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(54) **A rotary fan**

(57) A rotary fan comprising a rotor and a fan support structure. The rotor comprises a plurality of permanent magnets located along a circumference of the rotor and a plurality of fan blades. The support structure comprises a plurality of electromagnets. At least some of the plurality of electromagnets are configured to cause the rotor to rotate when powered by an alternating electric current.

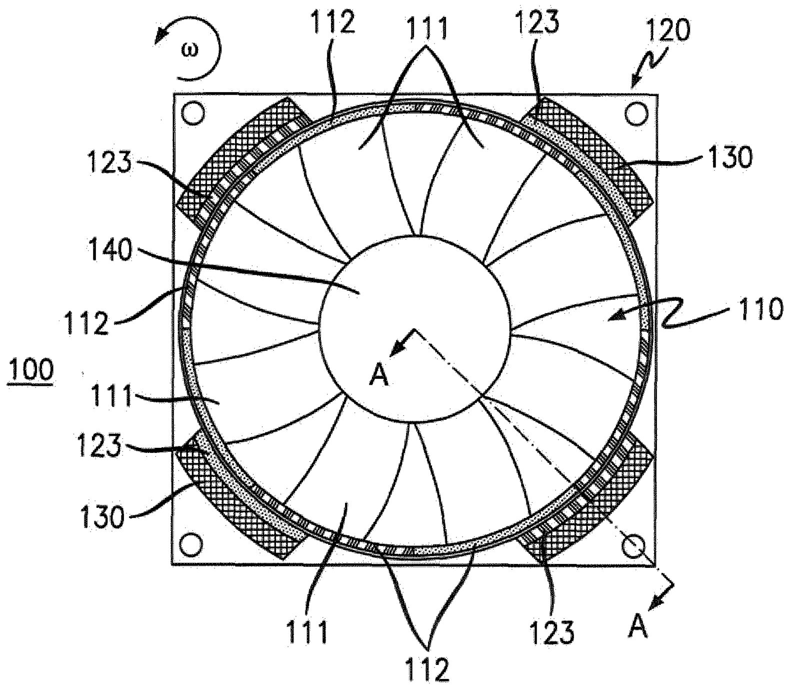

FIG. 2A

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Description

[0001] The present invention relates to rotary fans.

BACKGROUND

[0002] One major challenge in thermal management of electronic or electric equipment is maintaining reliable component temperatures while enabling increased functionality. The challenge becomes even more significant when such increased functionality is required within reduced volumes. This is in particular the case for telecommunications equipment, although similar challenges may exist in many other sectors of industry.

SUMMARY

[0003] Natural or passive cooling techniques have, in many occasions, proven insufficient for the thermal management of modern equipment. In an attempt to improve the thermal management of the equipment some solutions have extended the use of natural or passive cooling by incorporating forced cooling techniques such as rotary fans.

[0004] However, rotary fans also suffer from certain drawbacks. One such drawback is their relatively low reliability in terms of their useful life time which is in the range of 5 to 10 years typically depending on usage, environment, motor and bearing technologies used. Therefore, although the known rotary fans can improve the shortcoming of passive cooling systems, they may still not be able to provide a satisfactory solution towards an efficient thermal management of modern equipment. An example of a known axial rotary fan is illustrated in figures 1a, 1b and 1c. Figure 1a illustrates a top (upper side) view and figure 1b the bottom (underside, opposite to top) view of a known rotary fan with four struts. Figure 1c illustrates a perspective view of another known rotary fan with three struts with a cross section of the fan showing sections of the fan as will be described below. The direction of rotation in each figure is represented by arrow ω. Unless otherwise provided, like reference numerals in these figures correspond to like elements in each figure.

[0005] The rotary fan 100, herein below also referred to as fan, comprises a rotor 110 and a fan support structure 120, herein below also referred to as shroud. The rotor comprises a plurality of fan blades 111 and a motor housed inside a hub (the hub and the motor are not specifically shown in the figures as they are inside the support structure base 121). The motor may be a brushless or a brushed motor.

[0006] In the known rotor structures such as the one illustrated in figures 1a, 1b and 1c, a motor support structure is typically necessary to provide the motor with a fixing point. This structure comprises a base 121 (typically with comparable shape and dimensions as the rotor hub to conveniently accommodate the hub therein) and a plurality of struts 122 that mechanically connect the base 121 to the fan shroud 120. The motor and any associated bearing configuration which is contained within the fan hub are typically fixedly housed inside the base 121.

[0007] The number and size of the struts 122 may depend on the mechanical requirements, for example 3 (as in figure 1c) or 4 (as in figures 1a and 1b) which are typical. One of the struts 122 is typically made larger than the others, to accommodate the electrical cabling 130 for supplying power to the motor. However, the presence of struts can have a significant impact on increasing acoustic emissions and degrading heat transfer performance due to air flow interactions. Figure 1c illustrates an example of such air flow interaction in a known fan 100. In figure 1c, the fan 100 is shown such that parts of the shroud 120, a strut 122a and a fan blade 111 are cross-sectioned. As it is schematically represented in figure 1c, when the motor of the fan 100 rotates in the direction ω, an air flow is generated which is represented in the figure by arrow AF1. However as the air flows in said direction AF1, it impacts on the strut 122a and is therefore deviated in the directions AF2 and AF3. This interaction implies a blockage to the air flow which may become significant in small scale fans (typically used in electronics cooling) thereby reducing heat transfer performance which may reach levels of up to 20%.

[0008] Furthermore, the reliability of rotating fans may be driven by the reliability of the fan propulsion mechanism used. Such propulsion is typically caused by the electric motor and bearing housed within the hub. A brushed motor typically has quite low reliability due to the mechanical contact required for electrical connection between the power source and armature. Brushless motors typically use electronic controls to program switching of electromagnetic poles, therefore removing the need for mechanical brushes which can wear out. However, all approaches require bearing technologies to rotate the rotor about a centre point. These bearings are susceptible to lubricant failure and ultimately bearing failure. Furthermore, even with a sufficiently lubricated system, some noise is typically generated when the fan is rotated as the parts of the fan run in physical contact. In some products which currently implement fan cooling, this noise may be a significant limitation as operational standards must be met for attended and unattended equipment.

[0009] Embodiments of the disclosure address the above limitations of the currently known solutions to improve reliability, reduce noise emission, and improve thermal performance of rotating fans.

[0010] Some embodiments feature a fan comprising a rotor and a fan support structure, the rotor comprises a plurality of permanent magnets located along a circumference of the rotor and a plurality of fan blades; and the support structure comprises a plurality of electromagnets wherein at least some of the plurality of electromagnets are configured to cause the rotor to rotate in response to being powered by an alternating electric current.

[0011] According to some specific embodiments, the rotor is surrounded by a cavity within the support structure, said cavity having a circular cross-section. .According to some specific embodiments the fan rotor further comprises a circumferential ring located around a circumference of the fan rotor.

[0012] According to some specific embodiments the fan support structure comprises a further electromagnet configured to provide a further magnetic polarity in response to an electric current wherein the further magnetic polarity is configured to attract or repel a permanent magnet of the fan rotor in a direction parallel to the axis of rotation of the rotor thereby providing contactless support for the fan rotor.

[0013] According to some specific embodiments the rotor comprises a circumferential ring disposed around the circumference of the rotor and the support structure comprises a plurality of stepped structures located circumferentially around an internal surface of the support structure configured to generate a hydrodynamic air pressure during a rotation of the rotor to push the rotor in a direction parallel to the axis of said rotation thereby providing contactless support of the rotor. According to some specific embodiments the support structure further comprises a plurality of air conduits configured to allow the passage of an air flow from an air supply source to the stepped structures.

[0014] According to some specific embodiments the fan further comprises an air supply source.

[0015] According to some specific embodiments the air supply source is a piezoelectric fan or pump.

[0016] According to some specific embodiments a fan blade radially extends from the center of rotation to the circumference of the rotor and a permanent magnet is located at an end of the blade.

[0017] According to some specific embodiments the rotor comprises an impeller and a fan blade projects out of the impeller and a permanent magnet is located on a circumference of the impeller.

[0018] Some embodiments feature an equipment configured to operate using electricity, comprising the fan as disclosed herein.

[0019] These and further features and advantages of the present invention are described in more detail, for the purpose of illustration and not limitation, in the following description as well as in the claims with the aid of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Figures 1a, is a schematic top view and figure 1b is a schematic bottom view of a known rotary fan with four struts and figure 1c is a schematic perspective and sectioned view of another known rotary fan with three struts.

Figure 2a is a schematic top view and figure 2b is a schematic bottom view of an exemplary rotary fan according to some embodiments; figure 2c is an exemplary representation of a cross-sectional view along the line A-A of the fan of figure 2a and figure 2d is a partial view of the fan 100 of figure 2a in which the polarity arrangement is illustrated in further detail.

Figure 3 is a cross-sectional view of the rotary fan of figures 2a and 2b according to some embodiments.

Figures 4a is a cross-sectional view and figure 4b is another cross-sectional view of the rotary fan of figures 2a and 2b according to some embodiments.

Figure 5a is a cross-sectional view and figure 5b is another cross-sectional view of the rotary fan of figures 2a and 2b according to some embodiments.

Figure 6a is a schematic top view, figure 6b is a schematic cross-sectional view and figure 6c is another schematic cross-sectional view of an exemplary rotary fan according to some embodiments.

DETAILED DESCRIPTION

[0021] Embodiments of the disclosure feature a novel configuration in which the use of a conventional electric motor and bearing arrangement from the fan hub are not needed, and instead use is made of electromagnets housed within the fan shroud, and fixed polarity magnets positioned on the circumference of the rotor. This arrangement can be used to induce a rotational force as will be described in further detail below.

[0022] Figures 2a and 2b are respective schematic top view and schematic bottom view of an exemplary rotary fan according to some embodiments. By way of nonlimiting example it may be assumed that figure 2a represents an inlet side for the air flow and figure 2b represents an outlets side for the air flow. Figure 2c is an exemplary representation of a cross-sectional view along the line A-A of the fan of figures 2a. In figures 2a, 2b and 2c, like elements have been given like reference numerals as those of figures 1a and 1b.

[0023] With simultaneous reference to figures 2a, 2b and 2c, the fan 100 comprises a rotor 110 and a fan support structure 120, herein below also referred to as shroud. The rotor comprises a plurality of fan blades 111 and a fan hub 140. It is to be noted that in the present embodiment the hub does not need to contain a motor. Furthermore the support structure 120 does not need to have a support structure base and associated struts as was the case in the known fan of figures 1a and 1b.

[0024] The rotor 110 comprises a plurality of fixed magnets 112. Preferably the fixed magnets have a fixed polarity and are mounted along the circumference of the rotor, such that the rotor remains balanced in weight as shown in the figures. As used herein, the term "fixed magnet" is to be understood to have the same meaning as the term "permanent magnet" which is a term widely known in the art. A non-exhaustive definition for a permanent magnet is a magnet that retains it magnetism without the presence of a magnetizing force.

[0025] Preferably the fixed magnets 112 are positioned with opposite polarity placed adjacently around the circumference of the rotor. This is schematically shown in figures 2a and 2b using different hatchings for each polarity. Therefore, in the example of figures 2a and 2b, there are four fixed magnets 112 shown each having a north pole and a south pole. Those skilled in the related however will realize that number of fixed magnets (on the rotor) and electromagnets (on the shroud) may be more or less than four and may be determined to suit the specific application, while weight balance in the rotor is maintained.

[0026] The fan shroud 120 comprises a plurality of electromagnets 123 (e.g. coils) located within the body of the fan shroud 120. Electric power may be supplied using cables, generally shown by reference numeral 130, to each of the electromagnets 123 to produce the required arrangement in polarity around the fan shroud 120. The polarity of the electromagnets 123 may be electronically controlled so that changes to the polarity of the electromagnet, and the corresponding magnetic effect (attracting or repelling) on the fixed magnets 112 results in a rotation of the fan rotor 110. Such control of the polarity of the electromagnets may be performed by applying an alternating current to the electromagnets. The frequency of such alternating current may be set according to the specific design requirements.

[0027] Figure 2d shows a partial top view of the fan 100 of figure 2a in which the polarity arrangement is illustrated in further detail. In this figure, unless otherwise indicated, like elements have been given like reference numerals as those of figure 2a.

[0028] Referring to figure 2d, the rotor 110 of fan 100 comprises fixed magnets 112-1 and 112-2, each having a south pole 112-1S and 112-2S and a north pole 112-1N and 112-2N. As can be seen in the figure the north pole 112-1N of magnet 112-1 is adjacent the south pole 112-2S of the magnet 112-2.

[0029] The shroud 120 comprises electromagnets 123-1N and 123-2S. It is assumed that 123-1N represents north polarity and 123-2S represents south polarity. The polarity of the aforementioned electromagnets may be controlled by applying electric current using cables 130-1 and 130-2 respectively. For example the desired polarity of the electromagnets 123-1N and 123-2S may be obtained by using respective coils for each electromagnet such that electric current in one electromagnet is driven in a direction which is opposite to the electric current driven in the other electromagnet.

[0030] In the scenario shown in figure 2d, it may be seen that the polarity of the electromagnet 123-1N is such that it will attract the south pole 112-1S of the fixed magnet 112-1, as they are of opposite polarity, while it repels the north pole 112-1N of the fixed magnet 112-1, as they are of the same polarity. As the fixed magnet 112-1 is mounted on the circumference of the rotor 110, the interaction between the electromagnet and the fixed magnet as described above, causes the rotor 110 to rotate in the direction of arrow ω.

[0031] In the next instant, as the rotor turns in the direction ω, the north pole 112-1N of the fixed magnet 112-1 approaches the next electromagnet 123-2S having an opposite polarity and therefore the fixed magnet is further attracted to the electromagnet 123-2S. Furthermore, as the rotor rotates in the direction ω, the electromagnet 123-2S repels the south pole 112-2S of the fixed magnet 112-2, as they are of the same polarity. The above scenario is repeated with respect to any subsequent electromagnet-fixed magnet combinations as the rotor rotates thereby maintaining the continuity of the rotation.

[0032] This solution therefore removes the need for a conventional electric motor to be housed within the fan hub with associated motor support structures. This solution also enables greater freedom to reduce the size of the hub region, as it no longer requires the volume to house a motor.

[0033] The position of the fixed magnets 112 may be determined along the circumference of the rotor 110 (e. g. at the tips of the blades) which in turn provides a circumferential structure that may improve fan performance by reducing possible adverse effects of blade discontinuity.

[0034] In order to reduce possible turbulent eddies which may be generated at the tip of the blades 111 due to blade discontinuity, use may be made of a ring (e.g. a plastic ring) around the fan rotor 110.

[0035] The provision of a contactless arrangement and persevering the axial position of the rotor during operation is described in the following.

[0036] According to one embodiment, use is made of electromagnetism to levitate the rotor and create a contactless arrangement between the rotor and housing during operation. Figure 3 illustrates an exemplary representation of a cross-sectional view along the section A-A of the fan of figure 2a in which such use is made. In this figure, unless otherwise provided, like elements have been given like reference numerals as those of figure 2a.

[0037] Referring to figure 3, the fan 100 comprises a rotor 110 and a fan support structure, or shroud 120. The rotor is shown to comprise a fan blade 111 and a fan hub 140. As mentioned above in relation figure 2a, the support structure 120 does not need to have a support structure base and associated struts. The rotor 110 has a fixed magnet 112.

[0038] According to this embodiment, the fan shroud 120 comprises at least two electromagnet elements 123a and 123b configured to provide two sets of opposing magnetic poles. One set of poles of the electromagnets, 123a and 123b, may be configured to induce propulsion and the other set of electromagnetic poles, may be configured to provide contactless (nonmechanical) support of the rotor in the axial direction. It is to be noted that both electromagnets for this embodiment may provide rotation and contactless support. In the example of figure 3, the north poles may provide rotation, while the south poles may provide axial support.

[0039] The fixed magnet 112 of the rotor projects a certain distance out of the tip of the blade 111 and into a cavity 124 within the body of the shroud 120. The cavity 124 may be suitably designed, e.g. a circumferential recess inside the shroud 120 with a circular cross-section, to surround the rotor and accommodate the rotation of the fixed magnets 112 as the rotor 111 rotates. With this arrangement, when the fan is powered off, the rotor 110 sits, e.g. due to gravity, within the fan shroud 120 by resting the fixed magnets 112 within the cavity 124 thereby being physically supported but non-moving. This arrangement also may avoid significant wear as the rotor is simply resting under its own mass due to gravity. As the power is turned on, electromagnets, in this example 123a and 123b, are activated with an electric current to produce a polarity which would favor the attraction of the fixed magnet 112, and thus the levitation of the entire body of the rotor. In the example shown in figure 3, the north pole N of the electromagnets 123a and 123b may attract the south pole S of the fixed magnet 112 to induce rotation as already described in relation to figures 2a, 2b and 2c. In parallel, the south pole S of the electromagnets 123a and 123b may act to avoid contact between the electromagnets 123a and 123b and the fixed magnet 112 during rotation. It is to be noted that this action is performed relative to other electromagnets located in the various positions within the shroud 120, for example four positions as shown in figure 2a, thereby generating a combined and substantially balanced electromagnetic action to levitate the fan 110. Another embodiment for the provision of a contactless arrangement and persevering the axial position of the rotor during operation is described in relation to figures 4a and 4b. According to this embodiment, use is made of a hydrodynamic bearing configuration to create the desired contactless environment under operation. Figure 4a illustrates an exemplary representation of a cross-sectional view along the section A-A of the fan of figure 2a in which such use is made. Figure 4b is a cross-sectional view along the section B-B of the fan of figure 4a. In these figures, unless otherwise provided, like elements have given like reference numerals as those of figure 2a.

[0040] Referring simultaneously to figures 4a and 4b, the fan 100 comprises a rotor 110 and a fan support structure, or shroud 120. The rotor is shown to comprise a fan blade 111 and a fan hub 140. As mentioned above in relation figure 2a, the support structure 120 does not need to have a support structure base and associated struts. The rotor 110 has a fixed magnet 112.

[0041] The fixed magnet 112 of the rotor projects a certain distance out of the tip of the blade 111 and into a cavity 124 within the body of the shroud 120. The cavity 124 may be suitably designed, e.g. a circumferential recess inside the shroud 120 with a circular cross-section, to surround the rotor and accommodate the rotation of the fixed magnets 112 as the rotor 111 rotates.

[0042] In addition, the rotor 110 preferably comprises a circumferential ring 113 disposed around the circumference of the rotor 110. In some embodiments the circumferential ring 113 is hollow and surrounds the tips of the blades 111 of the rotor such that the fixed magnets 112 are located within the hollow body of the circumferential ring 113 as shown in figures 4a and 4b. In some embodiments ring 113 may be completely solid or partly hollow and partly solid. In case the ring 113 is solid, it may surround the outer surfaces of the fixed magnets 112 instead of surrounding the tips of the blades 111. In case the ring is partly solid and partly hollow, the fixed magnets 112 may be housed within selected hollow parts of the ring 113.

[0043] With this arrangement, when the fan is powered off, the rotor 110 sits, e.g. due to gravity, within the fan shroud 120 by resting the ring 113 and/or the fixed magnets 112 within the cavity 124 thereby being physically supported but non-moving. Similar to the previous embodiment of figure 3, this embodiment may also help avoiding significant wear as the rotor is simply resting under its own mass due to gravity.

[0044] This embodiment also uses similar electromagnetic propulsion approach as described in relation to figures 2a to 2d. In particular electromagnets 123 are activated by suitable electric current and an interaction between the polarities of the electromagnets 123 and the fixed magnets 112 provides a rotational movement.

[0045] However, in order to provide a contactless rotation, use is made of an opposing hydrodynamic bearing configuration to maintain the axial location of the rotor and remove frictional wear under operation. The bearing configuration may operate on the principal of the Rayleigh step bearing which is known to those skilled in the related art. In the present embodiment, as the rotor 110 is caused to rotate, the circumferential ring 113 acts as a moving wall relative to the internal surfaces 125 of the fixed shroud 120 (more clearly observable in figure 4b). The shroud internal surfaces 125 adjacent to the outer surfaces of moving ring 113 have stepped structures 126 around the internal circumference of the cavity 124. During rotation, a film of air flows within the cavity between the internal surfaces 125 and the outer surfaces of moving ring 113 as represented by arrows F.

[0046] It is to be noted that in a practical implementation, there may be a short period of time at the start of rotation where the moving ring 113 is in contact with the internal surfaces 126 until the desired speed is reached for lift to be generated. Although wear can occur in this short instance, the remainder of operation is contactless. This frictional wear however may be minor in the many applications where continuous rotation is necessary, without frequent stops and starts.

[0047] The direction of arrow F is the same as the direction of rotation of the rotor as shown by arrow ω. As the rotor rotates, the stepped structures 126 provide a sudden change in the thickness of the film of air. This generates a hydrodynamic pressure that pushes the body of the rotor (through the body of the circumferential ring) in a direction which is substantially perpendicular to the direction F of flow of the film of air.

[0048] The presence of opposing stepped structures 126 on the inner walls 125 serves to maintain the body of the rotor in contactless situation as it rotates. Such presence also generates a hydrodynamic pressure which addresses the force created by the rotor weight and the reaction forces that occur due to fan thrust, i.e. when the fan generates enough air pressure during rotation to lift its own mass.

[0049] Preferably the stepped structures are present on both upper and lower inner walls 125 of the support structure, as shown in figures 4a and 4b.

[0050] A still further embodiment for the provision of a contactless configuration and persevering the axial position of the rotor during operation is described in relation to figures 5a and 5b. Like elements in figures 5a and 5b are given like reference numerals as those of figures 4a and 4b. The present embodiment is similar to the embodiment of figures 4a and 4b as it utilizes a similar opposing hydrodynamic bearing configuration for the provision of a contactless configuration. Therefore a detailed description of the operation of the fan related to the aspects of this embodiment which are similar to those of the embodiment of figures 4a and 5b is considered not necessary.

[0051] However, the present embodiment provides the additional feature of supplying air pressure to generate or enhance the movement of the air film within the inner walls of the cavity of the shroud. The auxiliary air pressure may be supplied using an auxiliary air supply system.

[0052] Referring now to figures 5a and 5b, it may be observed that the shroud 120 comprises a plurality of air conduits 127. The air conduits are configured to allow the passage of an air flow from an auxiliary air supply source (not shown). The air flow within each of the conduits 127 is represented by an arrow A (figure 5b). As may be observed in figure 5, in operation, the air flow A may reach the cavity 124 and flow between the inner surfaces 125 (upper and lower surfaces in figures 5a and 5b) and the outer surfaces of the circumferential ring 113, thereby generating, or enhancing the air flow F. This auxiliary air supply system therefore provides the bearing configuration with increased air pressure during start-up of the fan when the rotational speed is low and the hydrodynamic pressure induced by the step alone is relatively low. Therefore this embodiment may be used to alleviate the short contact period during the initial start-up of the fan as already described in relation to figure 4a and 4b. This is beneficial to applications where fan rotation is frequently started and stopped over the lifetime.

[0053] In some embodiments, air may be supplied from one side first, e.g. from the lower side of the shroud 120 to help move the rotor in the direction of the flow of the air into the air conduits thereby reducing the friction between the rotor and support structure at rest, for example due to gravity. The supply of air from the other side may then start once the rotor is initially moved.

[0054] The number of conduits 127 to be provided in the shroud 120 may be determined to suit the application needs. The auxiliary supply of air can be provided by a reliable low power air supply source such as a high pressure - low flow rate piezoelectric pump or fan (also known as piezofan) which typically do not suffer from the same reliability issues as conventional motor-driven rotating fans. This type of auxiliary fan can also be integrated within the overall fan housing (i.e. the shroud 120) due to its small size which would result in limited impact on overall fan dimensions. The auxiliary air supply may be integrated in the fan or it may be a separate device which may be connected to the fan as required.

[0055] The above described contactless approach, in the various embodiments, may ultimately reduce noise emission during operation.

[0056] Those skilled in the related will realize that a combination of all of the above embodiments is also possible.

[0057] The previous embodiments all related to an axial type fan arrangement in which the flow of air generated by the fan is substantially in the direction of the axis of rotation of the rotor which is perpendicular to the plane of rotation of the rotor. However, the present solution may likewise be applied to centrifugal type fans in which the flow of air generated by the fan is in the direction of the plane of rotation of the rotor. In this arrangement the hydrodynamic bearing system is located beneath the fan rotor and the propulsion system remains at the circumference of the rotor as shown in the previous embodiments.

[0058] Referring now figures 6a, 6b and 6c, an exemplary embodiment of such centrifugal fan utilizing the principles of the disclosure is described. Figure 6a illustrates an exemplary top view of a centrifugal rotary fan according to some embodiments. Figure 6b is a representation of a cross-sectional view along the section A-A of the fan of figure 6a and figure 6c is a cross-sectional view along the section B-B of the fan of figure 6b. In these figures, unless otherwise provided, like elements have been given like reference numerals as those of figures 4a and 4b.

[0059] Referring simultaneously to figures 6a, 6b and 6b, the fan 100 comprises a rotor 110 and a fan support structure, or shroud 120. The rotor comprises a plurality of fan blades 111. However, differently from the previous embodiments described in which the blades were radially extended from the center of rotation of the rotor, the fan blades in this embodiment project out of a base plate, herein referred to as an impeller, 115 and a fan hub 140 is located in the central portion of the impeller 115. Here also, the support structure 120 does not need to have a support structure base and associated struts. The rotor 110 has fixed magnets 112 located along the circumference of the rotor. The shroud 120 comprises a plurality of electromagnets 123 which are activated using cables

130 to generate electromagnetic polarities. The principle of operation involving the interaction between the fixed magnets 112 and the electromagnets 123 in this embodiment is similar to that described in relation to figures 2a-2d and therefore a detailed description thereof is considered not necessary.

[0060] The shroud 120 comprises an opening 128 to allow air outlet during the operation of the fan. The direction of rotation of the rotor is represented by arrow ω. As may be observed in figure 6a, the direction of flow of the air out of the fan is substantially parallel to the plane of rotation of the rotor 110. The shroud comprises a central cavity 129 (more clearly shown in figure 6b) having a circular cross-section and surrounding circumferentially the structure of the rotor.

[0061] With this arrangement, when the fan is powered off, the rotor 110 sits, e.g. due to gravity, within the fan shroud 120 by resting the impeller 115 within the cavity 129 thereby being physically supported but non-moving. Similar to the previous embodiments, this embodiment may also help avoiding significant wear as the rotor is simply resting under its own mass due to gravity.

[0062] However, in order to provide a contactless rotation, use is made of an opposing hydrodynamic bearing configuration to maintain the axial location of the rotor and remove frictional wear under operation. The bearing configuration may operate on the principal of the Rayleigh step bearing similar to that described in relation to figures 4a and 4b. In the present embodiment, as the rotor 110 is caused to rotate the impeller 115 acts as a moving wall relative to the internal surfaces 125 of the cavity 129 (more clearly observable in figure 6c). The shroud internal surface 125 adjacent to the outer surfaces of impeller 114 has stepped structures 126 located on the internal surface of the cavity and preferably distributed over the circumference of the cavity 129. During rotation, a film of air flows within the cavity between the internal surface 125 of the cavity and the opposing surface 116 of the moving impeller 115 as represented by arrows F. The direction of arrow F is the same as the direction of rotation of the rotor as shown by arrow ω. As the rotor rotates, the stepped structures 126 provide sudden change in the thickness of the film of air. This generates a hydrodynamic pressure that pushes the body of the rotor (through the body of the impeller 115) in a direction which is substantially perpendicular to the direction F of flow of the film of air. Here again the presence of opposing stepped structures 126 serves to maintain the body of the rotor in contactless situation as it rotates and also generates a hydrodynamic pressure which addresses the reaction forces that occur due to fan thrust. As already discussed in relation to figure 5a and 5b, an auxiliary air supply system can be used to compliment the stepped structures and improve performance. Consequently, the solution proposed herein, in the various embodiments described, removes the need for a conventional motor and lubricated bearing arrangement, thereby improving reliability of the fan unit over current state of the art. In addition, the solution removes the need for intrusive motor support structures. This results in improved air flow and consequently better heat transfer, while also reducing acoustic emissions.

[0063] However, it is emphasized that although the present solution removes the need for a conventional motor and bearing arrangement with the associated struts, it does not exclude the use of a bearing arrangement and struts, even though such use is not preferred. In other words, the solution proposed herein may also be applied to provide a structure having a combination of any of the embodiments as described above with a support structure having a plurality of struts.

[0064] The improved reliability of the fan as proposed herein may in turn enable integration of such fans within equipment that have high reliability requirements but are at the limit of passive cooling, for example telecommunications equipment. This will facilitate the transition from passive to active cooling, therefore assisting in volume reduction and functionality increases for future products. However a rotary fan according to the various embodiments disclosed herein is not limited to telecommunications applications and it may be designed for use in many other applications in which equipment configured to use electricity for operation are involved wherein cooling of electric and/or electronic components may be needed.

[0065] The various embodiments of the present invention may be combined as long as such combination is compatible and/or complimentary.

[0066] It is to be noted that the list of structures corresponding to the claimed means is not exhaustive and that one skilled in the art understands that equivalent structures can be substituted for the recited structure without departing from the scope of the invention.

[0067] It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention.

Claims

1. A fan comprising a rotor and a fan support structure, the rotor comprises a plurality of permanent magnets located along a circumference of the rotor and a plurality of fan blades; and the support structure comprises a plurality of electromagnets wherein at least some of the plurality of electromagnets are configured to cause the rotor to rotate in response to being powered by an alternating electric current.

2. The fan of claim 1 wherein the rotor is surrounded by a cavity within the support structure, said cavity having a circular cross-section.

3. The fan of any one of claims 1 or 2 wherein the fan rotor further comprises a circumferential ring located around a circumference of the fan rotor.

4. The fan of any one of the preceding claims wherein the fan support structure comprises a further electromagnet configured to provide a further magnetic polarity in response to an electric current wherein the further magnetic polarity is configured to attract or repel a permanent magnet of the fan rotor in a direction parallel to the axis of rotation of the rotor thereby providing contactless support for the fan rotor.

5. The fan of any one of the preceding claims wherein the rotor comprises a circumferential ring disposed around the circumference of the rotor and the support structure comprises a plurality of stepped structures located circumferentially around an internal surface of the support structure configured to generate a hydrodynamic air pressure during a rotation of the rotor to push the rotor in a direction parallel to the axis of said rotation thereby providing contactless support of the rotor.

6. The fan of claim 5 wherein the support structure further comprises a plurality of air conduits configured to allow the passage of an air flow from an air supply source to the stepped structures.

7. The fan of claim 6 further comprising an air supply source.

8. The fan of claim 7 wherein the air supply source is a piezoelectric fan or pump.

9. The fan of any one of the preceding claims wherein a fan blade radially extends from the center of rotation to the circumference of the rotor and a permanent magnet is located at an end of the blade.

10. The fan of any one of the preceding claims 1 to 7 wherein the rotor comprises an impeller and a fan blade projects out of the impeller and a permanent magnet is located on a circumference of the impeller.

11. An equipment configured to operate using electricity, comprising the fan of any one of claims 1 to 10.

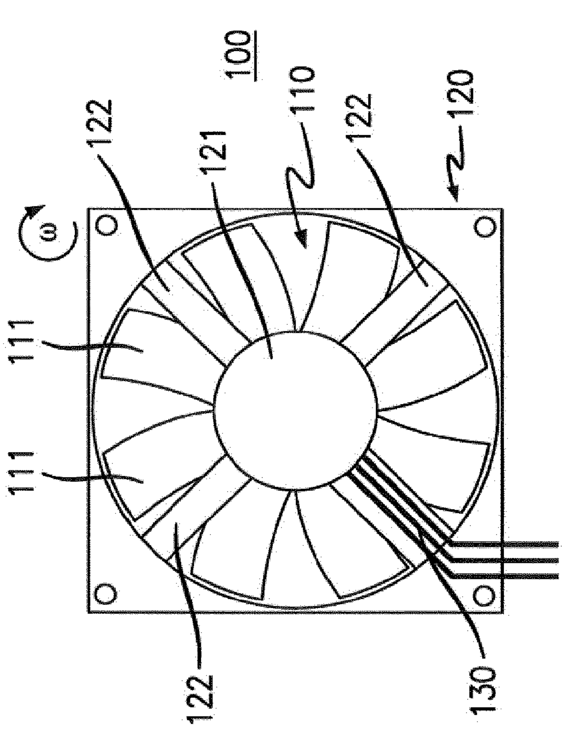


FIG. 1B

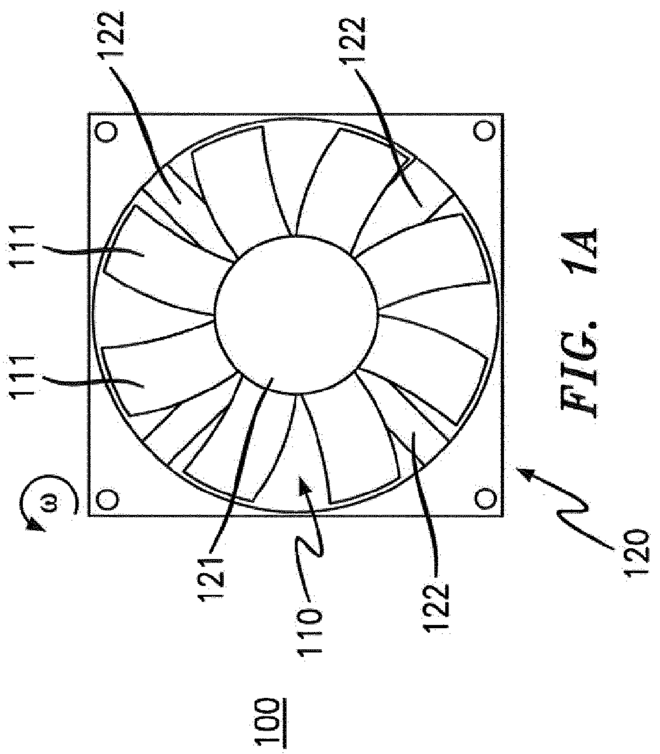


FIG. 1A

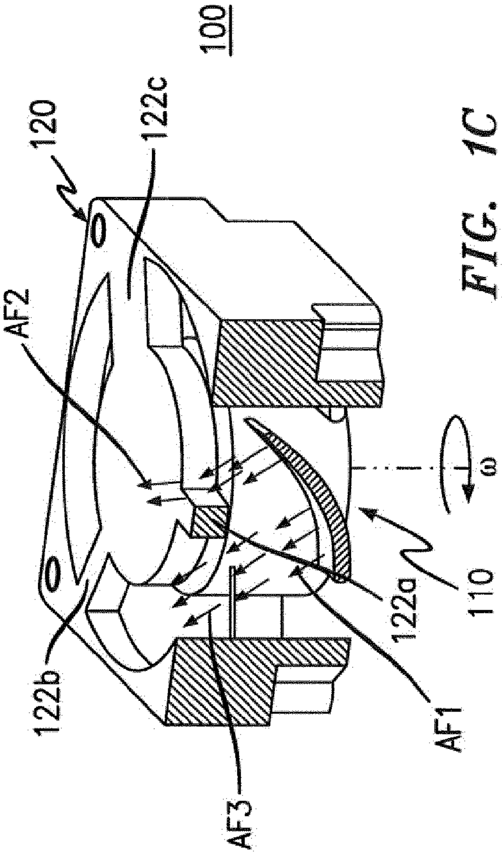
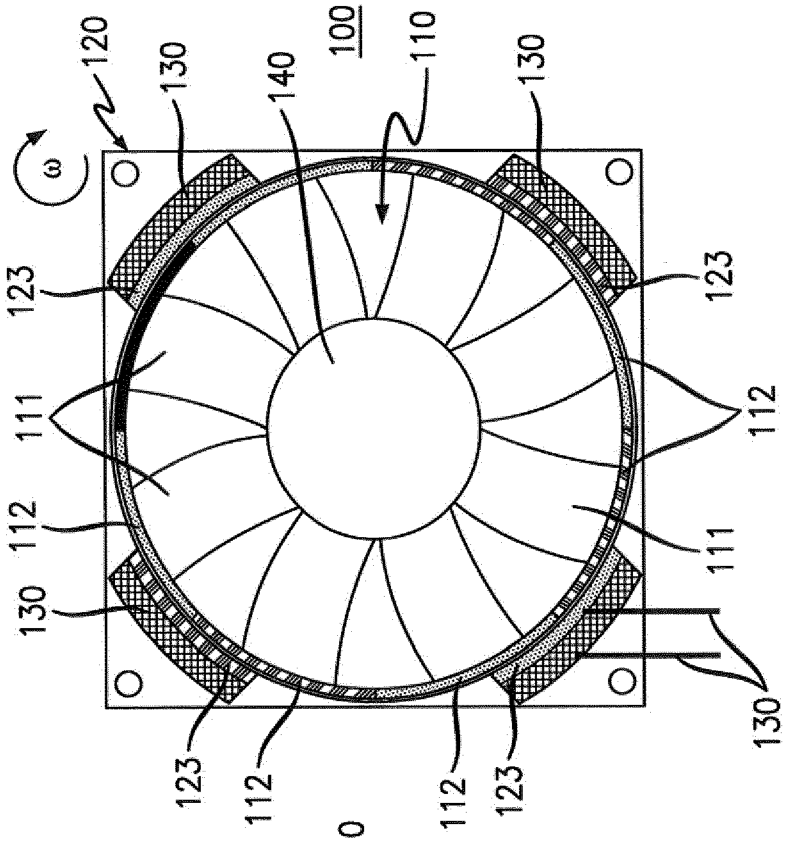
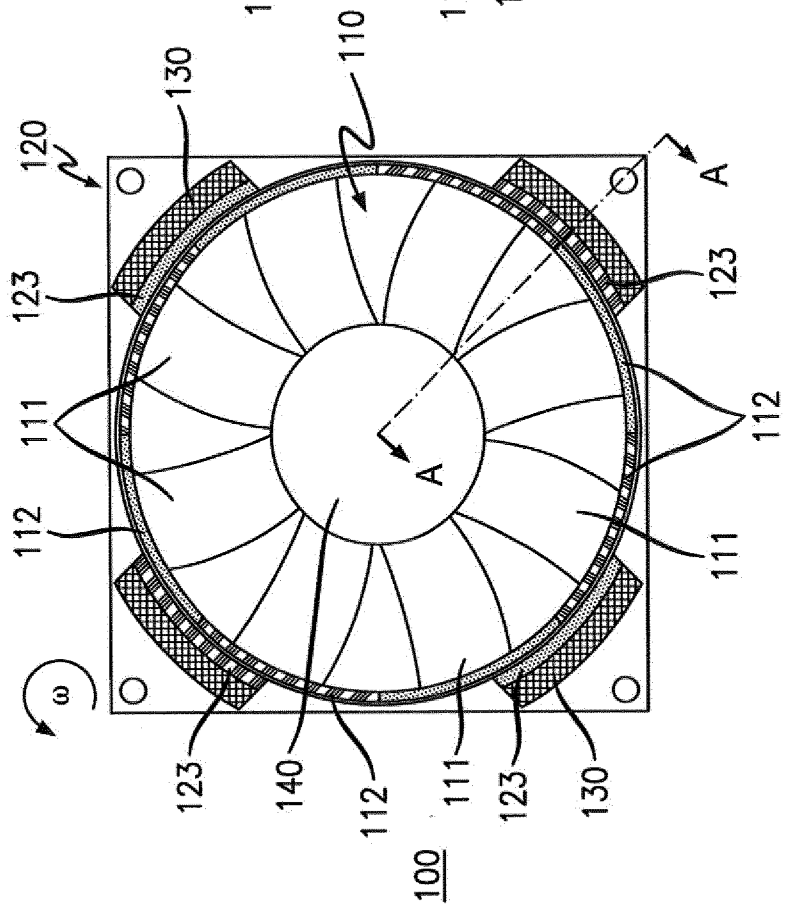


FIG. 1C



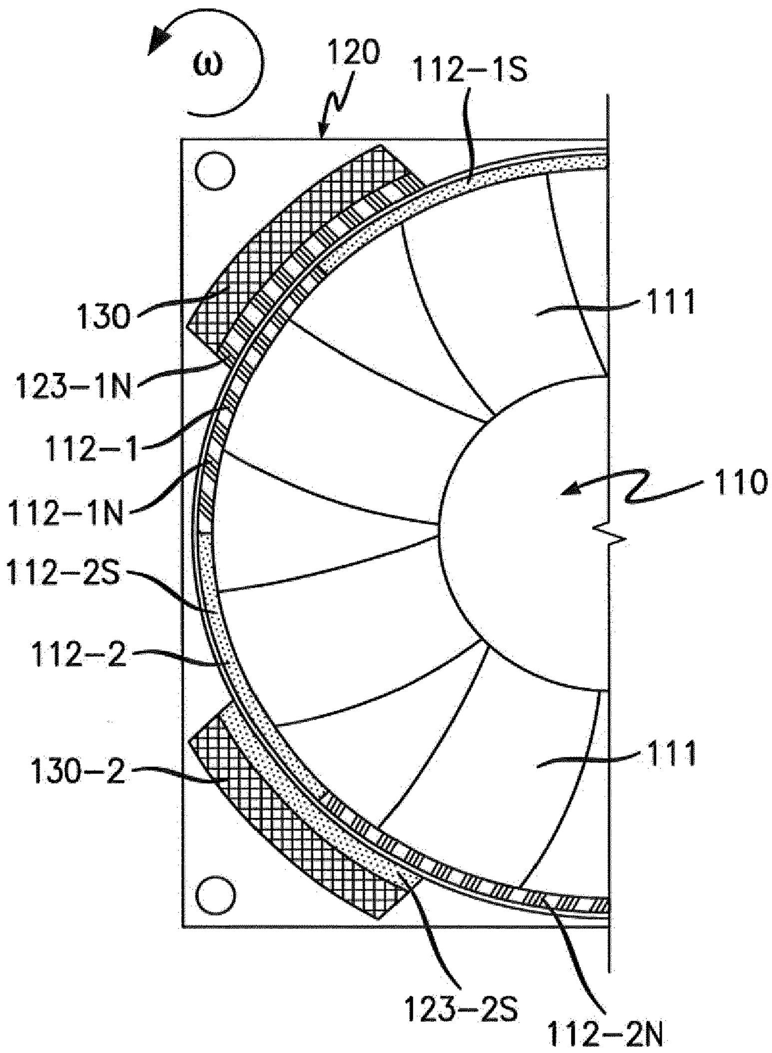
100
110
111
112
120
123
130
140
ω

FIG. 2B



100
110
111
112
120
123
130
140
A
ω

FIG. 2A


ω
120
112−1S
130
111
123−1N
112−1
110
112−1N
112−2S
112−2
130−2
111
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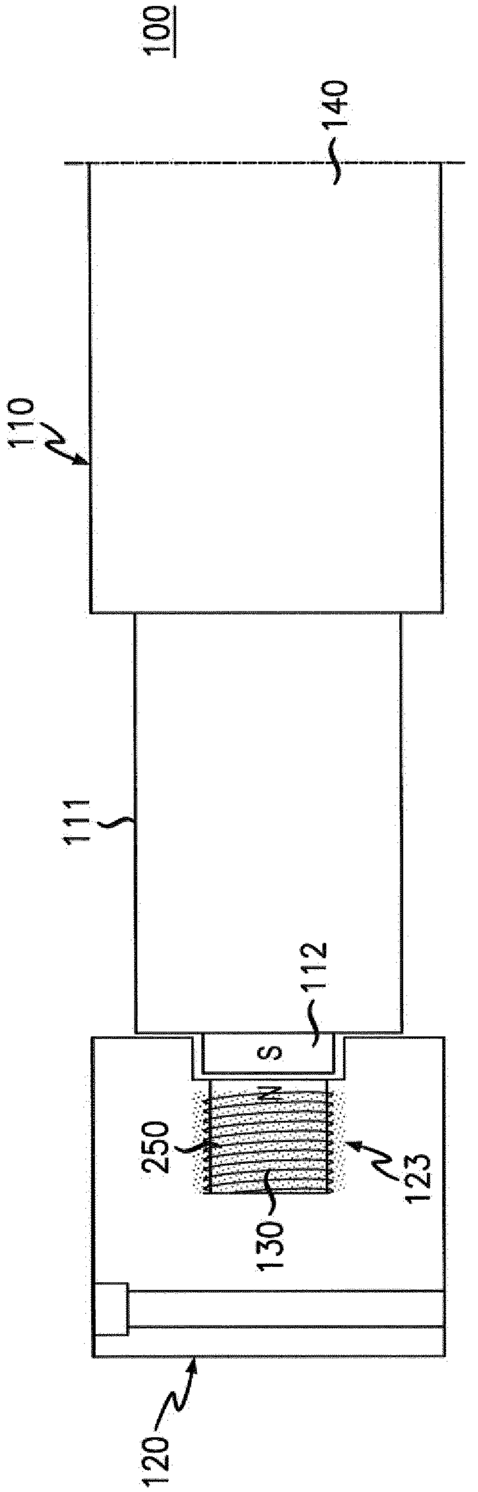
112−2N

FIG. 2D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S
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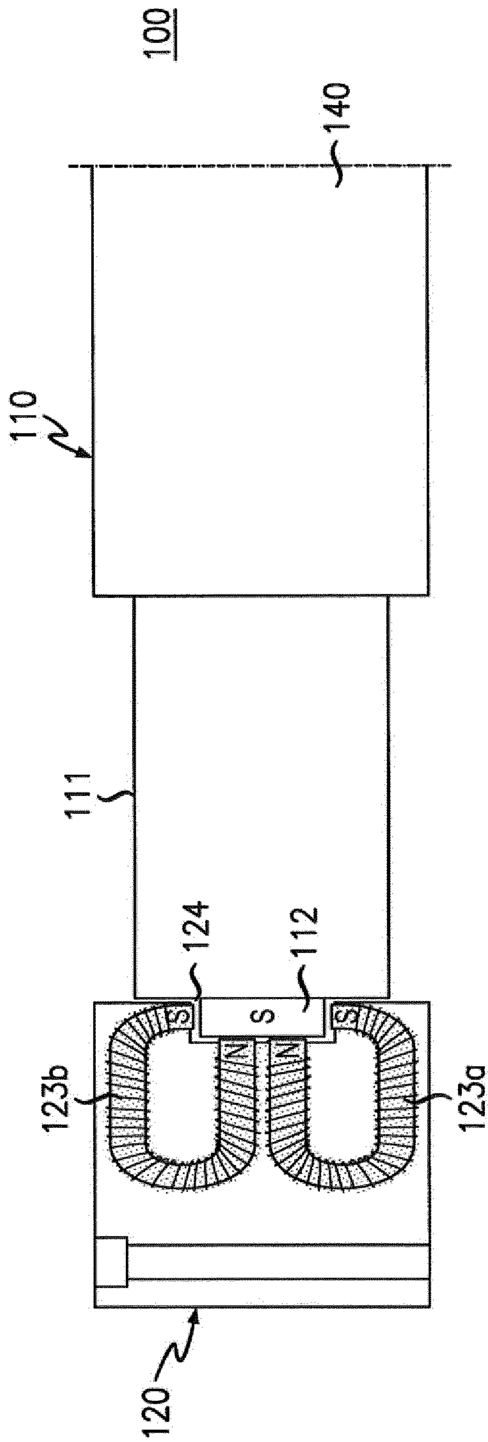
130
120

FIG. 2C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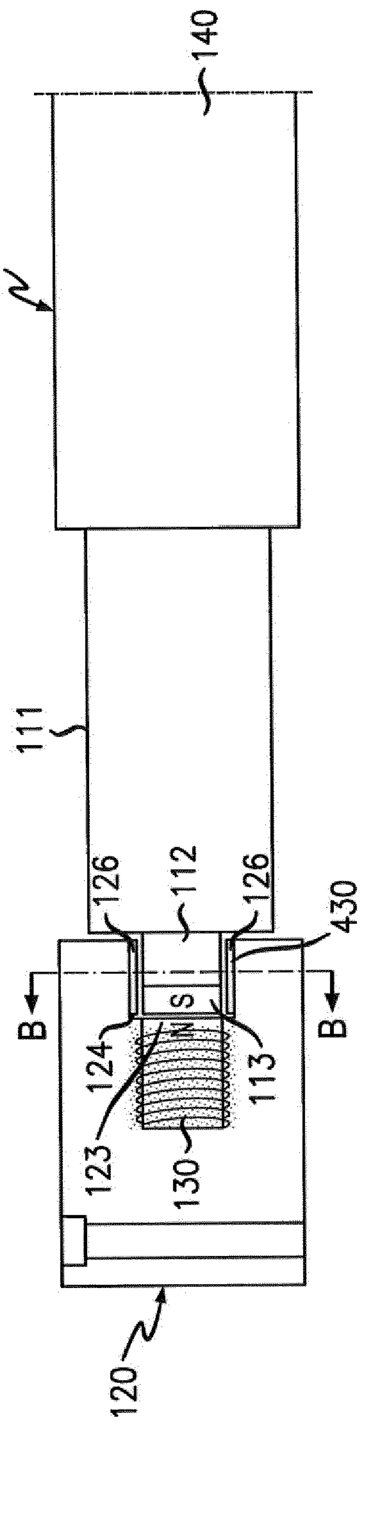
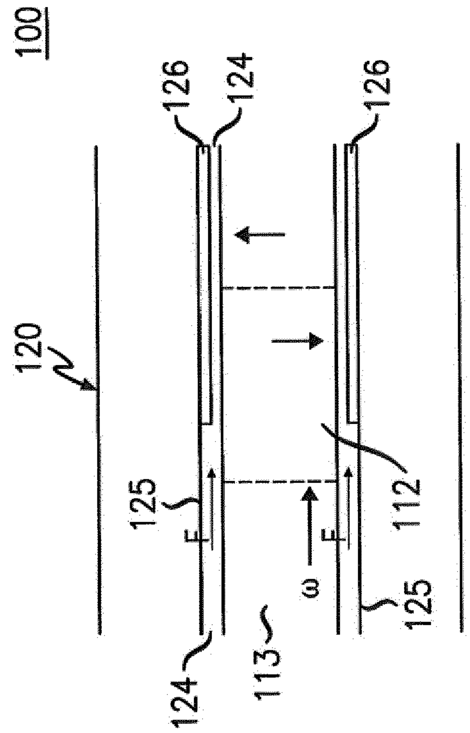
110
111
124
112
S
N
123b
123a
120

FIG. 3



100
110
140
111
126
112
126
430
B
B
124
S
N
113
123
130
120

FIG. 4A



100
126
124
126
120
125
F
112
ω
F
125
124
113

FIG. 4B

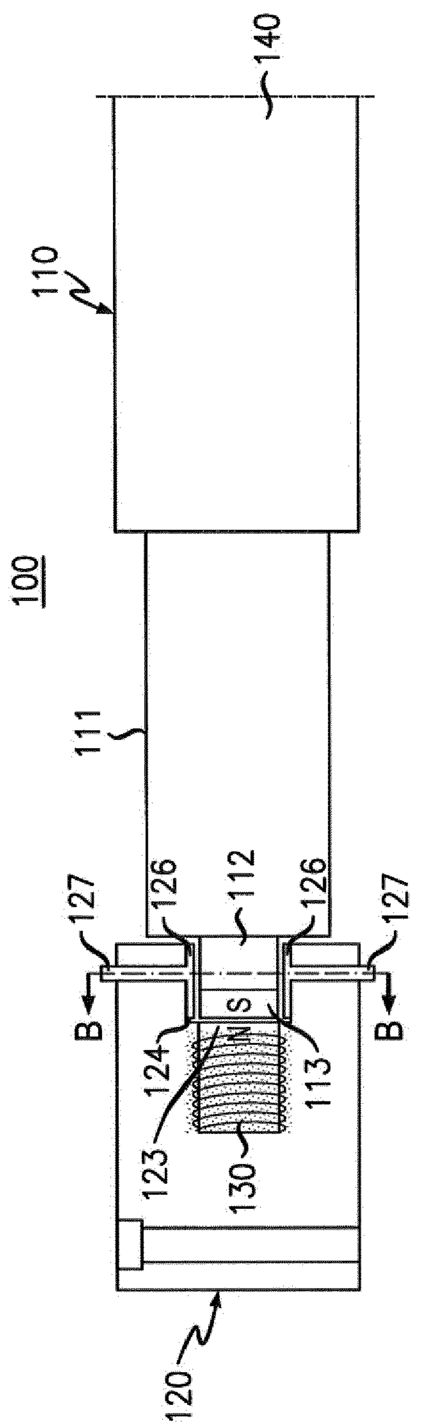

100
110
140
111
127
126
112
126
127
B
B
124
123
130
113
N
S
120

FIG. 5A

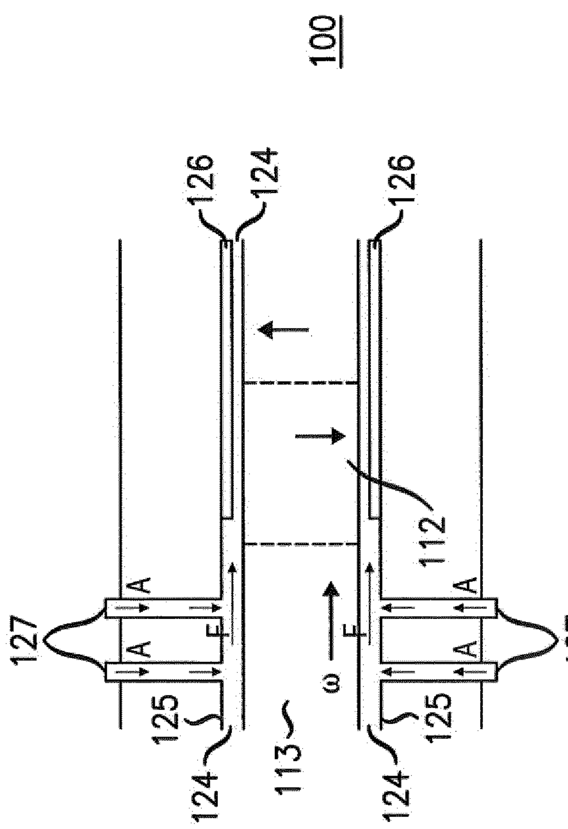

100
126
124
126
127
A
A
F
F
A
A
127
125
125
124
113
124
ω
112

FIG. 5B

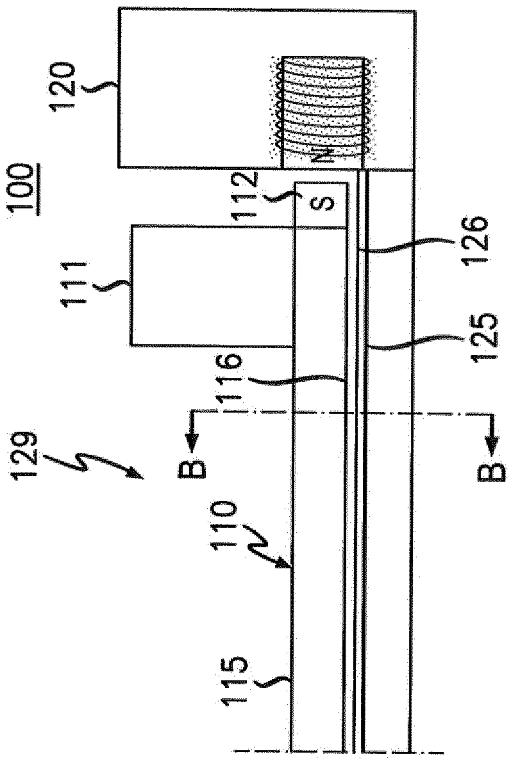


FIG. 6B

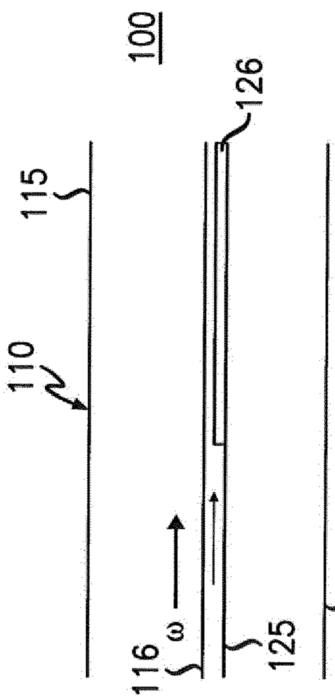


FIG. 6C

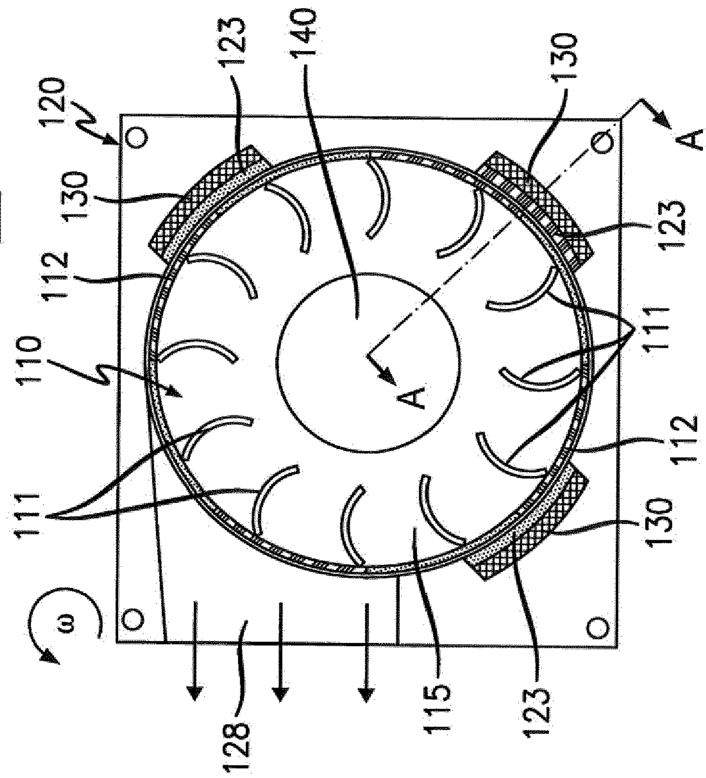


FIG. 6A

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EUROPEAN SEARCH REPORT

Application Number
EP 13 30 6348

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2004/086394 A1 (KOHONEN REIJO [FI] ET AL) 6 May 2004 (2004-05-06) * the whole document *	1-4,11	INV. F04D25/06
X	"SEMIPERMANENT LIFE AND LOW-ACOUSTIC NOISE AIR-MOVING DEVICE WITH SEPARATION OF ROTOR AND STATOR", IBM TECHNICAL DISCLOSURE BULLETIN, INTERNATIONAL BUSINESS MACHINES CORP. (THORNWOOD), US, vol. 40, no. 2, 1 February 1997 (1997-02-01), page 95/96, XP000692184, ISSN: 0018-8689 * the whole document *	1-4,11	
X	NL 9 401 288 A (ABB LUMMUS HEAT TRANSFER [NL]) 1 March 1996 (1996-03-01) * the whole document * * figures 1,2 *	1-4,11	
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	3 March 2014	Ingelbrecht, Peter

CATEGORY OF CITED DOCUMENTS

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03-03-2014

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82