



(51) International Patent Classification:

F02D 11/10 (2006.01) F16K 31/04 (2006.01)
F02D 9/02 (2006.01) H02P 7/00 (2016.01)

(21) International Application Number:

PCT/SE2016/051245

(22) International Filing Date:

12 December 2016 (12.12.2016)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1650010-0 5 January 2016 (05.01.2016) 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, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, 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, SA, 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, ST, 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, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

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

(54) Title: SPRING RETURN THROTTLE ACTUATOR, METHOD OF CONTROL THEREOF AND THROTTLE ASSEMBLY

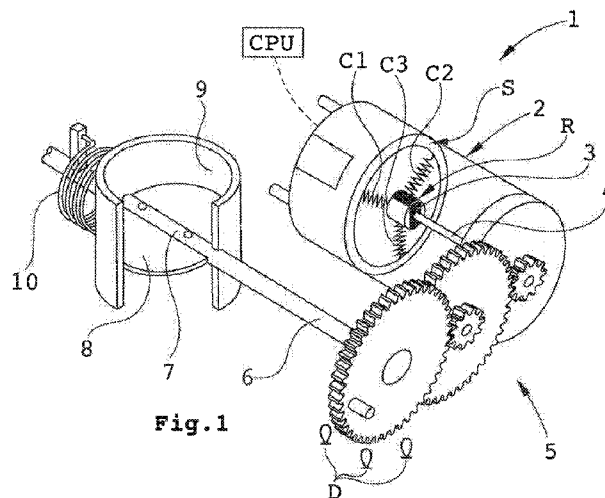


Fig. 1

(57) Abstract: A spring return throttle actuator (1) including: an electric, plural-coil (C1, C2, C3) DC motor (2) having an output shaft (4), a throttle return spring (10), a gear transmission (5) connected to the output shaft, a control unit (CPU) adapted to control power supply to the DC motor (2), wherein the spring return throttle actuator (1) has a movement range between closed throttle and fully opened throttle. The control unit (CPU) includes a monitoring circuit adapted to monitor DC motor movement. The monitoring circuit is arranged to receive signals from at least one voltage sensor adapted to sense voltage induced in at least one of the DC motor coils (C1, C2, C3) during a spring forced return of the throttle, and the monitoring circuit is arranged to create a representation of DC motor movement based on said signals.



SPRING RETURN THROTTLE ACTUATOR, METHOD OF CONTROL THEREOF AND
THROTTLE ASSEMBLY

FIELD OF THE INVENTION

5 The invention relates to a spring return throttle actuator including: an electric, plural-coil, DC motor having an output shaft, a throttle return spring, a gear transmission connected to the output shaft, a control unit adapted to control power supply to the DC motor, wherein the actuator has
10 a movement range between closed throttle and fully opened throttle. The invention also relates to a method for control thereof and a throttle assembly.

BACKGROUND OF THE INVENTION

15 Throttle assemblies are employed to control gas streams in respect of vehicle engines. The actuator DC motor is typically supplied with an electric current to switch from a normally open to a closed throttle position or from a normally closed to an open throttle position.

20 It could be mentioned that in respect of for example an air inlet throttle valve, the throttle is normally open whereas in an EGR valve the throttle is normally closed.

 As a rule, the return spring tends to move the throttle to a determined "normal" position which will guarantee
25 operation also in the event that the DC motor is without current. It is thereby an aim to maintain the required exhaust gas values etc.

 In a background art throttle assembly, for reaching
30 intermediate positions between closed throttle and fully opened throttle, the DC motor is supplied with current to create a dynamic electromotive force which, by virtue of the control unit, balances the spring force to obtain a desired

stationary throttle position between closed throttle and fully open throttle.

It is previously known that there are occasionally problems with throttles for example because of mechanical deficiencies or some sort of obstruction preventing
5 unrestricted movement of the throttle. This might depend on the formation of ice or the accumulation of dirt around the seat of the throttle or in throttle shaft bearings, or a defective spring which for example has been damaged and
10 obtained unwanted properties.

The throttle can hereby be impossible or difficult to move properly and at proper speed over the whole or part of its movement range which is detrimental to the operation of the vehicle. It is, however, difficult to determine in what
15 way the throttle assembly is defective. Also relatively small influences on throttle movements may impair engine control.

AIM AND MOST IMPORTANT FEATURES OF THE INVENTION

It is an aim of the present invention to provide a
20 throttle actuator according to the above wherein the problems of the background art are addressed and at least reduced. This aim is obtained in a throttle actuator according to the above in that

- that the control unit includes a monitoring circuit adapted to monitor DC motor movement,
25
- that the monitoring circuit is arranged to receive signals from at least one voltage sensor adapted to sense voltage induced in at least one of the DC motor coils during a spring forced return of the throttle, and
- 30 - that the monitoring circuit is arranged to create a representation of DC motor movement based on said signals.

For analyzing the condition of the return spring, the spring is typically tensioned maximally whereupon the system

is made currentless, that means that the electric supply to the motor is interrupted. Thereupon the throttle together with the motor is returned to the "normal" position by the spring force. The time for the spring to press the throttle all the way back to that normal position will be a measurement
5 describing whether the spring or anything else in the mechanics is jammed or defective or if anything restricts the movement. At the same time, induced voltage will be measured.

The obtained value describes the resist electromotive
10 force generated by the electric motor when driven by an external force in the form of the return spring. Since said force in turn is depending on the rotational speed of the rotor of the actuator motor, it can hereby be established how fast the throttle moves. From that information it is possible
15 to analyze the nature of the defect, if any, that the return spring is suffering from.

It is also possible, in a simple embodiment, to set accept limits for momentary rotational speed as a function of time wherein values outside the limits are considered to
20 indicate defects.

A representation of DC motor movement is of course dependent on throttle movement and can be any one of throttle speed and throttle position. It can also simply be a sampled voltage value or a momentary voltage amplitude value
25 describing DC motor speed.

A throttle with defective return spring might either move with more or less constant speed against a restriction or move unrestricted over part or parts of its range and move with restricted speed in intermediate range part or parts. These
30 two scenarios can quite well give the same total time delay but has completely different basic background.

For that reason, it is advantageously preferred that the voltage sensor is arranged to measure the induced voltage

momentarily since this allows the monitoring circuit to produce a momentary representation of the amplitude thereby giving more advanced analyzing possibilities to more exactly diagnose what damage the spring suffers from.

5 One advantage here is thus the capability to provide a more detailed picture of an existing defect. A measured speed profile of the throttle can be compared to a plurality of stored throttle rotational speed profiles representing different kinds of defects so as to be coupled to one of them.

10 It is also possible to compare measured angular throttle position as a function of time to stored throttle position profiles. Such values are obtainable through conventional signal processing and derivable from measured voltage.

15 The results can in all cases be displayed to the operator visually on a screen and/or be signaled as return spring condition message, a light or a sound signal, particularly in the event that a defect has been detected.

20 Knowledge of prevailing throttle movement parameters can even be used for adapting possible control algorithms in the vehicle to adapt engine control to the prevailing problem in order to reduce impact of the defect.

 The DC motor advantageously includes three coils but may also include more than three coils.

25 The control unit preferably includes a bridge circuit having one branch connected to each one of the coils. Measuring induced voltage is then advantageously performed in relation to one of the branches. Each branch suitably includes a transistor switch connected to each one of the coils.

30 The invention also relates to a method of controlling a spring return throttle actuator, said actuator including: an electric, plural-coil, DC motor having an output shaft, a throttle return spring, a gear transmission connected to the output shaft, a control unit adapted to control power supply

to the DC motor, wherein the actuator has a movement range between closed throttle and fully opened throttle. The movement of the DC motor control unit is monitored by a monitoring circuit. Voltage induced in at least one of the DC motor coils during a spring forced return of the throttle is sensed by a voltage sensor of the monitoring circuit. A representation of DC motor movement is created based on said signals.

Advantages as above are obtained through the inventive method.

The DC motor preferably includes three coils wherein voltage induced in at least one of the DC motor coils is sensed.

The coils are supplied with power from each one branch of a bridge circuit being included in the control unit. In particular, when the coils are supplied with power from each one branch of a bridge circuit being included in the control unit, each branch is advantageously switched through separate transistor switches.

The invention also concerns a throttle assembly including a throttle, a throttle actuator and a control unit, wherein the throttle actuator is according to what is stated above.

Further features of and advantages of the invention will be explained below at the background of embodiments.

BRIEF DESCRIPTION OF DRAWINGS

The invention will now be described in greater detail by way of embodiments and with reference to the annexed drawings, wherein:

Fig. 1 illustrates a throttle assembly including a spring return throttle actuator according to the invention,

Fig. 2 shows a control circuit for the inventive throttle actuator,

Fig. 3 shows a simplified flow chart over an inventive method,

Fig. 4 shows a diagram over measured voltage as a function of elapsed time, and

5 Fig. 5 shows a diagram over signal processed momentary rotational speed as a function of elapsed time.

DESCRIPTION OF EMBODIMENTS

Fig. 1, shows a throttle assembly whereof a spring return
10 throttle actuator is generally depicted with reference number 1. The actuator 1 includes a DC motor 2 having three coils C1, C2 and C3 in its stator S. The rotor R is as usual provided with a permanent rotor magnet 3 and an output shaft 4.

A gear transmission 5 is connected to the output shaft 4
15 and an outgoing shaft 6 from the gear transmission 5 is coupled with its distal end to a throttle shaft 7 of a throttle 8. The actuator has a movement range between closed throttle and fully opened throttle.

The throttle 8 is arranged in a channel 9 to control a
20 gas stream flowing through the channel 9.

A throttle return spring 10 is positioned around the
outgoing shaft 6 and functions to provide a spring torque urging the outgoing shaft 6 to rotate towards a "normal"
position of the throttle 8 which may be fully open or fully
25 closed depending on the nature of the throttle as explained above.

A control unit CPU is connected to the DC motor and is adapted to control supply of power to the DC motor and thereby to control the throttle position. Movement sensors, preferably
30 Hall effect sensors, are indicated with D.

Fig. 2 illustrates a bridge circuit 11 positioned between a 24 Volts current source 12 for the supply of power to the

three coils C1, C2 and C3 of the DC motor 3. It is to be noted that any suitable voltage can be used.

The bridge circuit includes a set of transistor switches T₁-T₆ that are made conductive - non conductive to controllably power supply the DC motor 3.

It is possible to make variations of the duration of conductivity of the transistor switches in order to apply force of different magnitudes by varying and by controlling transistor switches. It is possible to measure voltage in at least one of the conduits connected to the coils. A voltage detector can be active in respect of either one (or more than one) of the conduits associated with the coils C1 - C3 and signals therefrom be passed on to the CPU.

It is possible to receive information from the DC motor and associated cables about its operation. If the motor is rotated, the rotational speed is directly proportional to the voltage. It is also possible to measure voltage which momentarily results in knowledge about rotational speed. For detection of rotational position of the rotor of the motor, a plurality of detectors is preferably being used. This gives information about throttle position.

The detectors are suitably stationary and for example co-operating with a ring or part of a ring being rotationally associated with the rotor or with one of the shafts, said ring having a great number of evenly distributed marks or holes. Monitoring the durations between pulses from three distributed mark or hole detectors results in information of position and rotational speed. There is also a possibility to detect rotor acceleration if required for some reason.

In the simplified flow chart in Fig. 3, an exemplary method sequence related to the invention is briefly illustrated.

13 indicates start of sequence.

14 indicates initiating DC motor to position throttle in desired position where the return spring is strained and stretched and verifying that throttle has reached the desired position.

5 15 indicates cutting current to the DC motor and initiating voltage measuring in at least one of the conduits being connected to the coils.

16 indicates monitoring throttle movements effected by the return spring by voltage measuring.

10 17 indicates evaluating monitored throttle movement pattern in relation to a stored exemplary movement curve.

18 indicates amending and adapting engine control values to established prevailing throttle actuation conditions.

15 19 indicates issuing a return spring condition message to the user and ending of sequence.

The sequence may be supplemented with additional steps and is repeated as required.

20 Fig. 4 shows a diagram over measured voltage as a function of elapsed time. The meandering curve, I_m , represents momentary voltage signal output from a voltage detector associated with a coil conduit as a function of time (t). C_{mod} represents a modulated curve thereof.

25 Fig. 5 shows a diagram over signal processed momentary rotational speed (n_a) and voltage (u_a) as a function of elapsed time (t). C_{ex} represents an exemplary stored throttle rotational speed profile. As seen in Fig. 5, the rotational speed (n_a) and voltage (u_a) curves in the shown example have good conformity to the exemplary stored throttle rotational speed profile curve C_{ex} . Hereby the condition of the return
30 spring can be estimated to be as an exemplary return spring condition corresponding to the conforming stored profile. Furthermore, when a plurality of exemplary throttle rotational speed profile curves representing different return spring

conditions are stored, the return spring condition is estimated to be as corresponds to the profile curve that most closely conforms to the measured profile.

5 The invention can be modified within the scope of the annexed claims. For example, the control circuitry can be laid out differently as can be the DC motor, for instance, the number of coils of the DC motor can be other than three.

10 The feature "closed throttle" is intended to include a case with totally blocked opening as well as a case with a certain minimum opening that might exist. With the feature "opened throttle" is intended the maximum opening achievable for the throttle in question.

15 Different kinds of sensors may be employed and they can be positioned in various places in association with the throttle assembly, for example close to the throttle itself.

CLAIMS:

1. Spring return throttle actuator (1) including:

- an electric, plural-coil (C1, C2, C3) DC motor (2) having an
5 output shaft (4),
- a throttle return spring (10),
- a gear transmission (5) connected to the output shaft,
- a control unit (CPU) adapted to control power supply to the
DC motor (2),

10 wherein the spring return throttle actuator (1) has a movement
range between closed throttle and fully opened throttle,

characterized in

- that the control unit (CPU) includes a monitoring circuit
adapted to monitor DC motor movement,

15 - that the monitoring circuit is arranged to receive signals
from at least one voltage sensor adapted to sense voltage
induced in at least one of the DC motor coils (C1, C2, C3)
during a spring forced return of the throttle, and

20 - that the monitoring circuit is arranged to create a
representation of DC motor movement based on said signals.

2. Actuator according to claim 1, **characterized in**

- that the voltage sensor is arranged to measure the induced
voltage momentarily, and

25 - that the monitoring circuit is arranged to produce a
momentary representation of the amplitude of the voltage to
diagnose the spring.

3. Actuator according to claim 1 or 2, **characterized in**

30 - that the control unit (CPU) includes a bridge circuit having
one branch connected to each one of the coils.

4. Actuator according to claim 3, **characterized in**

- that each branch includes a transistor switch ($T_1 - T_6$) connected to each one of the coils (C1, C2, C3).

5 5. Actuator according to any one of the previous claims,
characterized in

- that the monitoring circuit is arranged to compare measured rotational speed values to stored rotational speed profiles for analyzing purposes.

10

6. Actuator according to any one of the previous claims,
characterized in

- that the monitoring circuit is arranged to compare measured angular throttle position values to stored throttle position profiles for analyzing purposes.

15

7. Method of controlling a spring return throttle actuator including:

- an electric, plural-coil (C1, C2, C3) DC motor (2) having an
20 output shaft (4),
- a throttle return spring (10),
- a gear transmission (5) connected to the output shaft (4),
- a control unit (CPU) adapted to control power supply to the DC motor (2),

25 wherein the actuator (1) has a movement range between closed throttle and fully opened throttle,

characterized in

- that the movement of the DC motor (2) is monitored by a monitoring circuit of the control unit (CPU),

30 - that voltage induced in at least one of the DC motor coils (C1, C2, C3) during a spring forced return of the throttle is sensed by a voltage sensor of the monitoring circuit, and

- that a representation of DC motor movement is created based on said signals.

8. Method according to claim 7, wherein the DC motor (2)
5 includes three coils, **characterized in**

- that voltage induced in at least one of the DC motor coils (C1, C2, C3) is sensed.

9. Method according to claim 7 or 8, **characterized in**

10 - that the DC motor coils (C1, C2, C3) are supplied with power from each one branch of a bridge circuit being included in the control unit (CPU).

10. Method according to any one claims 7 - 9, **characterized in**

15 - that measured rotational speed values are compared to stored rotational speed profiles for analyzing purposes.

11. Actuator according to any one of claims 7 - 10,
characterized in

20 - that measured angular throttle position values are compared to stored throttle position profiles for analyzing purposes.

12. Throttle assembly including a throttle and a throttle actuator, **characterized in** that the throttle actuator is

25 according to any one of claims 1 - 6.

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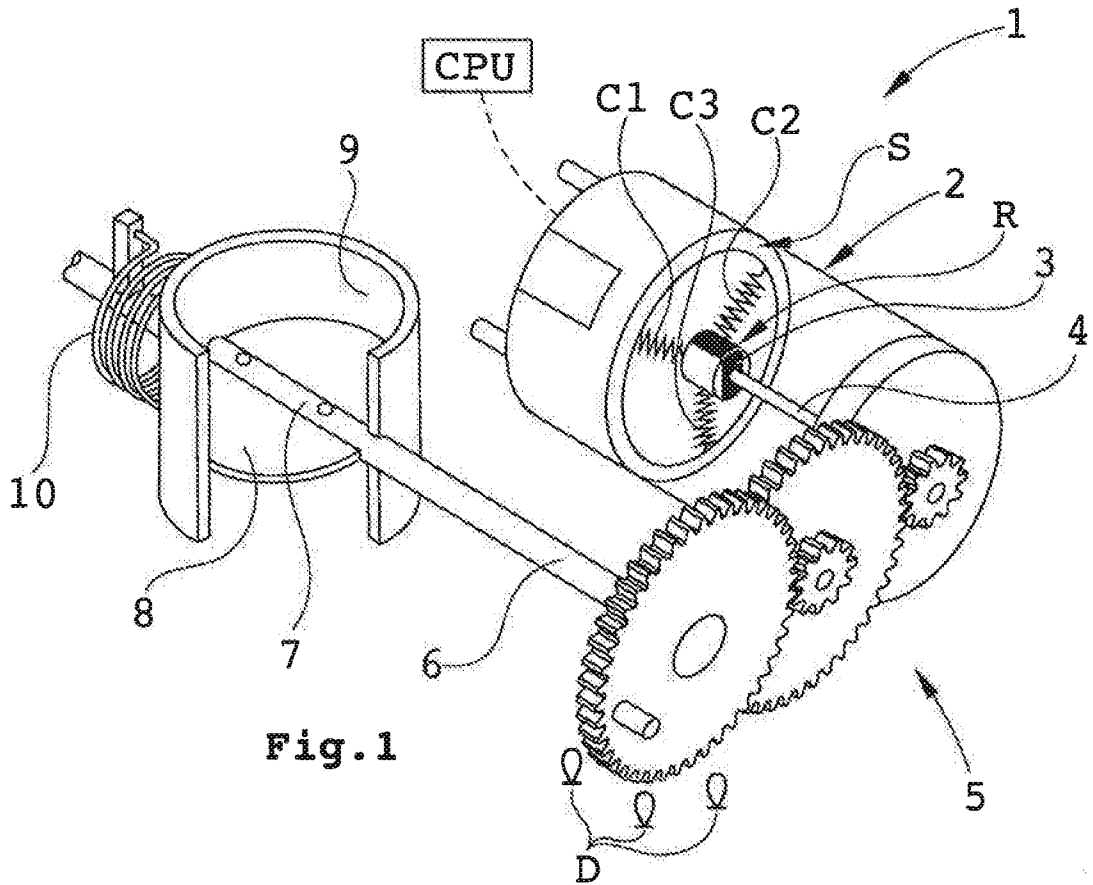


Fig. 1

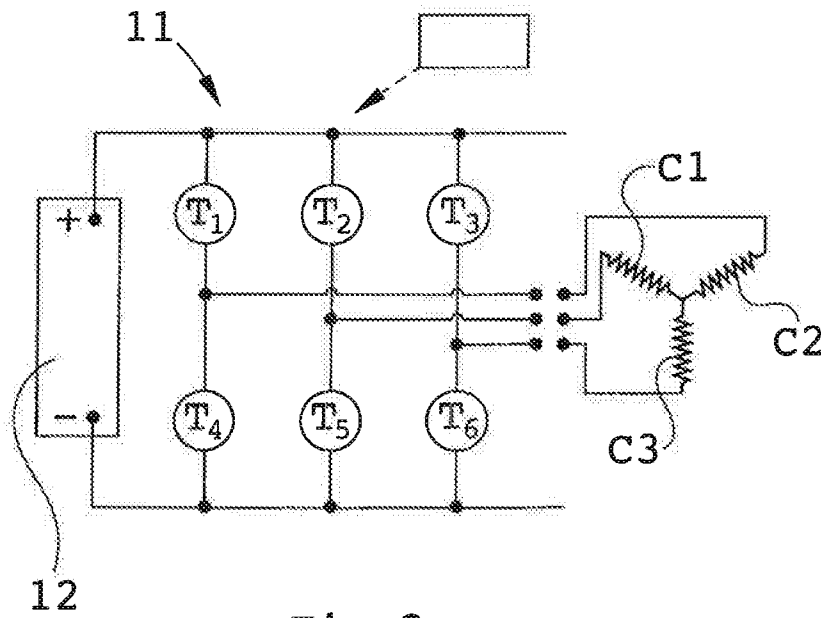


Fig. 2

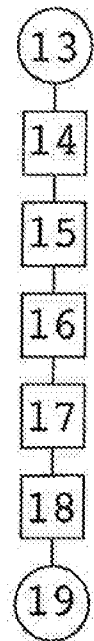


Fig. 3

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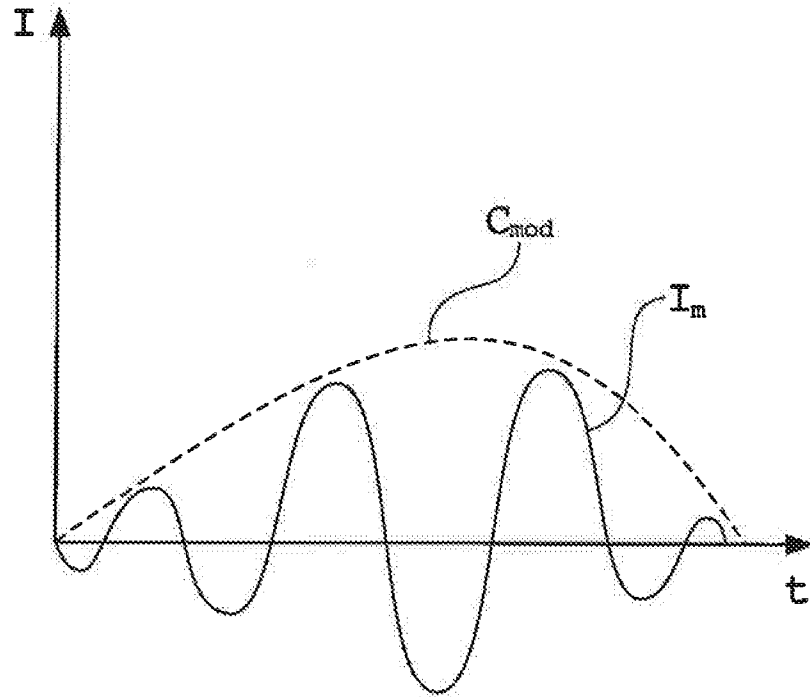


Fig. 4

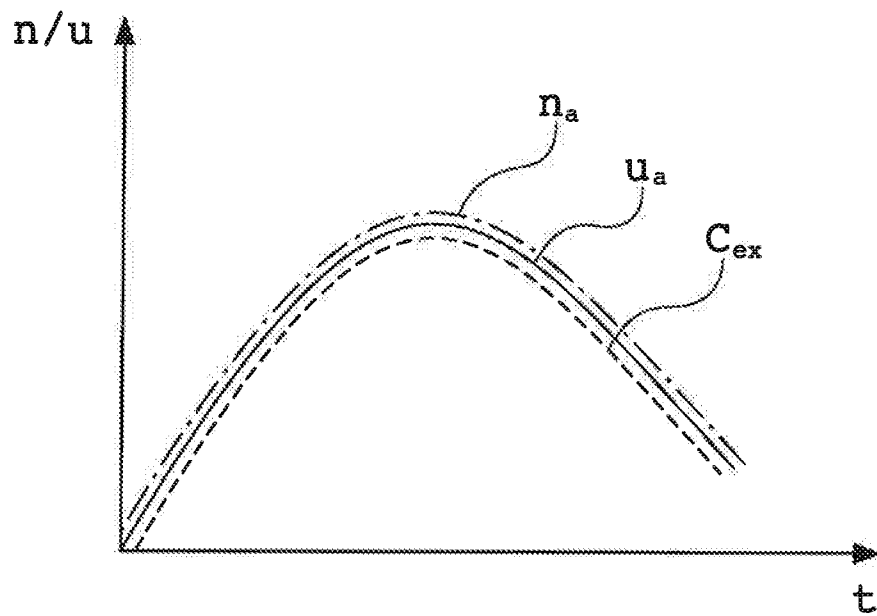


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2016/051245

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: F02D, F16K, H02P		
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 20040212336 A1 (MCMILLAN SCOTT D ET AL), 28 October 2004 (2004-10-28); abstract; paragraphs [0048]-[0052] --	1-12
A	US 20040149260 A1 (WATANABE SHINJI), 5 August 2004 (2004-08-05); abstract; paragraphs [0021]-[0023] --	1-12
A	US 20040059496 A1 (PURSIFULL ROSS D ET AL), 23 March 2004 (2004-03-23); paragraphs [0029], [0052] --	1-12
A	JP 11190230 A (HITACHI LTD ET AL), 13 July 1999 (1999-07-13); paragraphs [0006], [0043]; abstract from PAJ --	1-12
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> 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 "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "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 27-02-2017		Date of mailing of the international search report 28-02-2017
Name and mailing address of the ISA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86		Authorized officer Marianne Dickman Telephone No. + 46 8 782 28 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2016/051245

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20060016427 A1 (UDA TOSHIKI ET AL), 26 January 2006 (2006-01-26); abstract; paragraphs [0006], [0046] -- -----	1-12

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International Patent Classification (IPC)

F02D 11/10 (2006.01)

F02D 9/02 (2006.01)

F16K 31/04 (2006.01)

H02P 7/00 (2016.01)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SE2016/051245

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