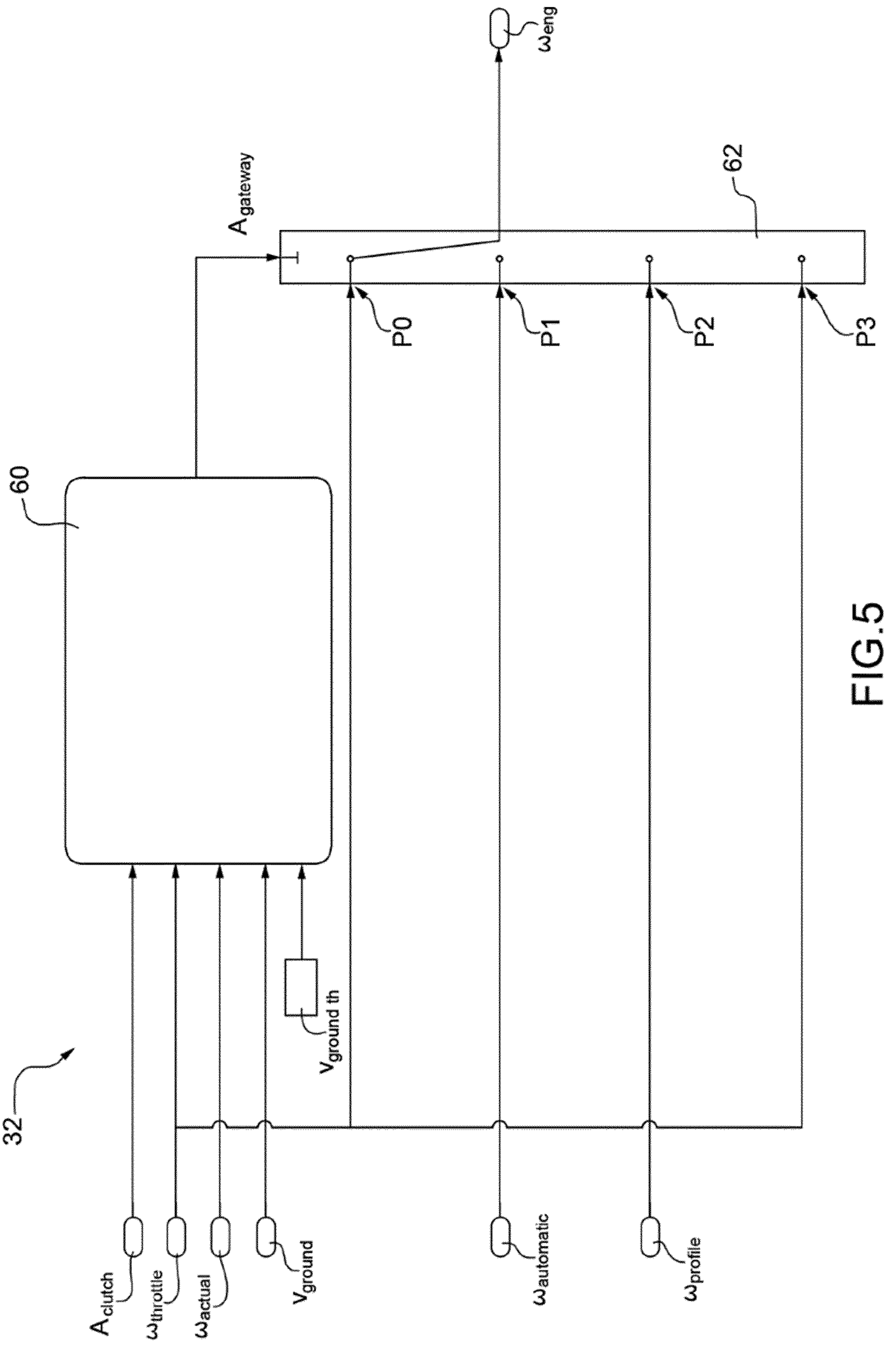

30
22
26
a_{set}
38
v_{set}
40
A_{reset}
A_{clutch}
42
v_{ground}
44
v_{stored}
v_{sum1}
46
v_{sum2}
48
e_{follow}
50
e_{engine}
52
$\omega_{feed\ forward}$
54
ω_{sum}
56
$\omega_{profile}$

FIG.4



32
60
62
$A_{gateway}$
ω_{eng}
P0
P1
P2
P3
A_{clutch}
$\omega_{throttle}$
ω_{actual}
v_{ground}
$v_{ground\ th}$
$\omega_{automatic}$
$\omega_{profile}$

FIG.5

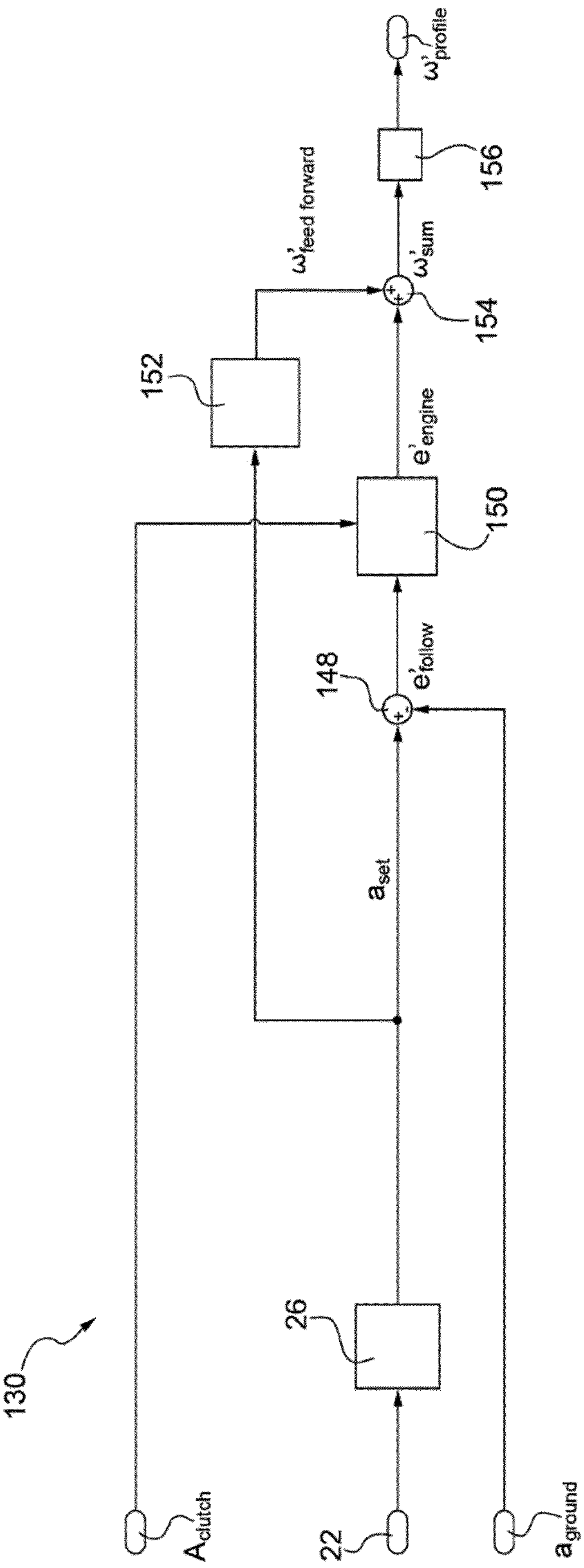

130
A_{clutch}
22
a_{ground}
26
a_{set}
148
e'_{follow}
150
e'_{engine}
152
154
$\omega'_{feed\ forward}$
ω'_{sum}
156
$\omega'_{profile}$

FIG.6

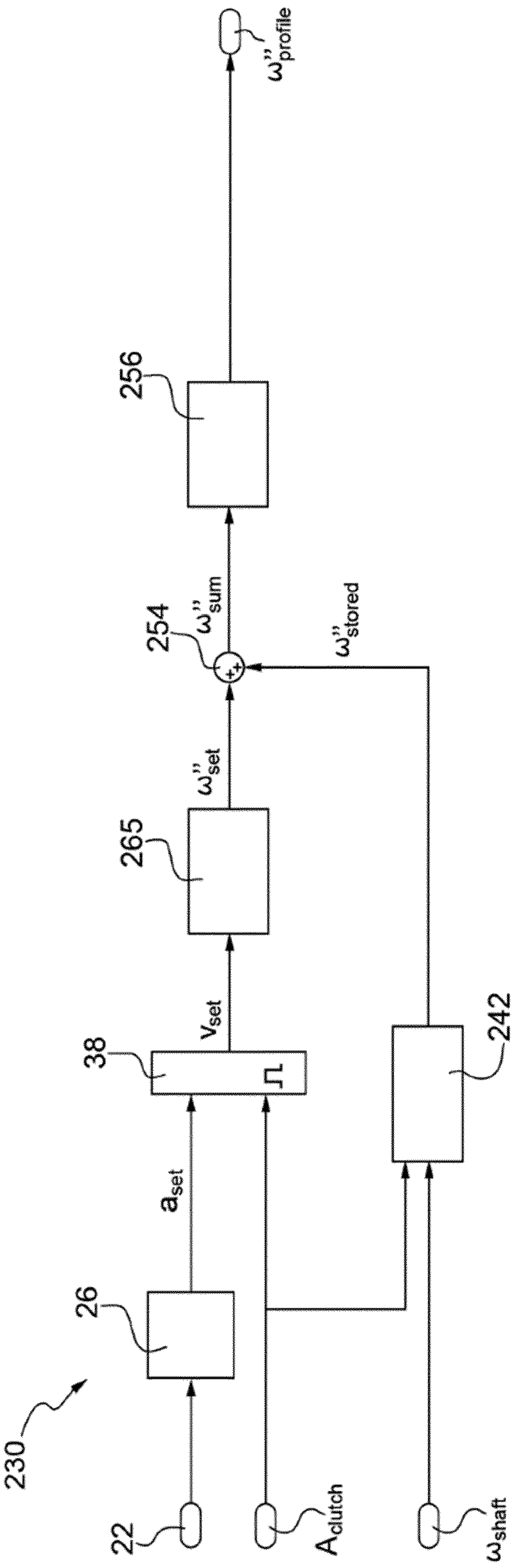

230
22
26
a_{set}
A_{clutch}
ω_{shaft}
38
v_{set}
242
265
ω''_{set}
254
ω''_{sum}
ω''_{stored}
256
$\omega''_{profile}$

FIG.7

REFERENCES CITED IN THE DESCRIPTION

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