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(71) Applicant: **PIAGGIO & C. S.P.A.** [IT/IT]; Viale Rinaldo Piaggio 25, I-56025 Pontedera (IT).

(72) Inventors: **CAPOZZELLA, Paolo**; c/o PIAGGIO & C. S.P.A, Viale Rinaldo Piaggio 25, I-56025 Pontedera (IT). **CANTINI, Jury**; c/o PIAGGIO & C. S.P.A, Viale Rinaldo Piaggio 25, I-56025 Pontedera (IT). **MILANI, Jeanpaul**; c/o PIAGGIO & C. S.P.A, Viale Rinaldo Piaggio 25, I-56025 Pontedera (IT).

(74) Agents: **LEONE, Mario** et al.; C/o Cantaluppi & Partners S.r.l., Viale Della Tecnica 205, I-00144 Rome (IT).

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(54) Title: PERMANENT MAGNET ELECTRIC MOTOR FOR AN INTERNAL COMBUSTION ENGINE AND RELATED STARTING CONTROL SYSTEM

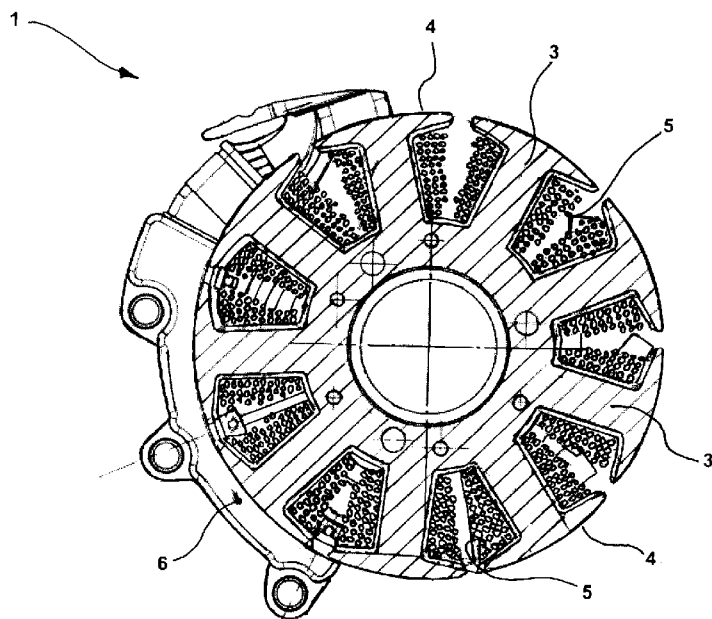


FIG. 3

(57) Abstract: An electric motor for starting internal combustion engines and a relative starting control system of such engine comprising said electric motor of the type with permanent magnets allows a more effective and simpler management of the internal combustion engine thereto the electric motor is connected, wherein a monitoring unit of the electric motor (EMU) and a monitoring unit of the internal combustion engine (ECU) are provided, wherein the electric motor comprises a direction sensor (18) providing a signal representing the rotation direction of the rotor (12) of the electric motor, which is connected to said monitoring unit of the internal combustion engine (ECU).





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**PERMANENT MAGNET ELECTRIC MOTOR FOR AN INTERNAL COMBUSTION
ENGINE AND RELATED STARTING CONTROL SYSTEM**

Description

5 The present invention relates to an electric motor of the type with permanent magnets, apt to be coupled with the crankshaft of an internal combustion engine for acting as starter motor and as electric generator, and to the relative starting control system of the internal combustion engine including it.

10 In particular, this electric motor has to perform the starting procedure in internal combustion engines wherein the automatic switch-off of the engine is provided when the vehicle is stopped, and preferably suits to single-cylinder engines for motorvehicles such as scooters and
15 the like, wherein the electric motor, which obviously even acts as generator, is fitted directly onto the crankshaft.

In this configuration, the electric motor is equipped with particular sensors, which are used by a monitoring
20 unit of the electric motor and by a monitoring unit of the internal combustion engine to manage the above-mentioned procedures.

To this purpose, when the engine has to be re-started, that is when the engine switches-off as the vehicle has
25 stopped, a re-starting procedure is used providing the rotation of the electric motor for arranging the piston, inside the cylinder, in the position requiring the lowest possible torque for the re-starting, by keeping in mind that the latter has to take place during a very short
30 instant, by absolutely avoiding the piston stall inside the cylinder.

The US patent Nr. 5,458,098 A describes a procedure of this type, devised for multi-cylinder engines of automobile type.

35 Generally, the electric motor in this phase is rotated with a limited torque therefore the piston cannot exceed the upper dead centre corresponding to the compression phase, by rotating the crankshaft both back and forth.

In the above-mentioned document, upon each stop a backward rotation is performed, said inverse rotation to move away the pistons from the more proximate compression phase: as from that moment the electric motor is rotated
5 forward for starting, the inertia which is accumulated during the forward rotation allows overcoming the more proximate compression phase by re-starting the engine, even if the torque would not have been sufficient to overcome it by starting from a much more approached
10 phase.

The inverse rotation is performed by a pre-established rotation angle ($\pi/4$ in case of a four-cylinder engine wherein there is a compression phase every $\pi/2$ of rotation) or for a pre-established rotation time,
15 provided that the piston does not lock the inverse rotation before.

However, in a single-cylinder engine, the adjacent compression phases are spaced apart therebetween, in terms of angle of rotation by a 2π angle, and therefore
20 it is difficult establishing a fixed inverse rotation angle and/or time to be sure of performing the re-starting.

Even in the US patent Nr. 5,713,320 A, a procedure similar to the previous one is described, wherein the
25 electric motor is rotated inversely with low power, until reaching the more proximate compression phase.

The European patent Nr. 1,046,813 describes an inverse rotation procedure, wherein the intervention of a sensor is provided, detecting the friction during it, to
30 understand when the inverse rotation can cease.

On the contrary, the European patent Nr. 1,233,175 describes a procedure using a sensor capable of detecting the absolute angular position of the crankshaft.

The European patent Nr. 1,321,666 describes still a
35 procedure wherein the inverse rotation angle applied to the crankshaft is detected.

The European patent application Nr. 1,396,629 A2 describes a starting control system of an internal combustion engine wherein a position sensor is used to

provide, together with other position sensors, a signal representing the way of the rotation direction.

The US patent application Nr. 2008□0105230 describes another control system providing three voltage sensors and a phase sensor, all connected to a monitoring unit of the internal combustion engine.

At last, the European patent Nr. 1,574,692 describes a starting control system of an internal combustion engine wherein the rotation direction of the electric motor, and then of the internal combustion engine, is detected by the sequence of the phase pulses coming from the phase sensors with Hall effect existing in the electric motor of the type with permanent magnets.

This piece of information, supplied to the monitoring unit of the internal combustion engine apart from the monitoring unit of the electric motor, of the starting control system, is also used to detect the forward rotation of the engine during starting, phase wherein the supply of electric current and fuel mix to the internal combustion engine is allowed.

Such system, wherein the same monitoring unit of the internal combustion engine has to manage three sensors instead of only one, occupies an excessive portion of the calculation resources available to the monitoring unit regulating the engine starting.

The technical problem underlying the present invention consists in providing an electric motor allowing to overcome the drawbacks mentioned with reference to the known art.

Such problem is solved by an electric motor with permanent magnets as specified above, comprising a stator in the reinforcement thereof phase sensors are provided, wherein an additional sensor with Hall effect is provided, supplying a signal representing the rotation direction of the rotor of the electric motor.

Such problem is also overcome by a starting control system of an electric combustion engine comprising an electric motor with permanent magnets, a monitoring unit of the electric motor and a monitoring unit of the

internal combustion engine, wherein the electric motor comprises a direction sensor providing a signal representing the rotation direction of the rotor of the electric motor, which is connected to said monitoring
5 unit of the internal combustion engine.

The main advantage of the electric motor and of the starting control system including it according to the present invention lies in allowing a more effective and simpler management of the internal combustion engine
10 thereto the electric motor is connected.

The present invention will be described hereinafter according to a preferred embodiment example, provided by way of example and not with limitative purpose by referring to the enclosed drawings wherein:

- 15 * figure 1 shows a side view of the stator of an electric motor according to the present invention;
- * figure 2 shows a cross section of the stator of an electric motor of figure 1;
- * figure 3 shows an enlarged detail of the section of
20 figure 2;
- * figure 4 shows a side view of the rotor of an electric motor according to the present invention;
- * figure 5 shows an enlargement of a portion of the stator of figure 1, with highlighted some constructive
25 details;
- * figures 5A and 5B show additional constructive details related to the stator portion of figure 5; and
- * figure 6 shows a scheme of a starting control system according to the invention including the electric motor
30 of the previous figures, and which performs a starting process with the electric motor according to the present invention.

By firstly referring to figure 6, as preliminary introduction a starting control system is described apt
35 to perform the starting process with the electric motor of the present embodiment example.

It comprises a three-phase electric motor, of the

brushless type with permanent magnets (THREE-PHASE MACHINE) which is driven by an actuating device (MOTOR DRIVER) which in turn receives electric current from a battery.

5 Both the actuating device and the battery are managed by a monitoring unit of the electric motor (EMU) arranged to receive a command for igniting the motor from a suitable input (START COMMAND). In the specific case, this input can receive a signal generated by a button, by the
10 rotation of a key, by the opening of the throttle valve of the carburettor deriving from an accelerator, by the shifting or by the detection of a pressure on the accelerator command and so on.

The last two types of signals are those used in case of
15 an engine and a starting system arranged for switching-off the engine upon each vehicle stop, or upon each stop exceeding a certain duration, to start it again automatically when the driver shows the intention to continue running as if the engine had not been previously
20 switched-off.

The engine monitoring unit (EMU) receives a piece of information relating the current supply to the electric motor from a suitable electric sensor (Current sensor); it further receives pulses which are representative of
25 the relative position of the rotor of the electric motor with respect to the stator from phase sensors, typically with Hall effect, arranged in the electric motor.

In the present embodiment example such pulses are phase pulses generated by the phase sensors of the stator of
30 the electric motor (Position sensor), or the three sensors with Hall effect therewith the stator is equipped.

The electric motor is mechanically connected to the internal combustion engine directly by means of the
35 crankshaft, which coincides with the shaft of the electric motor.

Furthermore, the stator of the electric motor is even equipped with a particular direction sensor, which will be detailed hereinafter, supplying a signal representing

the rotation direction of the rotor with respect to the stator.

Such signal is not collected to the monitoring unit of the electric motor, but to a monitoring unit of the
5 internal combustion engine (ECU) regulating the power supply of the internal combustion engine, that is the sparking plugs, and the supply of the fuel mix.

By referring to the present embodiment example, such starting control system is arranged for a single-cylinder
10 four stroke engine of substantially motorcycle type.

By referring instead to the figures from one onwards, the electric motor of the present embodiment example is described in greater detail.

The engine è of the type with permanent magnets and it
15 has three phases, with a rotor constituted by nine teeth, divided into groups made of three teeth for each phase.

This type of electric motor is particularly suitable to be assembled on the axis of the crankshaft of a four stroke engine, in particular a single-cylinder engine,
20 for acting both as starter motor and as generator.

It comprises a stator illustrated in cross-section and it is designated with 1 in figures 1 and 3.

The stator 1 is implemented in an element full of a ferromagnetic material comprising a central core 2
25 therefrom a plurality of the teeth 3 extend outside and radially, each one ending with an enlarged head 4, so as to implement between tooth and tooth a compartment which is filled-up with windings 5 of conducting wire made of copper arranged around each tooth.

30 The teeth 3 then have an outer joining surface formed by the respective heads 4.

The stator 1 further comprises an outer reinforcement portion 6 occupying a circular sector of the stator (figure 2). The cables of all windings branch therefrom
35 through a connecting element 7 outside the stator 1, then joined to the inside of a sheath 8 and connected to a respective plug 9 which will be connected to the battery.

From the reinforcement portion 6 even other cables

branch, connected to Hall sensors (figure 2), generally phase position sensors, placed between said reinforcement portion 6 and the teeth 3 positioned therein.

5 The sheath 8 even includes said other cables, then connected to respective connectors 10 and 11.

As said previously, the teeth 3 are divided into three groups, each one corresponding to a phase: the teeth of each group are adjacent therebetween and thus occupy a single circular sector of the stator 1, with the width of
10 120°.

The windings are implemented by a plurality of turns of the same wire made of enamelled copper, arranged on several layers on the same tooth.

The electric motor further comprises a rotor 12 (figure
15 4), connected to the not represented crankshaft which comprises, at its own crown, a plurality of suitably spaced-apart permanent magnets 13.

By referring to the previously mentioned Hall sensors, they are arranged equidistant at free spaces between
20 adjacent heads 4, under the reinforcement portion 6.

They are three: a first phase sensor 14, a second phase sensor 15 and a third phase sensor 16 (figure 5B, section A-A).

The second phase sensor 15, which is in the centre of the
25 other two, is arranged in an enlarged compartment of the reinforcement portion 6 (figure 5, section D-D) receiving even a direction sensor 18 (figure 5A, sections B-B and C-C).

In this embodiment example, the direction sensor 18 is a
30 double-channel sensor with Hall effect and it is capable of providing a signal indicating the rotation direction of the rotor 12 with respect to the stator 1.

This signal, for example 0 for the forward rotation and 1 for the inverse rotation, does not provide phase pulses.

35 It is then particularly suitable to inhibit (inverse rotation) or to allow (forward rotation) the power supply to the sparking plug and the fuel mix in the chamber, from the monitoring unit of the combustion engine (ECU),

which will receive directly this signal.

To the above-described electric motor a person skilled in the art, to the purpose of satisfying additional and contingent needs, could introduce several additional
5 modifications and variants, however all within the protective scope of the present invention, as defined by the enclosed claims.

CLAIMS

1. An electric motor with permanent magnets, apt to be coupled with the crankshaft of an internal combustion engine for acting as starter motor and as electric generator, comprising a stator (1) in the reinforcement thereof (6) there are provided:
- a first phase sensor (14), a second phase sensor (15) and a third phase sensor (16), each one providing a phase signal to a monitoring unit of the electric motor (EMU); and
 - an additional direction sensor (18) providing a signal representing the rotation direction of the rotor of the electric motor to a monitoring unit of the internal combustion engine (ECU).
2. The electric motor according to claim 1, wherein said direction sensor (28) is arranged at one of the phase sensors (15).
3. The electric motor according to claim 1 or 2, wherein said direction sensor is a double-channel sensor with Hall effect.
4. A starting control system of a combustion engine comprising an electric motor with permanent magnets, a monitoring unit of the electric motor (EMU) and a monitoring unit of the internal combustion engine (ECU), wherein the electric motor comprises:
- a first phase sensor (14), a second phase sensor (15) and a third phase sensor (16) each one providing a phase signal to the monitoring unit of the electric motor (EMU); and
 - an additional direction sensor (18) providing a signal representing the rotation direction of the rotor of the electric motor to the monitoring unit of the internal combustion engine (ECU).
5. The control system according to claim 4, wherein said direction sensor (28) is arranged at one of the phase sensors (15).
6. The control system according to claim 4 or 5, wherein said direction sensor is a double-channel sensor

with Hall effect.

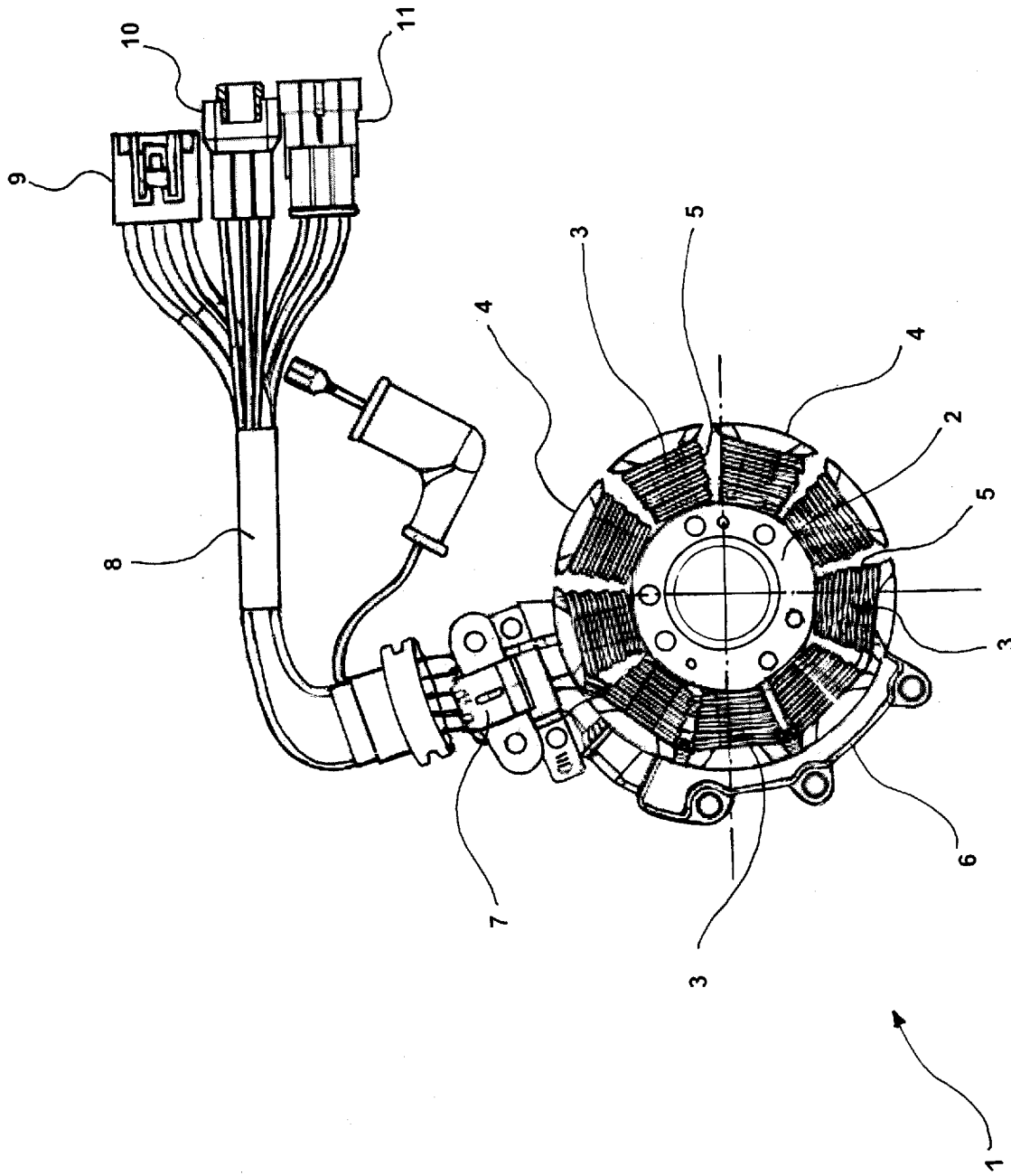


FIG.1

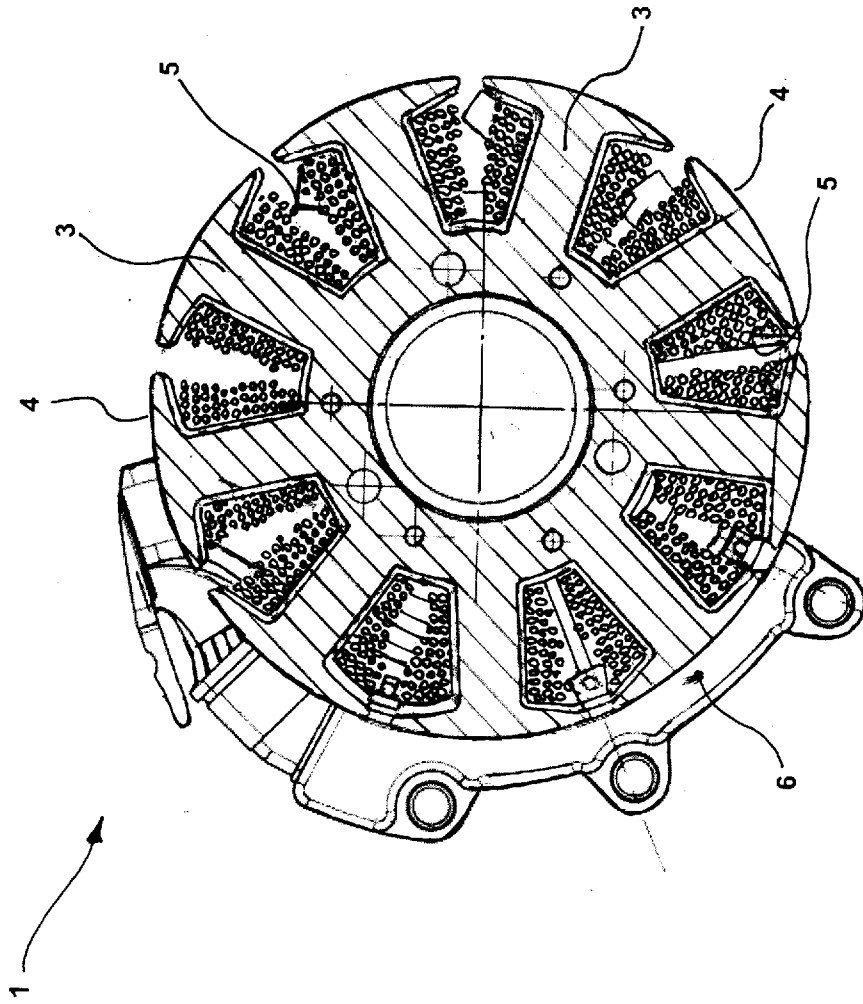


FIG.3

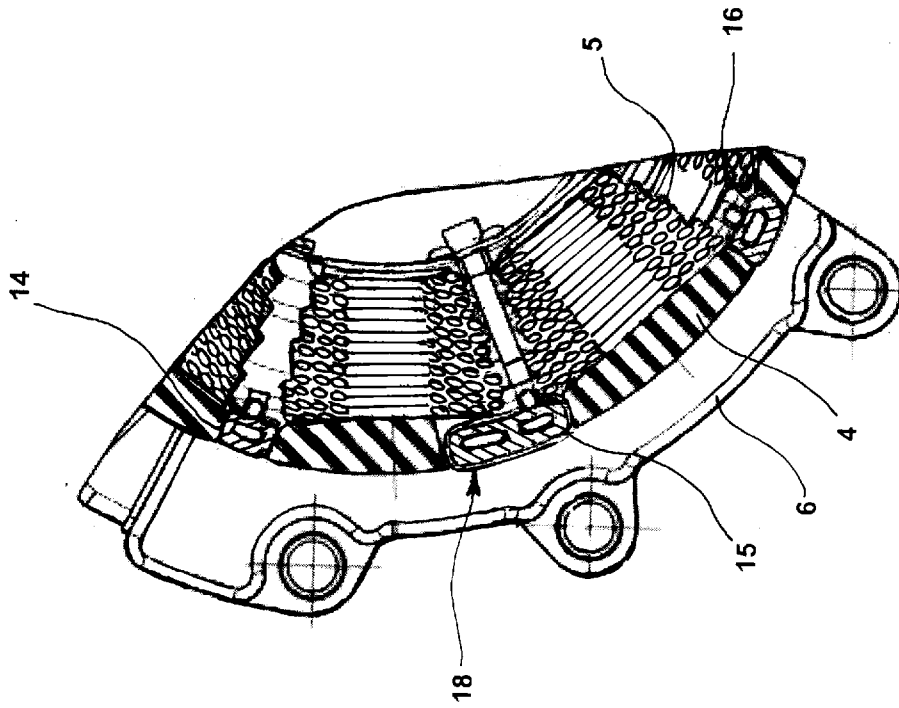


FIG.2

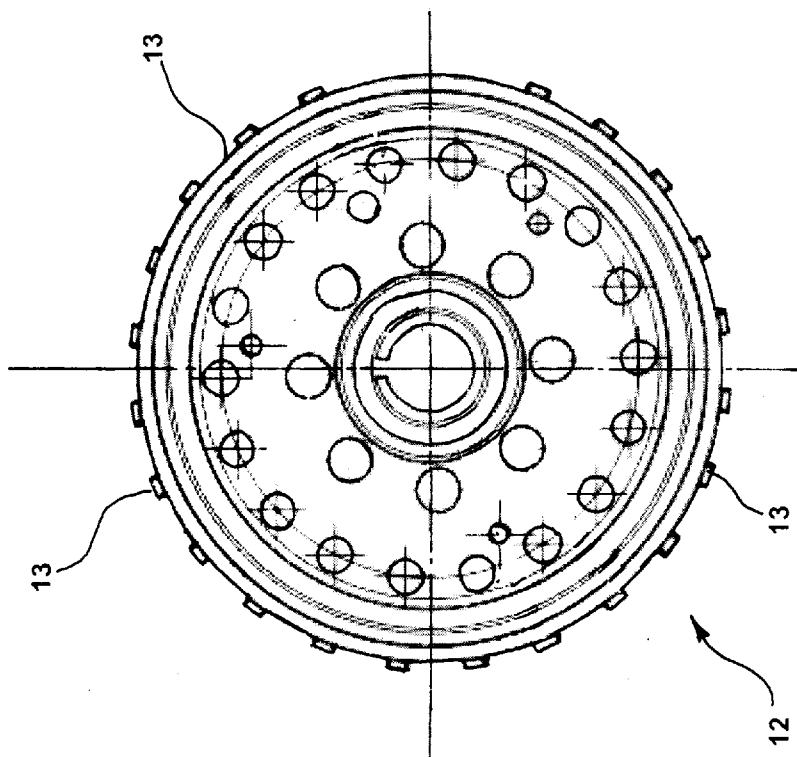


FIG. 4

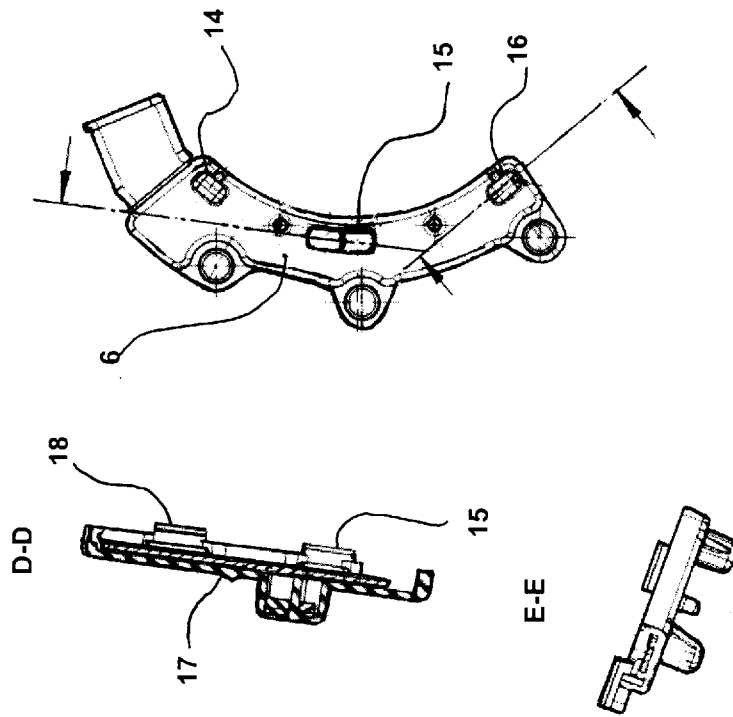


FIG. 5

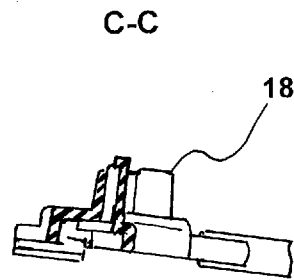
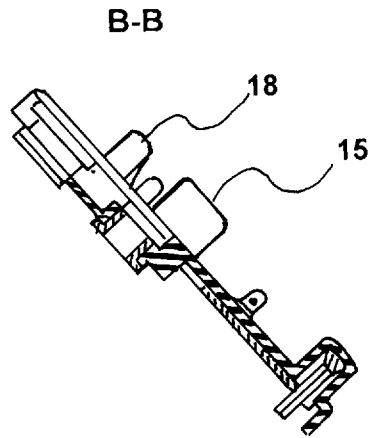


FIG.5A

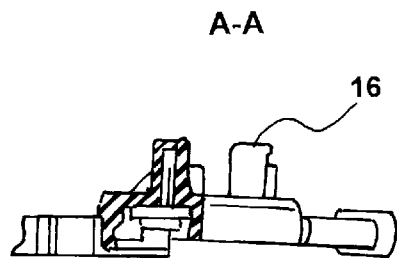


FIG.5B

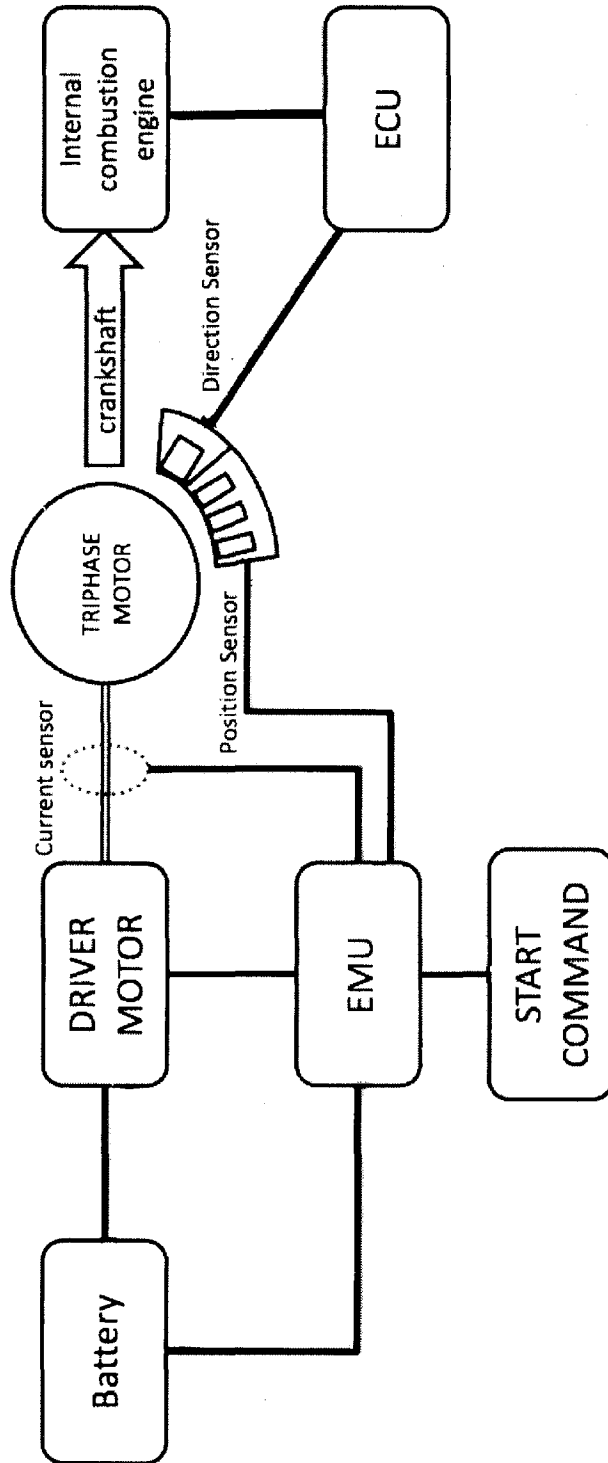


FIG.6

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
 INV. F02N11/04 H02P6/16
 ADD. F02D41/00 H02P6/00 H02K29/08

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)
 F02D F02N H02P H02K

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 practicable, 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. |
|-----------|--|-----------------------|
| X | EP 1 396 629 A2 (HONDA MOTOR CO LTD [JP]) 10 March 2004 (2004-03-10) paragraphs [0001] - [0003], [0011], [0017] - [0021]; figures 1,2,4 ----- | 1-6 |
| X | US 2008/105230 A1 (KISHIBATA KAZUYOSHI [JP] ET AL) 8 May 2008 (2008-05-08) paragraphs [0043], [0049], [0052], [0061], [0062]; figures 1,2 , 9A-9E paragraphs [0103], [0116], [0131] ----- | 1-6 |
| A | US 2005/216177 A1 (KASSNER UWE [DE]) 29 September 2005 (2005-09-29) abstract; figures 1,2 paragraphs [0020], [0029] ----- | 3,6 |
| | -/-- | |

Further documents are listed in the continuation of Box C.

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| Date of the actual completion of the international search 18 November 2015 | Date of mailing of the international search report 03/12/2015 |
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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/055713

| 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 2004/021457 A1 (JOHNSON CURTIS B [US]) 5 February 2004 (2004-02-05) abstract; figure 5 paragraph [0015] ----- | 3,6 |
| A | EP 2 149 975 A1 (C R D CT RICERCHE DUCATI TRENT [IT] C R D CT RICERCHE DUCATI TRENTO S) 3 February 2010 (2010-02-03) paragraphs [0009] - [0012], [0015], [0017], [0023] - [0026], [0066]; figures 1-3 ----- | 1,4 |
| A | JP 2007 132335 A (KOKUSAN DENKI CO) 31 May 2007 (2007-05-31) abstract; figures 1,2 ----- | 1,4 |

INTERNATIONAL SEARCH REPORT

Information on patent family members

| |
|---|
| International application No PCT/IB2015/055713 |
|---|

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|--|------------------|-------------------------|--------------------|
| EP 1396629 | A2 | 10-03-2004 | BR 0302882 A |
| | | | CA 2437376 A1 |
| | | | CN 1495406 A |
| | | | EP 1396629 A2 |
| | | | ES 2294227 T3 |
| | | | JP 3945696 B2 |
| | | | JP 2004101234 A |
| | | | KR 20040022153 A |
| | | | MX PA03007558 A |
| | | | MY 135569 A |
| | | | TW I231084 B |
| | | | |
| US 2008105230 | A1 | 08-05-2008 | JP 4682966 B2 |
| | | | JP 2008115787 A |
| | | | US 2008105230 A1 |
| | | | |
| US 2005216177 | A1 | 29-09-2005 | CN 1721856 A |
| | | | DE 102004015037 A1 |
| | | | FR 2868157 A1 |
| | | | US 2005216177 A1 |
| | | | |
| US 2004021457 | A1 | 05-02-2004 | AU 2003259251 A1 |
| | | | EP 1532455 A1 |
| | | | US 2004021457 A1 |
| | | | WO 2004013641 A1 |
| | | | |
| EP 2149975 | A1 | 03-02-2010 | NONE |
| | | | |
| JP 2007132335 | A | 31-05-2007 | NONE |
| | | | |