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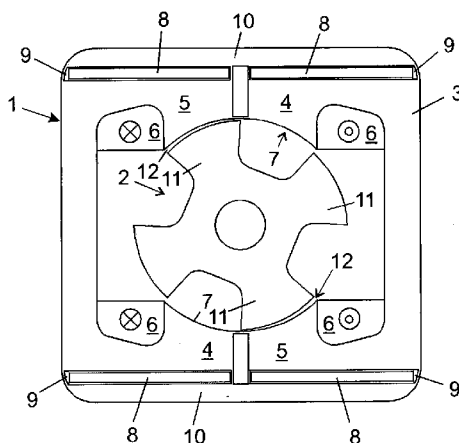


FIG. 1

(57) Abstract: The present invention refers to an electric motor preferably a switched reluctant motor-type, which is designed for application in hermetic compressors commonly used in refrigeration equipments and systems. More specifically, said electric motor of the present invention comprises a stator (1) and a rotor (2), wherein said stator (1) comprises a body (3) subdivided into right pole (4) and left pole (5) forming poles stator (7), in which coils (6) are wound, wherein said body (3) further comprises permanent magnets (8) disposed in recesses (9) provided in outer regions of said body (3); and said rotor (2) is composed of protruding poles (11), which comprise a structural configuration which air gap portion (12) is variable.



SWITCHED RELUCTANCE ELECTRIC MOTOR

Field of the Invention

The present invention refers to an electric motor more preferably developed for application in hermetic compressors commonly used in refrigeration equipments and systems. More particularly, the electric motor of the present invention is a switched reluctance-type, comprising innovative technical and functional features capable of improving operation conditions and the yield of this electric motor type.

Background of the Invention

As generally known in the art, electric motors are equipments designed to transform electric energy into mechanical energy, particularly into rotational mechanical energy, which is generated by a rotor movement resulting from interaction of magnetic fields formed by the stator.

In this sense, it is important to point out that electric motors comprise a very relevant feature concerning the ability to control their operational speed, that is, the possibility and facility to control the rotational speed. Such features of electric motors is essential, mainly for application in hermetic compressors commonly used in refrigeration systems and equipments in general, since it permits to vary refrigeration capacity of compressors for adaptation to load levels required by the refrigeration system and, consequently, power consumption is reduced.

According to the state of the art, several categories of electric motors are known, which are developed and designed according to the power supply source to be applied. By way of example, there may be cited DC electric motors whose speed variation is proportional to the variation in the power supply voltage amplitude, wherein the variation in rotor rotational speed is proportional to the variation in the power supply voltage frequency. Physical construction of these motors is well known by those skilled in the art so that a detailed description of the case is unnecessary.

In this context, it should be pointed out that despite the fact that methods for operating DC electric motors are still simple, their realization in operational electromechanical systems of these motors is substantially complex and, consequently, they are in many cases economically impracticable. This stems from the fact that a DC electric motor or its power supply source should be sized to combine higher power supply voltage amplitude with the highest desired rotor speed.

Differently, the realization of electronic and/or electromechanical systems for operation of DC electric motors is simpler. Such a realization can make use of the so-called frequency inverters, whose purpose is to controllably alter frequency and magnitude of the power electric motor voltage from an electric network voltage whose frequency and magnitude are essentially constant.

Thus, as can be appreciated by those skilled in the art, frequency inverters are the most suitable devices to obtain rotational speed variation of AC motors. Based on this principle, attempts are being made to define which would be the best topology of these electric motors to achieve the best results which usually lead to the conclusion that said
5 motor can be an induction-type motor having permanent magnets, or a switched reluctance motor (SRM).

In this sense, it can be noted that induction motors show an extremely simple design, allowing for speed variation when used in conjunction with an inverter. However, such motor does not operate in synchrony so that efficiency is negatively affected, and
10 depending on the load to which same is subjected, the speed variation control is significantly affected.

With regard to motors with permanent magnets, it can be observed that they have a performance superior to induction motors since they may work in synchrony. This is the best option when looking for fractional power motor but they will then require a more complex
15 building process than the induction motor, mainly because of the positioning and magnetizing of said magnets.

Finally, the switched reluctance motors (SRM) also exhibit a performance superior to that of the induction motors as well as do not present significant losses in the speed variation control since they can work in synchrony. Nevertheless, due to the fact that they do
20 not contain magnets in the rotor, it is required that stator is responsible for the whole magnetic field flow. In practice, it is noted that said switched reluctance motors hardly overcome the performance levels of motors having permanent magnets. Nevertheless, due to the absence of rotor magnets, a substantial reduction in costs is achieved.

In view of the foregoing, it can be noted that each electric motor model will present
25 benefits and drawbacks which should be taken into account for each practical application.

Particularly, with regard to switched reluctance motors, it is observed that although presenting advantages in determined practical applications they contain limitations and restrictions directly affecting efficiency and costs so that it will make difficult their
30 implementation in most designs developed by industries. More particularly, it is possible that efficiency of this motor type is usually lower than efficiency of brushless motors with magnets in the rotor.

Furthermore, switched reluctance electric motors require more powerful and consequently more complex electronic controllers, thereby increasing costs when compared to brushless motors. By this way, due to the increase in the costs involved, mainly by virtue
35 of the electronic control complexity, demand for this kind of motor is reduced.

Additionally, it is observed that switched reluctance motors produce, during operation, noises and vibrations higher than that produced by brushless motors, which also

has influence on the choice of other motors rather than on the choice of these switched reluctance motors.

Thus, based on the context above, it is noted that there is a need in the state of the art for a solution that effectively makes it possible and more attractive to use switched reluctance motors. More particularly, it is noted that electric motors already known from the state of the art need solutions which would increase the performance of these motors and make their manufacture and mounting more cost-effective.

Objects of the Invention

Therefore, in view of the scenario above, an object of the present invention is to provide an electric motor preferably for application in refrigeration systems and equipments, which comprises innovative technical and functional features and capable of improving the operational conditions of these motors as well as producing a structural configuration specifically designed to improve yield and reduce costs in order to render application thereof viable.

Further another object of the present invention is to provide an electric motor, preferably a brushless single phase synchronous motor with magnets, which features have been developed to reduce and/or eliminate the drawbacks presented in the state of the art so as to promote its use in industrial application.

Yet another object of the present invention is to provide an electric motor using concepts applied to the structural mounting of single phase motors with permanent magnets, which, by doing so, will permit to increase the amount of magnets in the motor and, therefore, efficiency in a level superior to that of conventional and already known switched reluctance motors can be improved.

Another object of the present invention is to provide an electric motor wherein its structural mounting will significantly simplify insertion/removal of magnets after accommodating the stator coil. Hence, a technical advantage of reducing magnet sensitiveness to demagnetization is then achieved.

Furthermore, it is also an object of the present invention to provide an electric motor having a configuration which structure and specifications of the rotor make the starting method easier, mainly due to the fact that said rotor comprises a variable gap to ensure the natural positioning of the rotor at a certain known angle.

Additionally, the object of said electric motor of the present invention is also to provide a structure that eliminates the need for position sensors, such as Hall cells and cost reduction is achieved because it allows for an inverter with H-bridge configuration.

Summary of the Invention

These and other objects of the present invention are accomplished by means of a switched reluctance electric motor, which comprises a stator which body is subdivided into

right and left poles so as to obtain the so-called stator poles, in which coils for electric current circulation are wound, which generate magnetic flux in conjunction with permanent magnets arranged in recesses provided in the outer regions of said body. Further, the motor of the present invention comprises a rotor composed of protruding poles having a structural configuration capable of generating a variable gap portion, that is, not homogeneous, to generate torque, and, consequently, to move said motor.

Additionally, in accordance with a variation of an embodiment of the present invention, said permanent magnets are arranged in a return iron of the stator body (1) of the switched reluctance electric motor to permit to increase the amounts of magnets to generate magnetic flux.

Another possible embodiment of the switched reluctance electric motor, in accordance with the present invention, allows said stator poles to be shaped in a configuration which size is twice the size of said rotor protruding poles, which are advantageously arranged in a number of four.

Further, in accordance with an economically advantageous embodiment, said stator magnets are made of ferrite to reduce manufacturing and mounting costs of the switched reluctance electric motor.

Moreover, according to a possible embodiment of the present invention, the switched reluctance electric motor has a configuration in which the rotor is outside.

In addition, the switched reluctance electric motor, in accordance with the present invention, comprises a control which does not require the use of position sensors, and it may be configured from an inverter with H-bridge.

Brief Description of the Drawings

Features, advantages and technical effects of the present invention, as mentioned above, will be better understood by a person skilled in the art from a detailed description, made by way of non-limitative example, of a preferred embodiment, and with reference to the attached drawings, in which:

Fig. 1 illustrates a cut view of an electronically controlled single phase reluctance electric motor of the present invention;

Figs. 2A and 2B illustrate cut views of the electric motor of the present invention, highlighting the magnetic flux according to the polarity of the power supply electric current;

Figs. 3A, 3B, 3C and 3D sequentially illustrate the electric power operation of the present application, highlighting the magnetic flux generated by the electric current of the electric power source.

Detailed Description of the Invention

In accordance with the schematic drawings mentioned above, the electric motor of the present invention comprises a stator 1 and a rotor 2, wherein a body 3 of said rotor 1 is

subdivided into right pole 4 and left pole 5 forming poles of stator 7 in which coils 6 are wound to generate magnetic fields to move said rotor 2. Additionally, said body 3 of the stator 1 comprises permanent magnets 8 disposed in recesses 9 provided in the outer regions of said body 3, more preferably in the region called iron return 10.

5 Said rotor 2 comprises protruding poles 11, which comprise a structural configuration duly designed to form an air gap portion 12 which is variable and because of that it permits to ensure natural positioning of said rotor 2 at a known angle, thus facilitating the motor starting method. Said variable air gap 12 allows for a positive torque at the moment at which said protruding poles 11 are underneath the left pole 4 of the stator 7. In
10 case that the gap is uniform, a torque at this position would be near zero and thus the motor operation would be impaired. Characteristics of non-uniformity may vary depending on the geometry of the stator 1 and rotor 2, but typically a 2:2.5 ratio (ratio between maximum gap and minimum gap along the protruding poles 11) is used.

In one of possible geometrical configurations, said poles of the stator 7 comprise
15 twice the size of said protruding poles 11 of said rotor 2. Such particularity ensures that only a portion, preferably half, of the poles of said stator 7 forms the preferred path of the flow passage for each half-period of the current in the coils 6.

According to a preferred and non-restrictive embodiment, said rotor 2 is composed of four protruding poles 11 since there is a certain restriction relative to the amount of
20 magnets accommodated in the stator. This kind of configuration is also capable of avoiding an excessive increase of losses in the steel when being at very high rotations. Therefore, as can be immediately appreciated by those skilled in the art, despite the fact that such structural configuration is shown to be more efficient, there is no restriction to increase the amount of protruding poles, where necessary, wherein this will depend on each design and
25 application of the present electric motor.

In alternative embodiments, more specifically those designed for lower speeds, it is also possible to increase the amount of poles 7 of stator 1. By this way, with a higher number of poles 7, it is possible to reduce the rotor rotation speed with no need to reduce the frequency of currents in the inverter. The range of rotations which can be achieved, however,
30 is not only a function of the inverter current frequency but also of the frequency range used by the control and as required for each application.

From Figs. 2A and 2B, it is possible to observe the working principle of the electric motor in accordance with the present invention. More particularly, the electric motor of the present invention operates based on the fact that said magnets 8 disposed in the outer
35 region of stator 1 generate magnetic flux which predominantly passes through the left pole 5 of the stator when the electric current is with positive polarity, that is, when the current is acting in the positive half-period of the motor supply voltage sine wave, such as illustrated in

graph of Fig. 2A.

On the other hand, when the electric current is with negative polarity, that is, when the current is acting in the negative half-period of the motor supply voltage sine wave, such as illustrated in graph of Fig. 2B, the magnetic flux generated by magnets 8 will
5 predominantly pass through the right pole 4 of the stator.

It is worth to mention that such a phenomenon of magnetic flux reversal is the base for operating and obtaining effects and advantages of the electric motor of the present invention.

Figs. 3A, 3B, 3C and 3D show the sequential mode in which the electric motor of
10 the present invention works. By way of non-limitative example, the cycle of rotor 1 will be described below based on reference "A" indicated in one of the protruding poles of rotor 2.

By this way, in accordance with Fig. 3A, the electric motor is energized and then the electric current in the positive direction, such as depicted in graph of said figure, begins flowing through said coils 6 such that the magnetic flux will easily travel through the right pole
15 of the stator 5. Considering that the air gap portion 12 is not homogeneous, a force is generated which tends to attract in clockwise direction the protruding pole 11 of rotor 2 until the entire protruding pole 11 of rotor 2 is fully positioned underneath the left 5 of stator 1.

At this moment, when the protruding pole 11 of rotor 2 is aligned with the left pole 5 of stator 1, the electric current changes direction, as shown in Fig. 3C and indicated in its
20 graph. Hence, the magnetic flux is reversed and prefers to travel through the right pole 4 of stator 1. Because of that, the protruding pole 11 of rotor 2 is then attracted toward the right pole 4 of stator 1 due to the air gap portion 12 which is not homogenous and, consequently reinforces the torque in clockwise direction.

Continuing with the cycle, as can be seen from Fig. 3D and indicated in its graph,
25 the electric current is still in negative semi-cycle and magnetic flux continues preferably passing through the right pole 4 of stator 1 until the protruding pole 11 of rotor 2 is fully aligned beneath the right pole 4, at which moment the electric current once again changes polarity passing to the positive semi-cycle and restarts the magnetic flux sequence as indicated above from Fig. 3A.

30 According to an advantageous embodiment of the invention, and considering that said magnets 8 are arranged in the outer region of stator 1, particularly in the iron return 10 of stator 1, said magnets 8 comprise a reasonable area and, therefore, they can be made of ferrite, thus reducing manufacture costs without affecting the generated magnetic flux.

According to an alternative embodiment of the present invention, the electric motor
35 can have a configuration similar to that disclosed herein but with an external rotor. In this configuration, the magnets should be arranged within the stator, and the stator poles will be disposed in its outer portion adjacent the gap.

With regard to the effective control of the electric motor of the present invention, it should be pointed out that same thus not require the use of position sensors, such as the so-called Hall cells, and which can be formed from an inverter with H-bridge, which also helps to reduce motor costs.

5 It should be clear that the description above intends to describe in an exemplificative form a preferred embodiment of the electric motor in accordance with the invention. Therefore, a person skilled in the art will understand that several modifications, variations, and construction and structural combinations of features which exert substantially the same function in the same way to achieve the same results are within the scope of protection
10 delimited by the appended claims.

CLAIMS

1. Switched reluctance electric motor comprised by a stator (1) and a rotor (2),
CHARACTERIZED in that said stator (1) comprises a body (3) subdivided into right pole (4)
and left pole (5) forming poles of the stator (7), in which coils (6) are wound, wherein said
5 body (3) further comprises permanent magnets (8) disposed in recesses (9) provided in the
outer regions of said body (3); and said rotor (2) is composed of protruding poles (11), which
comprise a structural configuration which air gap portion (12) is variable.

2. Switched reluctance electric motor, in accordance with claim 1,
CHARACTERIZED in that said magnets (8) are disposed in an iron return (10) of the body
10 (3) of said stator (1).

3. Switched reluctance electric motor, in accordance with claim 1,
CHARACTERIZED in that said poles of the stator (7) are twice the size of said protruding
poles (11) of the rotor (2).

4. Switched reluctance electric motor, in accordance with claim 1,
15 CHARACTERIZED in that said rotor (2) comprises four protruding poles (11).

5. Switched reluctance electric motor, in accordance with claim 1,
CHARACTERIZED in that said magnets (8) are made of ferrite.

6. Switched reluctance electric motor, in accordance with claim 1,
CHARACTERIZED in that it comprises a configuration which rotor is disposed outside,
20 wherein the magnets are arranged in the innermost portion of the stator.

7. Switched reluctance electric motor, in accordance with claim 1,
CHARACTERIZED in that the control thereof is configured from an inverter with H-bridge.

8. Switched reluctance electric motor, in accordance with claim 1,
CHARACTERIZED in that the non-uniformity of said air gap (12) varies in function of the
25 geometry of the stator (1) and rotor (2), preferably in a 2 to 2,5 ratio referring to the ratio
between the maximum gap and minimum gap along said protruding poles (11).

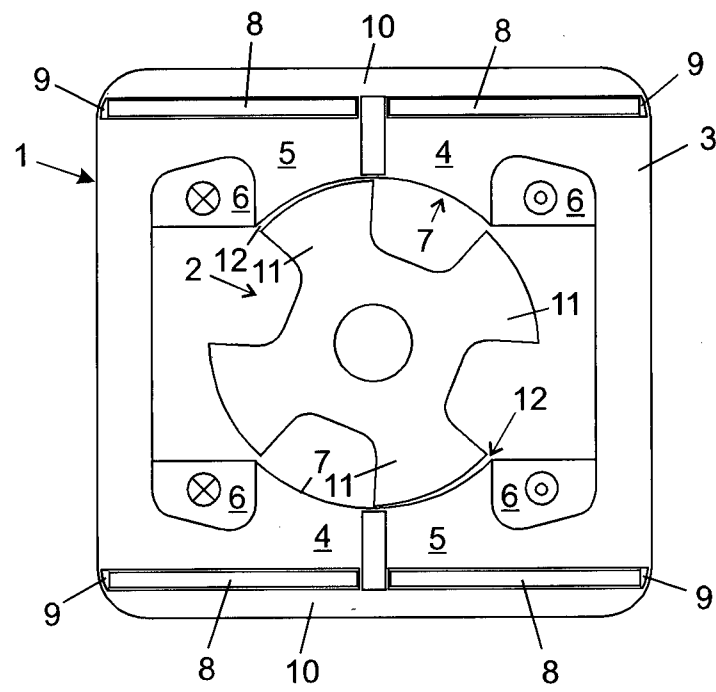
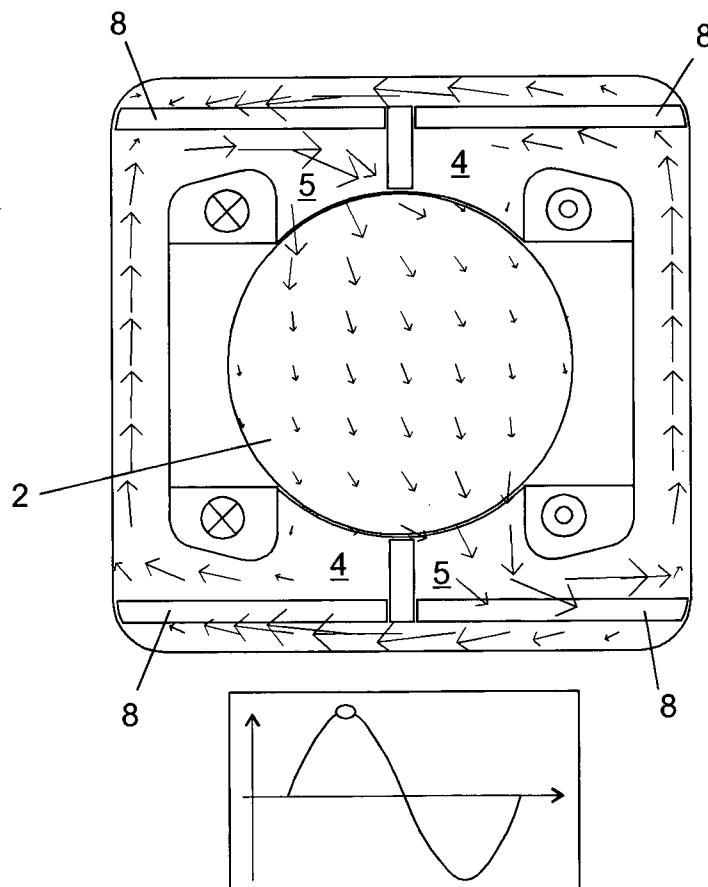
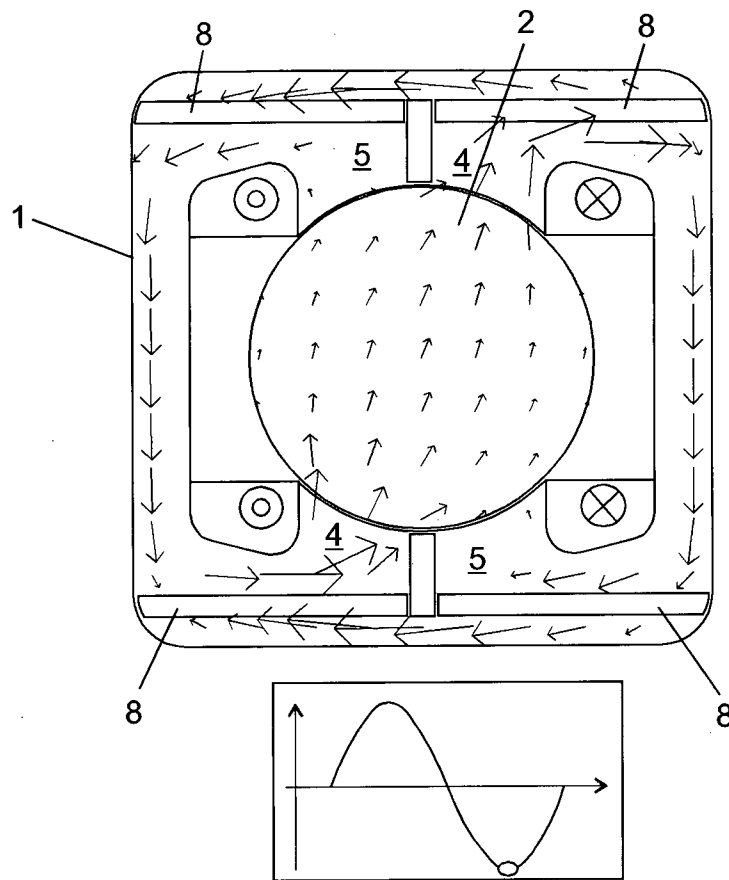


FIG.1



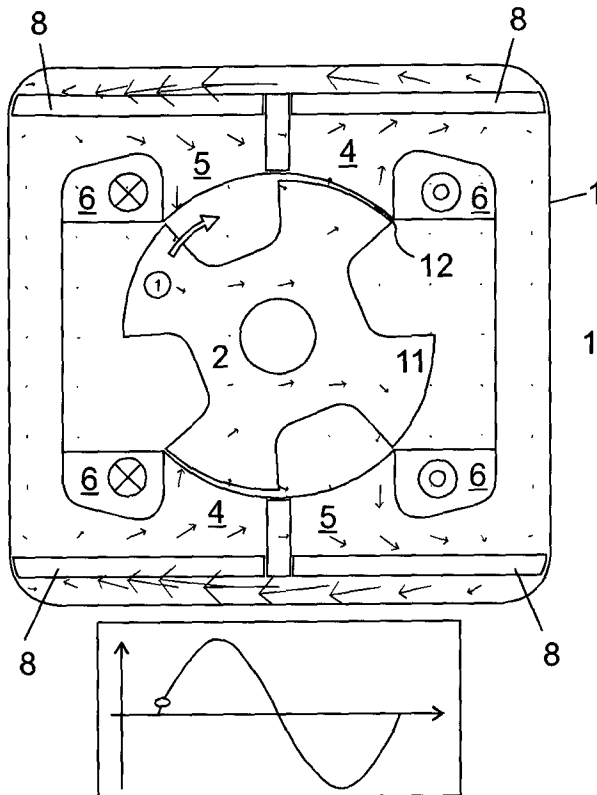


FIG. 3A

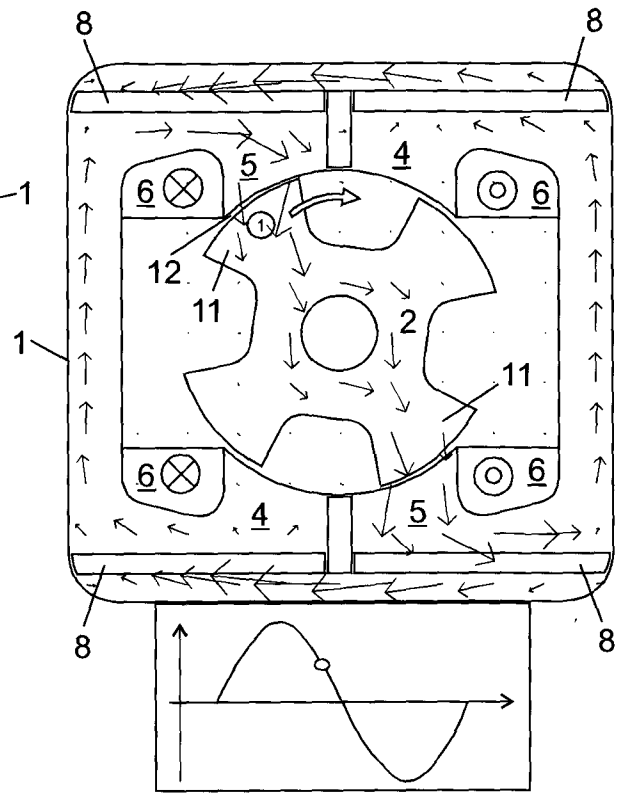


FIG. 3B

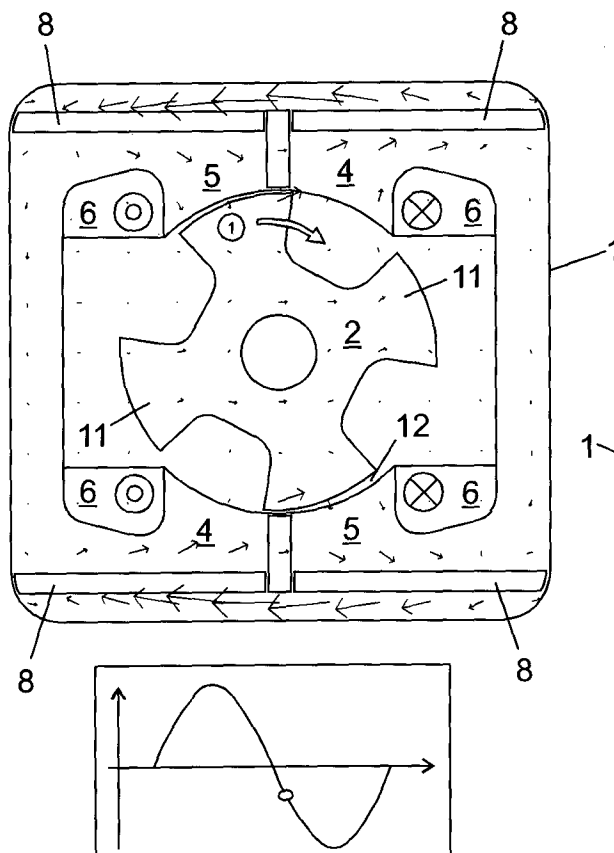


FIG. 3C

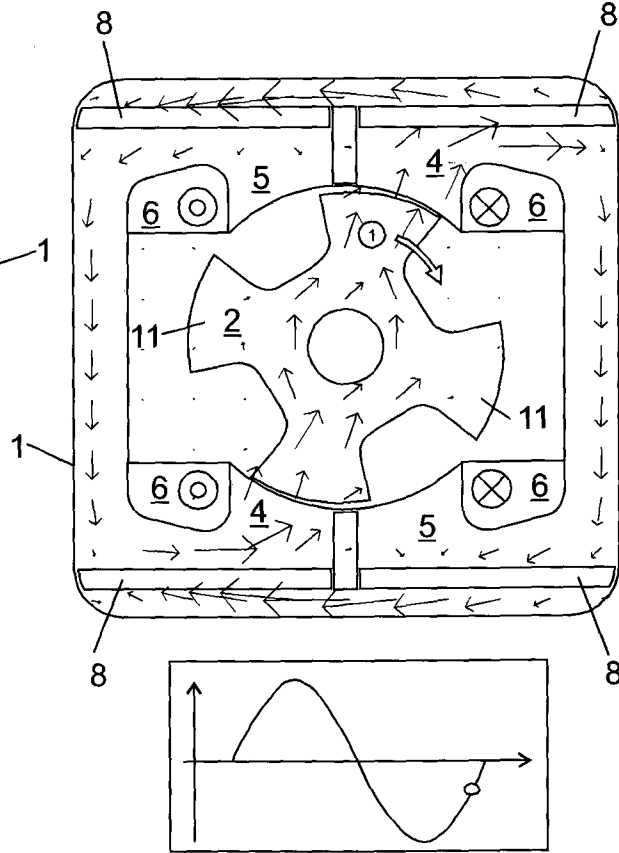


FIG. 3D