



(51) International Patent Classification:

B60W 10/18 (2012.01) *B60W 10/08* (2006.01)
B60K 6/365 (2007.10) *B60W 10/11* (2012.01)
B60L 7/10 (2006.01)

(21) International Application Number:

PCT/SE2013/050791

(22) International Filing Date:

26 June 2013 (26.06.2013)

(25) Filing Language:

Swedish

(26) Publication Language:

English

(30) Priority Data:

1250698-6 27 June 2012 (27.06.2012) SE

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

[Continued on next page]

(54) Title: A METHOD FOR BRAKING A VEHICLE

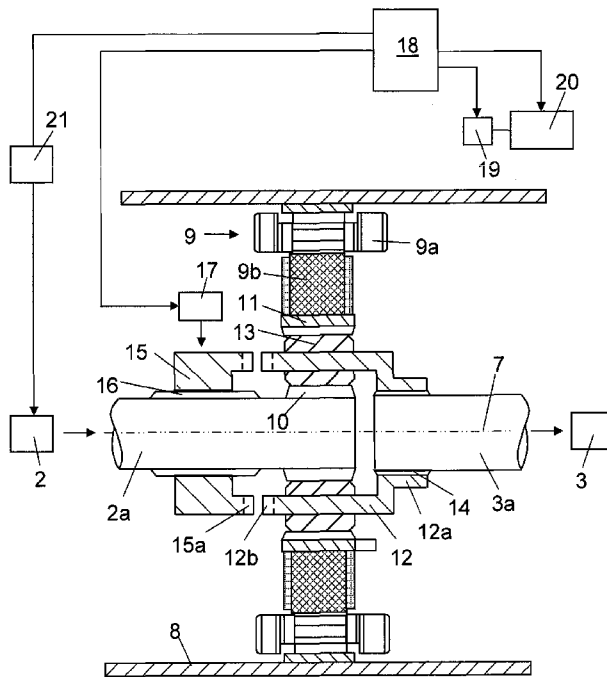


Fig 2

(57) Abstract: A method for braking a vehicle driving forward towards stop, said vehicle having a propulsion system comprising a combustion engine with an output shaft (2a), a gearbox (3) with an input shaft (3a), an electric machine (9) comprising a stator and a rotor, and a planetary gear comprising a sun gear (10), a ring gear (11) and a planet wheel carrier (12). When braking the vehicle a reverse gear of the gearbox is engaged and the electric machine is controlled to apply brake torque requested to the input shaft of the gearbox.

WO 2014/003671 A1



TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, —
KM, ML, MR, NE, SN, TD, TG).

*before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments (Rule 48.2(h))*

Published:

— *with international search report (Art. 21(3))*

A METHOD FOR BRAKING A VEHICLE

FIELD OF THE INVENTION AND PRIOR ART

5 The present invention relates to a method for braking a vehicle driving forward towards stop according to the preamble of appended claim 1.

The invention is especially but not exclusively directed to carry-
10 ing out such a method for motor vehicles in the form of wheeled utility vehicles, especially heavy such vehicles, such as trucks and buses.

“Brake towards stop” means that the braking is carried out at
15 comparatively low speeds of the vehicle, and when the method is started there is an aim to bring the vehicle to stop, but it is not at all necessary that this is done, but depending upon the actual circumstances the method may very well be carried out so that the vehicle will not reach any position of standing still.

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Accordingly, the invention relates to a method for braking a hybrid vehicle driving forward towards stop, in which such a vehicle is generally a vehicle which may be driven by a primary engine, here a combustion engine, and a secondary engine, here an
25 electric machine. The electric machine is suitably provided with means for storing energy, such as a battery or a capacitor for storing electric energy, and regulating equipment for regulating the flow of electrical energy between said means and the electric machine. The electric machine may by this operate as motor and
30 generator depending upon the state of operation of the vehicle.

When the vehicle is braked the electric machine generates electrical energy which may be stored, and the electrical energy stored may later be utilized for for example driving the vehicle.

- 5 The utilization of a conventional clutch mechanism disconnecting the input shaft of the gearbox with respect to the combustion engine during the gearchanging process in the gearbox results in disadvantages, such as heating of the discs of the clutch mechanism, which results in an increased fuel consumption and wear of
10 the clutch discs. Considerable losses are then also caused when starting the vehicle. Furthermore, a conventional clutch mechanism is comparatively heavy and costly. It requires also a comparatively large space in the vehicle. Friction losses are also created when using a hydraulic converter/torque transformer
15 usually used in automatic gearboxes. The conventional clutch mechanism and said disadvantages associated therewith may be avoided by providing for that the vehicle has a propulsion system in which the output shaft of the combustion engine, the rotor of the electric machine and the input shaft of the gearbox are inter-
20 connected by a planetary gear. A vehicle having a propulsion system of this type is known through EP 1 319 546.

There is of course an ongoing attempt to improve the way to drive a vehicle having such a propulsion system with respect to
25 energy efficiency and to regenerate as much as possible of the brake energy when braking the vehicle.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a method of the type defined in the introduction considering the attempt mentioned above. This object is according to the invention obtained by providing a method according to the appended claim 1.

By utilizing the possibility of a vehicle having a said propulsion system according to the invention to engage a reverse gear when driving forward a braking being very advantageous from the energy regenerating point of view may be carried out. It is attempted to change gear as few times as possible during braking and braking by the electric machine with full electric machine torque for the existing rotational speed of the rotor of the electric machine for obtaining the object to regenerate maximum brake energy when braking a vehicle of this type. The method according to the invention makes it possible to brake by means of the electric machine during the entire braking procedure until the vehicle stands still, if the method is continued until this is obtained, with full electric machine torque for the existing rotational speed of the rotor of the electric machine and without carrying out any further gearchange than from said forward gear to said reverse gear. If instead a forward gear had been chosen during the braking the combustion engine would get an increased rotational speed when a higher brake torque is created by the electric machine.

According to an embodiment of the invention the method is carried out for a vehicle having a propulsion system with the sun gear as said first component and the ring gear as said third com-

ponent, and such a propulsion system is described in the still unpublished SE 1051384-4 and has a number of advantages with respect to a propulsion system according to EP 1 319 546 mentioned above, which has the ring gear as the first component and the sun gear as the third component. A compact construction being easy to build in in spaces already existing for drivetrains (propulsion systems) having clutch mechanisms instead of planetary gears is obtained by connecting the electric machine with the ring gear and the output shaft of the combustion engine with the sun gear. A hybridized gearbox may by this be made size and weight compatible with a standard gearbox and standardized interfaces may be maintained. This means that the weight increase normally associated with a hybridization may be reduced considerably. Another advantage is that a connection of the electric machine with the ring gear means a higher possible brake torque through this than would it instead be connected to the sun gear. Thus, the planet wheel carrier is in this embodiment connected to the input shaft of the gearbox, and to engage the reverse gear when braking regeneratively while driving forward does then work well. The electric machine is according to a further embodiment connected to the sun gear, the output shaft of the combustion engine is connected to the ring gear and the input shaft of the gearbox is connected to the planet wheel carrier. But this method could also function for other combinations of first, second and third components than the one of this embodiment.

According to another embodiment of the invention the method is carried out for a vehicle with a propulsion system comprising a range gear, and according to another embodiment of the inven-

tion being a further development of the preceding one it is before carrying out of said steps ensured that a high range gear is engaged. The utilization of the gear combination of reverse gear and high range gear normally not used in vehicles of this type
5 makes it possible to start the method according to the invention for braking a vehicle having a considerably higher speed than would instead the low range gear be engaged. However, it is pointed out that it is well possible to carry out the method according to the invention with the low range gear engaged in the
10 case the speed of the vehicle is sufficiently low when a desire to brake the vehicle towards stop arises.

According to another embodiment of the invention step g) is carried out repeatedly or continuously while carrying out step h),
15 and the rotational speed of the output shaft of the combustion engine is controlled towards a predetermined rotational speed of the combustion engine as long as said checking indicates that brake torque is requested. The output shaft of the combustion engine is then advantageously controlled towards a predetermined
20 rotational speed in the form of a low rotational speed, such as a so-called idle rotational speed, of the combustion engine. The fuel consumption of the combustion engine is by this kept at a low level during the braking.

25 According to another embodiment of the invention step g) is carried out repeatedly or continuously while carrying out step h), and, as long as said checking indicates that brake torque is requested, the combustion engine is controlled to deliver a rotational speed of the output shaft thereof which is so depend-
30 ent on the rotational speed of the rotor of the electric machine

that the electric machine is in step h) controllable to brake the input shaft of the gearbox while generating a maximum electric regenerative power. It may by such a control of the combustion engine be ensured that the rotor of the electric machine will during the entire braking procedure rotate with a sufficiently high rotational speed for enabling a maximum electric regenerative power to be generated in the electric machine.

According to another embodiment of the invention the fuel injection in the combustion engine is stopped while carrying out step h) and when the output shaft of the combustion engine has substantially stopped this shaft is locked against rotation, and step h) is continued with the combustion engine turned off. Locking of the output shaft of the combustion engine against rotation may be accomplished by a controllable brake for which the torque may be controlled, a spring loaded brake having a fixed brake torque or any type of locking pin able to lock the flywheel of the engine. The brake may act upon the flywheel of the combustion engine, upon the shaft to the planetary gear or upon the sun gear of the planetary gear. Accordingly, it is after that changed to purely electrical driving. This means a favourable state of the propulsion system for driving away or a short acceleration which may then be carried out with full torque of the electric machine changed up through the planetary gear.

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According to another embodiment of the invention the checking in step g) is carried out repeatedly or continuously while carrying out step h), and when said checking shows that instead of a brake torque an acceleration torque of the propulsion system is requested and the acceleration torque is less than the product of

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on one hand the torque needed for driving the combustion engine to rotate and on the other the transmission ratio of the planetary gear the electric machine is controlled to reverse the direction of the torque applied to the input shaft of the gearbox through the
5 third component so as to apply said requested acceleration torque to this shaft. When such a low acceleration torque is suddenly requested during the braking procedure according to the present invention this may easily be obtained by said control of the electric machine. This may for example be the case if a
10 bus brakes for stopping at a bus stop but the driver just before the bus stops estimates that it would be better to drive the bus a little bit further than was previously the intention, for example since another bus has suddenly driven away. Thus, no gear-change being negative from the power consumption/regenerating
15 point of view would in such a case be required for obtaining this.

According to another embodiment of the invention the checking in step g) is carried out repeatedly or continuously while carrying out step h), and when said checking shows that instead of a
20 brake torque an acceleration torque of the propulsion system is requested and the acceleration torque is less than the product of on one hand the torque needed for driving the combustion engine to rotate and on the other the transmission ratio of the planetary gear the electric machine or the electric machine and the com-
25 bustion engine is/are controlled so that it/they through the input shaft of the gearbox gives/give a state of zero torque in the gearbox, whereupon the reverse gear is disengaged, the electric machine and/or combustion engine is/are controlled so that the rotational speed of the third component together with the
30 rotational speed of the output shaft of the combustion engine

give the input shaft of the gearbox a rotational speed which for the existing speed of the vehicle is synchronized with the shaft rotational speed for a forward gear of the gearbox and said forward gear of the gearbox is then engaged. This way to
5 proceed may be chosen when there is a desire to continue to accelerate the vehicle.

According to another embodiment of the invention the checking in step g) is carried out repeatedly or continuously while carrying
10 out step h), and when said checking shows that instead of a brake torque an acceleration torque of the propulsion system is requested and the acceleration torque is larger than the product of on one hand the torque needed for driving the combustion engine to rotate and on the other the transmission ratio of the
15 planetary gear the electric machine or the electric machine and the combustion engine is/are controlled so that it/they through the input shaft of the gearbox gives/give a state of zero torque in the gearbox, whereupon the reverse gear is disengaged, the electric machine and/or combustion engine is/are controlled so
20 that the rotational speed of the third component together with the rotational speed of the output shaft of the combustion engine give the input shaft of the gearbox a rotational speed which for the existing speed of the vehicle is synchronized with the shaft rotational speed for a forward gear of the gearbox and said
25 forward gear of the gearbox is then engaged.

The method according to the invention may in this way be terminated and left, whereupon said locking means may if desired be transferred to the locking position if the electric machine and the
30 combustion engine are firstly controlled so that the first and third

components get the same rotational speed as the input shaft of the gearbox.

According to another embodiment of the invention step a) comprises a calculation of the rotational speed by which the input shaft of the gearbox is to be driven for a state of zero torque between the components interlocked by the locking means for the existing speed of the vehicle and the gear engaged in the gearbox as well as calculation of the rotational speeds of the output shaft of the combustion engine and the rotor of the electric machine required for obtaining this state.

According to another embodiment of the invention step c) comprises a calculation of the rotational speed by which the input shaft of the gearbox is to be driven for a state of zero torque in the gearbox for the existing speed of the vehicle and gear engaged in the gearbox as well as a calculation of the rotational speeds of the output shaft of the combustion engine and the rotor of the electric machine required for obtaining this state.

According to another embodiment of the invention step e) comprises a calculation of the rotational speed which the input shaft of the gearbox would get if for the existing speed of the vehicle said reverse gear of the gearbox would be engaged as well as calculation of the rotational speed of the ring gear and the rotational speed of the output shaft of the combustion engine which together would give the input shaft of the gearbox said rotational speed calculated for the reverse gear engaged.

According to a further development of the embodiment mentioned above relating to said dependence of the rotational speed of the output shaft of the combustion engine on the rotational speed of the rotor of the electric machine the step h) comprises a
5 calculation of the rotational speed to be assumed by the output shaft of the combustion engine for giving the electric machine a rotational speed enabling it to brake while generating a maximum regenerative power.

10 The invention also relates to a computer program having the features listed in claim 16, a computer program product having the features listed in claim 17, an electronic control unit having the features listed in claim 18 and a vehicle according to claim
19.

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Other advantageous features and advantages of the invention appear from the description following below.

BRIEF DESCRIPTION OF THE DRAWINGS

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With reference to the appended drawings, below follows a description of an embodiment of the invention cited as an example.

In the drawings:

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Fig 1 is a very simplified view of a drivetrain of a vehicle for which a method according to the invention may be carried out,

- Fig 2 is a still simplified but more detailed view of a part of a said propulsion system,
- Fig 3 is a principle sketch of an electronic control unit for implementing a method according to the invention,
- Fig 4 shows how the rotational speed for the members (shaft of combustion engine, rotor of electric machine and input shaft to the gearbox) connected to the planetary gear of the propulsion system according to Fig 2 as well as vehicle speed and torque of the electric machine vary over time when carrying out a method according to an embodiment of the invention for braking the vehicle driving forward towards stop,
- Fig 5 is a flow chart illustrating a method according to a first embodiment of the invention, and
- Fig 6 is a flow chart illustrating a method according to a second embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

- Fig 1 shows a drivetrain for a heavy vehicle 1. The drivetrain comprises a combustion engine 2, a gearbox 3, a number of drive shafts 4 and drive wheels 5. The drivetrain has between the combustion engine 2 and the gearbox 3 an intermediate portion 6. Fig 2 shows more in detail the components in the intermediate portion 6. The combustion engine 2 is provided with an output

shaft 2a and the gearbox 3 with an input shaft 3a in the intermediate portion 6. The output shaft 2a of the combustion engine is arranged coaxially with respect to the input shaft 3a of the gearbox. The output shaft 2a of the combustion engine and the input shaft 3a of the gearbox are arranged to rotate around a rotation axis 7 in common. The intermediate portion 6 comprises a housing 8 enclosing an electric machine 9 and a planetary gear. The electric machine 9 comprises as usual a stator 9a and a rotor 9b. The stator 9a comprises a stator core secured in a suitable way on the inner side of the housing 8. The stator core comprises stator windings. The electric machine 9 is adapted to in certain operation situations utilize electric energy stored for supplying drive power to the input shaft 3a of the gearbox and in other operation situations utilize kinetic energy of the input shaft 3 of the gearbox for generating and storing electric energy.

The planetary gear is arranged substantially radially internally of the stator 9a and the rotor 9b of the electric machine. The planetary gear comprises as usual a sun gear 10, a ring gear 11 and a planet wheel carrier 12. The planet wheel carrier 12 carries a number of gear wheels 13 being rotatably arranged in a radial space between the teeth of the sun gear 10 and the ring gear 11. The sun gear 10 is secured to a circumferential surface of the output shaft 2a of the combustion engine. The sun gear 10 and the output shaft 2a of the combustion engine rotate as a unit with a first rotational speed n_1 . The planet wheel carrier 12 comprises a fastening portion 12a being fastened to a circumferential surface of the input shaft 3a of the gearbox by means of a splined connection 14. The planet wheel carrier 12 and the input shaft 3a of the gearbox may by means of this connection rotate as a unit

with a second rotational speed n_2 . The ring gear 11 comprises an external circumferential surface onto which the rotor 9b is secured. The rotor 9b and the ring gear 11 form a rotatable unit rotating with a third rotational speed n_3 .

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The propulsion system comprises a locking means by the fact that the output shaft 2a of the combustion engine is provided with a displaceable coupling member 15. The coupling member 15 is fastened to the output shaft 2a of the combustion engine by means of a splined connection 16. The coupling member 15 is in this case fixed against rotation to the output shaft 2a of the combustion engine and displaceable in the axial direction on the output shaft 2a of the combustion engine. The coupling member 15 comprises a coupling portion 15a connectable to a coupling portion 12b of the planet wheel carrier 12. A displacing member 17 schematically shown is adapted to displace the coupling member 15 between a first position in which the coupling portion 15a, 12b are not mutually engaged corresponding to a releasing position of the locking means and a second position in which the coupling portions 15a, 12b are mutually engaged corresponding to a locking position of the locking means. The output shaft 2a of the combustion engine and the input shaft 3a of the gearbox will in this locking position be interlocked and these and the rotor of the electric machine will by that rotate with the same rotational speed. This state may be called locked planet. The locking mechanism may also comprise a sleeve provided with first splines which in the releasing position engage second splines on a first component of the planetary gear and in the locking position engage third splines on a second component of the planetary gear. The first component is in this case preferably the

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planet wheel carrier and a second component the sun gear. The locking mechanism may then be designed as a sleeve with a ring shape enclosing the planet wheel carrier substantially concentrically.

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An electric control unit 18 is designed to control the displacing member 17. The control unit 18 is also configured to decide on which occasions the electric machine shall operate as motor and on which occasions it shall operate as generator. The control unit 10 18 may for deciding this receive current information about suitable operation parameters. The control unit 18 may be a computer with software for this task. The control unit 18 controls a regulating equipment 19 schematically shown, which regulates the flow of electric energy between a hybrid battery 20 and the 15 stator windings 9a of the electric machine. On occasions when the electric machine 9 operates as motor electric energy stored is supplied from the hybrid battery 20 to the stator 9a. On occasions on which the electric machine operates as generator electric energy is supplied from the stator 9a to the hybrid battery 20.

20 The hybrid battery 20 delivers and stores electric energy with a voltage being in the order of 200-800 volts. Since the intermediate portion 6 between the combustion engine 2 and the gearbox 3 in a vehicle is restricted it is required that the electric machine 9 and the planetary gear constitute a compact unit. The 25 components 10, 11, 12 of the planetary gear are here arranged substantially radially internally of the stator 9a of the electric machine. The rotor 9b of the electric machine, the ring gear 11 of the planetary gear, the output shaft 2a of the combustion engine and the input shaft 3a of the gearbox are here arranged to rotate 30 around a rotation axis 5 in common. The electric machine 9 and

the planetary gear occupy through such a design a comparatively small space. The vehicle 1 is provided with a motor control function 21 through which the rotational speed n_1 of the combustion engine 2 may be regulated. The control unit 18 has by that a possibility to activate the motor control function 21 and create a state of zero torque in the gearbox when gears in the gearbox 3 are engaged and disengaged. The propulsion system may of course instead of being controlled by one single control unit 18 be controlled by several different control units.

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Fig 5 shows a flow chart illustrating a method according to a first embodiment of the present invention for braking a vehicle driving forward towards stop, in which the vehicle has a propulsion system of the type shown in Fig 2. It is now also referred to Fig 4, in which the development of the rotational speeds of the output shaft of the combustion engine, the input shaft of the gearbox and the rotor of the electric machine n_1 , n_2 and n_3 , respectively, the speed v of the vehicle and the brake torque M of the electric machine are plotted versus the time for carrying out this method.

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When the method is started the vehicle is driven forward with the locking means in the locking position and a forward gear and the high range gear engaged in a range gear not shown of the vehicle. This means that all three components of planetary gear rotate with the same rotational speed. A need to brake the vehicle towards stop is then detected, for example for stopping the vehicle, which we here assume to be a bus, at a bus stop.

The method is then started by the control unit 21 controlling the combustion engine 2 so that a state of zero torque is obtained

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between the output shaft 2a of the combustion engine and the input shaft 3a of the gearbox, i.e. the components interlocked, sun gear and planet wheel carrier, of the planetary gear. The locking means is then transferred to the releasing position by
5 displacing the coupling member 15.

The method is continued by using the control units 18 and 21 to control the electric machine 9 and the combustion engine 2, respectively, so that they deliver a state of zero torque in the
10 gearbox 3 through the input shaft 3a of the gearbox. This may for example be obtained by controlling one of the electric machine and the combustion engine to transfer a zero torque to the input shaft of the gearbox and the rotational speed of the other is controlled or both are controlled to a said zero torque. When the
15 state of zero torque is obtained in the gearbox the existing gear in the gearbox is disengaged, i.e. the gearbox is transferred to neutral position.

The electric machine 9 and the combustion engine 2 are then
20 through the control units 18 and 21, respectively, controlled so that the rotational speed n_3 of the ring gear together with the rotational speed n_1 of the output shaft of the combustion engine give the input shaft of the gearbox a rotational speed n_2 which for the existing speed v of the vehicle is synchronized with the shaft
25 rotational speed for a reverse gear of the gearbox having the high range gear engaged. By having the high range gear engaged the reverse gear may be engaged at a speed which for a normal range gear relation is about four times as high as would instead the low range gear be engaged. Said reverse gear of the
30 gearbox is now engaged. We have now arrived to the time t_1 in

Fig 4 and the method has for example so far taken 1-2 seconds. It is now checked how high the brake torque requested of the propulsion system is and the electric machine is controlled through the control unit 18 to apply the brake torque requested through the ring gear 11 on the input shaft of the gearbox. The output shaft of the combustion engine is simultaneously controlled towards a predetermined rotational speed in the form of a low rotational speed, such as a so-called idle rotational speed. It may through the fact that a reverse gear is engaged be braked by means of the electric machine all the way until the vehicle stands still by a full electric machine torque M . If instead a forward gear would have been chosen that would result in an increase of the rotational speed of the combustion engine to a high number of revolutions would a high brake torque be applied through the electric machine.

The driver of the bus discovers at the time t_2 that the bus should stop further ahead than the driver has planned so far, and said checking of the brake torque requested of the propulsion system gives then suddenly the result that instead of a brake torque an acceleration torque of the propulsion system is requested, and this acceleration torque is less than the product of on one hand the torque M_f needed for rotating the combustion engine and on the other the transmission ratio U_p of the planetary gear. The transmission ratio of the planetary gear is the number teeth of the third component/(the number of teeth of the third component + the number of teeth of the first component). The control unit 18 does now according to the method according to the invention control the electric machine 9 to reverse the direction of the

torque applied to the input shaft of the gearbox through the ring gear for applying said acceleration torque requested to this shaft.

The checking of the brake torque requested gives at the time t_3
5 again the result that a brake torque is requested, and the control unit 18 controls the electric machine to again reverse the direction of the torque M . The vehicle is then braked until it stands still at the time t_4 and the method is terminated. It appears that the output shaft of the combustion engine now rotates with the
10 idle rotational speed while the rotor of the electric machine rotates in the opposite direction.

Accordingly, once the reverse gear has been engaged at the time t_1 on one hand the entire braking procedure until stop, including
15 the intermediate acceleration, could be carried out without any gearchange, and on the other it was possible to brake the vehicle by means of full torque of the electric machine for the existing rotational speed of the rotor thanks to the engagement of the reverse gear. Both these circumstances have had a favourable influence upon the attempt to regenerate as much as possible of
20 the kinetic energy of the vehicle lost during braking for storing this in the battery connected to the electric machine.

A method according to a second embodiment of the invention is
25 illustrated in Fig 6, in which this embodiment differs from the one illustrated in Fig 5 only with respect to the time after engaging a reverse gear, so that only those method steps are shown there and will now be described. The combustion engine is in this method controlled to deliver a rotational speed n_1 of the output
30 shaft thereof being so dependent on the rotational speed n_3 of

rotor of the electric machine that the electric machine is controllable to brake the input shaft of the gearbox while generating a maximum electric regenerative power. This maximizes the power by which the electric machine may brake, since the rotational speed of the electric machine may be kept sufficiently high also at the end of the braking procedure.

A third possibility with respect to the control of the combustion engine during braking is to stop fuel injection into the combustion engine and when the output shaft of the combustion engine substantially stands still lock this shaft against rotation. This locking may as mentioned for example be achieved by applying a brake to the flywheel of the combustion engine, to the sun gear or to any other part being fixed with respect to rotation to the output shaft of the combustion engine. Thus, it is in this case changed to purely electric driving of the vehicle. This means then a favourable state of the drivetrain for starting driving or a short acceleration which may then be carried out with full torque of the electric machine changed up through the planetary gear.

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It is in Fig 5 and 6 also illustrated how the method according to the invention may be interrupted, which is done in the case said checking shows that an acceleration torque is requested of the propulsion system and this torque is higher than the product of on one hand the torque needed for rotating the combustion engine and on the other the transmission ratio of the planetary gear. The electric machine or the electric machine and the combustion engine is/are in this case controlled so that it/they through the input shaft of the gearbox delivers/deliver a state of zero torque in the gearbox, whereupon the reverse gear is

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disengaged, the electric machine and/or the combustion engine is/are controlled so that the rotational speed of the ring gear together with the rotational speed of the output shaft of the combustion engine give the input shaft of the gearbox a rotational speed which for the existing speed of the vehicle is synchronized with the shaft rotational speed for a forward gear of the gearbox, and said forward gear of the gearbox is then engaged. The method is by that terminated.

10 Computer program code for implementing a method according to the invention is suitably included in a computer program which is readable into an internal memory of a computer, such as the internal memory of an electronic control unit of a motor vehicle. Such a computer program is suitably provided through a computer program product comprising a data storing medium readable by an electronic control unit, which data storing medium has the computer program stored thereon. Said data storing medium is for example an optical data storing medium in the form of a CD-ROM-disc, a DVD-disc, etc., a magnetic data storing medium in the form of a hard disc, a diskette, a tape etc., or a Flash memory or a memory of the type ROM, PROM, EPROM or EEPROM.

Fig 3 illustrates very schematically an electronic control unit 40 comprising an execution means 41, such as a central processor unit (CPU), for executing a computer program. The execution means 41 communicates with a memory 42, for example of the type RAM, through a data bus 43. The control unit 40 comprises also a data storing medium 44, for example in the form of a Flash memory or a memory of the type ROM, PROM, EPROM or

EEPROM. The execution means 41 communicates with the data storing medium 44 through a data bus 43. A computer program comprising computer program code for implementing a method according to the invention, for example in accordance with any of the embodiments illustrated in Fig 5 and 6, is stored on the data storing medium 44.

The invention is of course not in any way restricted to the embodiments described above, but many possibilities to modifications thereof would be apparent to a person with skill in the art without departing from the scope of the invention as defined in the appended claims.

The method may be applied to a vehicle without range gear, such as being common for a smaller truck.

The locking means may be designed to interlock any two of said three components.

A transmission could be arranged between the rotor and the ring gear and also between the output shaft of the combustion engine and the sun gear, such as upstream of the shaft shown in the figures to be connected to the sun gear. The transmission last mentioned could also be formed by a variable gear.

It is also conceivable that the method is carried out for a vehicle having the ring gear as the first component and the sun gear as the third component, although the opposite would probably often be preferred through the advantages thereof mentioned above.

Claims

1. A method for braking a vehicle driving forward towards stop, said vehicle having a propulsion system comprising a combustion engine (2) with an output shaft (2a), a gearbox (3) with an input shaft (3a), an electric machine (9) comprising a stator (9a) and a rotor (9b), and a planetary gear comprising three components in the form of a sun gear (10), a ring gear (11) and a planet wheel carrier (12), the output shaft (2a) of the combustion engine being connected to a first of said components of the planetary gear so that a rotation of this shaft results in a rotation of this component, said input shaft (3a) of the gearbox being connected to a second of said components of the planetary gear so that a rotation of this shaft results in a rotation of this component and the rotor (9b) of the electric machine being connected to a third of said components of the planetary gear so that a rotation of the rotor results in a rotation of this component, said propulsion system further comprising locking means transferable between a locking position in which two of said components are interlocked so that the three components (10-12) rotate with the same rotational speed and a releasing position in which the components are allowed to rotate with different rotational speeds,
- 25 **characterised** in that the method comprises the following steps:
- a) controlling the electric machine (9) and/or the combustion engine (2) so that a state of zero torque is obtained between the components (10, 11) interlocked by the locking means,

- b) transferring said locking means to said releasing position,
c) controlling the electric machine (9) and/or the combustion engine (2) so that they through the input shaft (3a) of the gearbox create a state of zero torque in the gearbox (3)
5 d) disengaging the gear presently engaged in the gearbox,
e) controlling the electric machine (9) and/or the combustion engine (2) so that the rotational speed of the third component (11) together with the rotational speed of the output shaft (2a) of the combustion engine give the input shaft
10 (3a) of the gearbox a rotational speed which for the existing speed of the vehicle is synchronized with the shaft rotational speed for a reverse gear of the gearbox,
f) engaging said reverse gear of the gearbox (3),
g) checking brake torque requested of the propulsion system,
15 and
h) controlling the electric machine (9) to apply brake torque requested through the third component (11) to the input shaft (3a) of the gearbox,
in which the steps a) and b) are omitted in case said locking
20 means is in the releasing position at the start of the method.

2. A method according to claim 1, **characterised** in that it is a vehicle having a said propulsion system with the sun gear (10) as said first component and the ring gear (11) as said
25 third component that is braked.

3. A method according to claim 1 or 2, **characterised** in that it is carried out for a vehicle having a propulsion system comprising a range gear.

4. A method according to claim 3, **characterised** in that before carrying out said steps it is ensured that a high range gear is engaged.
- 5 5. A method according to any of the preceding claims, **characterised** in that step g) is carried out repeatedly or continuously while carrying out step h), and that the rotational speed (n_1) of the output shaft (2a) of the combustion engine is controlled towards a predetermined rotational speed of the combustion engine as long as said checking indicates that
10 brake torque is requested.
6. A method according to claim 5, **characterised** in that the output shaft (2a) of the combustion engine is controlled towards
15 a predetermined rotational speed (n_1) in the form a low rotational speed, such as a so-called idle rotational speed, of the combustion engine.
7. A method according to any of claims 1-4, **characterised** in
20 that step g) is carried out repeatedly or continuously while carrying out step h), and that, as long as said checking indicates that brake torque is requested, the combustion engine (2) is controlled to deliver a rotational speed of the output shaft (2a) thereof which is so dependent on the rotational
25 speed (n_3) of the rotor (9b) of the electric machine that the electric machine is in step h) controllable to brake the input shaft (3a) of the gearbox while generating a maximum electric regenerative power.

8. A method according to any of claims 1-4, **characterised** in that the fuel injection in the combustion engine (2) is stopped while carrying out step h) and when the output shaft (2a) of the combustion engine has substantially stopped this shaft is locked against rotation, and that step h) is continued with the combustion engine turned off.
9. A method according to any of the preceding claims, **characterised** in that the checking in step g) is carried out repeatedly or continuously while carrying out step h), and when said checking shows that instead of a brake torque an acceleration torque of the propulsion system is requested and the acceleration torque is less than the product of on one hand the torque needed for driving the combustion engine to rotate and on the other the transmission ratio of the planetary gear the electric machine (9) is controlled to reverse the direction of the torque applied to the input shaft (3a) of the gearbox through the third component (11) so as to apply said acceleration torque requested to this shaft.
10. A method according to any of claims 1-8, **characterised** in that the checking in step g) is carried out repeatedly or continuously while carrying out step h), and that when said checking shows that instead of a brake torque an acceleration torque of the propulsion system is requested and the acceleration torque is less than the product of on one hand the torque needed for driving the combustion engine (2) to rotate and on the other the transmission ratio of the planetary gear the electric machine (9) or the electric machine and the combustion engine (2) is/are controlled so that it/they through

the input shaft (3a) of the gearbox gives/give a state of zero torque in the gearbox (3), whereupon the reverse gear is disengaged, the electric machine and/or combustion engine is/are controlled so that the rotational speed of the third component (11) together with the rotational speed of the output shaft (2a) of the combustion engine give the input shaft (3a) of the gearbox a rotational speed which for the existing speed of the vehicle is synchronized with the shaft rotational speed for a forward gear of the gearbox (3) and said forward gear of the gearbox is then engaged.

11. A method according to any of claims 1-8, **characterised** in that the checking in step g) is carried out repeatedly or continuously while carrying out step h), and that when said checking shows that instead of a brake torque an acceleration torque of the propulsion system is requested and the acceleration torque is larger than the product of on one hand the torque needed for driving the combustion engine (2) to rotate and on the other the transmission ratio of the planetary gear the electric machine (9) or the electric machine and the combustion engine (2) is/are controlled so that it/they through the input shaft (3a) of the gearbox gives/give a state of zero torque in the gearbox (3), whereupon the reverse gear is disengaged, the electric machine and/or combustion engine is/are controlled so that the rotational speed of the third component (11) together with the rotational speed of the output shaft (2a) of the combustion engine give the input shaft (3a) of the gearbox a rotational speed which for the existing speed of the vehicle is synchronized with the shaft rotational

speed for a forward gear of the gearbox (3) and said forward gear of the gearbox is then engaged.

- 5 12.A method according to any of the preceding claims, **characterised** in that step a) comprises a calculation of the rotational speed (n_2) by which the input shaft (3a) of the gearbox is to be driven for a state of zero torque between the components (10, 12) interlocked by the locking means for the existing speed of the vehicle and the gear engaged in the
10 gearbox as well as calculation of the rotational speeds (n_1 , n_3) of the output shaft (2a) of the combustion engine and the rotor (9b) of the electric machine required for obtaining this state.
- 15 13.A method according to any of the preceding claims, **characterised** in that step c) comprises a calculation of the rotational speed (n_2) by which the input shaft (3a) of the gearbox is to be driven for a state of zero torque in the gearbox (3) for the existing speed of the vehicle and gear engaged in
20 the gearbox as well as a calculation of the rotational speeds (n_1 , n_3) of the output shaft (2a) of the combustion engine and the rotor (9b) of the electric machine required for obtaining this state.
- 25 14.A method according to any of the preceding claims, **characterised** in that step e) comprises a calculation of the rotational speed (n_2) which the input shaft (3a) of the gearbox would get if for the existing speed of the vehicle said reverse gear of the gearbox (3) would be engaged as well as calculation
30 of the rotational speed (n_3) of the ring gear (11) and the

rotational speed (n_1) of the output shaft (2a) of the combustion engine which together would give the input shaft of the gearbox said rotational speed calculated for the reverse gear engaged.

5

15. A method according to claim 7, **characterised** in that step h) comprises a calculation of the rotational speed (n_1) to be assumed by the output shaft (2a) of the combustion engine for giving the electric machine (9) a rotational speed (n_3) enabling it to brake while generating a maximum regenerative power.

10

16. A computer program comprising computer program code for bringing a computer to implement a method according to any of claims 1-15 when the computer program code is executed in the computer.

15

17. A computer program product comprising a data storing medium readable by a computer, in which the computer program code of a computer program according to claim 16 is stored on the data storing medium.

20

18. An electronic control unit of a motor vehicle comprising an execution means, a memory (42) connected to the execution means (41) and a data storing medium (44) connected to the execution means, in which the computer program code of a computer program according to claim 16 is stored on said data storing medium (44).

25

19.A vehicle comprising an electronic control unit according to claim 18.

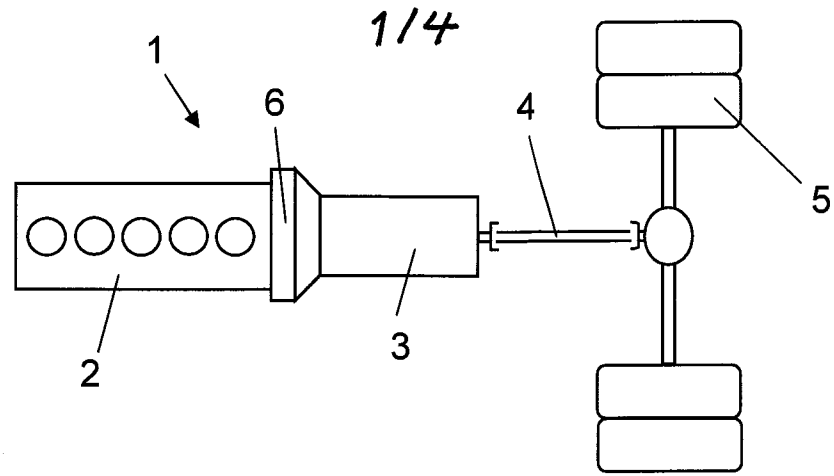


Fig 1

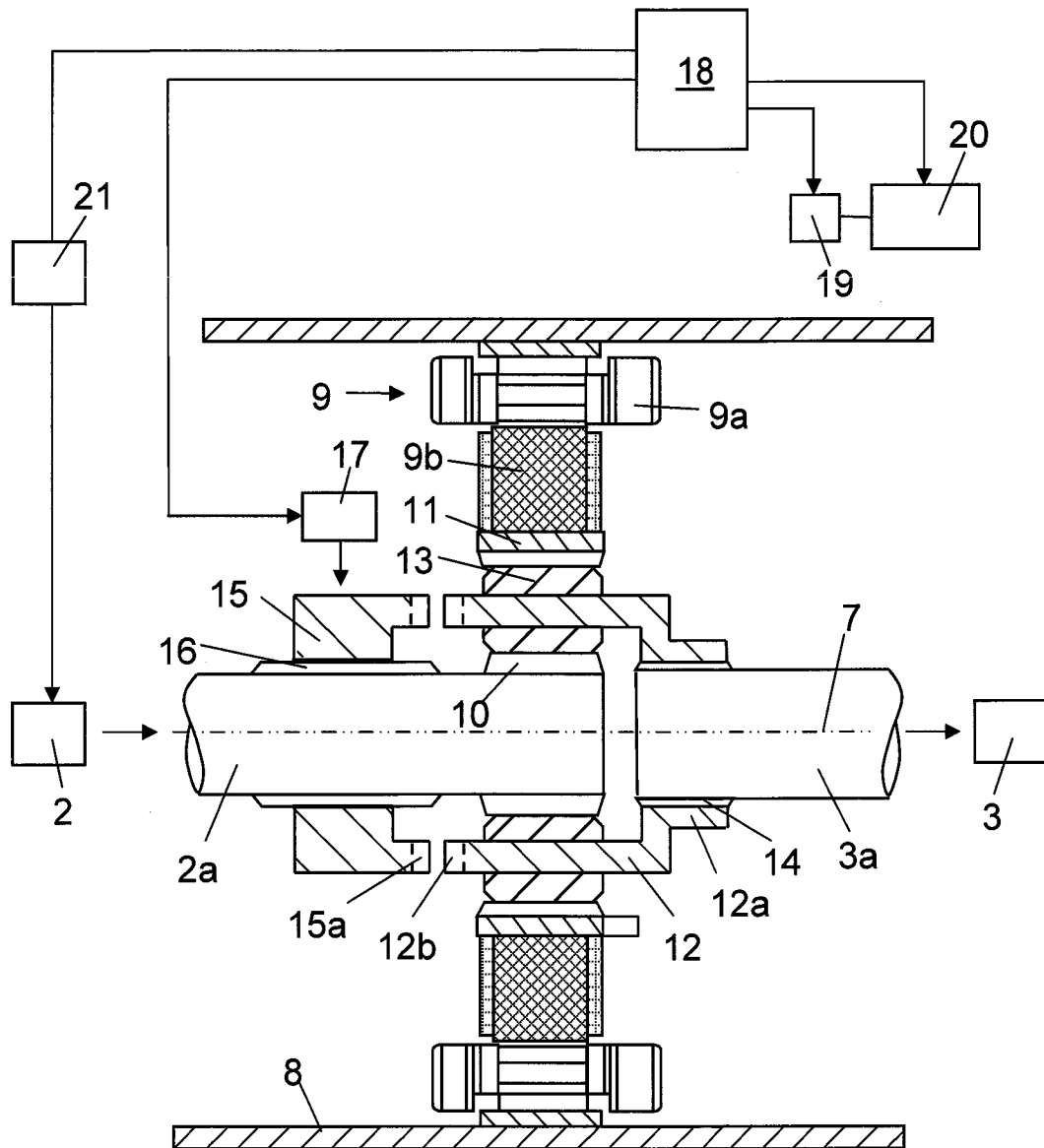


Fig 2

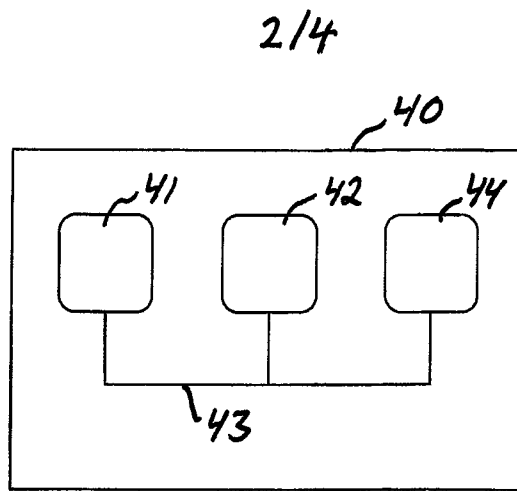


Fig 3

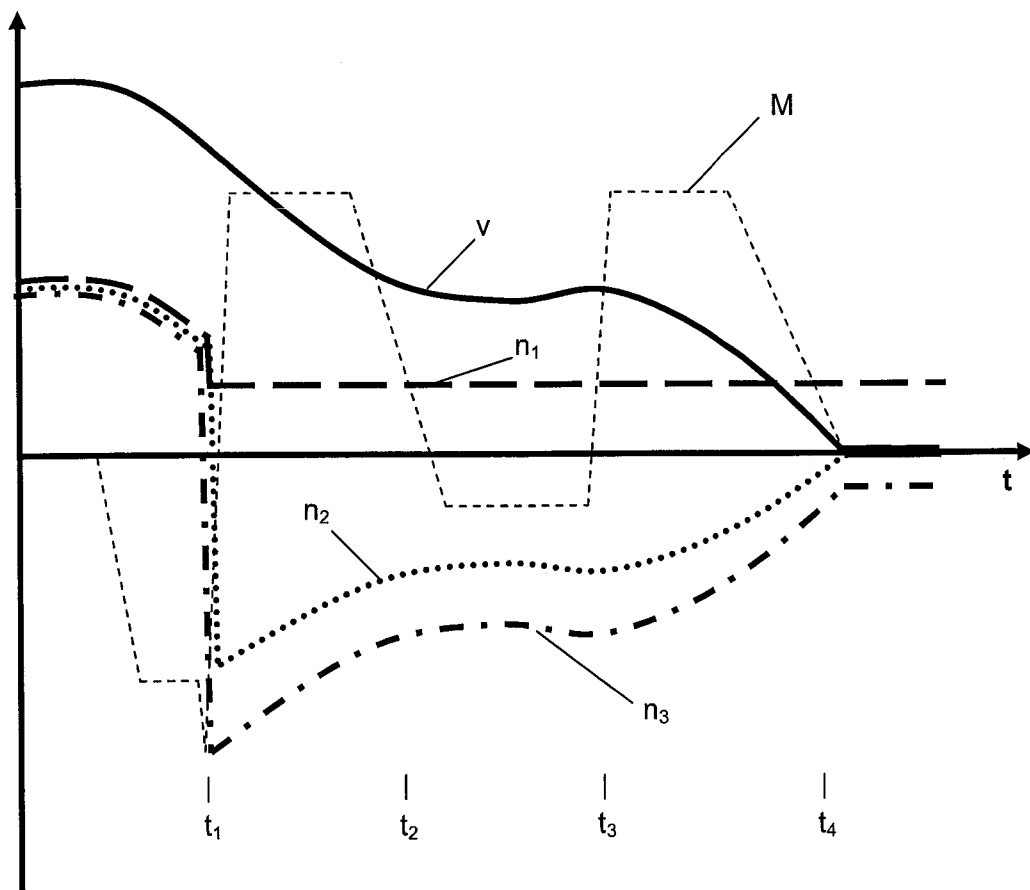


Fig 4

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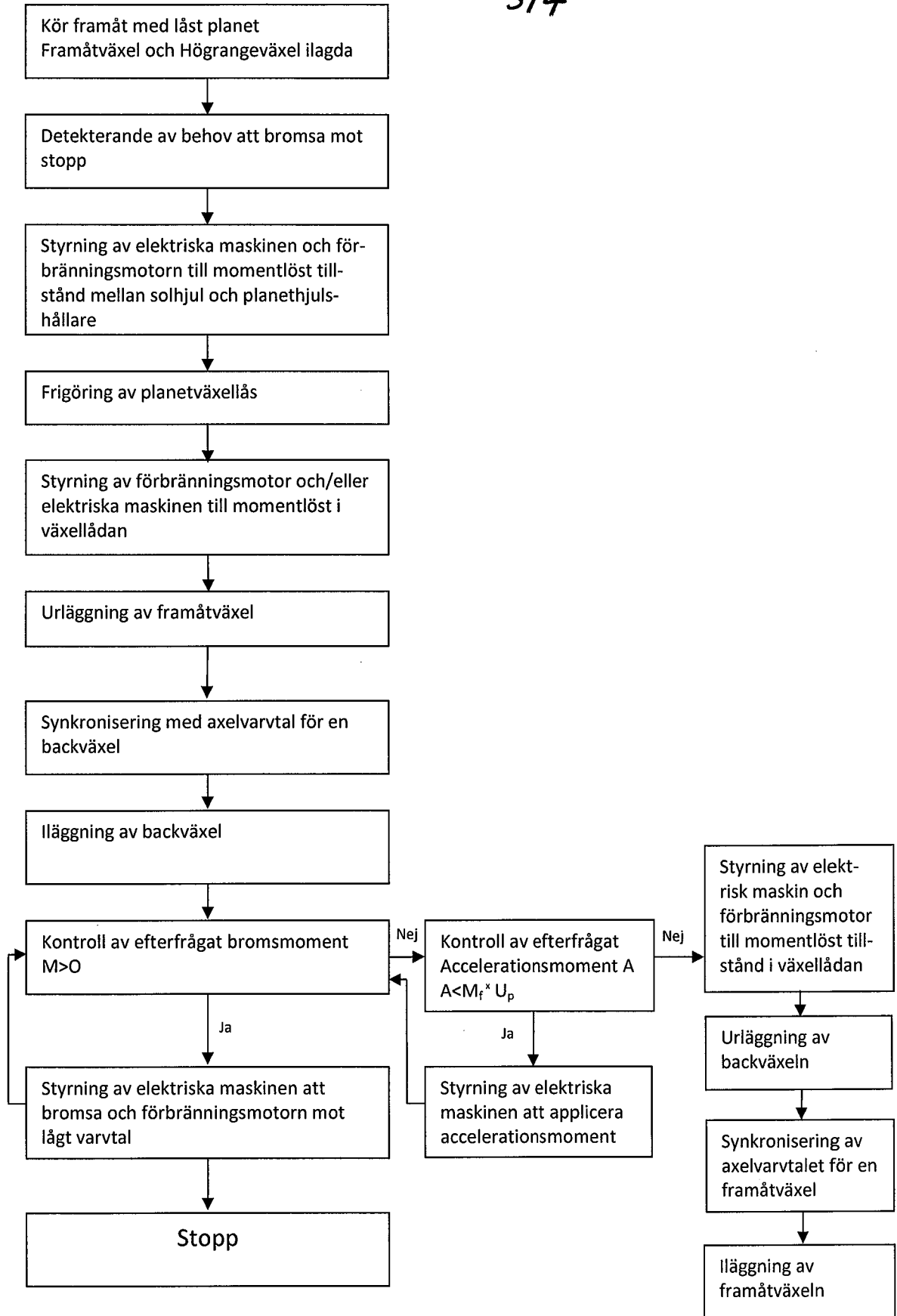


Fig. 5

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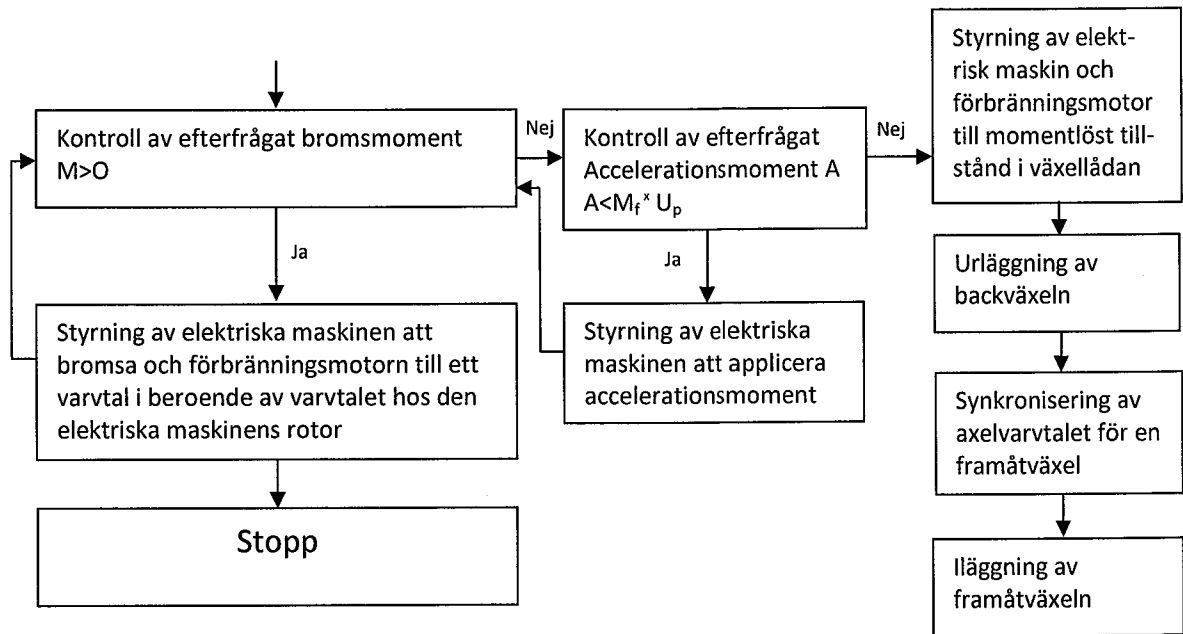


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2013/050791

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B60K, B60L, B60W, 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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20030062206 A1 (FUJIKAWA MASATO), 3 April 2003 (2003-04-03); abstract; figure 2; claim 1 --	1-19
A	US 20020094899 A1 (HAMAI KYUGO), 18 July 2002 (2002-07-18); paragraphs [0133]-[0135]; figure 1 --	1-19
A	US 20040168841 A1 (OHTA TAKASHI ET AL), 2 September 2004 (2004-09-02); abstract; paragraphs [0110], [0111]; figure 1 --	1-19

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:

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

“E” earlier application or patent but published on or after the international filing date

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

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search

14-11-2013

Date of mailing of the international search report

15-11-2013

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2013/050791

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 20020063000 A1 (KOJIMA MASAKIYO), 30 May 2002 (2002-05-30); abstract; figure 1; claim 1 --	1-19
A	US 20100173746 A1 (IDESHIO YUKIHIKO ET AL), 8 July 2010 (2010-07-08); abstract; figure 1 -- -----	1-19

Continuation of: second sheet

International Patent Classification (IPC)

B60W 10/18 (2012.01)

B60K 6/365 (2007.10)

B60L 7/10 (2006.01)

B60W 10/08 (2006.01)

B60W 10/11 (2012.01)

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