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(54) SHORT-SHAFT ELECTRIC COMPRESSOR

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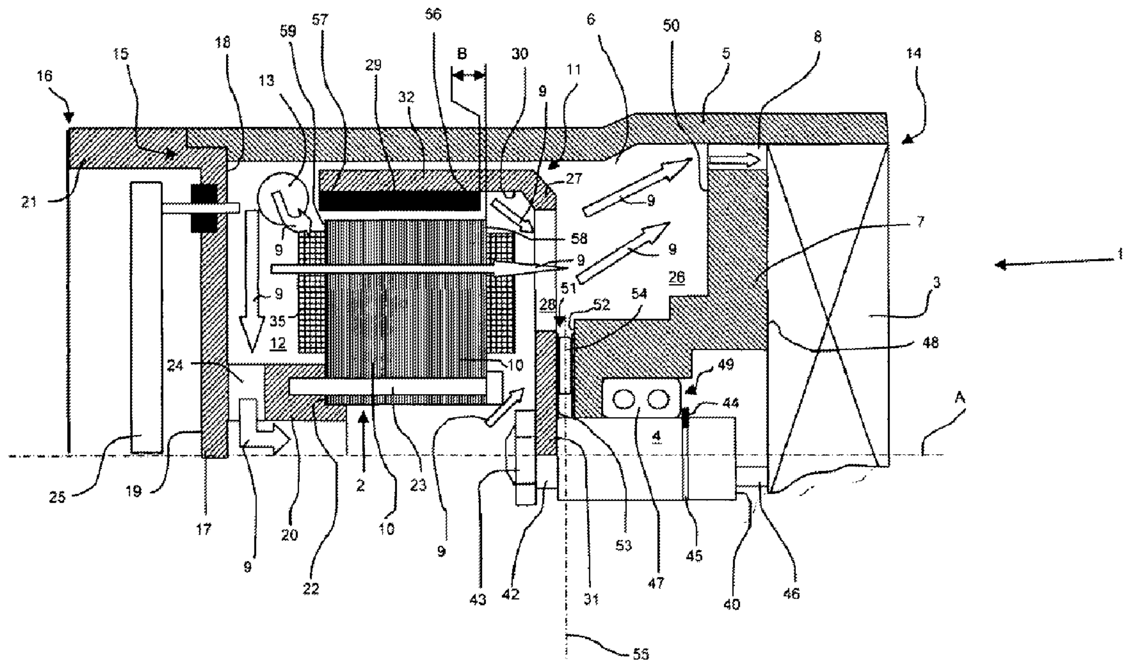
(57) **ABSTRACT**

The invention relates to an electric compressor (**1**) comprising a compression mechanism (**3**) rotated by a drive device that extends through a main casing (**5**) defining an internal volume (**6**) in which an electric motor (**2**) is installed. The electric motor comprises a stator (**10**) and a rotor (**11**) which extends at least partially on the outer periphery of the stator (**10**), said drive device comprising the rotor (**11**) solidly connected to a shaft (**4**) which extends through a plate (**7**) solidly connected to the main casing (**2**). The invention is characterised in that it includes a first rotation means (**47**) between the shaft (**4**) and the plate (**7**) and a second rotation means (**51**) between the drive device and the plate (**7**). The invention is suitable for motor vehicles.



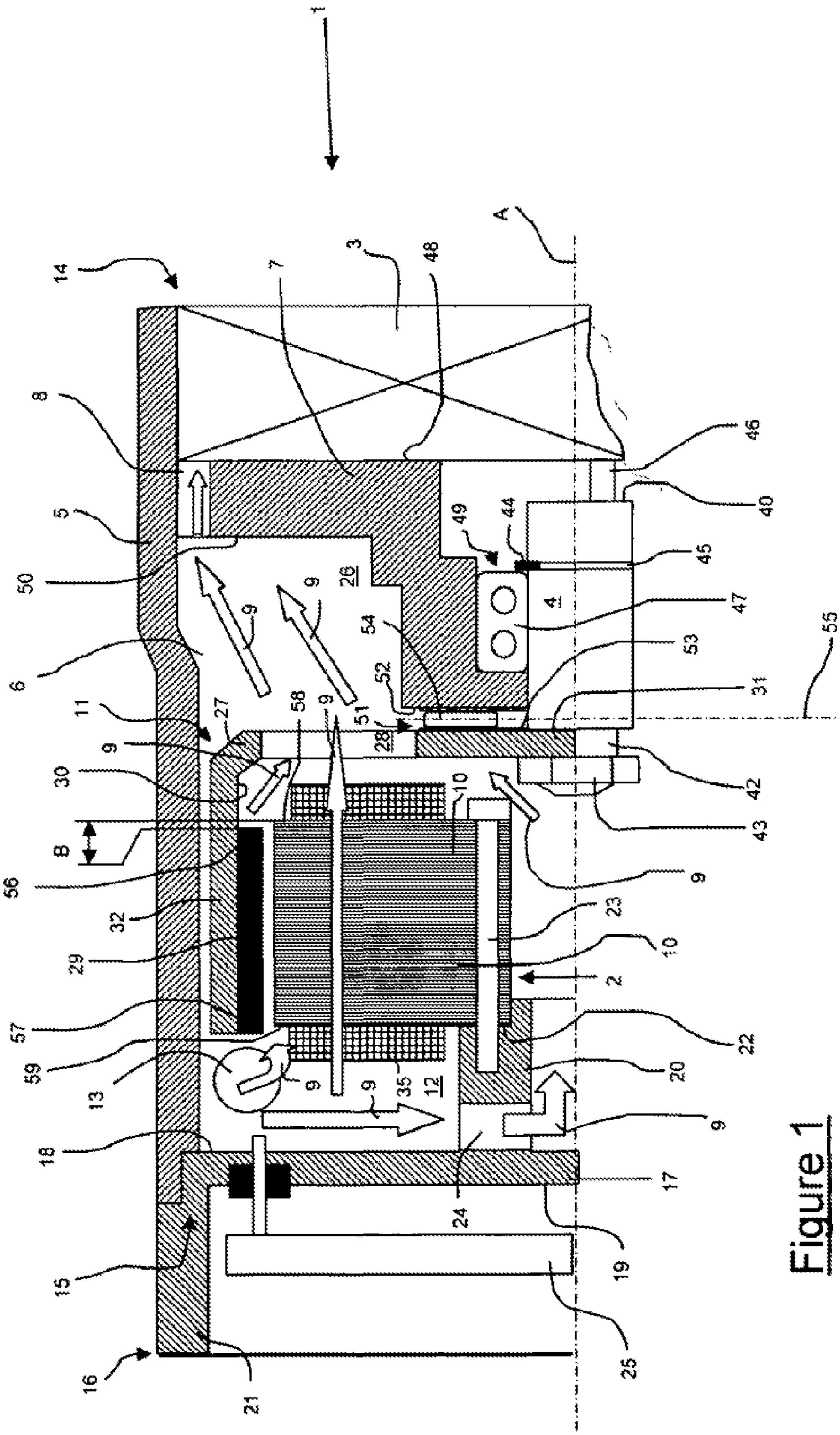

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Figure 1

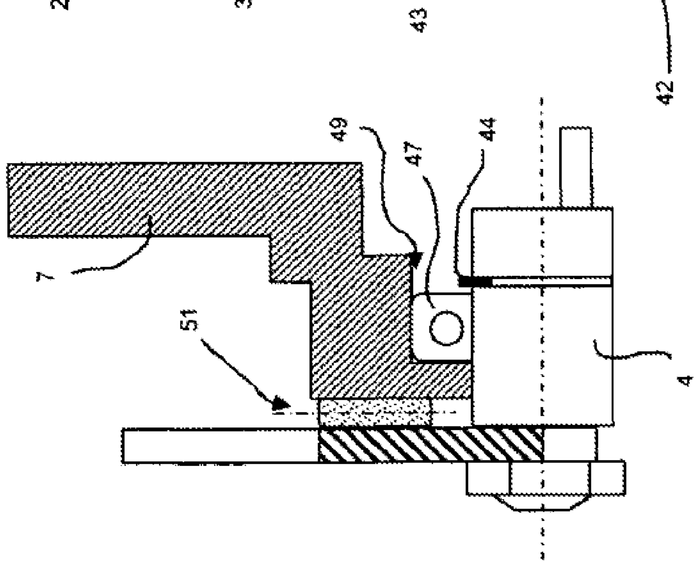

Figure 2

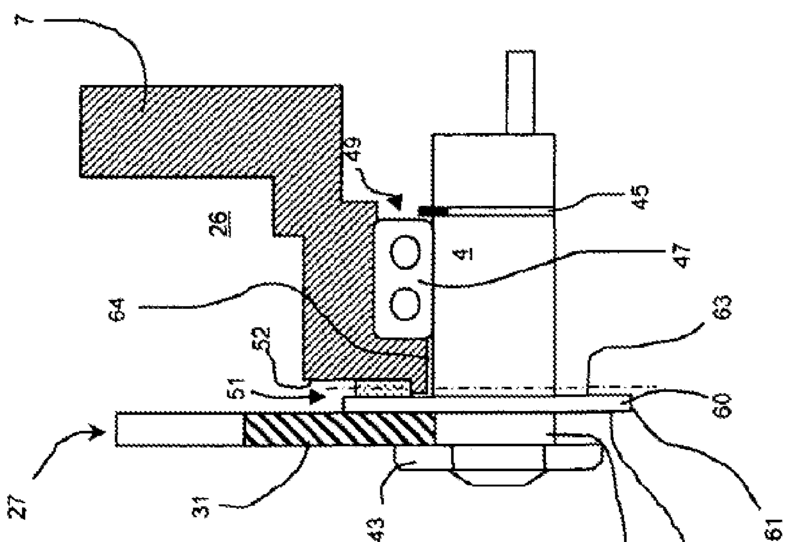

Figure 3

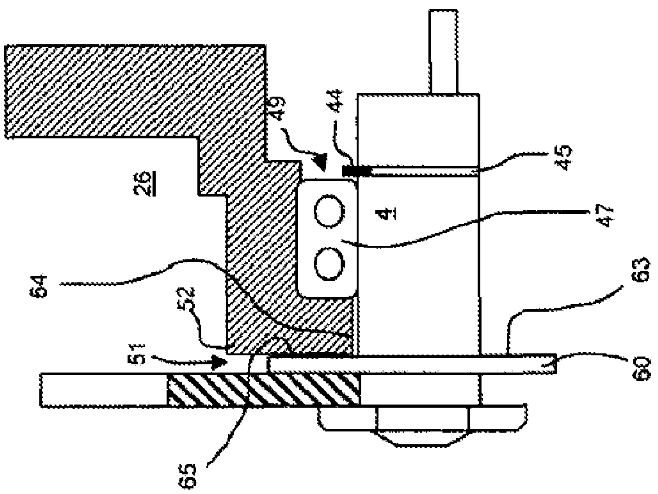

Figure 4

SHORT-SHAFT ELECTRIC COMPRESSOR

[0001] The technical field of the present invention is that of compressors as component parts of coolant systems equipping motor vehicles.

[0002] Coolant is conventionally made to circulate inside an air conditioning system by means of a compressor. In vehicles equipped with an internal combustion engine, this compressor is of mechanical type, since its rotation is driven by means of a pulley connected to the internal combustion engine by a belt.

[0003] The number of hybrid vehicles, that is to say of vehicles having an internal combustion engine coupled with an electric motor, or all electric vehicles, that is to say vehicles propelled exclusively by electric motors, is constantly increasing due to the increasing scarcity of the fossil fuels that supply energy to vehicles equipped with internal combustion engines.

[0004] The mechanical energy usually supplied by the internal combustion engine is therefore less available or totally unavailable in the case of all-electric vehicles.

[0005] Compressors driven by dedicated electric motors exist in the literature. Such an electric motor comprises a peripheral stator, inside which a rotor is installed. In other words, the rotor is located inside and in the center of the stator.

[0006] This type of electric motor has been replaced by an electric motor with an external rotor, where the rotor rotates peripherally around a stator installed fixedly at the center of the rotor. The document JP2009-287492 discloses such a compressor using an electric motor in which the rotor is installed on the outside of and peripheral to the stator.

[0007] However, the dimensions of the compressor of the prior art are not optimized, especially with respect to the positioning of the shaft connected to the rotor.

[0008] Furthermore, the circulation of coolant inside the compressor is unsuitable for the case where the coolant inlet and outlet are at the extremities of the compressor. In such a case, the coolant must pass around the electric motor. This particular circulation of coolant through the compressor was not considered in the document JP2009-287492, which makes the compressor shown in this document unusable in the case referred to above.

[0009] Another disadvantage of the abovementioned prior art resides in the fact that the stator is not cooled, since the latter is not in contact with the coolant in motion in the compressor.

[0010] The aim of the present invention is therefore to resolve the disadvantages described above, mainly by modifying the link between the central shaft and the casing, which allows this shaft to be shortened, thereby freeing the central part of the compressor at the level of the stator. This makes it possible to save on external dimensions, since the stator can be reduced and can occupy the space used by the shaft in the prior art. These freed spaces can also be used to circulate coolant without thereby changing the internal head loss, and at the same time cooling the stator of the electric motor.

[0011] The object of the invention is therefore an electric compressor comprising a compression mechanism rotated by a drive device that extends through a main casing delimiting an internal volume inside which an electric motor is installed, the electric motor comprising a stator and a rotor, which extends at least partially on the outer periphery of the stator, said drive device including the rotor, solidly connected to a shaft, which extends through a plate solidly connected to the main casing, characterized in that it includes a first rotation means between the shaft and the plate and a second rotation means between the drive device and the plate.

[0012] It will be understood here that the second rotation means is interposed between the plate and any one of the parts making up the drive device, for example the shaft, but also a support that is component part of the rotor.

[0013] The advantages referred to above are made feasible by the fact that the radial motion of the shaft of the compressor according to the invention is maintained by a first rotation means, while the axial motion of this shaft is limited by a second rotation means, these two rotation means being supported on the plate that is a component part of the compressor casing.

[0014] According to a first feature of the invention, the first rotation means has an axis of rotation and the second rotation means extends in a plane, said plane and said axis extending angularly one in relation to the other.

[0015] According to a second feature of the invention, the plate includes an inner wall turned toward the motor and said rotor includes a support to which a multiplicity of permanent magnets is solidly connected, said second rotation means being interposed between the support and the wall.

[0016] According to a variant, the plate includes an inner wall turned toward the electric motor and the shaft includes a disk, said second rotation means being interposed between said disk and the wall. Advantageously, the disk permanently connected to the shaft, either by fitting the disk on and welding it to the shaft, or by machining the disk directly from solid with the shaft.

[0017] According to another feature of the invention, the plate includes an outer wall turned toward the compression mechanism, said outer wall delimiting a housing for accommodating the first rotation means.

[0018] According to yet another feature of the invention, the support includes an end wall solidly connected to the shaft and which extends radially in relation to the shaft, said end wall including at least one opening for the circulation of a coolant.

[0019] According to yet another feature of the invention, the shaft incorporates a circumferential stop against which the first rotation means bears.

[0020] Advantageously, the multiplicity of permanent magnets and the stator are offset, said stator being offset toward the compression mechanism.

[0021] The first rotation means is a single-row ball bearing or a double-row ball bearing, this first rotation means being an axial rotation means.

[0022] For its part, the second rotation means is a roller bearing, this second rotation means being an axial rotation means.

[0023] Alternatively, the second rotation means is a plain bearing, the utilization of the latter being envisaged, for example, when of the disk is solidly connected to the shaft.

[0024] Also advantageously, the electric motor separates the internal volume, delimiting a first chamber on one side and a second chamber on the other, said first chamber being supplied with coolant through an inlet made in the main casing, while the second chamber supplies the compression mechanism through a passage passing through the plate.

[0025] A very first advantage of the invention resides in the ability to make the coolant circulate from one end of the compressor to the other, passing though the center of the latter, which allows an electric compressor design that utilizes an external rotor electric motor, at the same time maintaining dimensions that are reduced, especially with regard to its diameter, but also its length.

[0026] Another advantage resides in the ability to cool the electric motor by forcing coolant to circulate around the stator.

[0027] Other features, details and advantages of the invention will emerge more clearly on reading the description given below by way of indication with reference to the drawings, in which:

[0028] FIG. **1** is a view in section of a compressor according to the invention,

[0029] FIG. **2** is a partial view of a variant of FIG. **1**,

[0030] FIG. **3** is a partial view of a second embodiment variant of FIG. **1**,

[0031] FIG. **4** is a partial view of a third embodiment variant of FIG. **1**.

[0032] It should be noted that the figures reveal the invention in a detailed and sufficient manner; said figures may of course serve to define the invention better if necessary.

[0033] FIG. **1** illustrates an electric compressor as a a longitudinal section of the latter. The internal components represented on this figure are shown partially, but it must be understood that the axis A is an axis of symmetry about which the components are mirrored.

[0034] The compressor **1** is an electric compressor in so far as it integrates an electric motor **2**, which drives a compression mechanism **3** in rotation. This compression mechanism **3** is of a scroll type or a vane type, or even of a piston type, these examples being given by way of illustration without thereby limiting the scope of the invention.

[0035] The compression mechanism **3** includes fixed or moving parts, the latter being rotated by a drive device that includes, in a general manner, a rotor **11** (part of the electric motor **2**), solidly connected to a shaft **4** which extends longitudinally along the axis A. This shaft **4** thus extends in the central part of the compressor **1**, appreciably in the center of a main casing **5** that defines the external dimension of the compressor.

[0036] This main casing **5** is an aluminum or aluminum alloy part having a hollow circular shape including a peripheral wall defining an internal volume **6** terminated at one end by a first extremity **14** and at the other by a second extremity **15**. These two extremities are open prior to the installation of the other compressor components.

[0037] The first extremity **14** of the casing **5** is closed by the compression mechanism **3**. In the example of the figure, the compression mechanism **3** closes the casing by being slipped inside the latter at the extremity.

[0038] As for the second extremity **15**, it is blanked off by a secondary casing **16** which takes the shape of a basin and the end wall **17** of which presents a first side **18** turned toward the compression mechanism **3**. A protuberance **20** takes shape on the first side **18** in the form of a hollow tube extending parallel to the axis A and in the direction of the compression mechanism **3**. The secondary casing **16** and the protuberance **20** are cast simultaneously from aluminum or aluminum alloy. This protuberance **20** includes a mating edge **22** on which a stator **10** of the electric motor **2** is supported. This stator **10** is solidly connected to the protuberance **20** mechanically by means of at least one attachment means, for example a bolt **23**. This protuberance **20** also includes a circulation orifice **24** for the coolant **9** so that it can pass around the electric motor **2** by passing through the center thereof. This circulation orifice **24** is a hole extending along an axis perpendicular to the axis A, but in another alternative, the hole can present an inclination other than orthogonal, for example 45°, which assists the circulation of coolant in the internal volume of the compressor, and thus limits loss of head.

[0039] The secondary casing **16** includes a second side **19** opposite the first side **18**, that is to say turned toward the exterior of the compressor **1**. An edge **21** is located perpendicular to the end wall **17** and together delimits an area for accommodating a control circuit **25** for the electric motor. This control circuit **25** in the present case is an inverter converting a current of a direct-current form coming from the vehicle into a current of a sinusoidal form supplying the electric motor **2**.

[0040] The electric motor **2** is installed in the internal volume **6** of the compressor, more particularly in the part devoted to the electrical devices. This motor includes a stator **10** incorporating coils **35** and a rotor **11** rotating round, that is to say, on the outside of the stator **10**. It is therefore understood that the stator **10** is located fixedly inside rotor **11**, the latter surrounding the stator **10** in a peripheral and external manner.

[0041] The electric motor **2** located in the main casing **5** separates the internal volume **6** into a first chamber **12** and a second chamber **26**, the first chamber **12** receiving the coolant in the gaseous state coming from the coolant circuit.

[0042] The coolant enters the first chamber **12** by means of an inlet **13** made in the main casing **5**. This inlet takes the shape of a tube, extending radially toward the exterior of the main casing, and of a hole made in the wall of the main casing at the position of the tube.

[0043] Permanent magnets **29** are solidly connected to a support **27**, and more particularly to an inner wall **30** of the support. The latter takes the shape of a bowl with an end wall **31** and a circumferential strip **32**. The end wall **31** is solidly connected to the shaft **4** such that the support **27** drives the shaft **4** in rotation. This end wall **31** thus extends perpendicular to the axis A and the circumferential strip **32**, for its part, extends orthogonally in relation to the end wall **31**, taking shape on the latter. In other words, the circumferential strip **32** extends parallel to the axis A in the direction of the control device **25**.

[0044] The shaft **4** is a cylindrical tube comprising a first extremity **40** at the compression mechanism **3** end and a second extremity **41** opposite the first extremity and facing the secondary casing **16**. The shaft also incorporates a shoulder **42** in which the end wall **31** of the support **27** is accommodated. This shoulder includes a means of preventing rotation between the shaft **4** and the support **27** and which takes the form of a wedge inserted between these two parts, of complementary flats formed on these two parts or any other means allowing the end wall **31** to be slipped onto the shoulder **42**, while at the same time preventing any relative rotation between these two parts.

[0045] The end wall **31** of the support **27** is solidly connected to the extremity **41** of the shaft **4** by means of an attachment means **43**. It is therefore understood that the shaft **4** terminates appreciably at the position of the end wall **31** and that it does not extend in the center of the compressor **1** toward the secondary casing **16**. The shaft is therefore a short shaft so as to free the central space of the compressor and thus facilitate the circulation of the coolant **9**. In the example of FIG. **1**, the attachment means **43** takes the form of a nut screwed onto the end of the shaft **4** so as to block any translation of the support **27** in relation to the shaft **4**.

[0046] The shaft **4** also includes a circumferential stop **44**, which takes the form of a circlip or removable flexible ring caught in a groove **45** machined in the periphery of the shaft **4**. This circumferential stop **44** limits axial displacement of the shaft **4** in relation to the first rotation means in the direction of the electric motor **2**, that is to say the opposite direction to the compression mechanism. Axial displacement in the other direction, that is to say toward the compression mechanism **3**, is limited by the second rotation means **51**.

[0047] An actuating pin **46** of the compression mechanism **3** emerges from the first extremity **40**. This pin **46** extends longitudinally along an axis parallel to the axis A but offset in relation to the latter.

[0048] A plate **7** extends into the internal volume **6** in a direction perpendicular to the axis A so as to separate the internal volume **6** into a part devoted to the compression mechanism **3** and a part devoted to the electrical devices, especially the electric motor **2**. The plate **7** presents at least one passage **8** allowing the coolant symbolized by the arrows **9** to circulate from the part devoted to the electrical devices, and more particularly from the second chamber **26**, toward the compression mechanism **3**. It will be especially noted that this passage **8** is made through the plate **7** at the junction between this plate and the main casing **5**, that is to say, at the outer periphery of the plate **7**. This plate **7** is a casting, cast as one with the main casing, thereby forming a monobloc part in aluminum or aluminum alloy.

[0049] The shaft **4** that is a component part of the drive device passes through the center of the plate **7** from one side to the other.

[0050] This plate **7** includes an outer wall **48** turned toward the compression mechanism **3**, and this outer wall delimits a housing **49** for accommodating the first rotation means **47**. This housing takes the form of a cylindrical well the opening of which is at the compression mechanism **3** end. The housing **49** accommodates the first rotation means **47**, which takes the form in this embodiment of a cylindrical double-row ball bearing. This first rotation means **47**, and in particular the cylindrical double-row ball bearing presents an axis of rotation coincident with the axis A of the shaft **4**. In this particular case, an outer race of the bearing is an interference fit in the housing **49** while an inner race is a sliding fit on the shaft **4**. Since the shaft **4** can move by translation in the first rotation means **47**, this movement needs to be limited. This is the role of the circumferential stop **44**, which blocks a translation along the axis A of the shaft **4** toward the electric motor **2**, and against which the first rotation means **47** bears.

[0051] The plate **7** also includes an inner wall **50** opposite the outer wall **48**. Between the inner wall **50** and the rotor **11**, a second rotation means **51** is interposed, which is supported on one side on a face **52** of the plate **7** and forming part of the inner wall **50**, and on the other on an outer side **53** of the support **27**, that is to say a side turned toward the compression mechanism **3** level with the end wall **31**.

[0052] In FIG. **1**, the second rotation means **51** takes the form of a roller bearing, called a needle roller thrust bearing, wherein each roller **54** rotates round an axis **55** perpendicular to the axis A of the shaft **4**. Seen from the front, this roller bearing takes the form of a flat disk made from a multitude of rollers of which the axes of rotation all intersect at a single point. This flat disk forms the general plane of the second rotation means **51**.

[0053] It will be noted in particular that the plane in which the second rotation means **51** extends intersects the axis of rotation of the first rotation means **47**, as well as the axis A, since the latter two axes are coincident. The plane and the axis are therefore inclined one in relation to the other so as to describe an angle, which in the example of FIG. **1** is 90°. The rotation means **51** is therefore an axial rolling-contact bearing against which the end wall **31** of the support **27** bears.

[0054] At least one opening **28** passes right through the end wall **31** of the support **27** that is a component part of the rotor **11** so as to allow the circulation of a first part of the coolant **9** arriving from the circulation orifice **24**, of a second part passing through a gap between an outer peripheral wall of the stator **10** and an inner wall of the permanent magnets **29**, and of a third part of the coolant passing through the stator, circulating between the coils **35**. The support **27** includes between three and six openings in order to limit high-speed head losses.

[0055] The multiplicity of permanent magnets **29** presents a first lateral edge **56** at the compression mechanism end and a second lateral edge **57** facing the secondary casing **16**. For its part, the stator includes a first lateral face **58** turned toward the compression mechanism and a second lateral face **59** turned toward the secondary casing **16**. It can be seen from the figure that the multiplicity of permanent magnets **29** and the stator are not aligned on the same axis. In fact, the first lateral face **58** is offset in relation to the first lateral edge **56** by a distance illustrated by reference B.

[0056] This construction results in a surprising advantage. In fact, the magnetic attraction between the rotor and the stator creates an attraction of the rotor toward the stator, resulting in a bearing force of the support **27** against the second rotation means **51**. A continuous pressure is thus exerted on the rollers **54**, which prevents operating noise when the second rotation means **51** (needle roller thrust bearing) is not being constantly pushed by the rotor.

[0057] FIG. **2** illustrates an assembly that is identical except for the first rotation means **47**. In this variant, this rotation means takes the form of a single row ball bearing installed in the housing **49**, which allows the shaft **4** to be shortened and hence makes it possible to obtain a compressor of restricted length. In the same way as in the variant of FIG. **1**, the translation of the shaft **4** is limited at one end by the second rotation means and at the other end by the flexible ring **44**.

[0058] FIG. **3** is an example of the invention where the second rotation means **51** is installed differently. Whereas the second rotation means **51** in the examples of FIGS. **1** and **2** is interposed between the end wall **31** of the support **27** and the face **52** of the plate **7**, the second rotation means in the example of FIG. **3** is interposed between the shaft **4** and this same face of the plate **7**.

[0059] More particularly, the shaft **4** includes a disk **60**, solidly connected with the latter and formed on the shaft between the groove **45** and the shoulder **42** which accommodates the support **27**. This disk has a diameter greater than that of the shaft **4**. This disk **60** is delimited by a cylindrical outer edge **61**, a first side **62** against which the end wall **31** of the support **27** bears after tightening of the attachment means **43**, and a second side **63** against which the second rotation means **51** bears. The rollers **54** of the second rotation means **51** therefore rotate both against the second side **63** of the disk **60** and against the face **52** of the plate **7**.

[0060] Such a solution offers simplified management when taking account of tolerances on components having an impact on the second rotation means **51**. In fact, the presence of the disk **60** solidly connected to the shaft **4** avoids the need to take account of the dimensional tolerances on the end wall **31** of the support **27**, or the fastening tolerances inherent in the attachment means **43**.

[0061] A third variant of the invention is illustrated in FIG. **4**. In this case, the second rotation means **51** takes the form of a plain bearing **65** illustrated in this figure by a bold line. The disk **60**, and more particularly the second side **63** of this disk, is in contact with the face **52** of the plate **7** via the plain bearing **65**. In a more detailed fashion, this plain bearing **65** is a treatment of the mating surface so as to assist the sliding of the disk **60** over the face **52** of the plate **7** in spite of the axial forces acting on the shaft **4** in the direction of the compression mechanism **3**. This surface treatment is performed on the second side **63** of the disk **60** and/or on the face **52** of the plate **7**.

[0062] This surface treatment comprises three layers

[0063] a base layer formed by the second side **63** of the disk, in this case, made from steel,

[0064] an intermediate layer or sintered layer comprising solid lubricant particles thoroughly mixed with a synthetic material or bronze,

[0065] a friction or slip layer comprising a solid lubricant such as PTFE (polytetrafluoroethylene).

[0066] This plain bearing **65** thus guarantees the rotation between the disk **60** and the face **52** of the plate **7** without any wear on either one of these parts.

[0067] The plain bearing **65** has been described above as being interposed between the disk **60** and the face **52** of the plate **7**, but the invention also covers the case of a plain bearing directly interposed between the support **27** and the face **52**, that is to say in place of the needle bearing described in relation to FIGS. **1** and **2**.

[0068] FIGS. **3** and **4** also illustrate the existence of a lubricating duct **64** made between the plate **7** and the shaft **4**, and between the face **52** and the second side **63** of the disk **60** so as to allow the circulation of a lubricant from the housing **49** toward the second chamber **26** and hence to lubricate the first rotation means **47** and the second rotation means **51**, in particular the plain bearing (FIG. **4**) or the needle bearing (FIG. **3**).

[0069] The construction of the invention facilitates the circulation of the coolant **9** in the compressor **1**. This fluid enters through the inlet **13** and the first part of the coolant flows toward the center of the compressor in the direction of the circulation orifice **24**. In doing so, this part of the coolant **9** laps against the second lateral face **59** of the stator **10** and exchanges heat with the latter so as to cool it. The second part of the coolant **9**, which circulates between the rotor **11** and the stator **10**, laps against the outer peripheral wall of the stator **10** and exchanges heat with the latter. Finally, as it passes through the stator, the third part of the coolant exchanges with the coils **35** and cools the latter.

[0070] Thanks to the shaft **4** shortened according to the invention, the coolant **9** circulates in the space freed by the shaft and is directed toward the second chamber **26**. Finally, the presence of the openings in the end wall **31** concentrates the first and second parts of the coolant **9** where it exchanges heat with the first lateral face **58** of the stator **10**, which faces the compression mechanism **3**.

1. An electric compressor comprising a compression mechanism rotated by a drive device that extends through a main casing delimiting an internal volume inside which an electric motor is installed, the electric motor including a stator and a rotor, which extends at least partially on the outer periphery of the stator, said drive device including the rotor, solidly connected to a shaft, which extends through a plate solidly connected to the main casing, characterized in that it includes a first rotation means between the shaft and the plate and a second rotation means between the drive device and the plate.

2. The compressor as claimed in claim **1**, in which the first rotation means has an axis of rotation and the second rotation means extends in a plane, said plane and said axis extending angularly one in relation to the other.

3. The compressor as claimed in claim **1**, in which the plate includes an inner wall turned toward the electric motor and said rotor includes a support to which a multiplicity of permanent magnets is solidly connected, said second rotation means being interposed between the support and the wall.

4. The compressor as claimed in claim **1**, in which the plate includes an inner wall turned toward the electric motor and the shaft includes a disk, said second rotation means being interposed between said disk and the wall.

5. The compressor as claimed in claim **1**, in which the plate includes an outer wall turned toward the compression mechanism, said outer wall delimiting a housing for accommodating the first rotation means.

6. The compressor as claimed in claim **1**, in which the rotor includes a support to which a multiplicity of permanent magnets is solidly connected, said support includes an end wall solidly connected to the shaft and which extends radially in relation to the shaft, said end wall including at least one opening for the circulation of a coolant.

7. The compressor as claimed in claim **1**, in which the shaft incorporates a circumferential stop against which the first rotation means bears.

8. The compressor as claimed in claim **1**, in which the rotor includes a support to which a multiplicity of permanent magnets is solidly connected, said multiplicity of permanent magnets and the stator are offset, said stator being offset toward the compression mechanism.

9. The compressor as claimed in claim **1**, in which the first rotation means is a single-row ball bearing.

10. The compressor as claimed in claim **1**, in which the first rotation means is a double-row ball bearing.

11. The compressor as claimed in claim **1**, in which the second rotation means is a roller bearing.

12. The compressor as claimed in claim **1**, in which the second rotation means is a plain bearing.

13. The compressor as claimed in claim **1**, in which the electric motor separates the internal volume, delimiting a first chamber on one side and a second chamber on the other, said first chamber being supplied with coolant through an inlet made in the main casing, while the second chamber supplies the compression mechanism through a passage.

14. The compressor as claimed in claim **2**, in which the plate includes an inner wall turned toward the electric motor and said rotor includes a support to which a multiplicity of permanent magnets is solidly connected, said second rotation means being interposed between the support and the wall.

15. The compressor as claimed in claim **2**, in which the plate includes an inner wall turned toward the electric motor and the shaft includes a disk, said second rotation means being interposed between said disk and the wall.

16. The compressor as claimed in claim **2**, in which the plate includes an outer wall turned toward the compression mechanism, said outer wall delimiting a housing for accommodating the first rotation means.

17. The compressor as claimed in claim **3**, in which the plate includes an outer wall turned toward the compression mechanism, said outer wall delimiting a housing for accommodating the first rotation means.

18. The compressor as claimed in claim **4**, in which the plate includes an outer wall turned toward the compression mechanism, said outer wall delimiting a housing for accommodating the first rotation means.

* * * * *