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(54) **Title**: AUTOMOTIVE ELECTRIC LIQUID PUMP

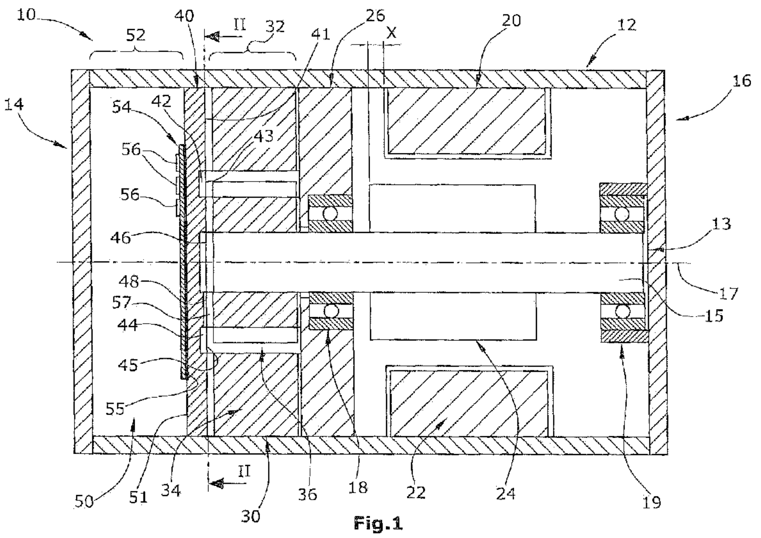

Fig.1

(57) **Abstract**: The invention refers to an automotive electric liquid pump (10) with a pump housing (12) and a rotor (13) defining the longitudinal rotor axis (17). The automotive pump (10) comprises • an electric motor (20) including stator coils (22) at one longitudinal end of the pump housing (12), • a power electronics chamber (50) with power semiconductors (56) for driving the stator coils (22), the power electronics chamber (50) being arranged at the other longitudinal end of the pump housing (12), • a pump chamber (30) wherein a pump rotor (36) driven by the electric motor (20) is rotating to pump a liquid from a pump chamber inlet (43) to a pump chamber outlet (45), and • a metal separation wall (40) in transversal plane, the separating wall (40) separating the pump chamber (30) from the power electronics chamber (50).

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Automotive electric liquid pump

The present invention is directed to an electric automotive liquid pump.

An electric automotive liquid pump is used to pump a liquid, for example a coolant or a lubricant, to an automotive engine or to other automotive devices.

State of the art pumps are divided into three functional parts, namely a motor section comprising an electric motor, a motor control electronics section and a pumping section, whereby the motor section is provided longitudinally in the middle between the motor electronics section and the pumping section. This arrangement allows a short electric connection between the motor electronics and the electric motor. The motor electronics comprise power semiconductors which have to be cooled to avoid their overheating and destruction. In state of the art pumps the cooling of the power semiconductors is normally realized by the housing which is cooled by the lubricant and by the environmental air outside the pump housing. However, since the liquid pumping section is remote from the motor control electronics section, the liquid itself can not help to cool the power semiconductors sufficiently and efficiently.

It is an object of the invention to provide an electronic automotive liquid pump with an improved cooling of the power semiconductors.

The electric automotive liquid pump according to claim 1 is provided with a pump housing and a rotor which defines the longitudinal axis of the pump. The pump comprises an electric motor including stator coils and being arranged at one longitudinal end of the pump housing, and not arranged axially between two other sections. A power electronics chamber is provided and defined in the pump housing, whereby the power electronics chamber is provided with power semiconductors for electrically driving the stator coils of the pump rotor. The power electronics chamber is arranged at the other longitudinal end of the pump housing and is not arranged between the other two sections. Between the power electronics chamber at one longitudinal pump end and the electric motor arranged at the other longitudinal pump end a pumping chamber is provided wherein a pump rotor driven by the electric motor via a rotor shaft is rotating to pump a liquid from a pump chamber inlet to a pump chamber outlet. In other words, the pumping chamber comprising the pump rotor is arranged between the power electronics chamber at one longitudinal side and the electric motor at the longitudinal other side. The pumping chamber is not necessarily arranged in the geometric longitudinal middle of the pump housing.

The pumping chamber and the power electronics chamber are separated by a metal separation wall which is lying in a transversal plane with respect to the longitudinal axis. Since the separation wall defines one wall of the pump chamber comprising the pumped liquid, the separation wall is always cooled by the liquid with a high cooling performance. Additionally, the total distance between the liquid in the pump chamber and the power semiconductors is very short, and be as short as a few millimeters. Since the maximum temperature of a coolant or a lubricant in an automotive application never is higher than 120°C, this arrangement guarantees that also the separation wall will, under normal circumstances, not become warmer than 120°C. Since power semiconductors with a maximum working temperature of 140°C up to 150°C are available, an overheating of these power semiconductors can reliably be excluded.

According to a preferred embodiment of the invention the power semiconductors are provided in heat-conduction connection with the separation wall. This does not necessarily mean that the power semiconductors are directly in contact with the separation wall. But it is essential that the power semiconductors are connected with the separation wall without an air gap between the semiconductor and the separation wall.

Preferably the power semiconductors are connected to the separation wall only by materials with good heat-conduction abilities, such as a metal, a heat-conductive paste and/or a heat-conductive glue or adhesive.

According to a preferred embodiment of the invention, the pump chamber inlet is realized as a recess in the plane separation wall surface facing the pump chamber. This feature leads to an increased total surface area so that the heat exchange between the liquid in the pump chamber and the separation wall is improved. Additionally, the liquid flowing into the pump chamber through the pump chamber inlet leads to a increase of the turbulences in the liquid close and adjacent to the separation wall which also increases the heat exchange between the liquid in the pump chamber and the separation wall.

Alternatively or additionally, the pump chamber outlet is realized as a recess in the plane surface of the separation wall, with the same effects and results as it is the case with the pump chamber inlet recess.

Preferably, the power semiconductors are arranged closer to the pump chamber inlet then to the pump chamber outlet. The region around and exactly opposite to the pump chamber inlet is the coldest region of the separation wall because of the increased total surface area, the increased liquid turbulences in this region and the fact that the incoming liquid is colder than the liquid flowing out of the pump chamber through the pump chamber outlet. The incoming liquid is colder because the pressurized liquid leaving the pump chamber is warmed by the thermodynamic effect caused by the increased liquid pressure at the chamber outlet. As a result, the cooling performance close to the pump chamber inlet is the highest cooling performance available at the separation wall.

According to a preferred embodiment of the invention, a center recess or pocket is provided in the radial center of the separation wall, whereby the center recess is provided axially opposite to the rotor shaft and/or to the pump rotor. This feature increases the total surface area of the separation wall surface facing the pump chamber so that the heat exchange between the liquid in the pump chamber and the separation wall is increased.

Preferably, the center recess is fluidically connected to the pump chamber outlet. The liquid pressure the pump chamber outlet is higher than in the pump chamber so that the liquid pressure in the center recess pushes the opposite rotor shaft and/or the opposite pump rotor away from the separation wall. As a result, a significant gap filled with the liquid is generated, whereby the liquid in the gap is highly turbulent as long as the rotor shaft and the pump rotor are rotating so that an intensive heat exchange is realized in this area between the liquid in the pump chamber and the separation wall. Preferably, the fluidic connection between the pump chamber outlet and the center recess is realized by a connection channel recess in the separation wall.

According to a preferred embodiment of the invention, the motor stator coils are axially offset with respect to the motor rotor to pull the rotor shaft and the pump rotor axially away from the separation wall. As a result, a significant transversal gap filled with the liquid is generated as long as the electric motor is electrically active, the gap being defined between the rotor shaft and/or the pump rotor at one side and the separation wall at the other side. This leads to a dramatically improved heat exchange between the liquid and the separation wall in this area.

Generally, the liquid pump is realized as a positive displacement pump, such as a screw compressor, a vane pump etc. Preferably, the liquid pump is realized as a lubricant pump, and, according to another preferred embodiment, the pump is a gerotor pump rotor.

One embodiment of the invention is described referring to the drawings wherein figure 1 shows a schematic longitudinal section of an automotive electric liquid pump including a separation wall separating a pump chamber from a power electronics chamber, and

figure 2 shows a cross section II-II of the pump of figure 1 showing the surface of the separation wall facing the pump chamber.

Figures 1 and 2 show an automotive electric liquid pump 10 which is realized as a lubricant pump for providing a pressurized lubricant for an automotive internal combustion engine.

The pump 10 comprises a pump housing 12 which houses, seen in longitudinal direction, three sections, i.e. an electric motor 20 at one longitudinal pump end, a power electronics chamber 50 defining an electronics section 52 at the other longitudinal pump end and a pump chamber 30 defining a pump section 32 being arranged between the power electronics chamber 15 and the electric motor 20. The pump 10 is provided with a rotor 13 comprising a rotor shaft 15 defining a longitudinal rotor axis 17. The rotor shaft 15 is rotatably supported by two roller bearings 18, 19 at the housing 12. The housing 12 substantially comprises a housing cylinder 20 which is closed by separate covers 14, 16 at both longitudinal ends of the housing 12.

The electric motor 20 is a brushless DC motor which is electronically commutated by a motor control electronics provided in the power electronics chamber 50. The motor 20 is provided with a permanent magnetic motor rotor 24 and with stator coils 22 which are electrically driven by several power semiconductors 56 arranged in the power electronics chamber 50.

A first transversal separation wall 26 separates the motor section from the pump section 32 with the pump chamber 30. In the pump chamber 30 an inner pump rotor 36 and an outer pump rotor 34 are provided both defining a gerotor pumping the lubricant from a pump chamber inlet 43 to a pump chamber outlet 45.

A second transversal metal separation wall 40 separates the pump chamber 30 from the electronics section 52 including the power electronics chamber 50 fluid-tight. The separation wall 40 is provided with a first plane surface 41 facing the pump chamber 13 and a second plane surface 51 facing the power electronics chamber 50. The separation wall 40 is provided with several recesses at the first plane surface 41 which are shown in figure 2 in plan view. The lateral pump chamber inlet 43 is defined by a sickle-shaped inlet recess 42 and the lateral pump chamber outlet 45 is defined by another sickle-shaped outlet recess 44.

The center of the second separation wall surface 51 is provided with a center recess 46 which is fluidically connected to the pump chamber outlet 45 by a radial connection channel recess 48 in the separation wall 40. The fluid pressure at the pump chamber outlet 45 is normally the highest of all pump chamber regions. Since the center recess 46 is fluidically connected with the pump chamber outlet 45, the high fluid pressure at the pump chamber outlet 45 is also present at the center recess 46. As a result, the rotor shaft 15 and the pump rotor 36 are pushed away from the second separation wall 40 so that a significant gap 57 between the rotor shaft 15 including the pump rotor 36 at one side and the separation wall surface 41 facing the pump chamber 30 at the other side is always realized. This gap 57 is filled with the pump liquid which is a lubricant in the present embodiment.

As can be seen in figure 1, the motor stator coils 22 are longitudinally offset with an offset X with respect to the motor rotor 24. If the stator coils 22 are energized, the permanent magnetic motor rotor 24 and the connected rotor shaft 15 including the pump rotor 36 are axially pulled away from the second separation wall 40 separating the power electronics chamber 50 from the pump chamber 30 so that the creation of the liquid-filled gap 57 is caused. The liquid-filled gap 57 avoids a frictional contact between the rotating parts of the rotor 13 and the separation wall 40, and leads to an improved heat exchange between the liquid in the pump chamber 30 and the separation wall 40.

The power semiconductors 56 are mounted to a printed circuit board 54 also comprising the control electronics for controlling the power semiconductors 56. The power semiconductors 56 can be power MOSFETs or any other kind of power semiconductors. The backside of the printed circuit board 54 is connected with the separation wall 40 by a layer 55 of a heat-conductive glue or adhesive so that a heat-conductive connection and coupling is guaranteed between the power semiconductors 56 and the metal separation wall 40.

As can be seen in figure 2, the power semiconductors 56 are all provided opposite and next to the pump chamber inlet 43 rather than to the pump chamber outlet 45. Since the temperature of the liquid is generally lower at the pump inlet 43, the arrangement of the power semiconductors 56 close to the pump chamber inlet 43 leads to an improved cooling of the power semiconductors 56.

CLAIMS

1. Automotive electric liquid pump (10) with a pump housing (12) and a rotor (13) defining the longitudinal rotor axis (17), comprising

   an electric motor (20) including stator coils (22) at one longitudinal end of the pump housing (12),

   a power electronics chamber (50) with power semiconductors (56) for driving the stator coils (22), the power electronics chamber (50) being arranged at the other longitudinal end of the pump housing (12),

   a pump chamber (30) wherein a pump rotor (36) driven by the electric motor (20) is rotating to pump a liquid from a pump chamber inlet (43) to a pump chamber outlet (45), and

   a metal separation wall (40) in transversal plane, the separating wall (40) separating the pump chamber (30) from the power electronics chamber (50).

2. Automotive electric liquid pump (10) of claim 1, whereby the power semiconductors (56) are provided in heat-conduction connection with the separation wall (40).

3. Automotive electric liquid pump (10) of one of the preceding claims, whereby the pump chamber inlet (43) is realized as a recess (42) in the plane surface (41) of the separation wall (40).

4. Automotive electric liquid pump (10) of one of the preceding claims, whereby the pump chamber outlet (45) is realized as a recess (44) in the plane surface (41) of the separation wall (40).

5. Automotive electric liquid pump (10) of one of the preceding claims, whereby the power semiconductors (56) are arranged closer to the pump chamber inlet (43) than to the pump chamber outlet (45).

6. Automotive electric liquid pump (10) of one of the preceding claims, whereby a center recess (46) is provided in the middle of the separation wall 40 and axially opposite to the rotor shaft (15) and/or to the pump rotor.

7. Automotive electric liquid pump (10) of claim 6, whereby the center recess (46) is fluidically connected to the pump chamber outlet (45).

8. Automotive electric liquid pump (10) of claim 7, whereby a connection channel recess (48) in the separation wall (40) is provided to connect the center recess (46) with the pump chamber outlet (45).

9. Automotive electric liquid pump (10) of one of the preceding claims, whereby the motor stator coils (22) are axially offset with respect to the motor rotor (24) to pull the pump rotor (36) axially away from the separation wall (40).

10. Automotive electric liquid pump (10) of one of the preceding claims, whereby the liquid pump is a lubricant pump.

11. Automotive electric liquid pump (10) of one of the preceding claims, whereby the pump rotor (36) is of the gerotor-type.

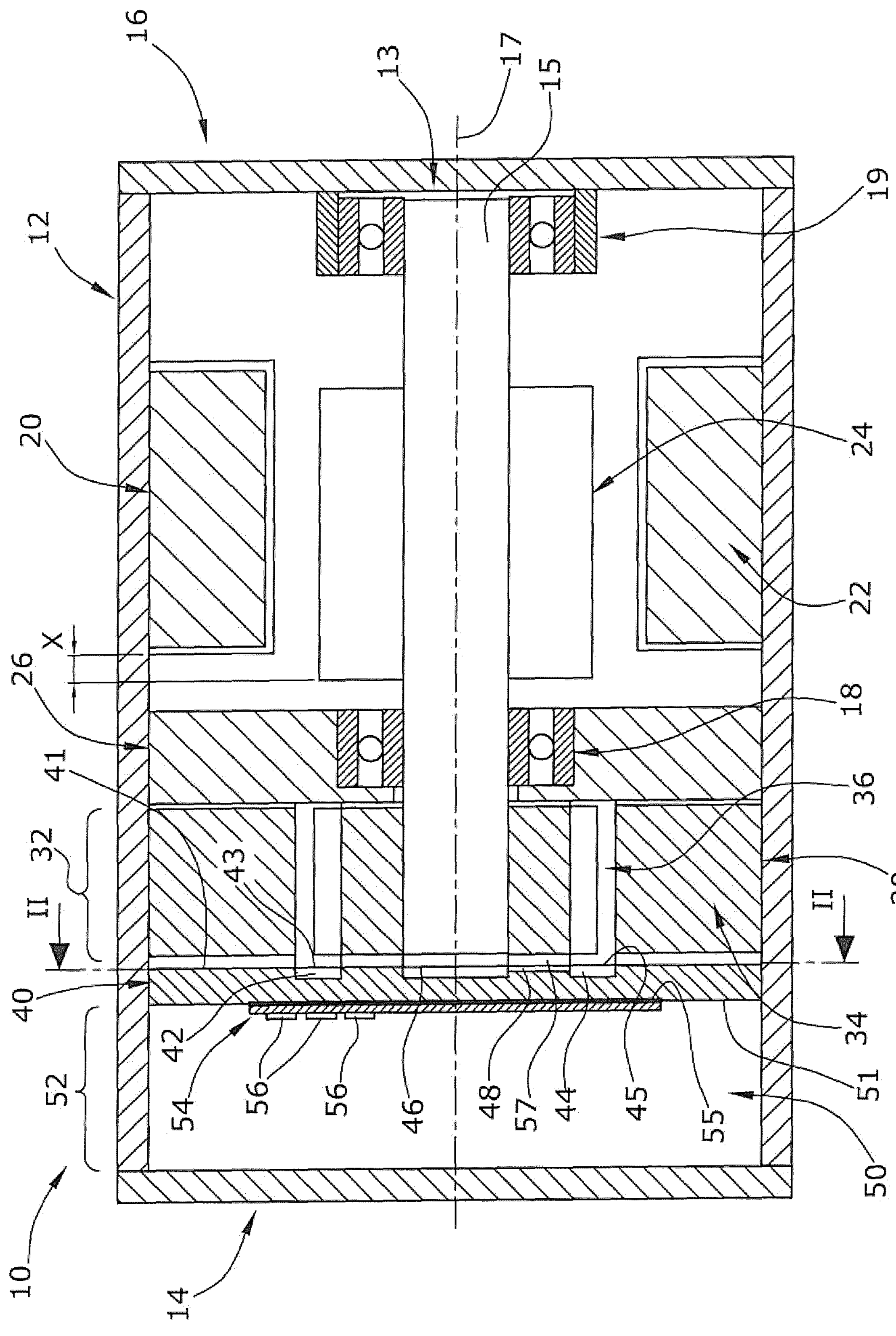

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Fig.1

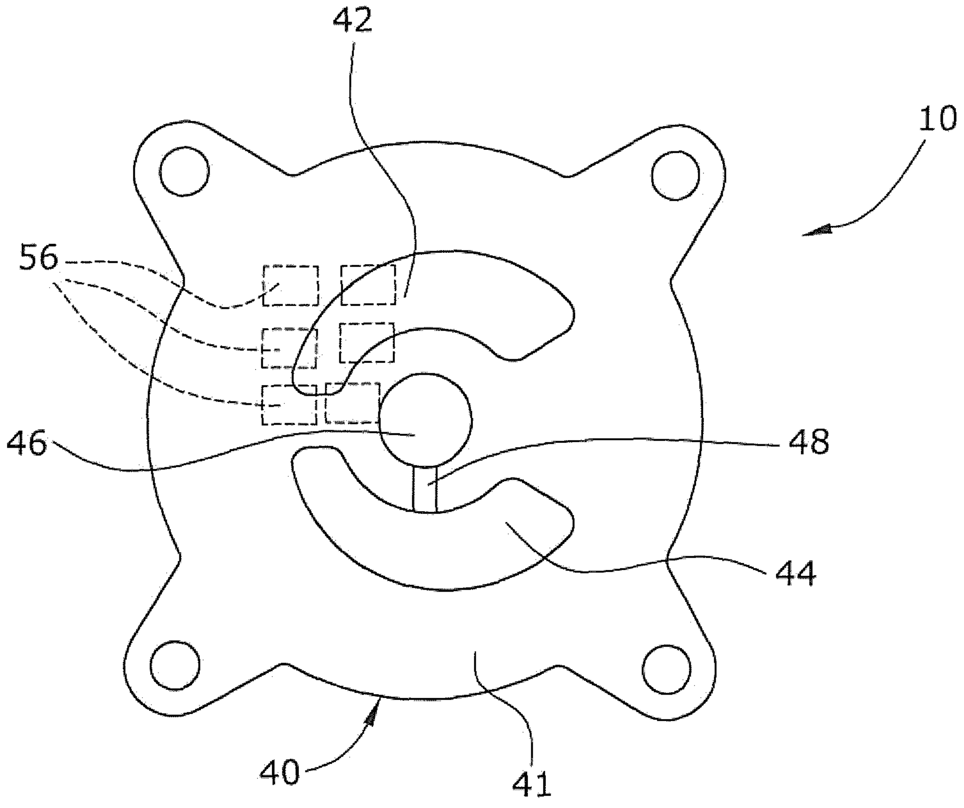

Fig.2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/071371

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01C21/10 F04C11/00 F04C15/00 F04C15/06
ADD.

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)
F01C F04C

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/035767 A1 (PANASONIC CORP [JP]; OGAWA NOBUAKI; GOTO NAOMI; ADACHI TORU; KAJITANI) 22 March 2012 (2012-03-22) abstract figures 1,2,6,7,11	1-3,5, 10,11
X	US 2004/109772 A1 (OGAWA NOBUAKI [JP] ET AL) 10 June 2004 (2004-06-10)	1,2,5, 10,11
Y	the whole document	1-5,10, 11
Y	EP 2 463 556 A1 (JTEKT CORP [JP]) 13 June 2012 (2012-06-13) the whole document	1-5,10, 11

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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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
5 July 2013	16/07/2013

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

Information on patent family members

International application No
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012035767 A1	22-03-2012	US 2012308414 A1	06-12-2012
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