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(54) Title: METHOD FOR MANAGING FUEL CONSUMPTION OF A HYBRID VEHICLE AND VEHICLE ADAPTED TO SUCH A METHOD

(57) Abstract: This method is for managing fuel consumption of a hybrid vehicle (T) on a given trip, said vehicle comprising an internal combustion engine (1), electric energy storage means (4) and at least an electric machine (2) adapted to work as a generator or as a motor. This method comprises at least the following steps: a) determination (101 -104), for the given trip, of a target value (R_T) of a parameter representative (R) of fuel economy resulting from the use of the electric machine, b) determination (106-107) of an actual value (R_A) of the parameter when the vehicle is running on the trip, c) comparison (108) of said target value (R_T) and said actual value (R_A), and d) information (109) of a user of said result of the comparison, at least at the end of said trip. The vehicle is provided with computation means and display means allowing steps c) and d) to take place onboard.

Fig.5

Method for managing fuel consumption of a hybrid vehicle and vehicle adapted to such a method

TECHNICAL FIELD OF THE INVENTION

This invention concerns a method for managing fuel consumption of a hybrid vehicle on a given trip, in order to optimize energy savings on such a trip. The invention also concerns a vehicle adapted to perform such a method.

5

BACKGROUND OF THE INVENTION

The reduction of fuel consumption of automotive vehicles, in particular trucks, is a major issue for the sustainability of road transport and is a key element for the competitiveness of truck manufacturers.

10   In order to optimize fuel consumption of an internal combustion engine of a vehicle, it is known, e.g. from US-B-7 240 750, to take into account future energy needs in a hybrid vehicle in order to pro-actively charge the vehicle battery to an appropriate level. Such an approach does not take into account the behaviour of the driver.

15   It is also known from JP-A-11 220 807 to compute, on the basis of the running state of a vehicle or the behaviour of a driver, a reference fuel consumption and to display an instantaneous actual fuel consumption and the reference fuel consumption. This comparative display is not connected to the actual trip being travelled through by the vehicle, so that optimization of the

20   energy needs is not fully effective.

SUMMARY OF THE INVENTION

This invention aims at proposing a new method for managing fuel consumption of a hybrid vehicle on a given trip, this method being such that

25   the energy savings resulting from the use of the hybrid components of the vehicle, which derive in particular from the behaviour of the driver, can be compared to a target or optimized value which can be determined on the basis of the trip to be travelled through and on the features of the vehicle.

With this respect, the invention relates to a method for managing fuel

30   consumption of a hybrid vehicle on a given trip, this vehicle comprising an

internal combustion engine, electric energy storage means and at least an electric machine adapted to work as a generator or as a motor. This method comprises at least the following steps:

  a) determination, for the given trip, of a target value of a parameter representative of fuel economy resulting from the use of the electric machine,

  b) determination of an actual value of this parameter when the vehicle is running on the given trip,

  c) comparison of the target value and actual value determined here-above, and

  d) information of a user of the result of the comparison, at least at the end of the trip.

The actual value of the parameter depends on the driving style or behaviour of the driver. Thanks to the invention, the driver or a fleet manager can be kept informed of the influence of the driver's style and/or behaviour onto the efficiency of the energy savings resulting from the use of the hybrid components of the vehicle. In other words, the driver and/or the fleet manager is/are aware of the influence of the driving style on the fuel savings for the given trip.

According to a first embodiment of the invention, step a) includes at least the following sub-steps:

  a1) performance of at least a trial run on the given trip with the vehicle and recordal of a dataset of the vehicle on this trial run,

  a2) computation, on the basis of at least the dataset, of a first energy needs value of the vehicle to travel the given trip when only an internal combustion engine is used,

  a3) computation, on the basis of at least the dataset, of a second energy needs value of the vehicle to travel the trip when the internal combustion engine, the storage means and the electric machine are used, and

  a4) computation of a target value of the parameter, on the basis of the first and second energy needs values.

In such a case, the dataset recorded in step a1) is advantageously representative of the trip and of the operation of the vehicle on the trip. This dataset can include at least a velocity profile of the vehicle along the trip.

Alternatively, and according to another embodiment of the invention, step a) includes at least the following steps:

a'1)   generation of a model of the trip and the vehicle,

a'2)   computation, on the basis of the model, of a first energy needs value of the vehicle to travel the given trip when only an internal combustion engine is used,

a'3)   computation, on the basis of the model, of a second energy needs value of the vehicle to travel the trip when the internal combustion engine, the storage means and the electric machine are used, and

a'4)   computation of a target value of the parameter, on the basis of the first and second energy needs values.

According to further aspects of the invention which are advantageous but not compulsory, this method can incorporate one or several of the following features:

-   steps a2) to a4) or a'2) to a'4) take place in an off-board computer;

-   the target value is stored onboard the vehicle after it has been determined;

-   step b) is performed onboard of the vehicle, on the basis of the actual working conditions of the internal combustion engine, the storage means and the electric machine, when the vehicle is running on the given trip;

-   step c) is performed onboard of the vehicle and, in step d), the driver is informed onboard of the result of the comparison,;

-   step d) can take place at the end of the trip or occur several times or continuously when the vehicle is running on the given trip,

-   alternatively or in addition, in step d), information is sent to a remote computer (202) with respect to the result of the comparison of step c).

- the parameter which represents fuel economy is a ratio of the energy needs of the vehicle for the given trip which corresponds to the energy savings resulting from the use of the storage means and the electric machine.

The invention also concerns a hybrid automotive vehicle which is adapted to perform the method mentioned here-above. This vehicle comprises an internal combustion engine, electric energy storage means, at least an electric machine adapted to work as a generator or as a motor, a memory adapted to store the target value, computation means adapted to determine the actual value of the parameter and to make the comparison of step c) and display means adapted to allow information of the driver according to step d).

The display means are advantageously adapted to display graphically a ratio of the actual value to the target value of the parameter representative of fuel economy.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be explained in correspondence with the annexed figures and as an illustrative example, without restricting the object of the invention. In the annexed figures:

- figure 1 is a schematic representation of a truck embodying the invention,
- figure 2 is a schematic graph showing a velocity profile on a trip, as a function of time,
- figure 3 is a schematic representation of the flow of information with a method of the invention.
- figure 4 is a diagram showing the energy repartition in a hybrid vehicle in different configurations, and
- figure 5 is a block diagram showing some main steps of a method of the invention,

DETAILED DESCRIPTION OF SOME EMBODIMENTS

The truck T represented on figure 1 includes a Diesel internal combustion engine 1; an electric machine 2 and a clutch 3 interposed between the engine and the electric machine. A set of batteries 4 is connected to the electric machine and is adapted to store electric energy generated by machine 2 when this machine works as a generator. Battery set 4 is also adapted to provide electric energy to machine 2 when it works as a motor.

Several other auxiliary equipments 51, 52 and 53, such as in a heating/cooling system for the cabin, electric windows or a radio set, are also fed by battery set 4 with electric energy.

Electric machine 2 is an integrated starter alternator motor or ISAM. It can work as a generator or as a motor since truck T is a hybrid automotive vehicle. More precisely, machine 2 works as a generator when truck T slows down. Under such circumstances, the main shaft 6 of the power transmission gear of truck T drives machine 2 which generates electric power. This power is directed towards battery set 4.

This electric energy, which is stored in battery set 4, can be used later to drive shaft 6 via machine 2 working as a motor, which allows not to use engine 1 or to reduce the use the engine 1 for at least a part of a trip. This saves fuel.

It should be noted here that, according to a non-represented alternative embodiment of the invention, truck T can include several electric machines of the type of machine 2. Although Figure 1 shows a parallel hybrid configuration, the invention could be applied to all types of hybrid configurations such as a series hybrid configuration or a parallel/series hybrid configuration.

An electronic control unit 7 is connected to engine 1, machine 2 and battery set 4 and is adapted to collect information with respect to these items, in the form of electric signals S_1, S_2, S_4 and to send command signals S'_1, S'_2, S'_4 respectively to these items in order to pilot them.

Control unit 7 is connected to a display 8 which is located in the driver's compartment. Control unit 7 includes a memory 71 and a microchip 72.

When one knows that truck T is going to follow a predetermined route, that is to run on a given trip, one can optimize fuel consumption in engine 1 by making the best use of the hybrid components of the system, in particular items 2 and 4.

5   According to one embodiment of the method of the invention, one follows the predetermined route with truck T, as a trial run or reference trip on the given trip.. During this trip, one records a set of data which will describe the trip. The set of data will for example include the velocity V of truck T as a function of time t. For example, a signal S_9 is provided to unit 7 on the basis of

10   the rotational speed of one wheel axle 9 of the truck T. The vehicle speed can also be obtained through a global positioning system (GPS) locator installed on-board the vehicle. This velocity profile can have the shape shown by curve V_P on figure 2 where t_1 represents the beginning of the trip and t_2 represents the end of the trip. During this trip other parameters can also be recorded and

15   stored such as:

- the slope of the road along the trip;
- the torque provided by the engine and the motor as a function of time;
- the battery state of charge as a function of time;

20   - the total vehicle weight, and its possible evolution along the trip;
- the instant gearbox ratio, etc....

The reference trip, which will serve as the basis to evaluate further trips, should be preferably preformed by a skilled driver driving the vehicle with maximum care to make the best use of the hybrid components of the system.

25   Once this reference trip recordal has been performed, a first dataset D_1 corresponding to velocity profile V_P and/or, if applicable, to one or several of the other parameters listed above, is transferred to a remote computer as shown by arrow A_1 on figure 3. This remote computer can be a fleet manager computer 201. This data transfer can occur via any suitable telecommunication

30   means, for instance via a wireless telephone network. The fleet manager can then forward this information to the truck original equipment manufacturer (OEM) server 202. Of course, direct communication of the truck with the OEM

server is also possible. The dataset D1, including the velocity profile V_P is then uploaded into this server, as shown by arrow A_2. This server 202 includes models for several hybrid vehicles, including truck T. The velocity profile V_P and the features of truck T are forwarded, in a second record data set D_2, as

5   shown by arrow A3, from server 202 to an OEM model computer 203 which is able to determine, on the basis of the data received from server 202, fuel consumption of truck T in different configurations during the given trip, between instants t_1 and t_2.

More precisely, model computer 203 is able to compute fuel

10   consumption of the truck T during the trip if it was equipped with only an internal combustion engine. In an embodiment of the invention, the computation is made with the hypothethis that the truck T is not equipped with its actual engine 1, but with a theoretical engine having the same power and torque ratings as the combination of engine 1 and motor 2. In other words,

15   model computer 203 computes the fuel consumption of truck T on the given trip if one does not make use of the hybrid components of this truck. This gives a first energy needs value N_1 for truck T on the given trip.

Model computer C can also compute the energy needs value N_2 for truck T when it runs the given trip with an optimized use of the hybrid

20   components 2 and 4, that is when the driver's behaviour is such that maximum fuel savings occur. This second energy needs value N_2 is an optimized value, which is smaller than the first value N_1.

Computations in computer 203 for determination of values N_1 and N_2 are made by taking into account the dataset recorded during the trial run. In

25   our example they take into account at least the velocity profile V_P. They can also take into account other parameters, such as those listed above.

Considering the energy distribution within truck T, as shown on figure 4, one can consider the energy A delivered by Diesel engine 1 or by the theoretical engine. When computing in the configuration where only the

30   theoretical engine is used to power truck T, the value of energy A equals N_1.

When truck T is used in hybrid mode, that is when one uses machine 2 to save fuel, at least a part B of the braking energy used to slow down the

truck T is transferred to the energy buffer formed by battery set 4. A part C of this energy, preferably the major part of this energy, is provided to the transmission train 11 of truck T as traction energy. The transfer of energy B occurs when electric machine works as a generator, whereas the transfer of

5   energy C occurs when machine 2 works as a motor.

When truck T works in hybrid mode, the value of energy A provided by Diesel engine 1 equals to N_1-C.

The value N_2 corresponds to an optimized value of A when transfer energy C has been maximized on the given trip.

10   One can compute, from values N_1 and N_2, a free energy rate R, which corresponds to the portion of the traction energy which has not been provided by fuel injected in engine 1. This free energy rate is a percentage representing the free energy and can be expressed as:

15

$$R = C/N_1 = (N_1-N_2) / N_1$$

This free energy rate is a parameter which is representative of the fuel savings resulting from the use of electric machine 2.

Model computer 203 runs in order to determine working conditions of

20   truck T along the given trip in a way which will maximize free energy rate R.

This maximized or optimized value of rate R forms a target value R_T which can be sent back to OEM server 202 together with value N_1, as shown by arrow A_4, and then to computer 201 and truck T, as shown by arrows A_5 and A_6. The target value R_T and the energy needs value N_1 can then be stored

25   in memory 71.

Communication between computers 201 and 203 and server 202 can occur via the Internet or any other adapted networks. Direct communication between computers 202 and 203 is also possible, in particular for what concerns the transfer of value R_T. Direct communication between

30   computer 203 and truck T can also be considered for the transfer of value R_T.

According to an alternative embodiment of the invention, instead of performing a trial run on the trip as explained here-above, one can generate in

model computer 203 a model of the trip, on the basis of a three dimensional map of said trip, and use data relating to truck T and coming from server 202. Computation of values N_1 and N_2, on the one hand, and of free energy rate R can then be performed in model computer 203 as explained here-above. This enables also to generate a target value R_T for this ratio.

When a driver uses truck T to run the given trip after determination of target value R_T, it is possible to collect data relating to the actual working conditions of items 1, 2 and 4. Of course, the truck T needs not necessarily be the same individual truck T as the one used to perform the reference trip mentioned above, but at least a truck having similar characteristics. In particular, it is possible to measure the instantaneous fuel consumption of engine 1 along this given trip. This is included in signal S_1. This enables microchip 72 to determine a third value N_3 of the energy needs for truck T on the given trip, this value corresponding to the actual needs of engine 1 which depends, in particular, on the behaviour of the driver. The free energy rate R can also be defined in this case as the actual free energy rate, namely:

$$R_A = (N_1 - N_3) / N_1$$

At the end of the trip, it is possible to compute the ratio Q of the actual free energy rate R_A on the target free energy rate R_T namely:

$$Q = R_A / R_T$$

This ratio Q can be considered as a sustainable driving indicator insofar as its value depends on the driving behaviour of the driver. The closer to 1 Q is, the better the driving behaviour is in terms of fuel consumption.

Once ratio Q has been computed, it can be displayed on display 8 in order to inform the driver. This can be done by changing the colour of a zone 81 of display 8. Markings 82 and 83 can be made on display 8 in order to facilitate its reading. In the example of figure 1, the larger zone 81 is, the higher ratio Q is.

Display 8 can also show ratio Q as an numerical value between 0 and 1.

As an alternative, the value of ratio Q can be sent, by the same means as the ones used to transfer the velocity profile V_P, to the fleet manager computer 201. This enables the fleet manager to know the influence of the driver's behaviour on fuel consumption.

Of course, both the driver and the fleet manager can be informed of the value of Q, if one so wishes.

Turning now to figure 5, the method of the invention includes a first step 101 where one creates a model of the given trip to be followed by the truck. As explained here-above, this can be done on the basis of a trial run on the trip, with generation of a dataset, or by creation of computed model.

Then, in a further step 102, one computes the energy needs value N_1. In another step 103, one computes energy needs value N_2. Steps 102 and 103 can occur one after the other or simultaneously in computer 203.

In a further step 104, one computes the target value R_T of the free energy rate R. This target value is then transferred to the truck T, together with value N_1, in a further step 105. Steps 101 to 105 form a preparatory part of the method of the invention, which is done once for the given trip.

Then, each time the truck T runs on the given trip, one can perform steps 106 to 109 to assess the sustainability of the driver's behaviour. In a step 106, one collects data of the actual energy needs N_3 for truck T. This value can be, for instance, the number of fuel liters needed to run the given trip or the energy output of engine 1. In a further step 107, one computes the actual free energy rate R_A, on the basis of value N_3 and of value N_1 previously stored in memory 71.

At the end of the trip, one compares in a step 108 this actual rate R_A to the target value R, in particular by determining the ratio Q.

In a further step 109, one informs the driver and/or the fleet manager of the result of this comparison, by displaying information corresponding to ratio Q.

In the method mentioned here-above, comparison step 108 takes place at the end of the trip. However, such a comparison can also take place on several occasions during the trip or even continuously during the trip, insofar as the target value of the free energy rate has been previously computed for different instants during the trip. In fact, a sub-trip can be considered between instant t_1 and any instant t between instant t_1 and t_2 and comparison can be said take place at the end of such a sub-trip.

According to an alternative method of the invention, computation of the actual free rate energy rate R_A and comparison with the target value R_T can take place off board truck T, e.g. in computer 201. In such a case, values N_1, N_3 and R_T are sent to computer 201 when available, that is at step 104 and at the end of step 106. The fleet manager can then be informed of the influence of the driver's behaviour independently of the driver. In such a case, the result of the comparison of step 108, which takes place on computer 201, is displayed on the screen of this computer at step 109.

According to an another alternative method of the invention, all or part of the computation which has been described as being carried off-board the vehicle can be carried on-board the vehicle.

Thanks to the invention, a so called "econometer" is provided for the driver and/or for the fleet manager which will inform him or them of the actual use of the hybrid capacities of the truck.

The invention also allows to compare the respective driving styles of several drivers on a given trip, for what concerns fuel savings. Once the given trip has been chosen as a reference trip, the drivers can drive one truck on this trip one after the other and their respective Q ratio can be compared.

The invention has been described with respect to its use with a truck. However, it can also be used with a passenger car or a bus and any other hybrid automotive vehicles.

CLAIMS

1. A method for managing fuel consumption of a hybrid vehicle (T) on a given trip, said vehicle comprising an internal combustion engine (1), electric energy storage means (4) and at least an electric machine (2) adapted to work as a generator or as a motor, this method comprising at least the following steps:

    a) determination (101-104), for said trip, of a target value (R_T) of a parameter (R) representative of fuel economy resulting from the use of the electric machine,

    b) determination (106-107) of an actual value (R_A) of said parameter when the vehicle is running on said trip,

    c) comparison (108) of said target value (R_T) and said actual value (R_A), and

    d) information (109) of a user of said result (Q) of the comparison, at least at the end of said trip.

2. Method according to claim 1, characterized in that step a) includes at least the following sub-steps:

    a1) performance (101) of at least a trial run on said trip, with said vehicle (T) and recordal of a dataset on said trial run,

    a2) computation (102), on the basis of at least said dataset, of a first energy needs value (N_1) of said vehicle to travel said trip when only an internal combustion engine (1) is used,

    a3) computation, on the basis of a least said dataset, of a second energy needs value (N_2) of said vehicle to travel said trip when said internal combustion engine (1), said storage means (4) and said electric machine (2) are used, and

    a4) computation of a target value (R_T) of said parameter (R), on the basis of said first and second energy needs values (N_1, N_2).

13

3. Method according to claim 2, characterized in the dataset recorded in step a1) is representative of the trip and of the operation of the vehicle on said trip.

4. Method according to one of claims 2 or 3, characterized in that the dataset recorded in step a1) includes at least a velocity profile of the vehicle along the trip.

5. Method according to claim 1, characterized in that step a) includes at least the following steps:

a'1) generation (101) of a model of said trip and said vehicle (T),

a'2) computation, on the basis of the model, of a first energy needs value (N_1) of said vehicle to travel said trip when only an internal combustion engine (1) is used,

a'3) computation, on the basis of said model, of a second energy needs value (N_2) of said vehicle to travel said trip when said internal combustion engine (1), said storage means and said electric machine (2) are used, and

a'4) computation of a target value (R_T) of said parameter (R), on the basis of said first and second energy needs values (N_1, N_2).

6. Method according to one of claims 2 to 5, characterized in that steps a2) to a4) or a'2) to a'4) take place in an off board computer (203).

7. Method according to any of the previous claims, characterized in that said target value (R_T) is stored onboard (71) said vehicle (T) after it has been determined.

8. Method according to one of the previous claims, characterized in that step b) is performed onboard (72) said vehicle (T) on the basis of the actual working conditions of said internal combustion engine (1), said storage

means (4) and said electric machine (2), when said vehicle is running on said trip.

9. Method according to one of the previous claims, characterized in that step c) is performed onboard said vehicle (7) and the driver, in step d), is informed onboard of the result of said comparison.

10. Method according to claim 9, characterized in that step d) takes place at the end of said trip.

11. Method according to claim 9, characterized in that step d) occurs several times or continuously when said vehicle (T) is running on said trip.

12. Method according to one of the previous claims, characterized in that in step d), information is sent to a remote computer (201) with respect to the result of said comparison of step c).

13. Method according to one of the previous claims, characterized in that said parameter is a ratio (R) of the energy needs of said vehicle for said trip corresponding to the energy savings (C) resulting from the use of said storage means (4) and said electric machine (2).

14. Hybrid automotive vehicle (T) adapted to the method of one of the previous claims, said vehicle comprising an internal combustion engine (1), electric energy storage means (4), at least an electric machine (2) adapted to work as a generator or as a motor, a memory (71) adapted to store said target value (R_T), computation means (72), adapted to determine said actual value (R_A) and to make the comparison of step c), and display means (8) adapted to allow information of the driver, according to step d).

15. Vehicle according to claim 14, characterized in that said display means (8) are adapted to display graphically a ratio (Q) of the actual value

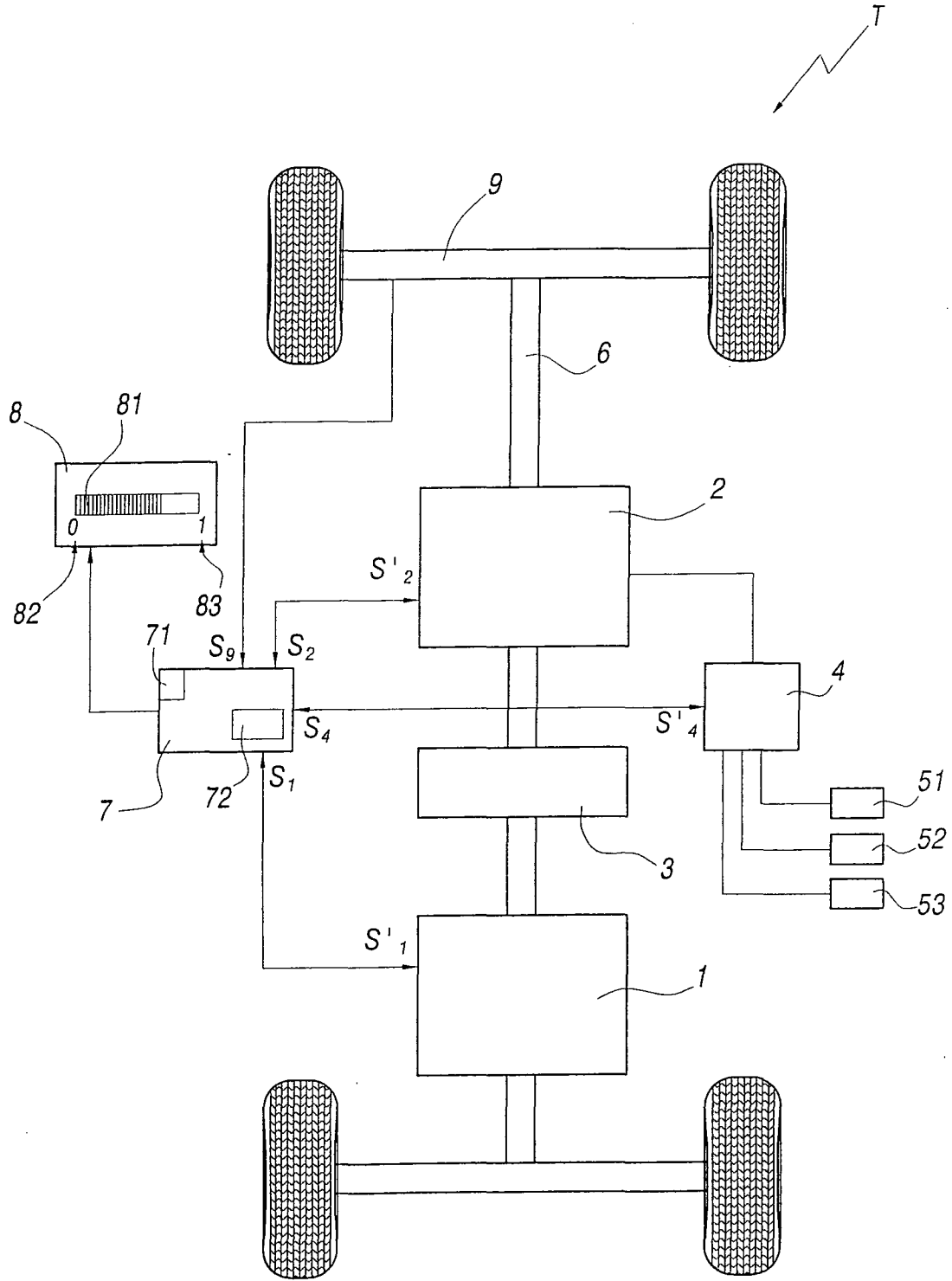(R_A) to the target value (R_T) of the parameter (R) representative of fuel economy (C).
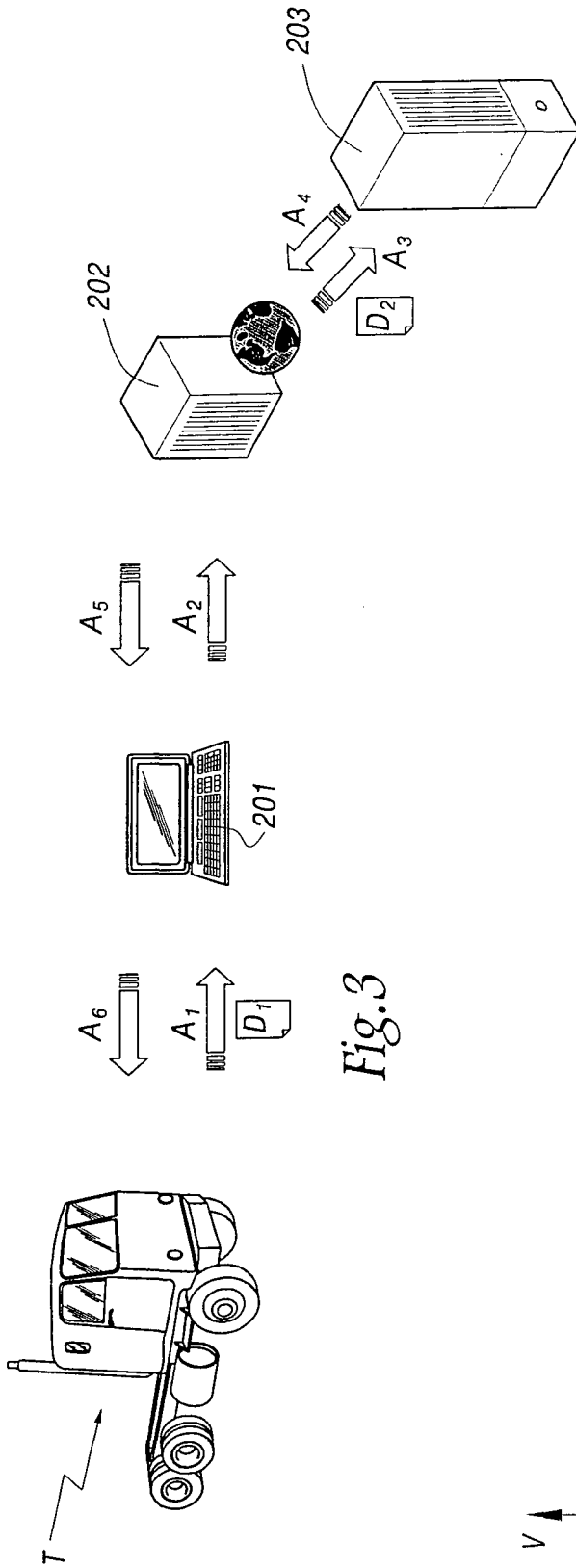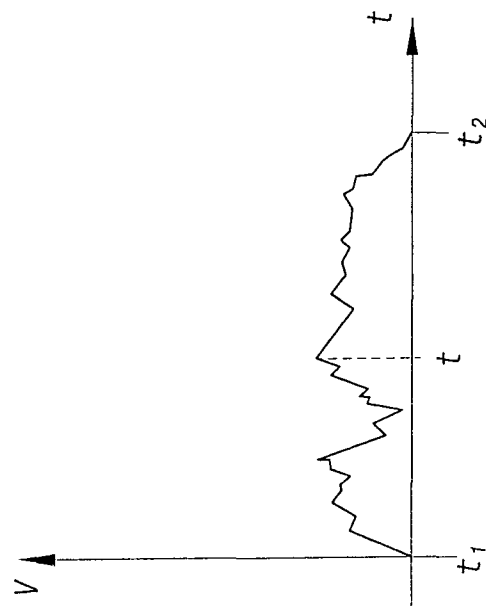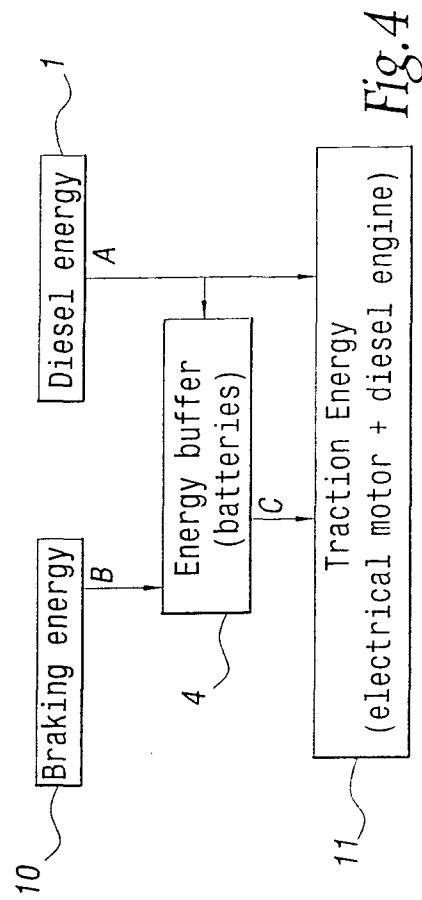
Fig. 1
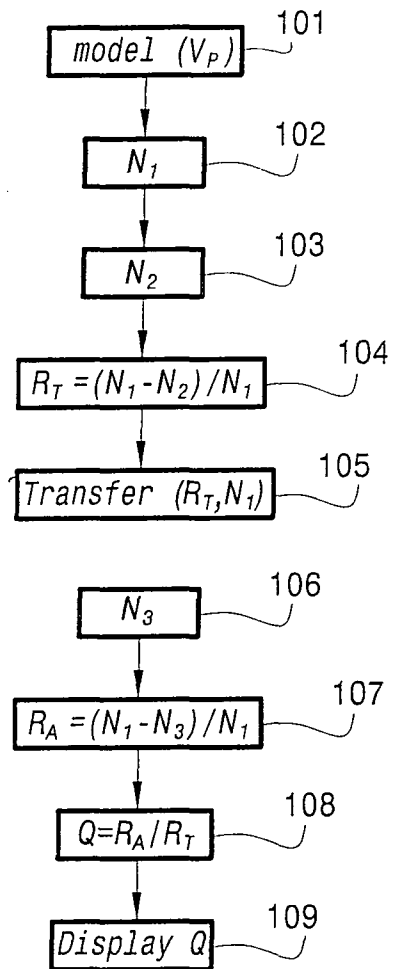
2/3

Fig.3

Fig.4

Fig.2

$$model \ (V_P)$$ — 101

$$N_1$$ — 102

$$N_2$$ — 103

$$R_T = (N_1 - N_2)/N_1$$ — 104

$$Transfer \ (R_T, N_1)$$ — 105

$$N_3$$ — 106

$$R_A = (N_1 - N_3)/N_1$$ — 107

$$Q = R_A/R_T$$ — 108

$$Display \ Q$$ — 109

Fig.5

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60K35/00 B60K37/00 B60W20/00 B60R16/023

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)
B60R B60K B60W

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2005/007444 A (TOYOTA MOTOR CO LTD [JP]; ISONO HIROSHI [JP]; SETO KEISUKE [JP]; KODAI) 27 January 2005 (2005-01-27)	1-13
X	the whole document	14,15
A	EP 1 256 476 A (FORD GLOBAL TECH INC [US]) 13 November 2002 (2002-11-13)	1-13
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X	the whole document	14,15
A	EP 0 076 764 A (RENAULT [FR]) 13 April 1983 (1983-04-13) the whole document	1-15

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[X]	Further documents are listed in the continuation of Box C.	[X]	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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"O" document referring to an oral disclosure, use, exhibition or other means

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"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

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Date of the actual completion of the international search	Date of mailing of the international search report
31 July 2008	25/08/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Granier, Frédéric

INTERNATIONAL SEARCH REPORT

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 10 2005 035306 A1 (BAYERISCHE MOTOREN WERKE AG [DE]) 1 February 2007 (2007-02-01)	1-13
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Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

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			EP	1646527 A1	19-04-2006
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