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(54) Title: A METHOD FOR ACCELERATING A HYBRID VEHICLE

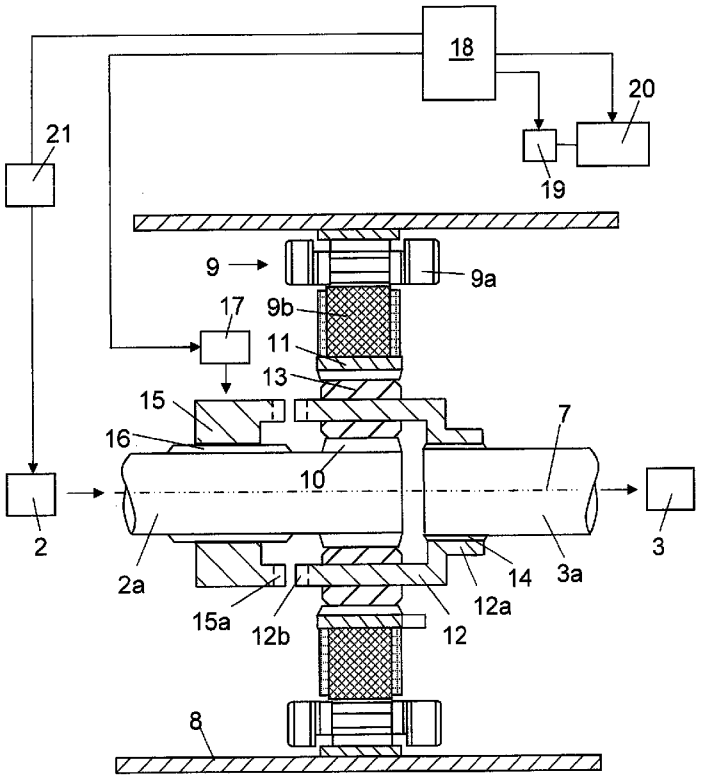

Fig 2

(57) Abstract: A method for accelerating a vehicle driving forward, in which the vehicle has 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 accelerating the vehicle the torque of the electric machine is controlled and the rotational speed of the combustion engine is controlled until the members of the planetary gear have the same rotational speed and may be interlocked.

WO 2014/003660 A1

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A method for accelerating a hybrid vehicle

FIELD OF THE INVENTION AND PRIOR ART

The present invention relates to a method for accelerating a vehicle driving forward according to the preamble of appended claim 1. Accordingly, the method is started when the vehicle is driving forward.

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

Accordingly, the invention relates to a method for accelerating a hybrid vehicle driving forward, 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 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 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.

The utilization of a conventional clutch mechanism disconnecting the input shaft of the gearbox with respect to the combustion en-

gine 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 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 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 interconnected 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 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 controlling the electric machine with respect to torque and the combustion engine with respect to rotational speed during the

entire method the first rotational speed and the rotation of the first component connected to the output shaft of the combustion engine will approaching each other until the interlocking may take place, and this does then take place without any torque interruption in the drivetrain formed by the propulsion system of the vehicle and the driver of the vehicle will not notice the transfer from free to locked planetary gear taken place through the method. Reasons for a transfer from free to locked planet may for example be that it is from the energy point of view more advantageous to drive in the locked position in the existing driving situation or energy stored for driving the electric machine starts to run out.

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 component, 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.

According to another embodiment of the invention the rotational speed of the input shaft of the gearbox is measured in step b) and the combustion engine is controlled to change the rotational speed thereof in the direction towards this rotational speed. This means a comparatively simple and reliable control of the combustion engine to the state in which the locking means may be transferred to the locking position.

According to another embodiment of the invention the method is started in a state of said propulsion system with a rotational speed of the first component being lower than said first rotational speed, and the combustion engine is in step b) controlled to increase the rotational speed thereof in the direction towards said first rotational speed. The rotational speed of the first component connected to the output shaft of the combustion engine is usually lower than said first rotational speed, and by then controlling the combustion engine to increase the rotational speed thereof for obtaining said locking position the combustion engine contributes to the acceleration requested of the vehicle.

According to another embodiment of the invention the sun gear and the planet wheel carrier are interlocked in step c). This is an advantageous position for carrying out said interlocking. Less torque is by this transferred through the planetary gear wheels. Only the torque of the electric machine is then transferred through these gear wheels.

The invention also relates to a computer program having the features listed in claim 6, a computer program product having the features listed in claim 7, an electronic control unit having the features listed in claim 8 and a vehicle according to claim 9.

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

BRIEF DESCRIPTION OF THE DRAWINGS

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

In the drawings:

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 combustion engine shaft connected to the planetary gear of the propulsion system according to Fig 2 and the input

shaft to the gearbox and the vehicle speed and the torque of the electric machine vary over time when carrying out a method according to an embodiment of the invention for accelerating a vehicle driving forward, and

Fig 5 is a flow chart illustrating a method according to an embodiment of the invention.

DETAILED DESCRIPTION OF AN EMBODIMENT 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.

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 out-

put 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 portions 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 planet wheel carrier and the 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.

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 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 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. 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 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 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.

Fig 5 shows a flow chart illustrating a method according to an embodiment of the present invention for accelerating a vehicle

driving forward, in which this vehicle has a propulsion system of the type shown in Fig 2. Reference is at the same time made to Fig 4, where the rotational speeds of the output shaft of the combustion engine and the input shaft of the gearbox n_1 and n_2, respectively, the speed v of the vehicle and the torque M of the electric machine are plotted versus the time for carrying out this method.

The vehicle is driven forward with the locking means in the releasing position and a forward gear engaged when the method is started. This means that all three components of planetary gear are allowed to rotate with different rotational speeds. The reason for driving the vehicle in this way may for example be that a gear- change has taken place in the gearbox, which had been advantageous to carry out with the planetary gear in the released state or that the vehicle is driven with a comparatively high speed and the combustion engine is driven at low rotational speeds since this is advantageous from the energy consumption point of view. A need to accelerate the vehicle and change to drive with the planetary gear in the locking position is then detected, for example because the energy level in a battery providing the electric machine with energy starts to run out.

The method is then started by the control unit 18, which at the time t_1 controls the electric machine 9 to deliver a torque M corresponding to the product of on one hand the propulsion system torque requested for the acceleration and on the other the transmission ratio of the planetary gear. The transmission ratio of the planetary gear is in this case the number of teeth of the ring gear/(the number of teeth of the sun gear + the number of teeth

of the ring gear). The rotational speed n_2 of the input shaft of the gearbox is at the same time measured and the combustion engine is controlled to change the rotational speed n_1 in the direction towards the rotational speed of the input shaft of the gearbox.

The rotational speeds n_1 and n_2 are at the time t_2 substantially equal, and the locking means is then transferred to the locking position by displacing the coupling member 15, whereupon the sun gear, the ring gear and the planet wheel carrier of the planetary gear will rotate with the same rotational speed and the vehicle will drive as if the planetary gear would not exist. Substantially equal means here that the difference between the rotational speeds is so small that an interlocking may take place.

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 the embodiment illustrated in Fig 5, 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 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.

It is possible that the component connected to the output shaft of the combustion engine has a higher rotational speed than said first rotational speed when the method is started, and the first rotational speed could also be chosen to be the rotational speed of the component connected to the electric machine.

Claims

1. A method for accelerating a vehicle driving forward, 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, said method being started when the vehicle is driven forward with the locking means in the releasing position,

characterised in that it comprises the following steps:

a) controlling the electric machine (9) to deliver a torque corresponding to the product of on one hand the propulsion

system torque requested for the acceleration and on the other the transmission ratio of the planetary gear,

b) at the same time as step a) measuring a first rotational speed of the input shaft of the gearbox or of the third component and controlling the combustion engine to change the rotational speed thereof in the direction towards said first rotational speed, and

c) transferring the locking means to the locking position when the rotational speed (n_1) of the first component is substantially equal to said first rotational speed (n_2).

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 third component that is accelerated.

3. A method according to claim 1 or 2, **characterised** in that in step b) the rotational speed (n_2) of the input shaft (3a) of the gearbox is measured and the combustion engine is controlled to change its rotational speed (n_1) in the direction towards this rotational speed.

4. A method according to any of the preceding claims, **characterised** in that the method is started in a state of said propulsion system with a rotational speed (n_1) of the first component being lower than said first rotational speed (n_2), and that in step b) the combustion engine (2) is controlled to increase the rotational speed thereof in the direction towards said first rotational speed.

5. A method according to any of the preceding claims, **characterised** in that in step c) the sun gear (10) and the planet wheel carrier (12) are interlocked.

6. A computer program comprising computer program code for bringing a computer to implement a method according to any of claims 1-5 when the computer program code is executed in the computer.

7. 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 6 is stored on the data storing medium.

8. 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 6 is stored on said data storing medium (44).

9. A vehicle comprising an electronic control unit according to claim 8.

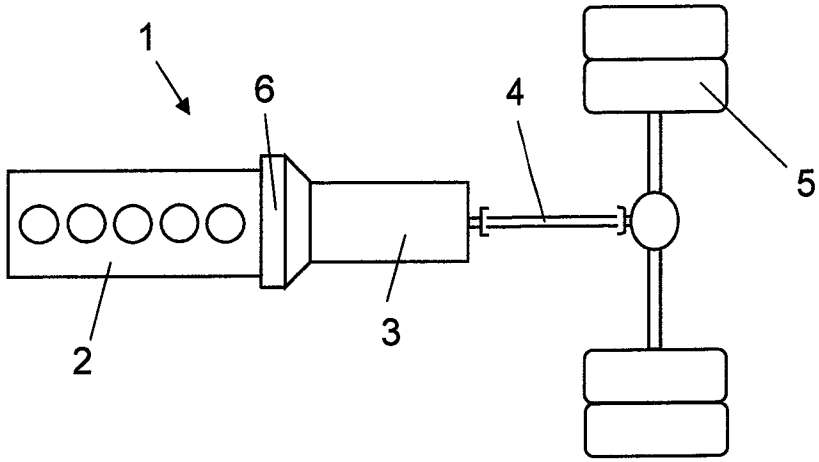
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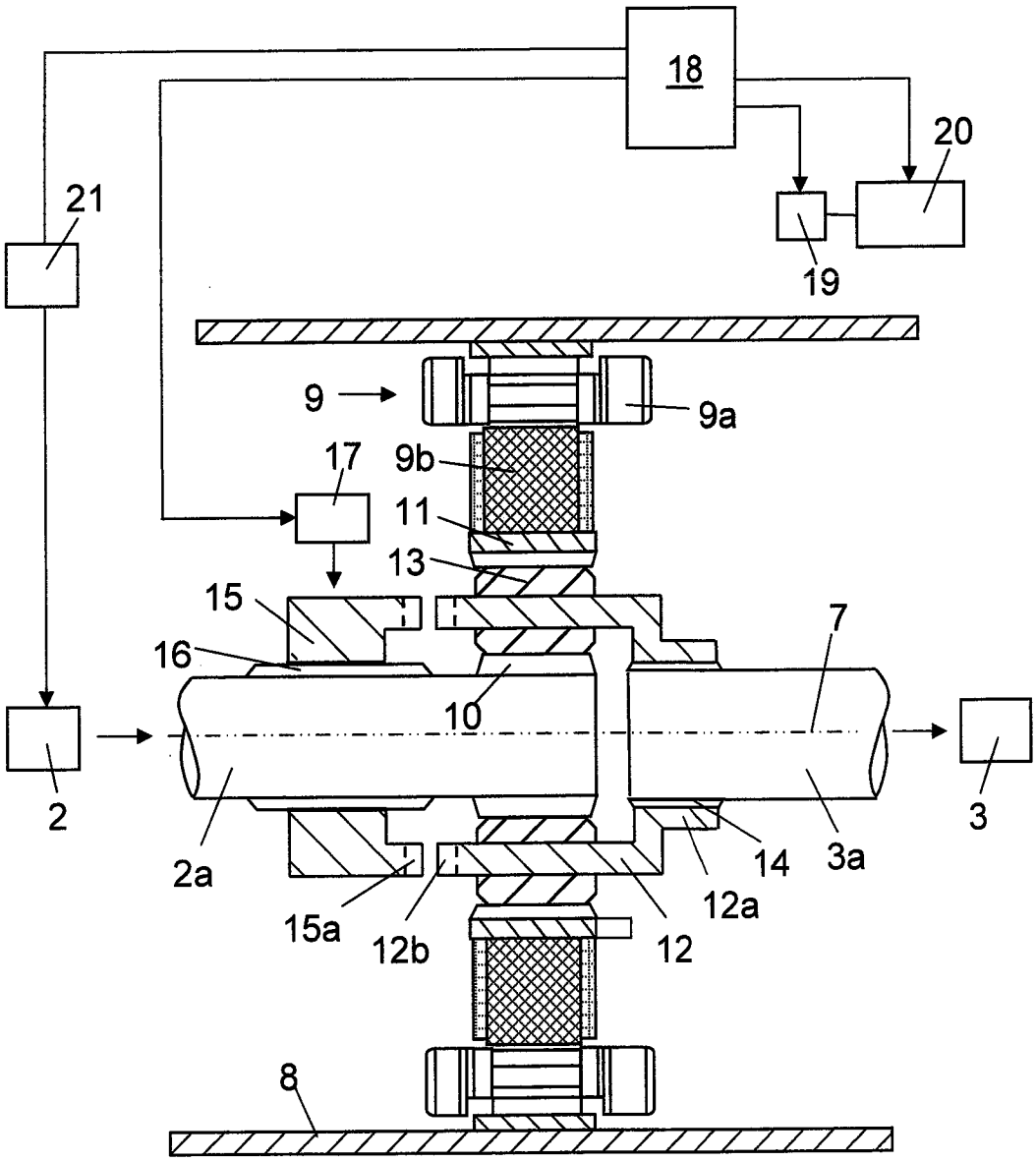
Fig 1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2a
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3a
12a
15a
12b
12
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Fig 2

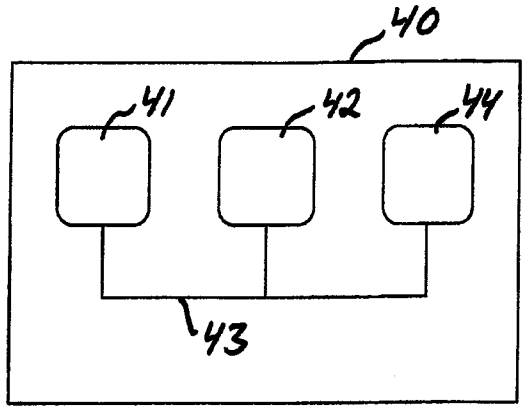

Fig 3

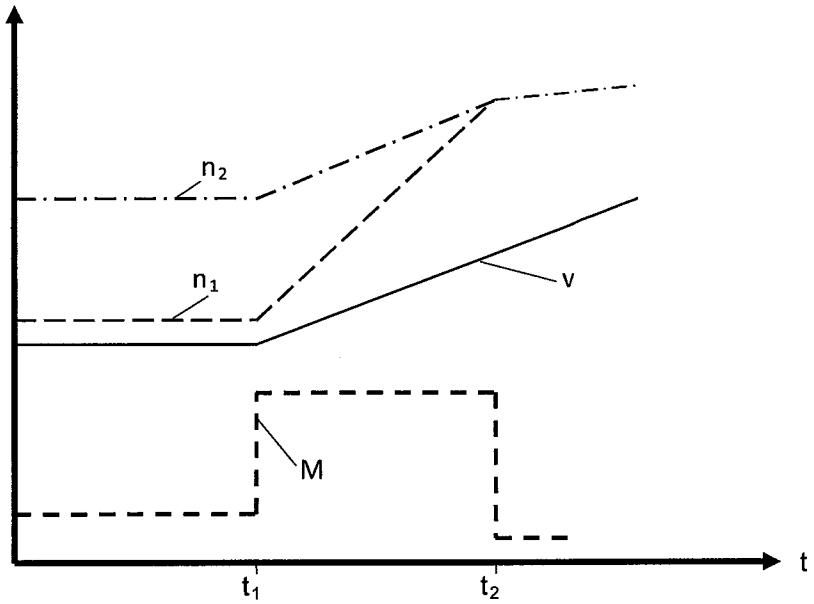

Fig 4

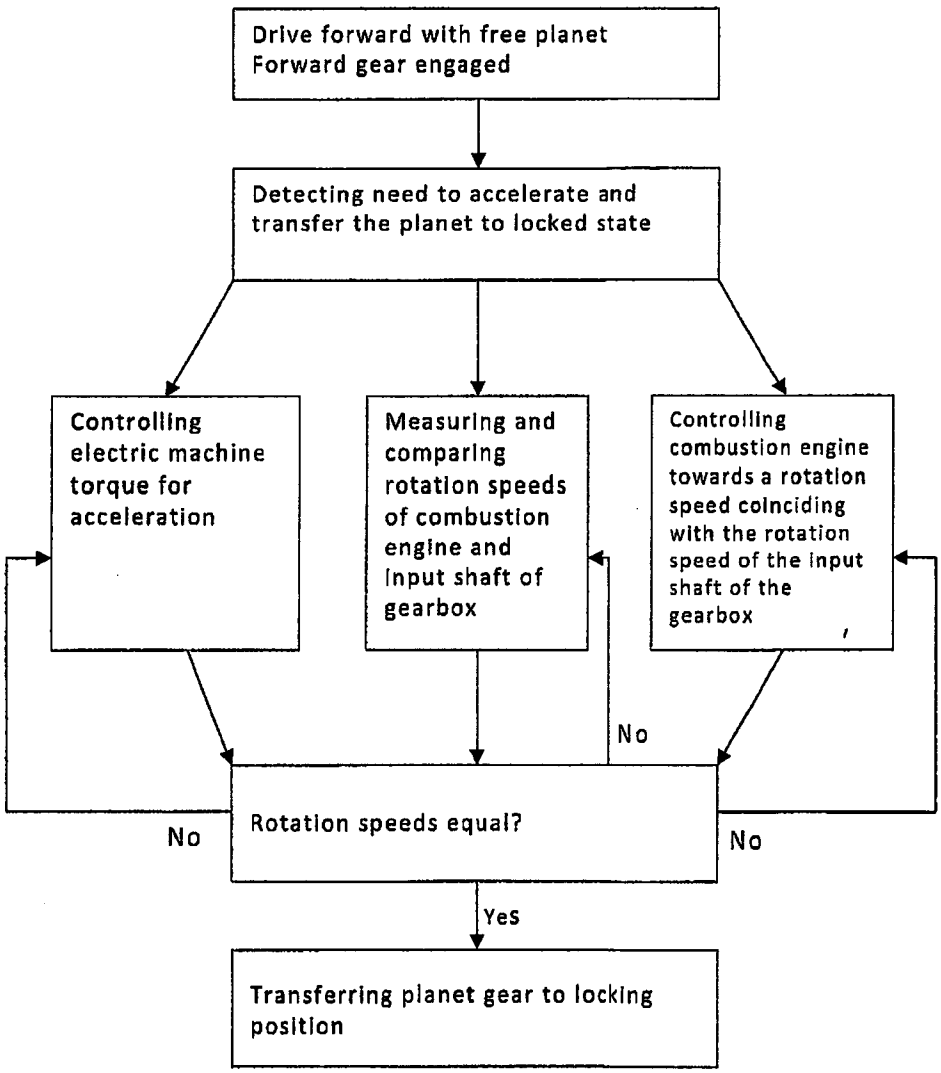
Drive forward with free planet
Forward gear engaged
Detecting need to accelerate and transfer the planet to locked state
Controlling electric machine torque for acceleration
Measuring and comparing rotation speeds of combustion engine and input shaft of gearbox
Controlling combustion engine towards a rotation speed coinciding with the rotation speed of the input shaft of the gearbox
No
No
Rotation speeds equal?
No
Yes
Transferring planet gear to locking position

Fig 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2013/050778

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B60K, B60W

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 20080277229 A1 (WALLNER STEFAN ET AL), 13 November 2008 (2008-11-13); abstract; paragraphs [0007]-[0008], [0017], [0025]-[0027]; figures 1-4 --	1-9
A	US 6054776 A (SUMI YASUO), 25 April 2000 (2000-04-25); abstract; column 18, line 29 - column 19, line 53; figures 2,19,20 --	1-9
A	DE 102005039929 A1 (ZAHNRADFABRIK FRIEDRICHSHAFEN), 1 March 2007 (2007-03-01); abstract; paragraphs [0005]-[0006]; figure 1; claims 1-6 --	1-9

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08-11-2013	08-11-2013

Name and mailing address of the ISA/SE	Authorized officer
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INTERNATIONAL SEARCH REPORT

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 102006003724 A1 (ZAHNRADFABRIK FRIEDRICHSHAFEN), 2 August 2007 (2007-08-02); abstract; paragraphs [0039]-[0040]; figures 1-4	1-9
A	DE 102006003725 A1 (ZAHNRADFABRIK FRIEDRICHSHAFEN), 2 August 2007 (2007-08-02); abstract; paragraph [0029]; figure 1	1-9
A	DE 102005039928 A1 (ZAHNRADFABRIK FRIEDRICHSHAFEN), 8 March 2007 (2007-03-08); abstract; paragraphs [0020]-[0023]; figures 1,3	1-9
A	EP 1319546 A1 (SIEMENS AG), 18 June 2003 (2003-06-18); abstract; paragraphs [0013]-[0016]; figures 1,2; cited in the application	1-9
A	US 20100113202 A1 (TREICHEL BENJAMIN A ET AL), 6 May 2010 (2010-05-06); abstract; paragraph [0032]; figures 1,2	1-9
A	DE 102006054405 A1 (ZAHNRADFABRIK FRIEDRICHSHAFEN), 5 June 2008 (2008-06-05); abstract; paragraphs [0030]-[0034]; figure 4	1-9

Continuation of: second sheet

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B60W 20/00 (2006.01)
B60W 30/18 (2012.01)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SE2013/050778

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