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(54) **ELECTRIC MOTOR FOR A WELL PUMP AS WELL AS ASSOCIATED PRODUCTION METHOD**

(71) Applicant: **WILO SE**, Dortmund (DE)

(72) Inventors: **Daniel HOEKE**, Dortmund (DE); **Oliver DRUBEL**, Dortmund (DE); **Henry KOHLER**, Dortmund (DE); **Roland Edmund UMMELMANN**, Dortmund (DE); **Heiko DOEHLER**, Dortmund (DE); **Heiko UNGER**, Dortmund (DE); **Volker NETSCH**, Dortmund (DE); **Michael MEIER-WAGNER**, Dortmund (DE); **Martin VOGT**, Dortmund (DE)

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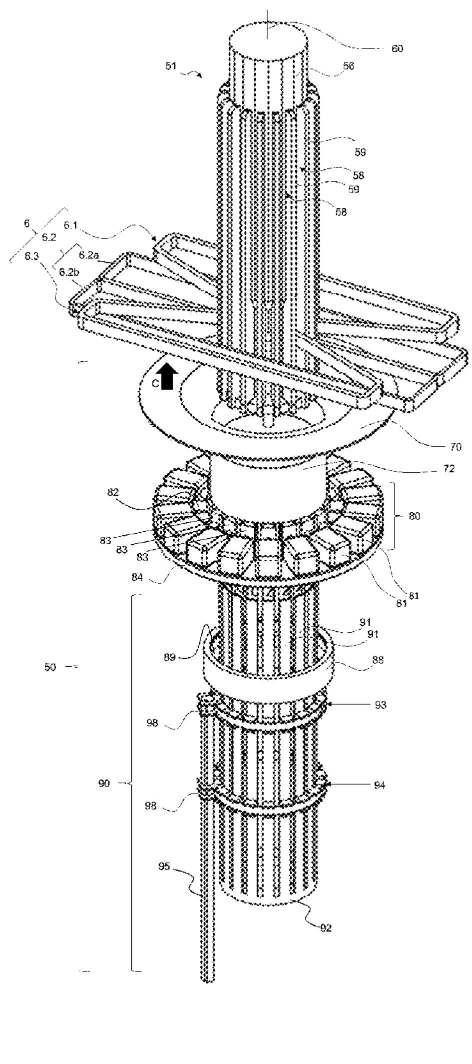
(57) **ABSTRACT**

Provided are a method and a tool for manufacturing a coil assembly of an electric motor for a deep well vertical turbine pump with a stator assembly that has a stator bore to receive a rotor and slots radially open to the inside which are respectively separated from each other by a stator tooth and in which electrical conductors of coils of the coil assembly lie, forming distributed windings and, at one axial end of the coil assembly, a winding head. The coil assembly is manufactured by shaping and encapsulating the coils within the tool so that the winding head extends only between an inner diameter and an outer diameter that is smaller than the diameter of the stator bore in order to enable axial insertion of the coil assembly into the stator assembly leading with the winding head in which the coils are respectively wound individually, drawn into the tool as wire bundles and encapsulated within it.



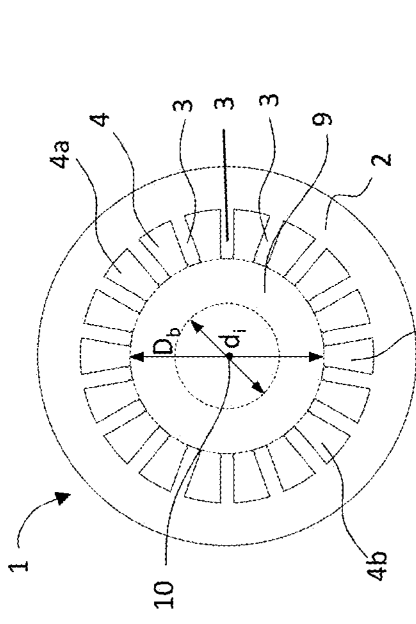


Fig. 1

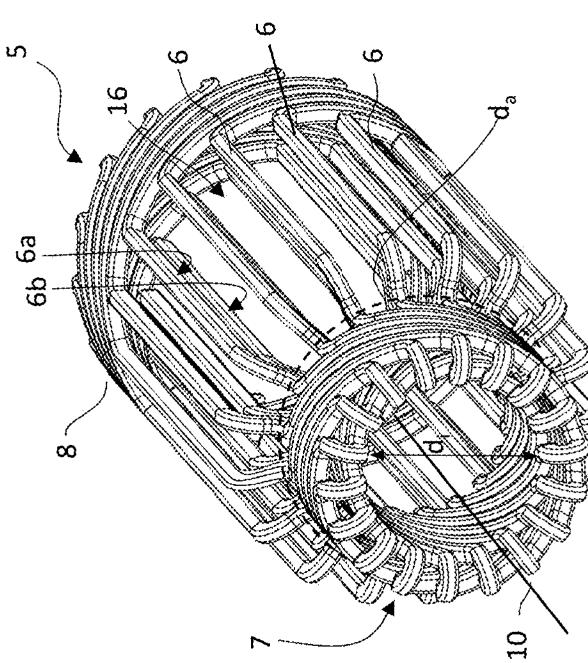


Fig. 2

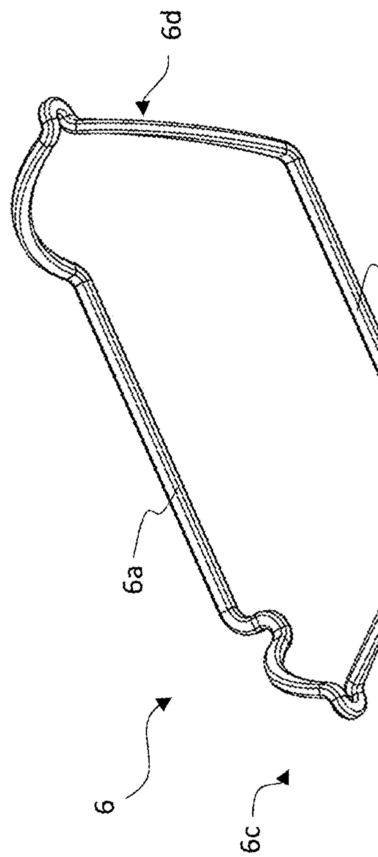


Fig. 3a

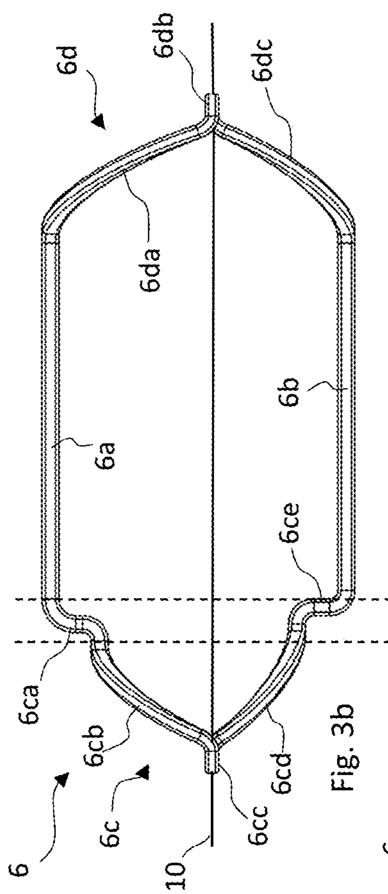


Fig. 3b

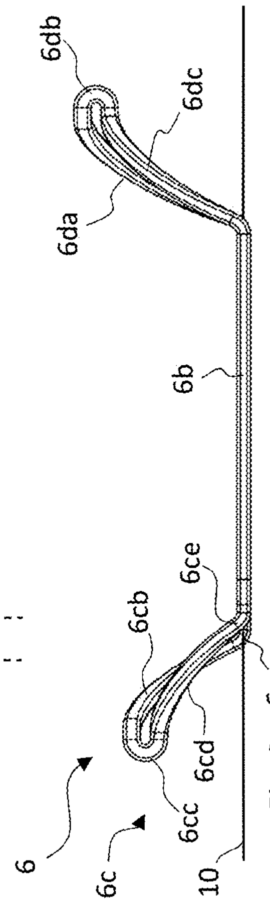


Fig. 3c

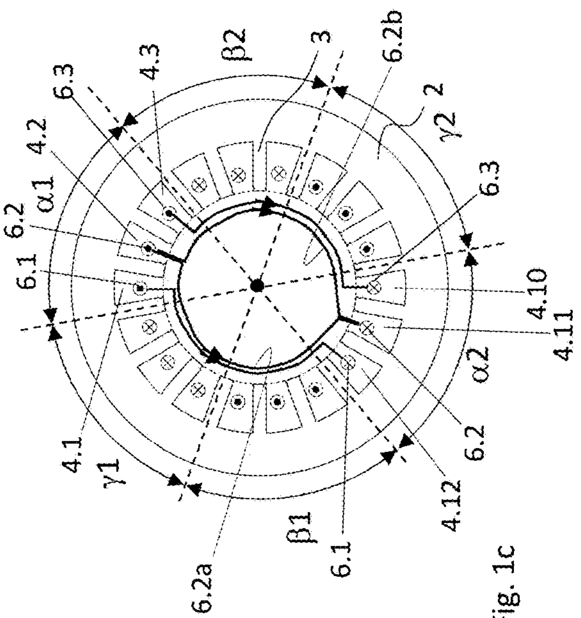


Fig. 1c

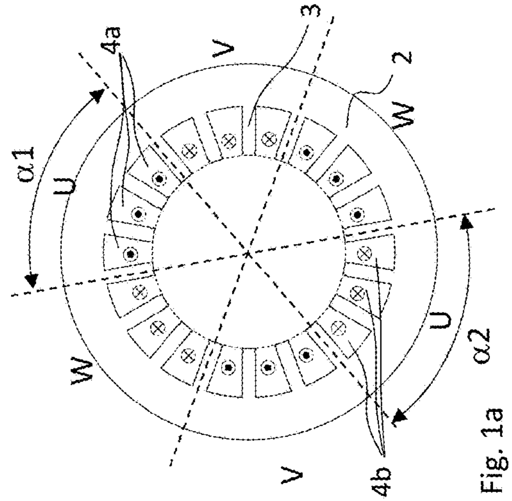


Fig. 1a

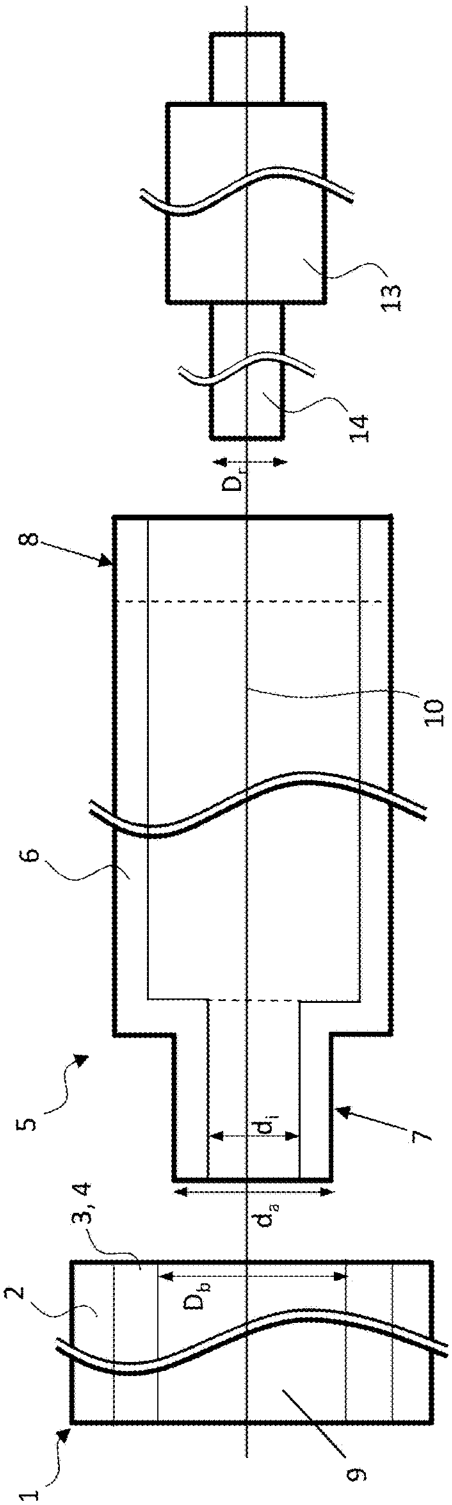


Fig. 1b

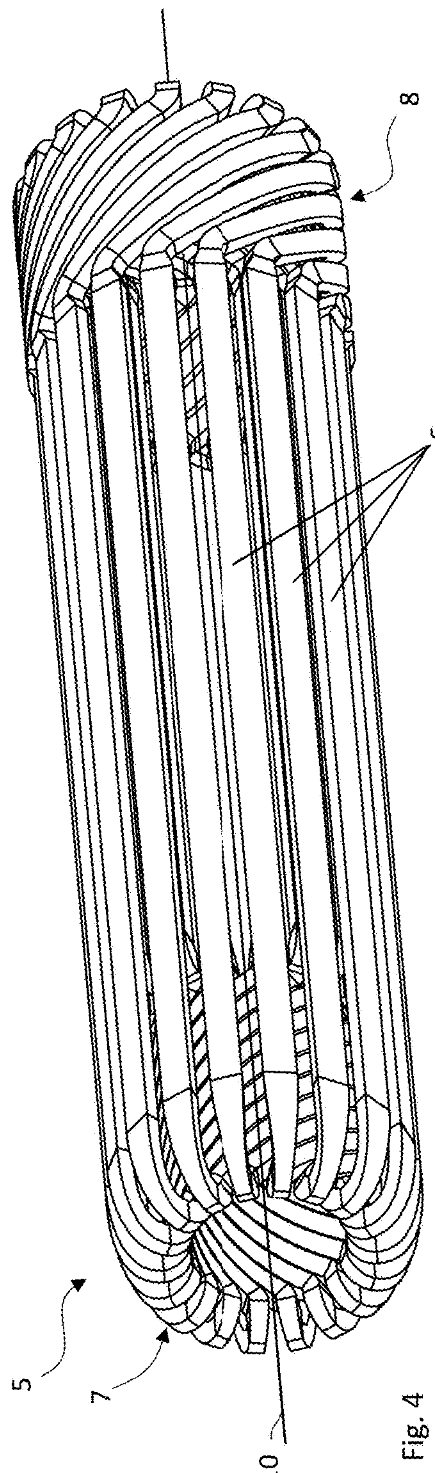


Fig. 4

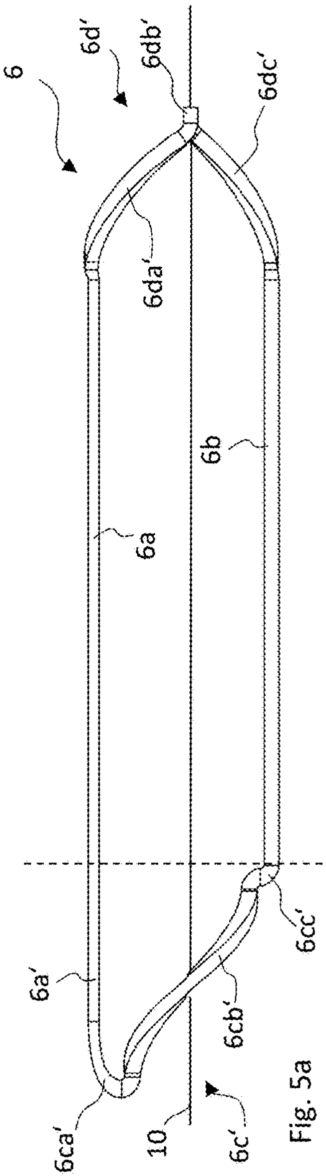


Fig. 5a

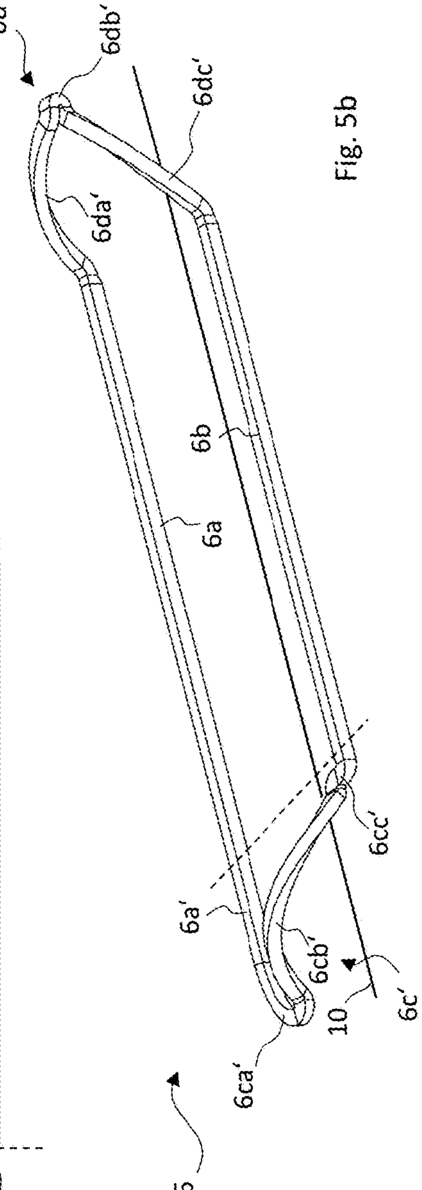


Fig. 5b

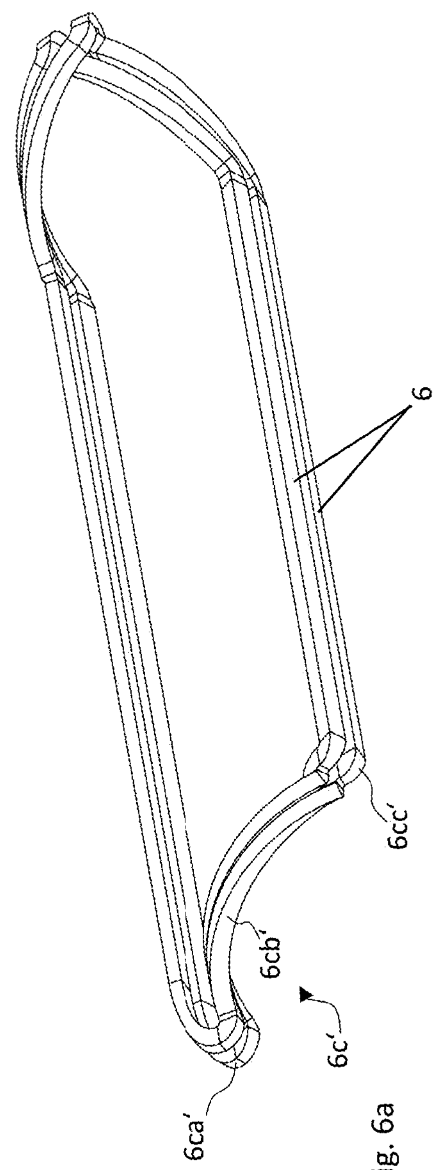


Fig. 6a

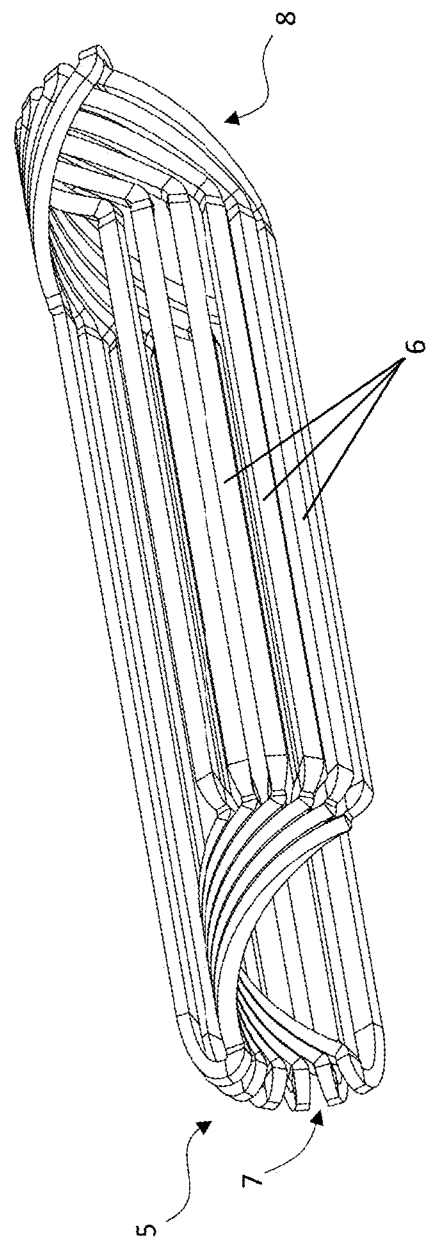


Fig. 6b

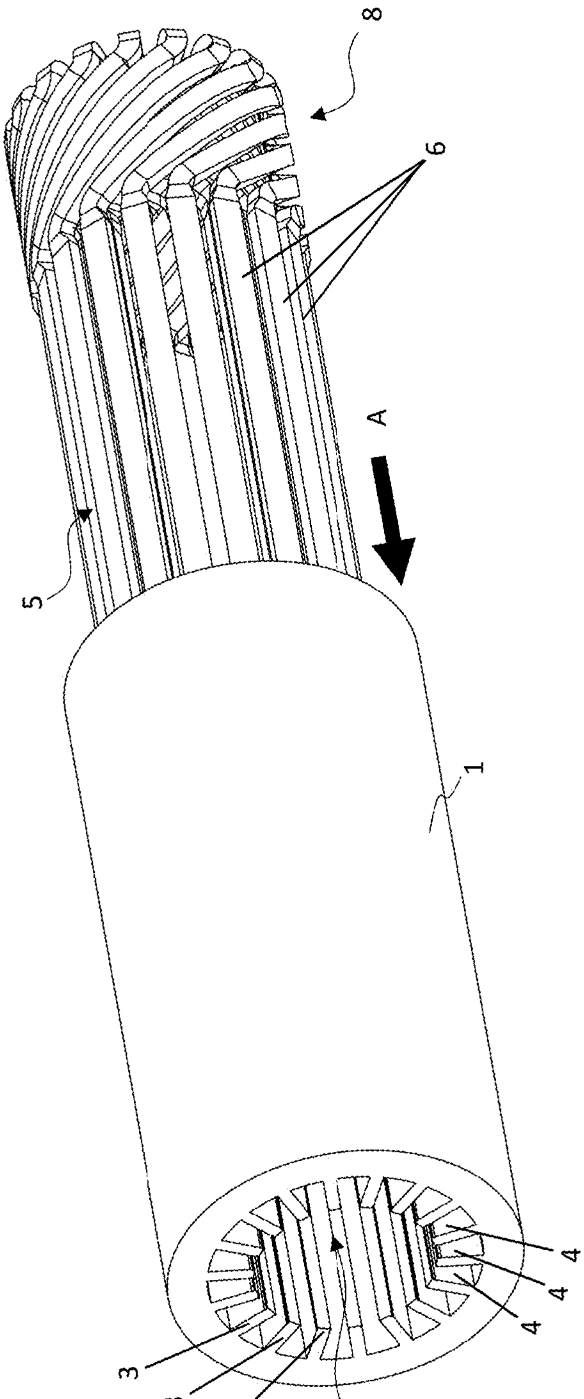


Fig. 7a

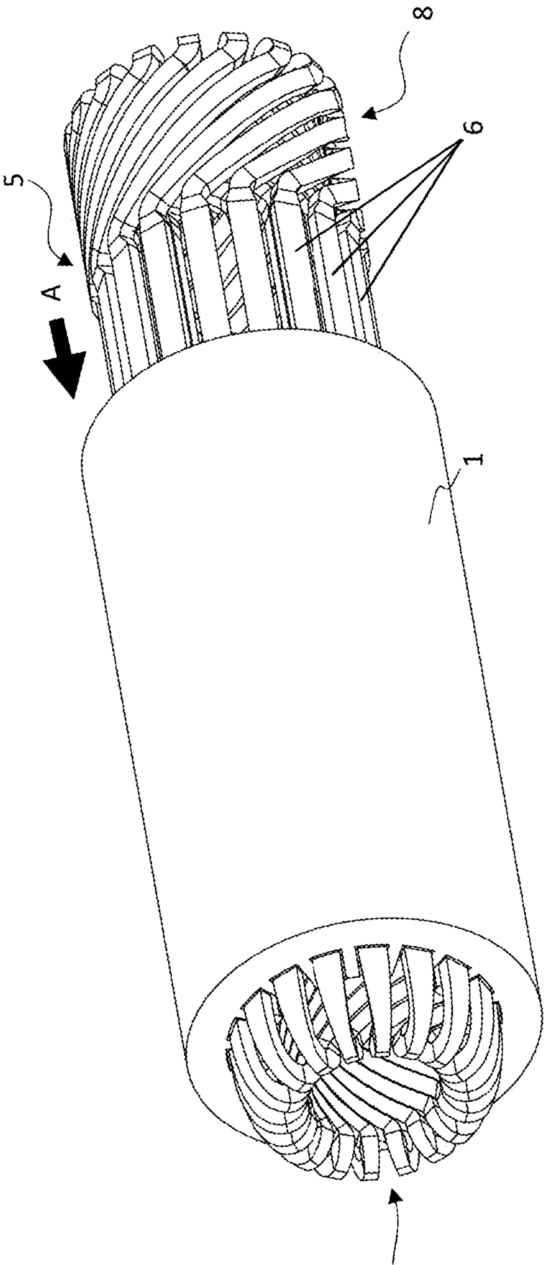


Fig. 7b

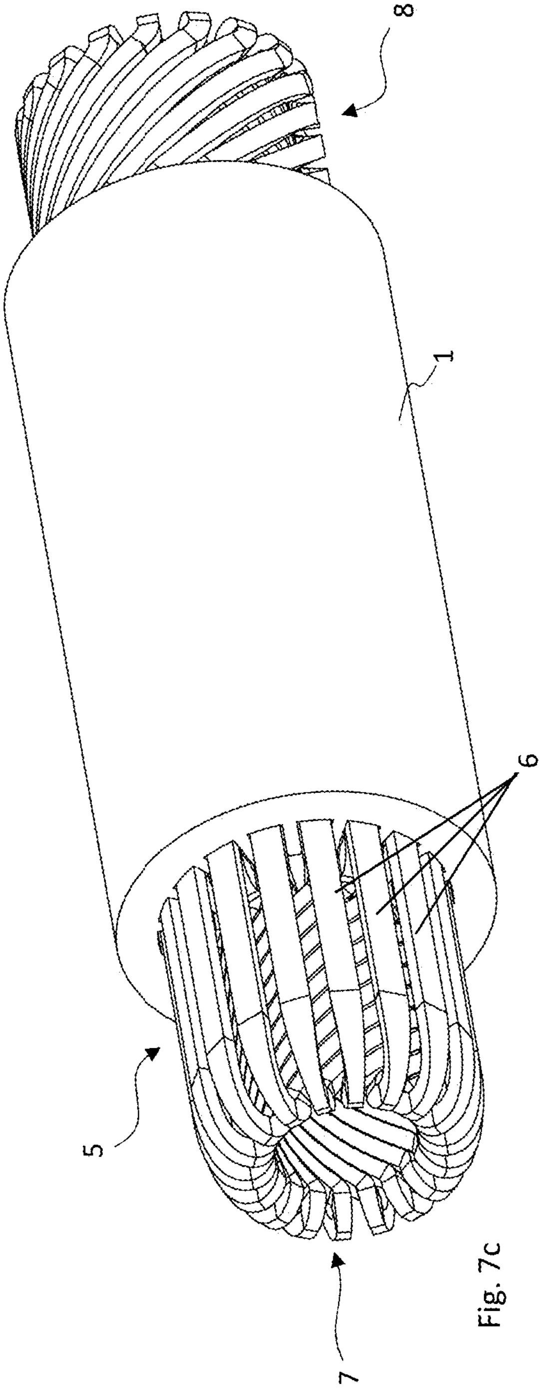


Fig. 7c

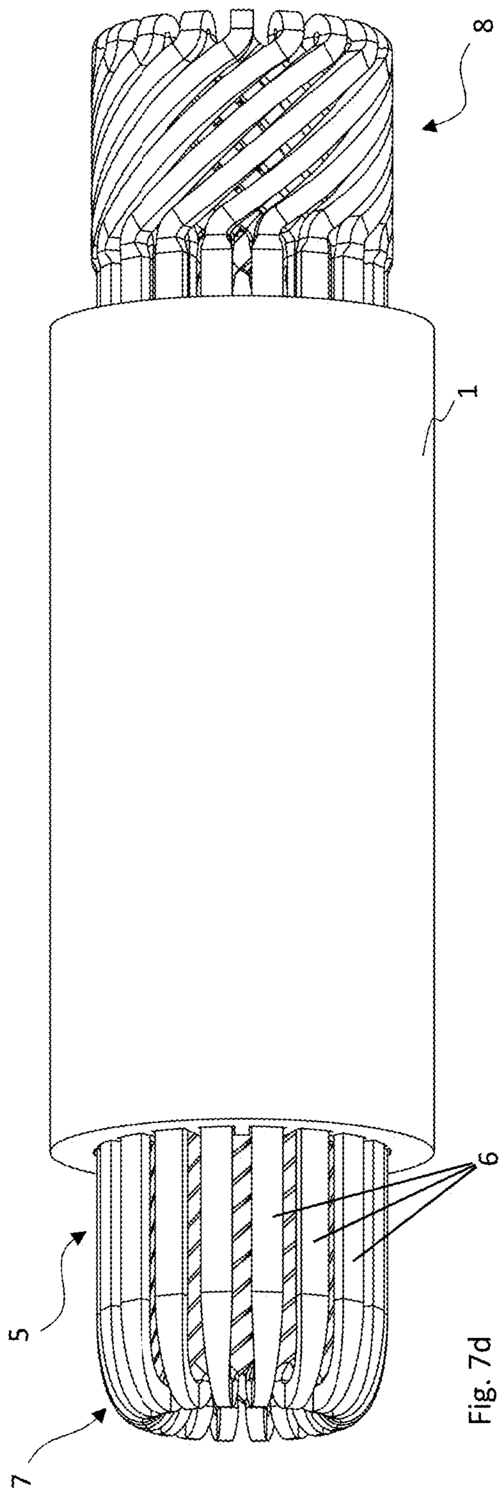


Fig. 7d

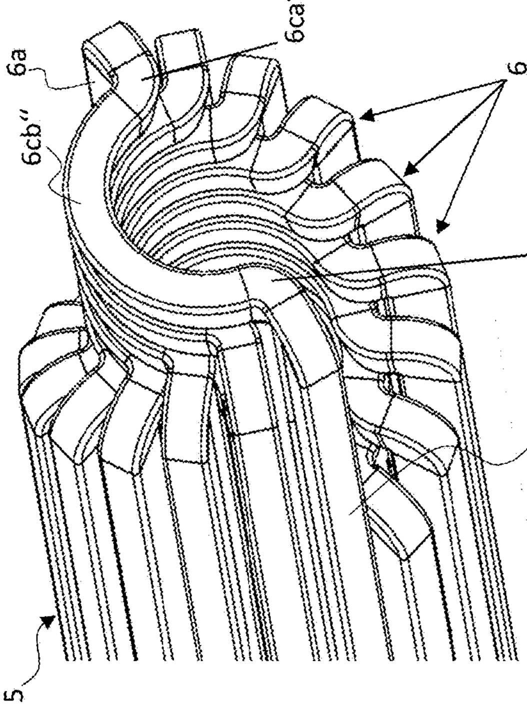


Fig. 8b

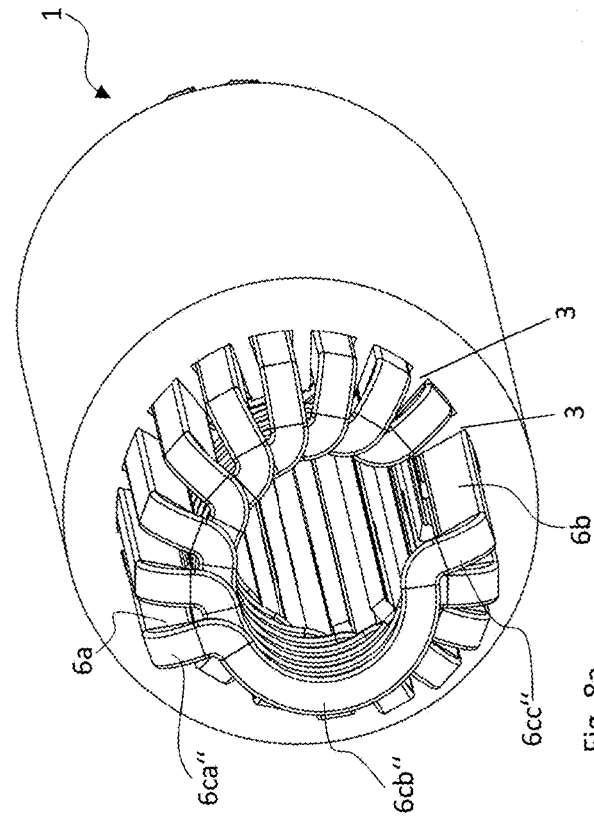


Fig. 8a

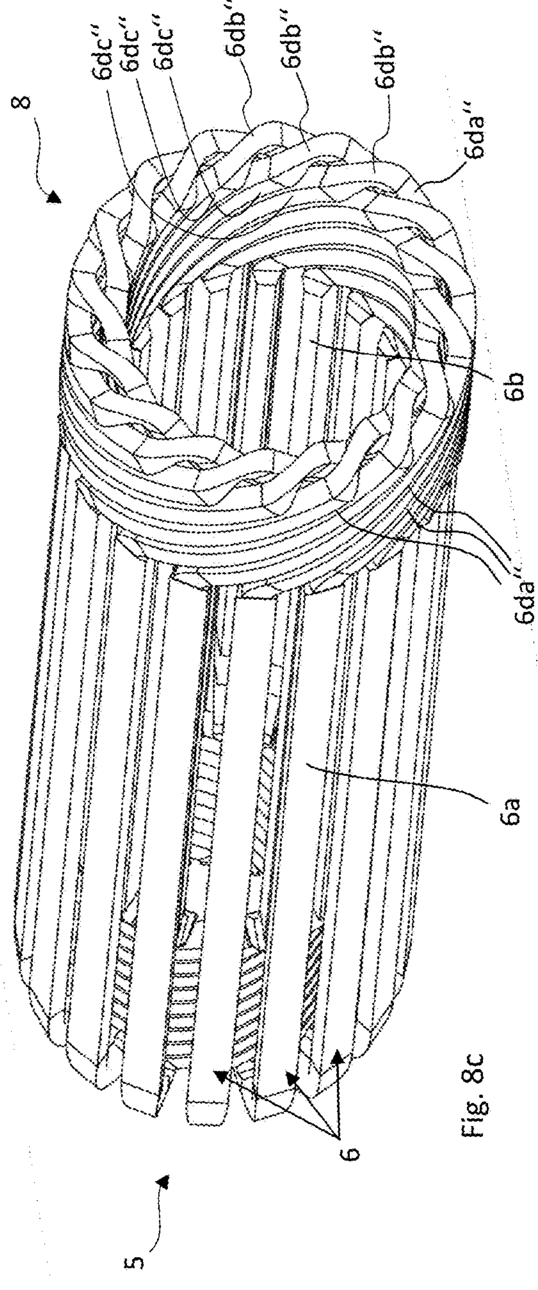
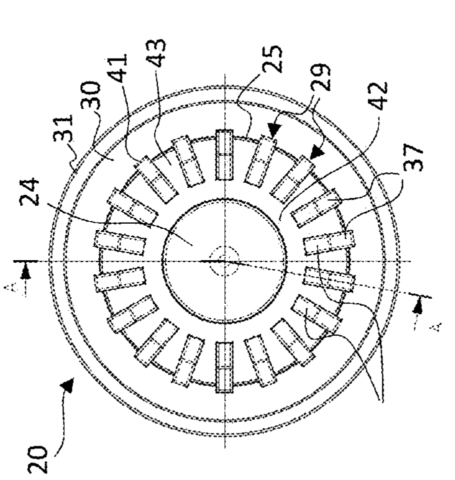


Fig. 8c



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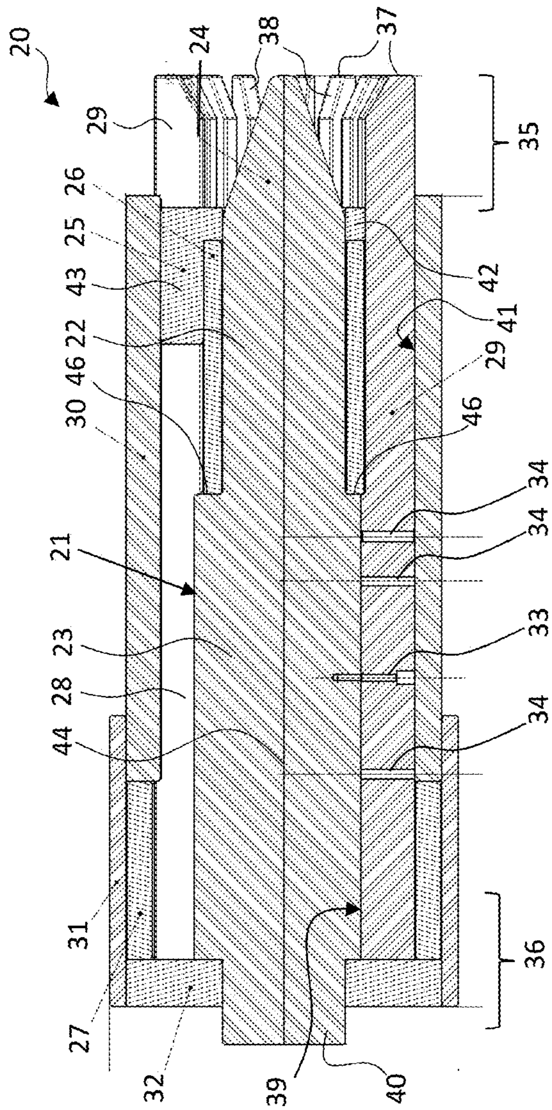

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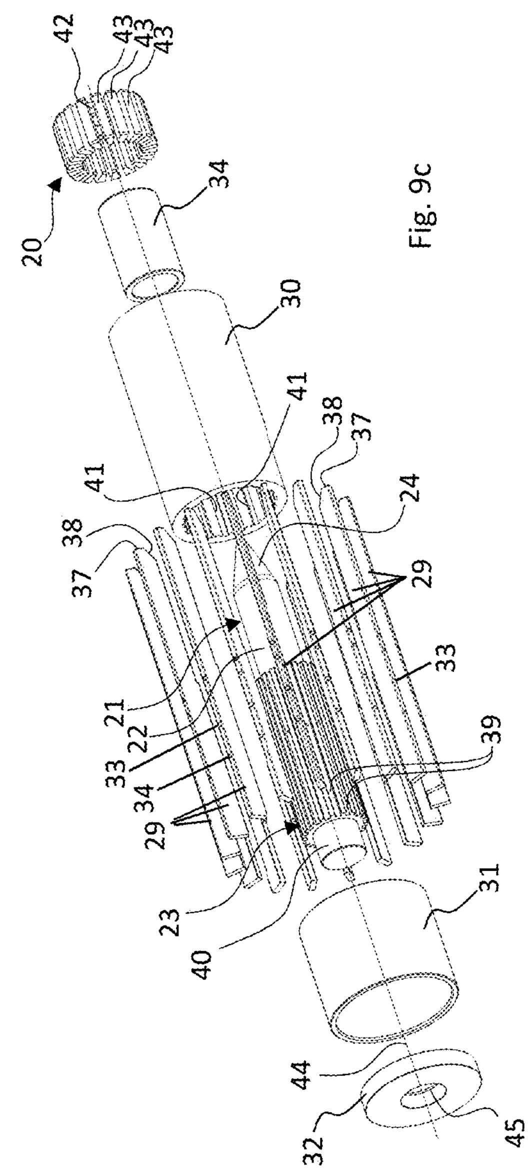


Fig. 9c

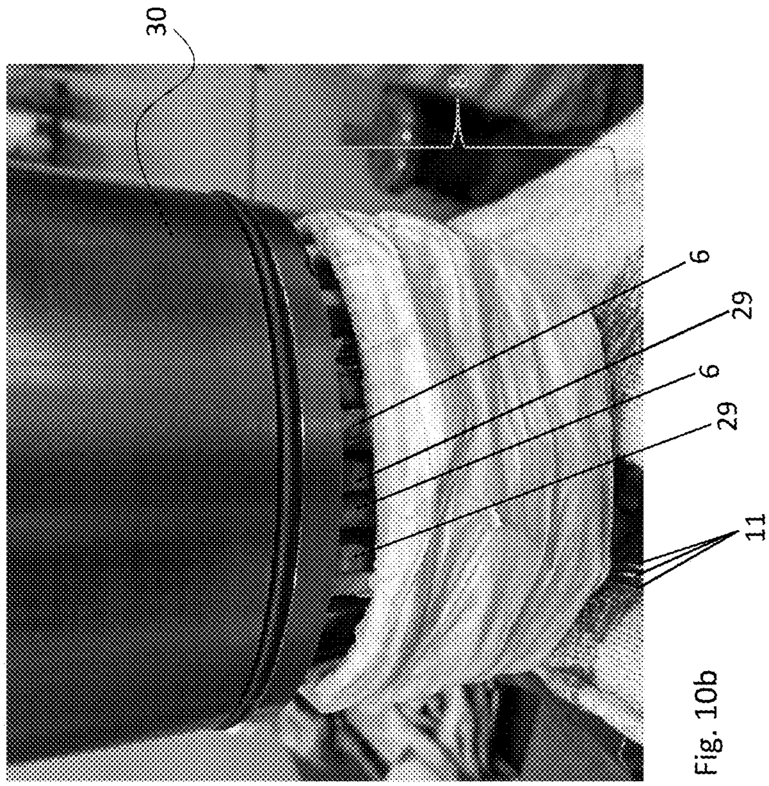
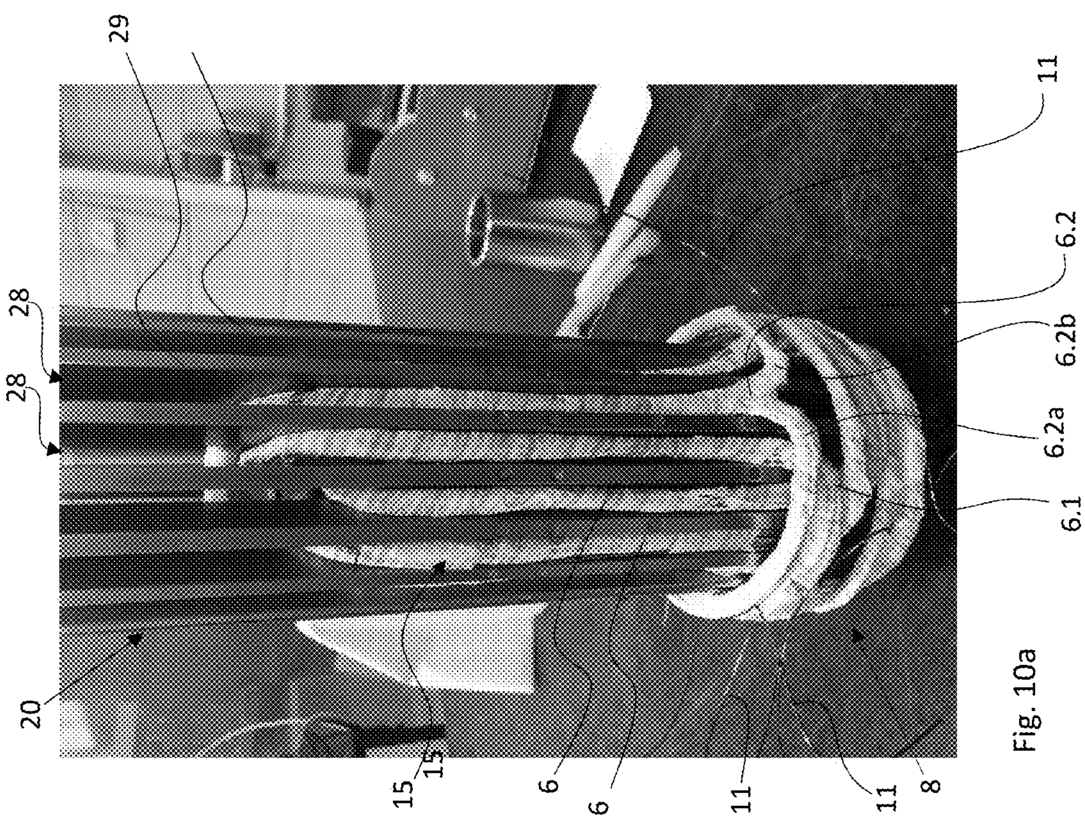


Fig. 10b



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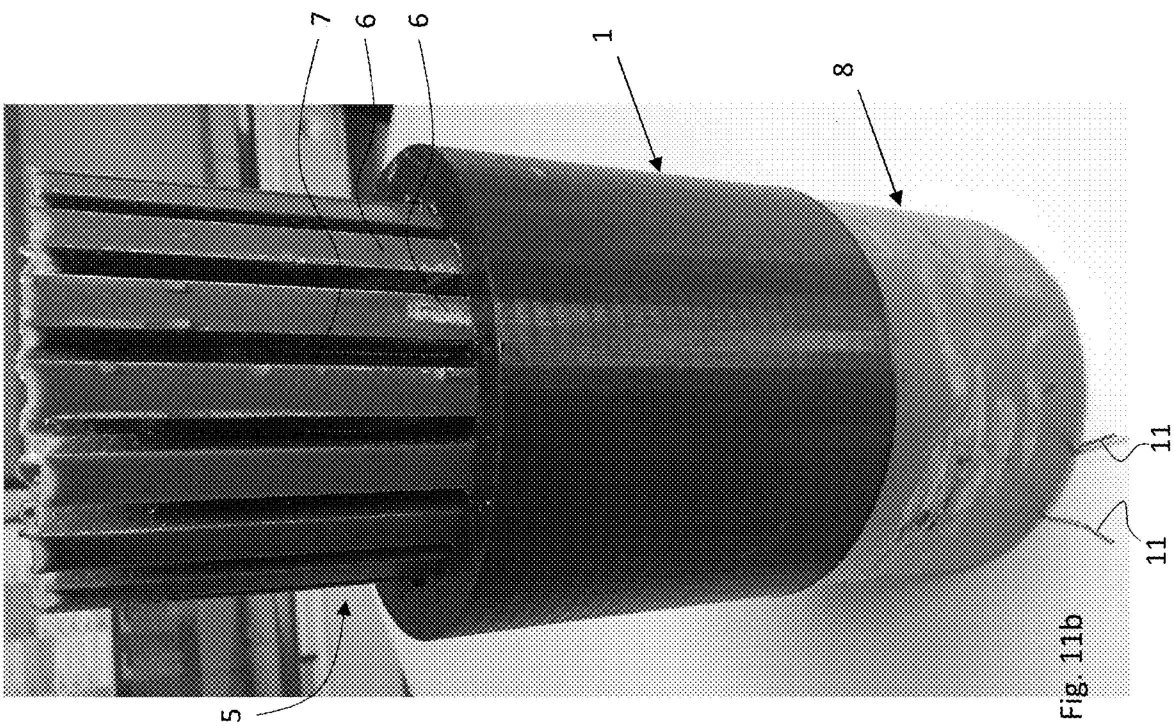
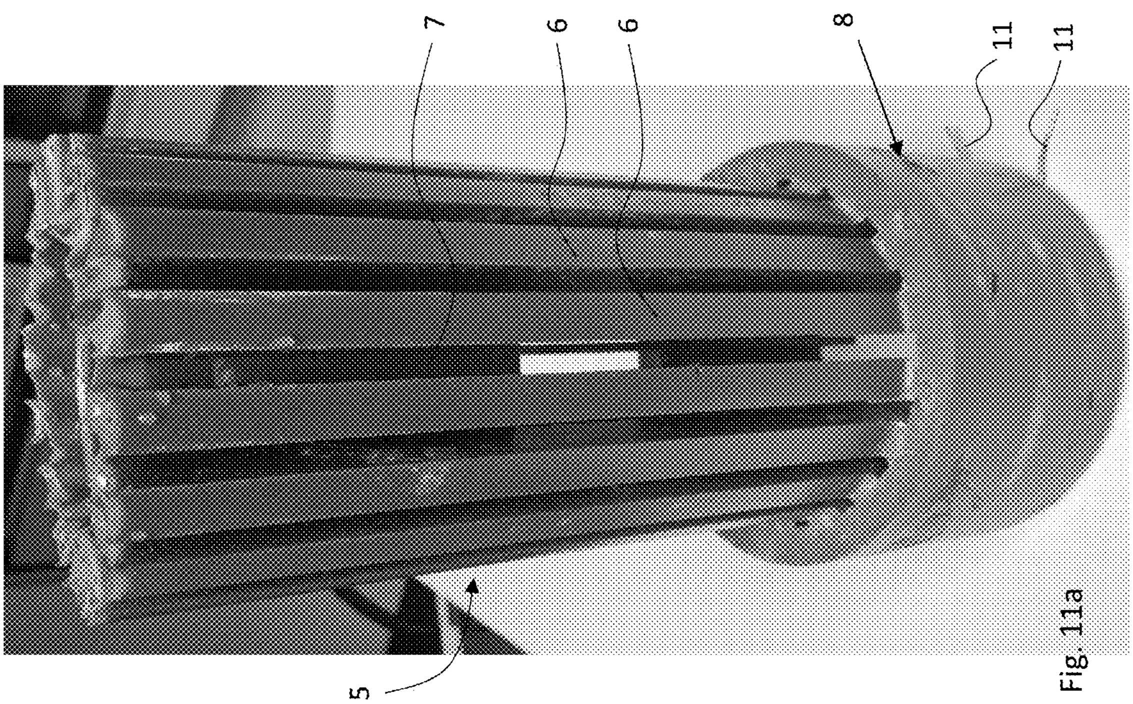


Fig. 11b



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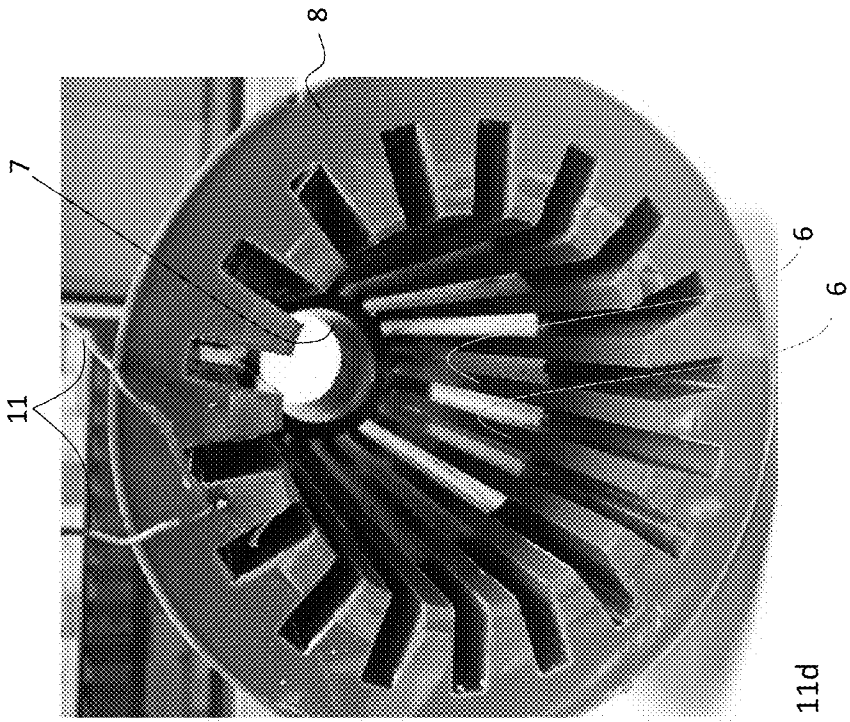


Fig. 11d

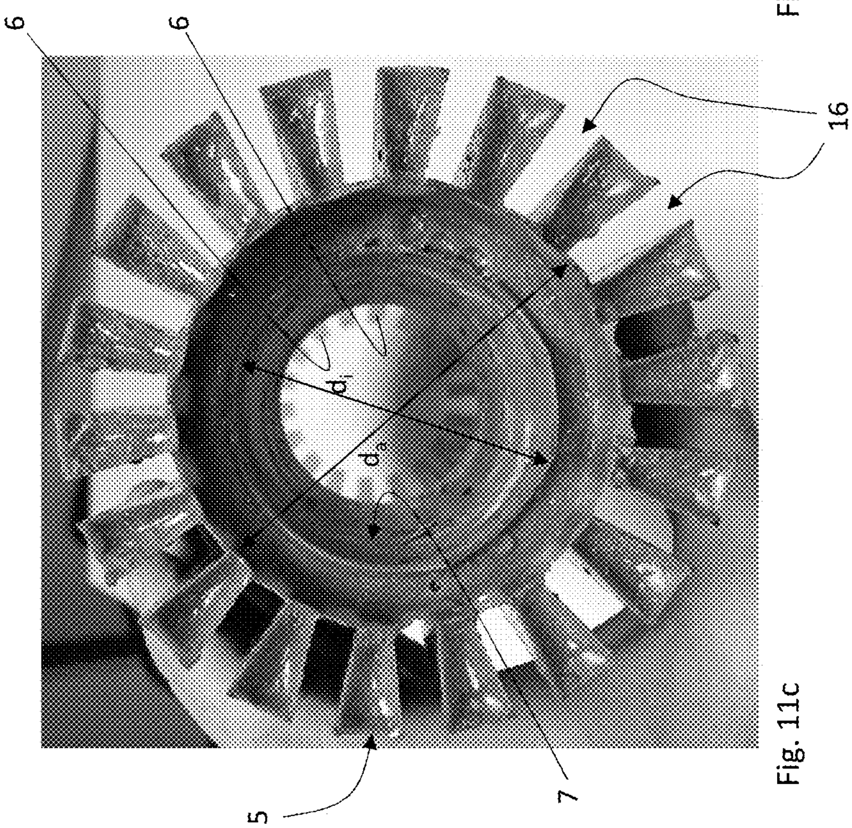


Fig. 11c

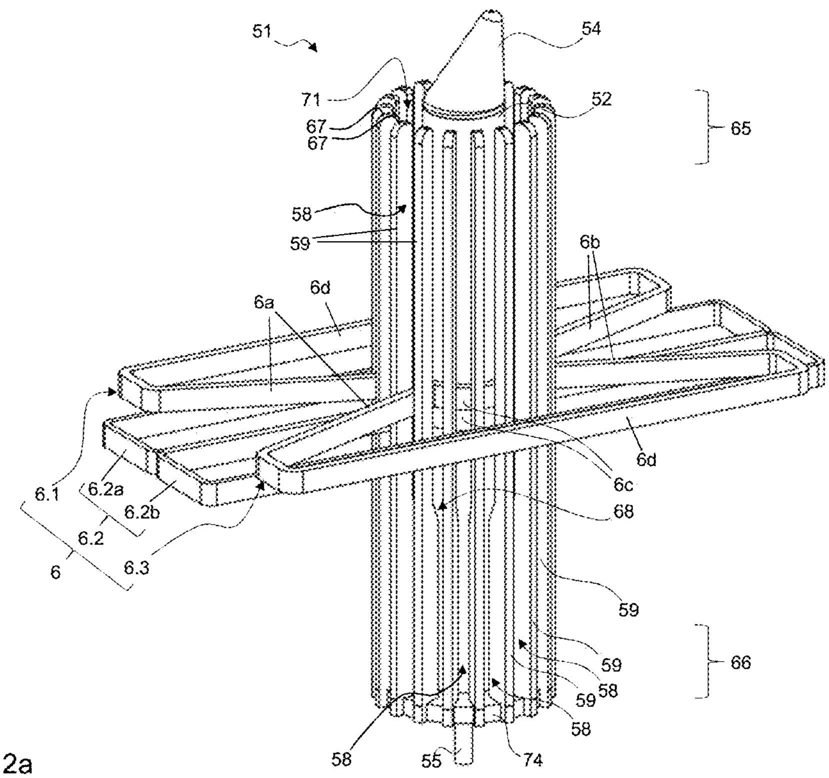
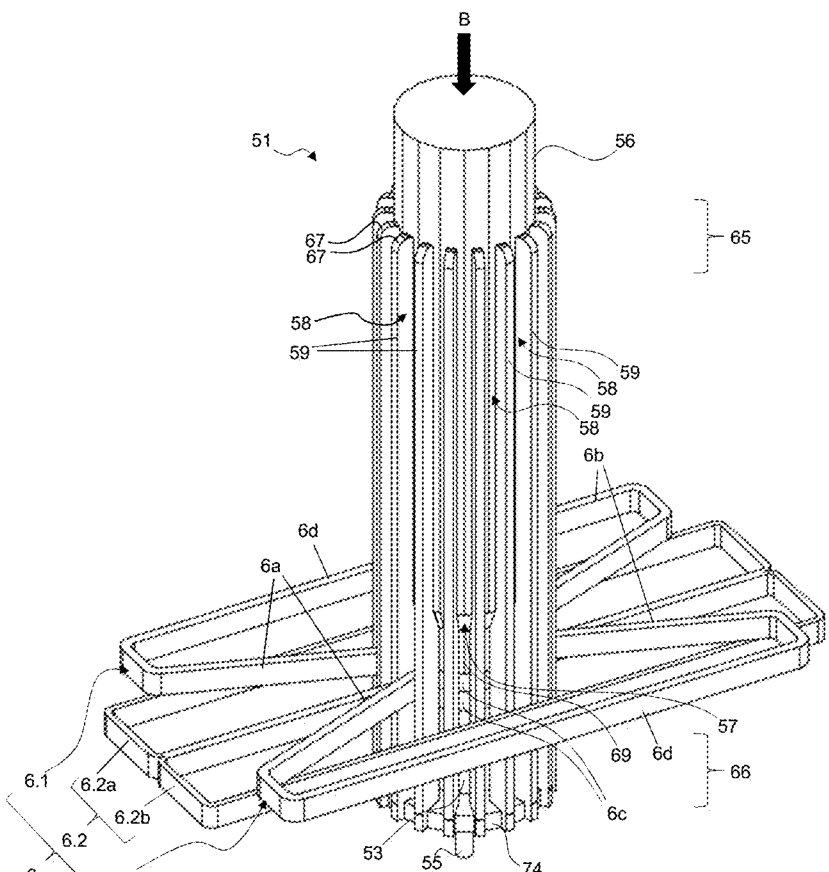


Fig. 12a



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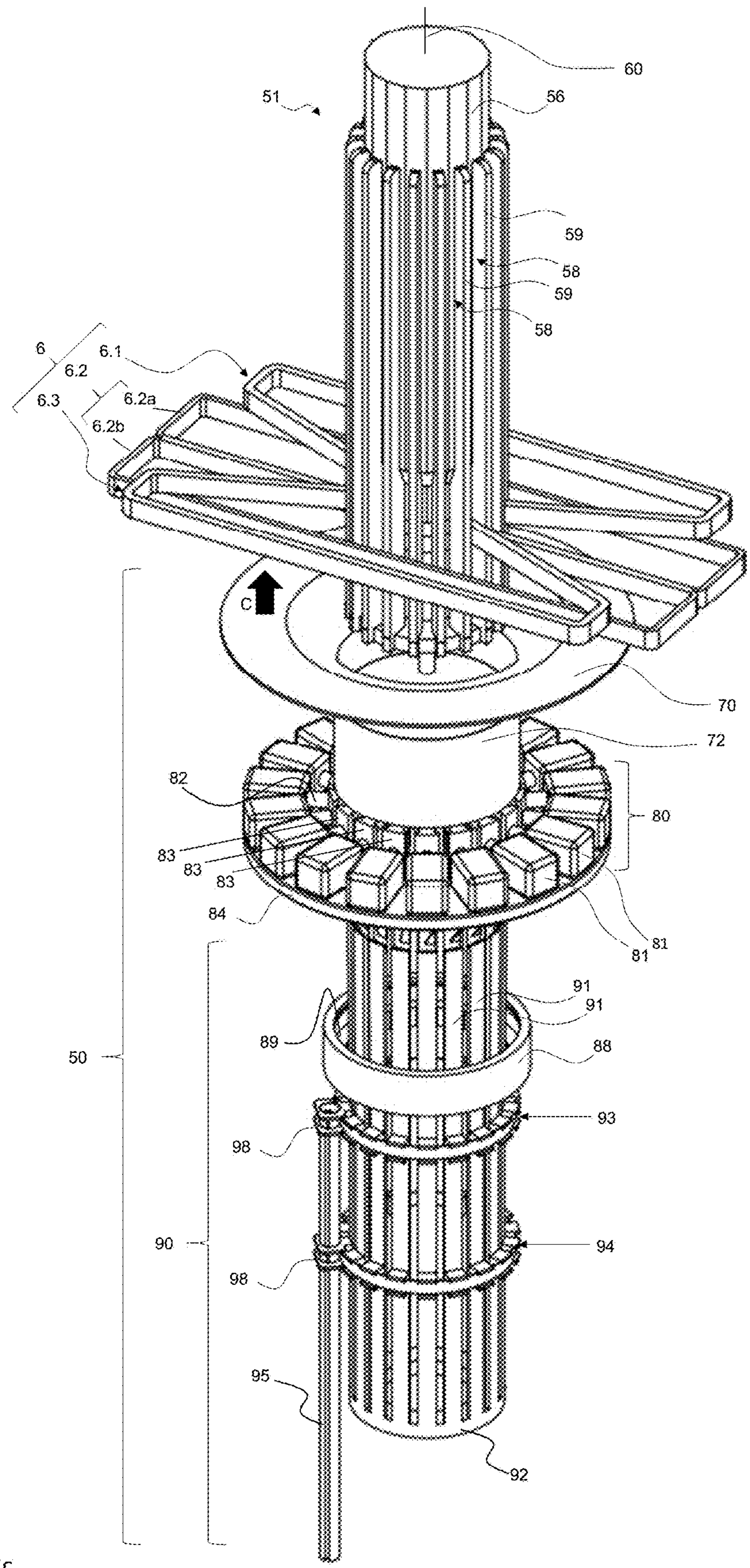
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Fig. 12c

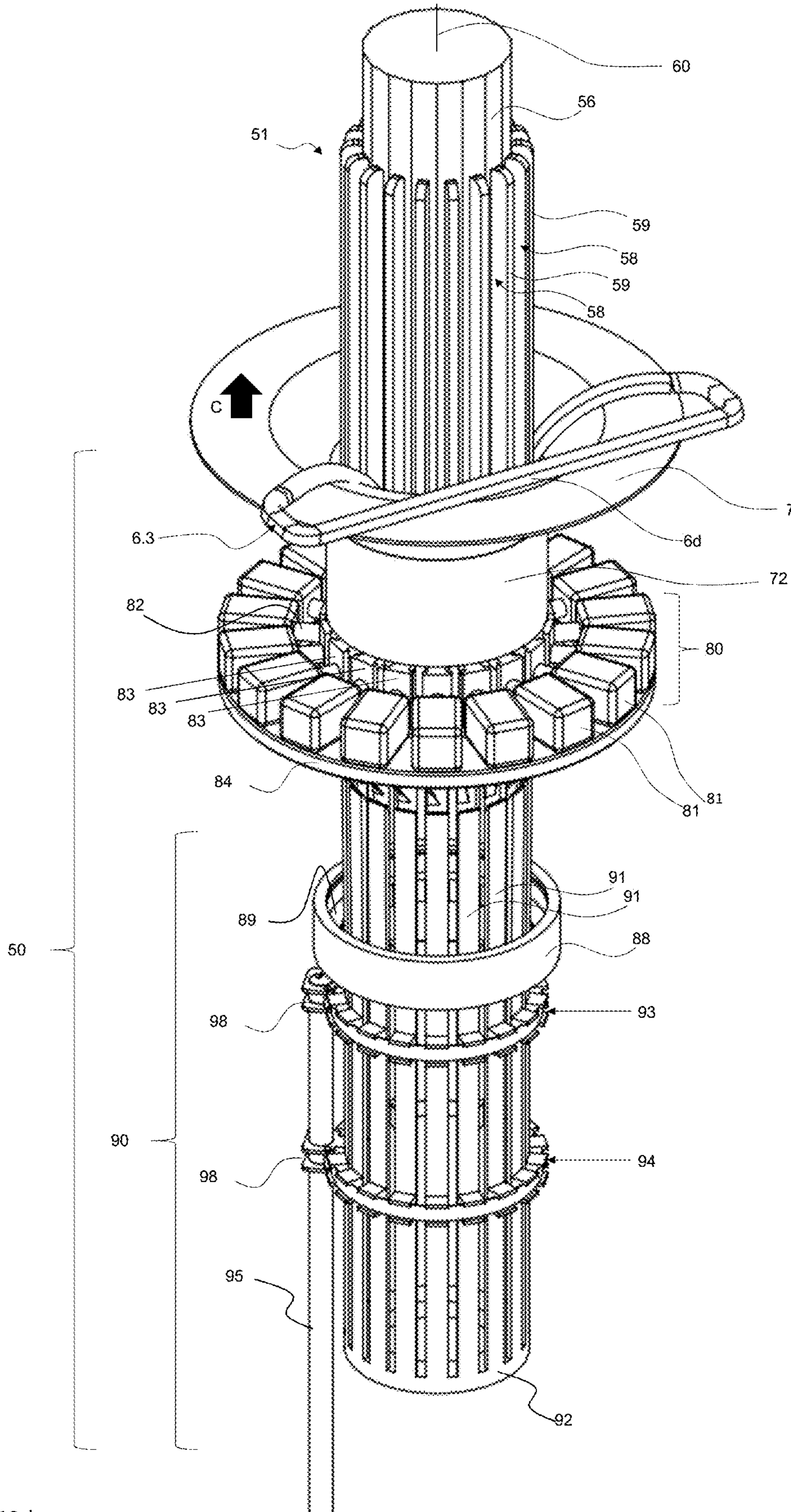
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Fig. 12d

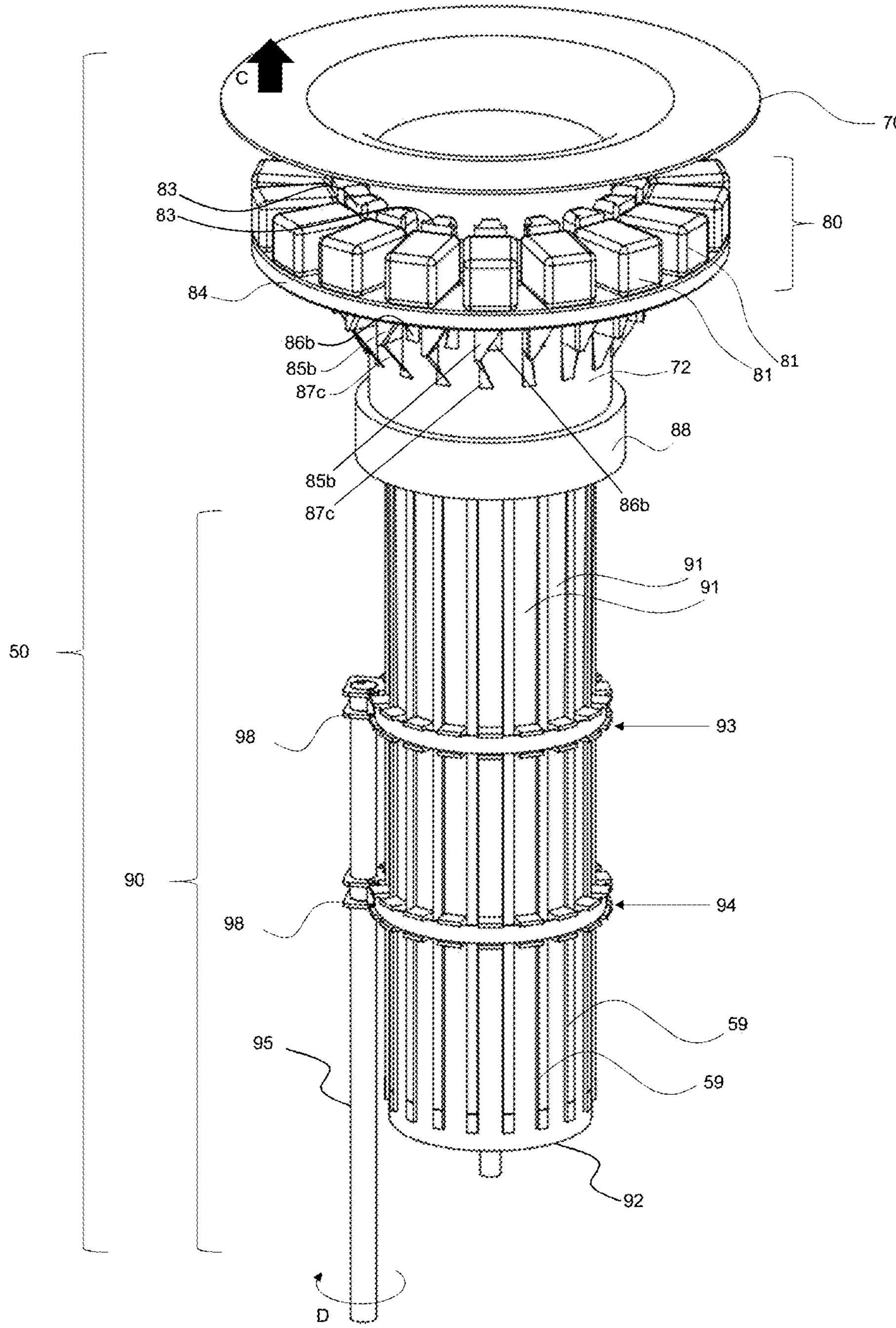
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Fig. 12e

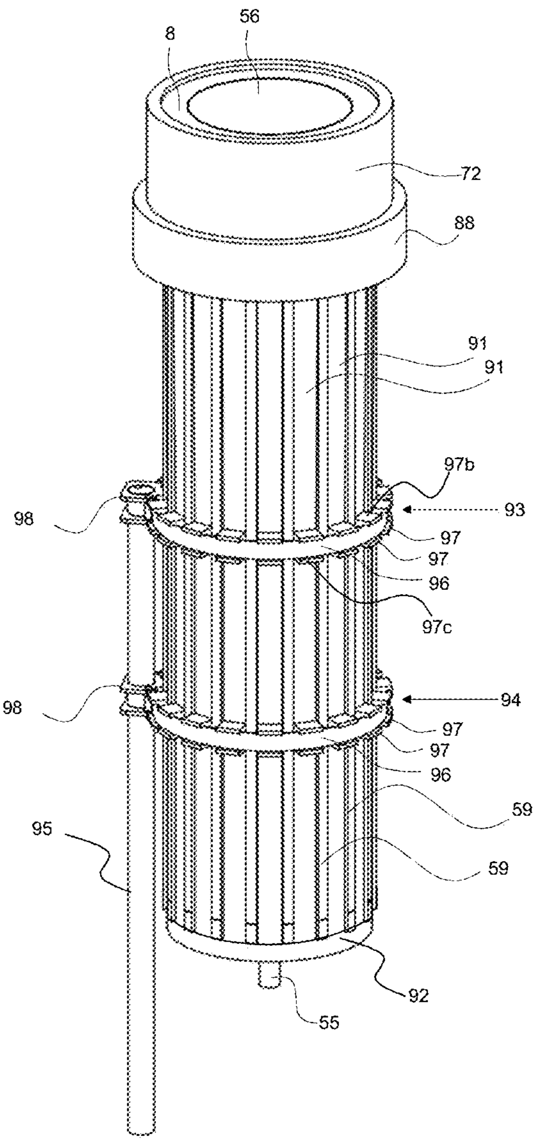

Fig. 12f

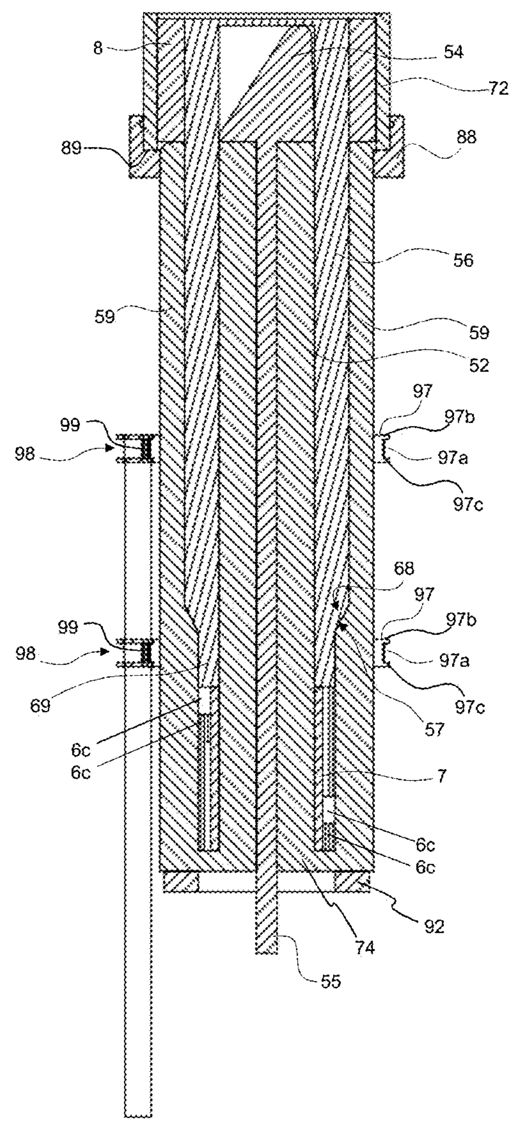

Fig. 13b

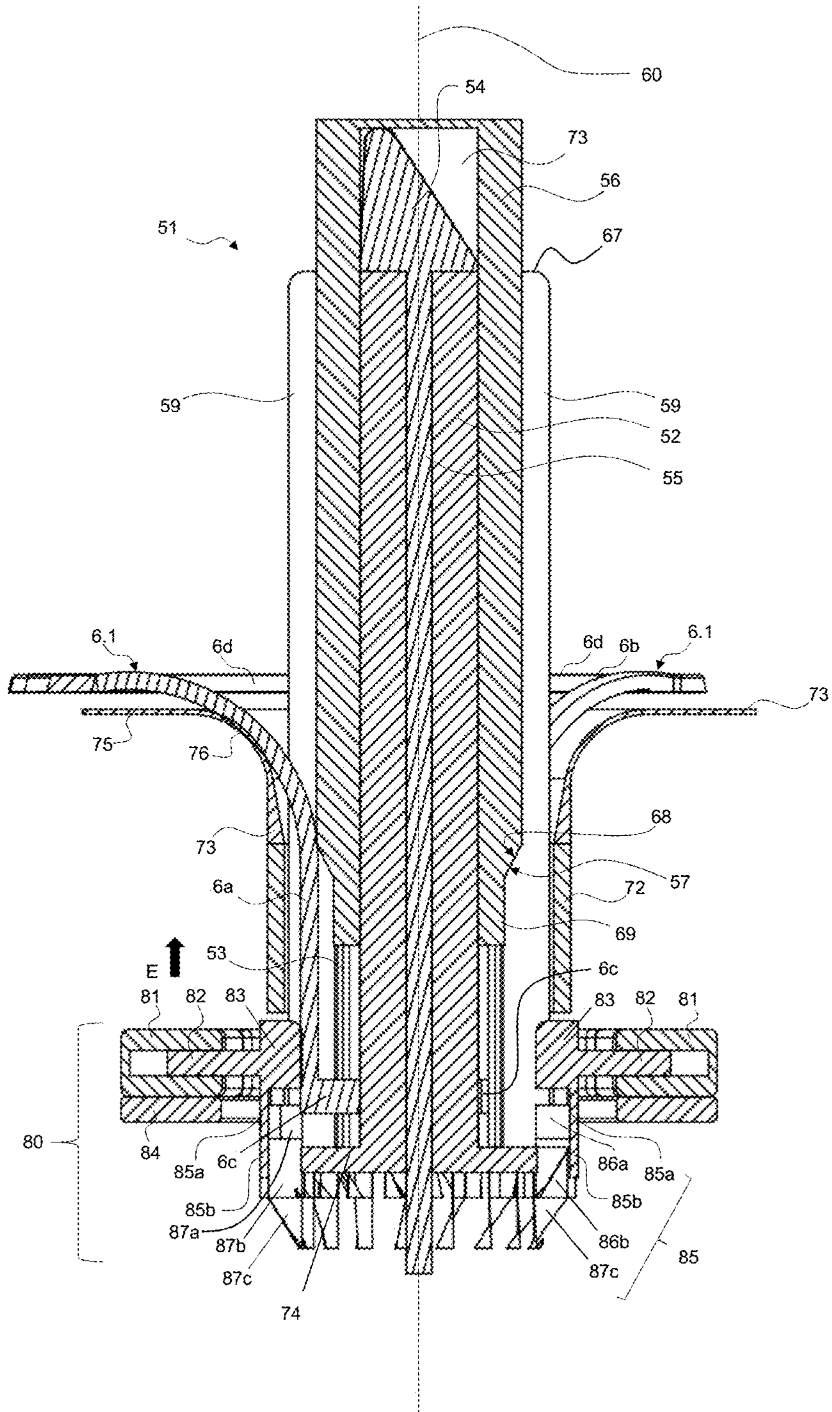
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Fig. 13a

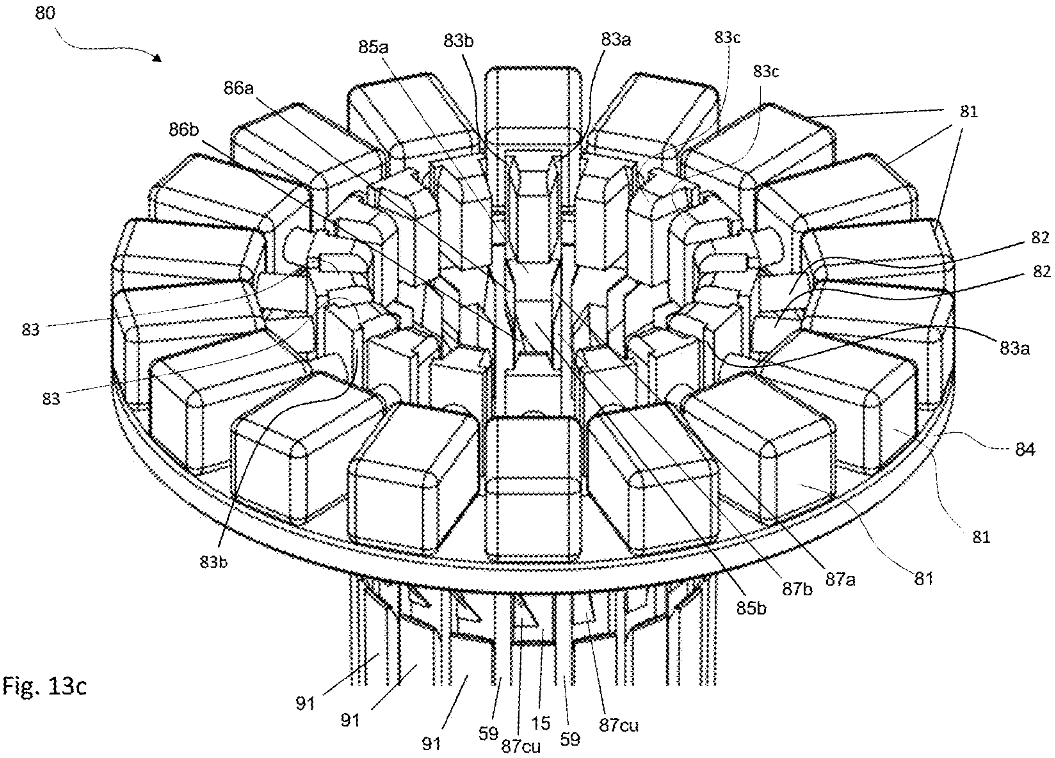

Fig. 13c

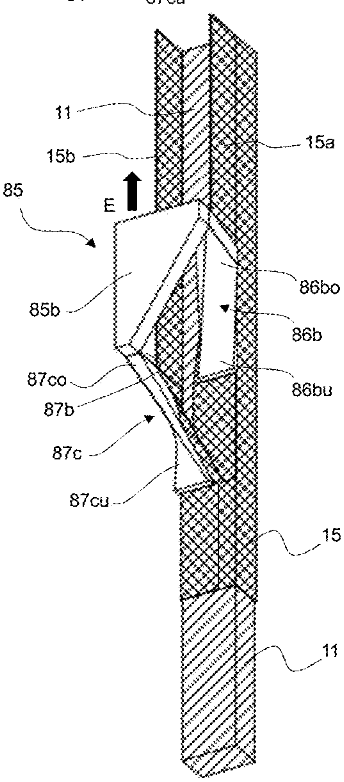

Fig. 13d

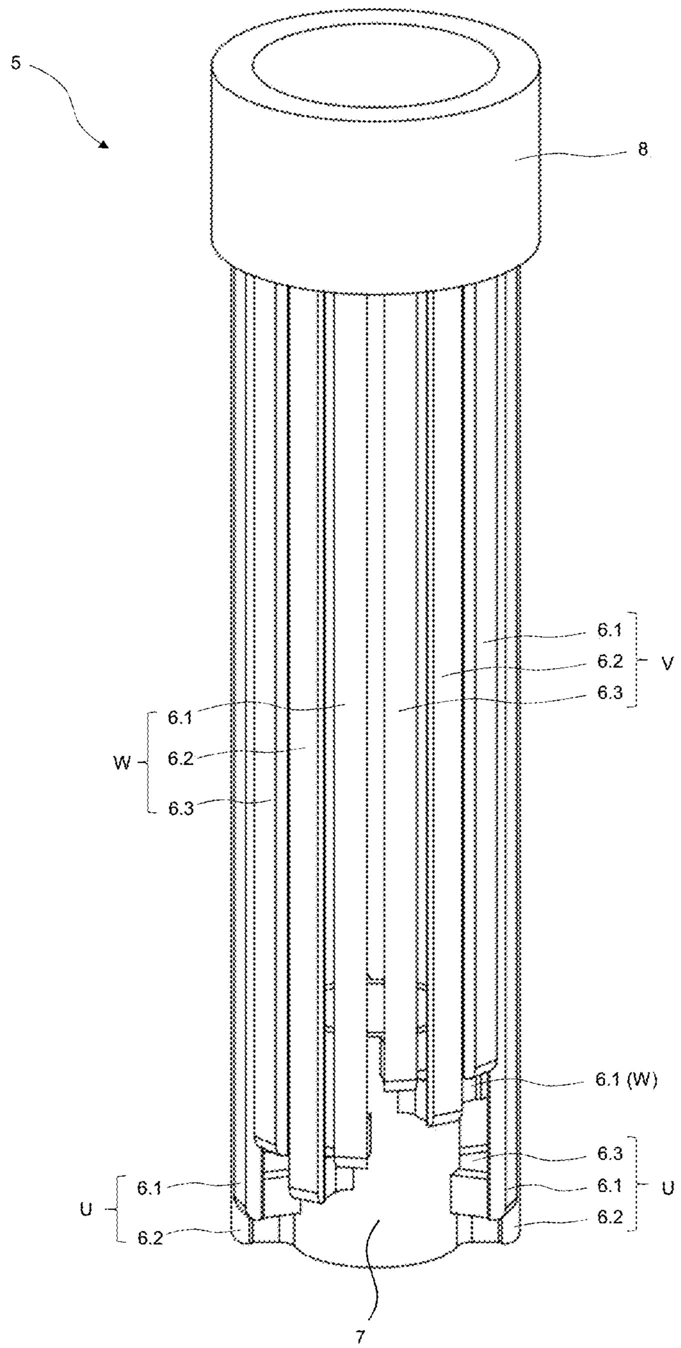

Fig. 13e

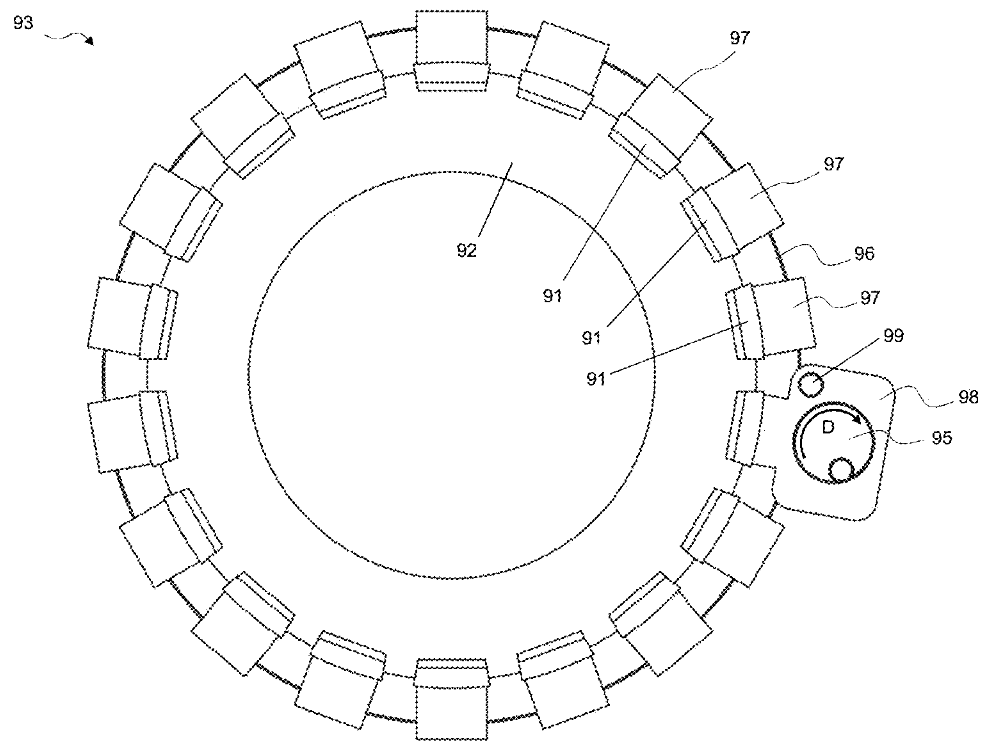

Fig. 13f

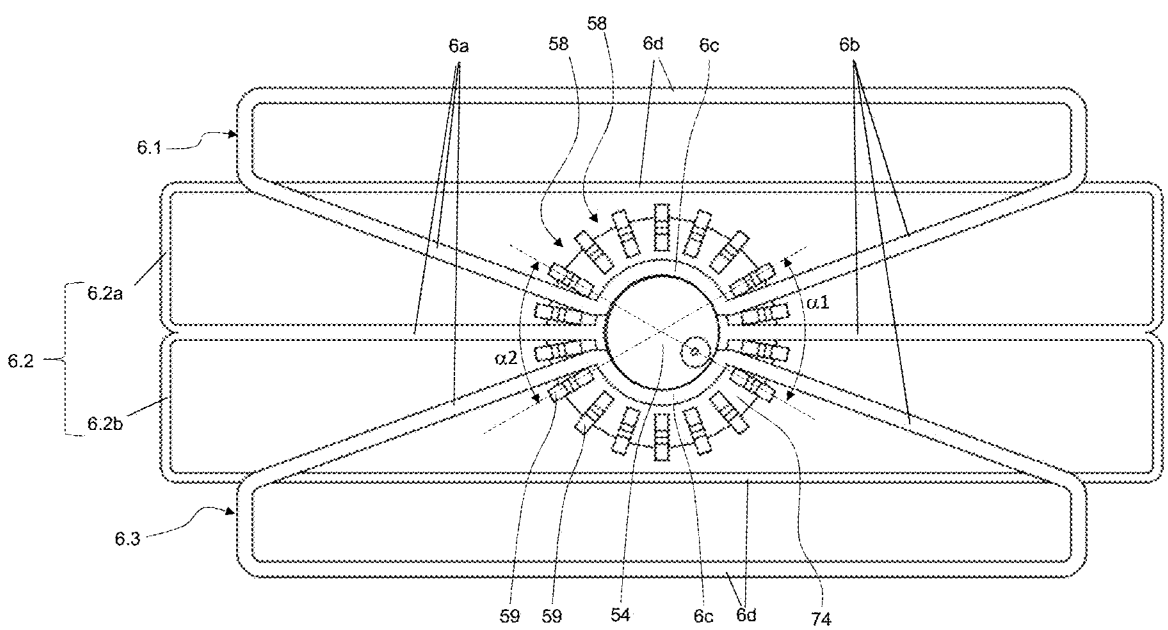

Fig. 13g

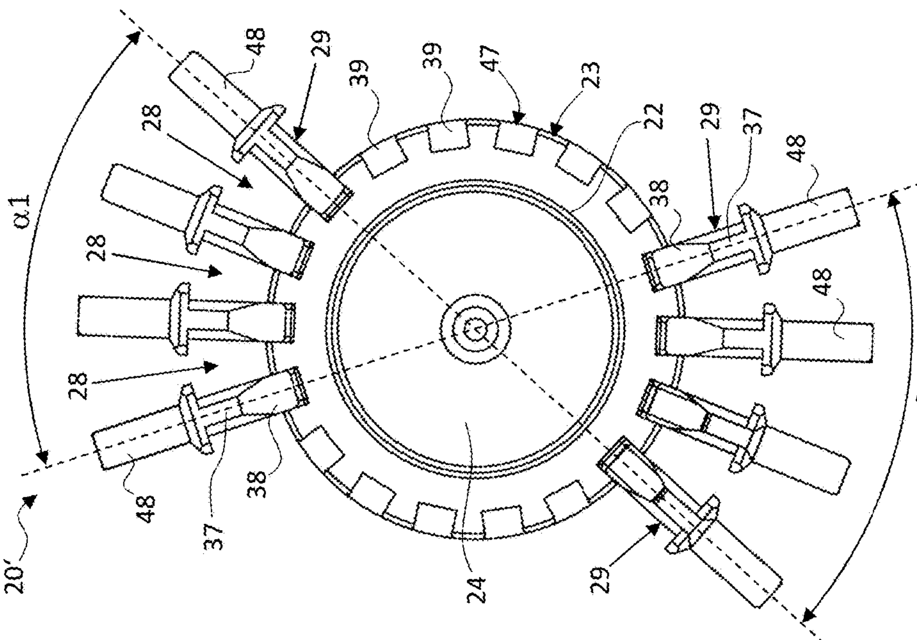

Fig. 4c

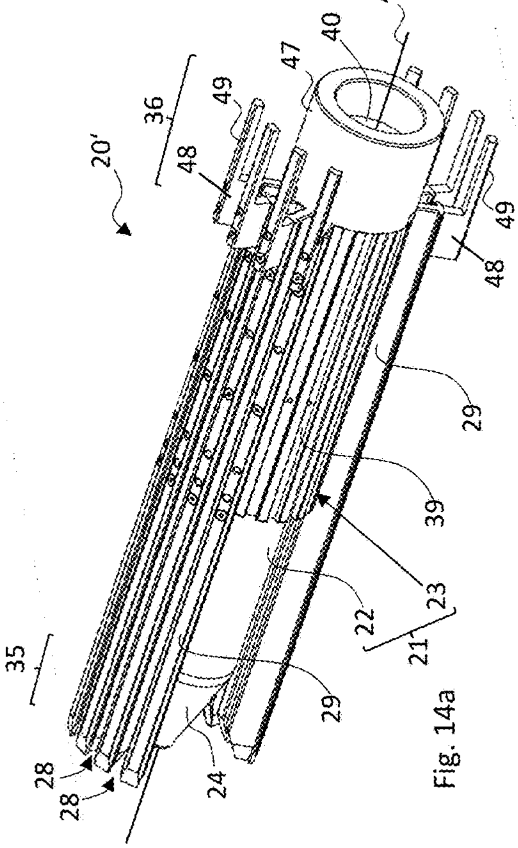

Fig. 14a

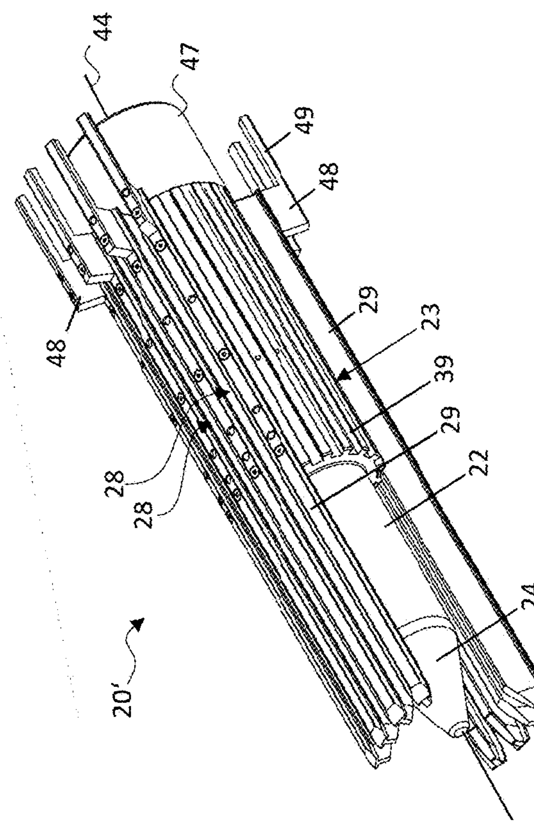

Fig. 14b

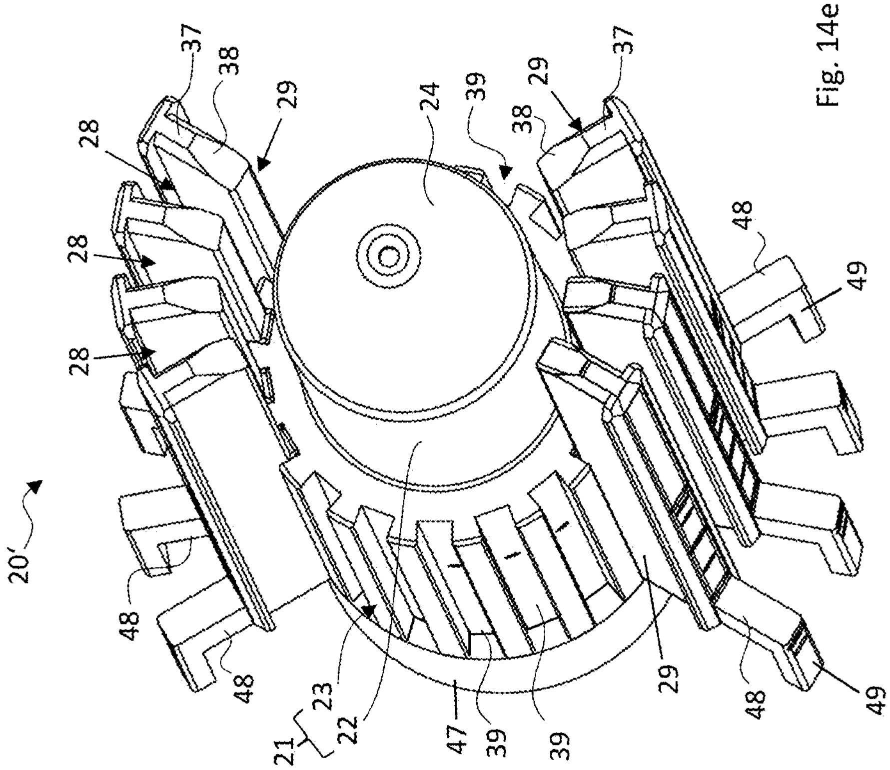

Fig. 14e

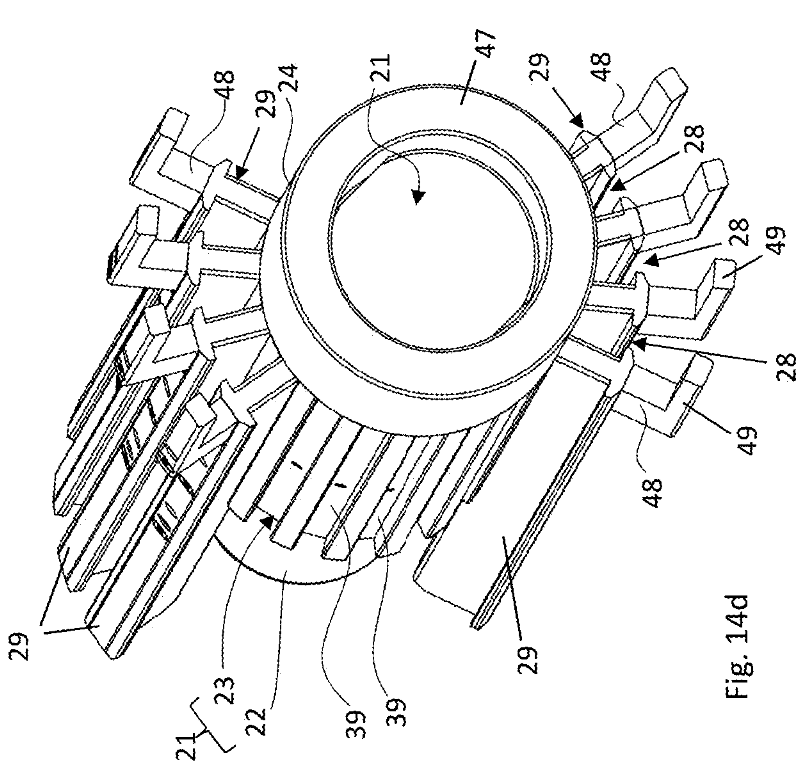

Fig. 14d

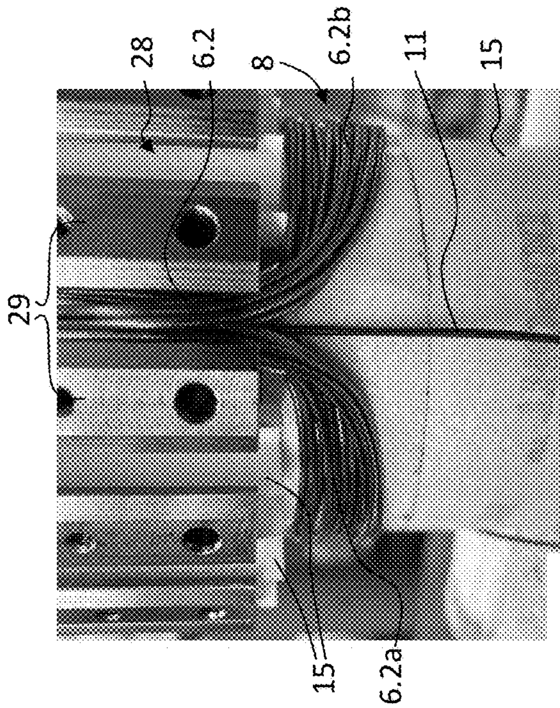

Fig. 15b

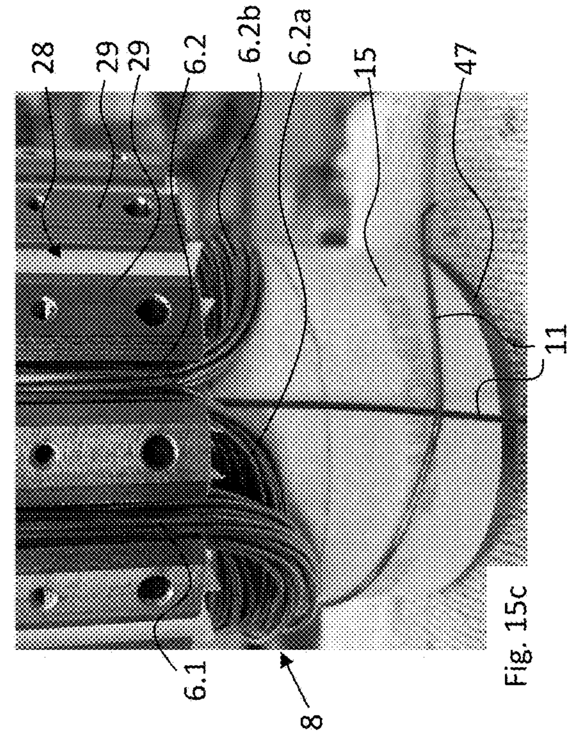

Fig. 15c

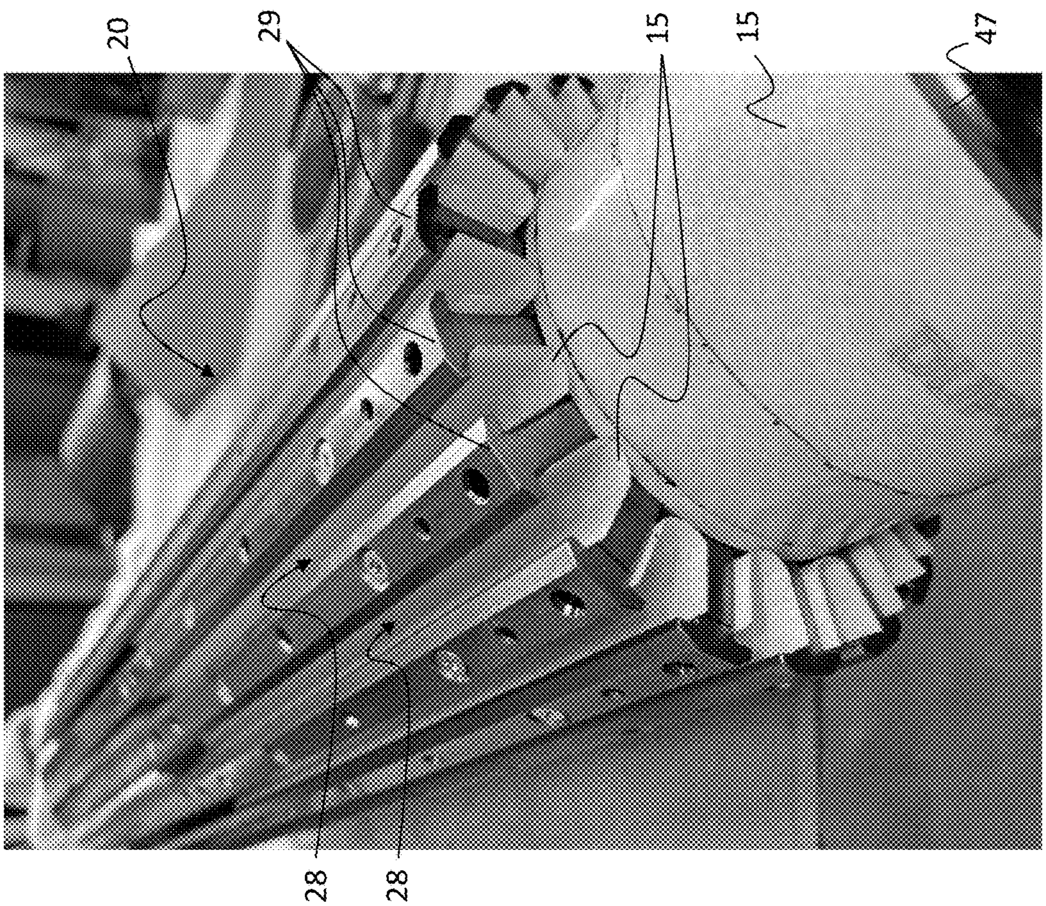

Fig. 15a

ELECTRIC MOTOR FOR A WELL PUMP AS WELL AS ASSOCIATED PRODUCTION METHOD

[0001] The invention relates to a method for manufacturing a coil assembly of an electric motor for a deep well vertical turbine pump with a stator assembly that has a stator bore to receive a rotor and slots radially open to the inside, which are respectively separated from each other by a stator tooth and in which electrical conductors of coils of the coil assembly lie, forming distributed windings and, at one axial end of the coil assembly, a winding head. Furthermore, the invention relates to a tool for manufacturing a coil assembly of distributed windings for axial insertion into the stator assembly of an electric motor.

[0002] Deep well vertical turbine pumps have an elongated, essentially cylindrical shape. They have a pump head driven by an electric motor, in which the pump head and the electric motor are installed in a single, cylindrical casing or in different casings with approximately the same outer diameter, for insertion into a well in accordance with their purpose. Thus the outer diameter of a deep well vertical turbine pump defines its range of use. It is small compared to the axial length of the deep well vertical turbine pump, often less than 20 cm. As a rule, deep well vertical turbine pumps with motors of various ratings and the same outer diameter therefore have different motor lengths, for example, up to 1.5 m in order to provide the required output.

[0003] Since the electric motor is also under high pressure of up to 50 bar, high quality standards apply for deep well vertical turbine pumps and their electric motors. Air pockets in deep well vertical turbine pumps are detrimental due to the ambient pressure. Wet rotor motors are therefore used in this application. This means that the rotor, which is typically equipped with permanent magnets as in a synchronous motor, rotates in the liquid being pumped or in another liquid. As a rule, the stator is encapsulated or also flooded by the liquid being pumped.

[0004] In the flooded version, the electrical conductors lying in the stator slots are usually what are known as submarine cables. These are bundles of copper conductors that are sheathed with synthetic material and therefore waterproof. Their synthetic insulation has a relatively large radial thickness of approx. 0.5 mm, increasing the overall diameter of a conductor bundle with a thickness of 1 mm to the size of the submarine cable at approx. 2 mm. From this it follows that a large proportion of the slot cross-section is needed for the insulation. Viewed differently, the slot cannot be filled with copper due to the insulation of the submarine cable. Consequently, this version has a lower filling factor and therefore requires a larger axial installation length to obtain a certain output than an electric motor with an encapsulated stator. Encapsulation means the plastic sheathing of the electrical conductors can be omitted, so that more electrical conductors fit into the slot cross-section. Electric motors with an encapsulated stator therefore have a higher power density with a larger copper cross-section in a stator slot.

[0005] The material used for encapsulation is typically a casting resin that fills the cavities between the unsheathed electrical conductors and between the electrical conductors and the stator assembly. The electrical conductors are encapsulated directly in the stator assembly, so that the casting resin also coats the stator assembly, if applicable penetrating it at least in part when it consists of individual plates in the usual manner, and/or even encapsulating the stator assembly entirely. Thus the stator forms a unit in which the coils are encapsulated.

[0006] A disadvantage of the encapsulated version is that the electric motor cannot be repaired, since non-destructive separation of the electrical part of the stator from the purely mechanical part, i.e. the stator assembly, is not possible. Instead the entire stator has to be disposed of in case of a defect, which is a disadvantage because mono-fraction recycling is not possible.

[0007] Motors wound using submarine cables on the other hand can be repaired by removing the submarine cables and simply rewinding the stator assembly with new submarine cables. However, the cables are very expensive and, as previously explained, reduce the degree of filling/copper cross-section in the slots. This results in a larger axial installation length of the motor and the deep well vertical turbine pump for the same output compared to the encapsulated type. Consequently it is currently not possible to rewind deep well vertical turbine pumps with a larger copper cross-section in the slots.

[0008] Thus one purpose of the present invention is to overcome at least some of the aforementioned disadvantages and to provide a method and a tool that makes it possible to manufacture a coil assembly for the electric motor of a deep well vertical turbine pump with encapsulated, distributed windings that can be axially inserted into the stator assembly of the electric motor and are replaceable.

[0009] This purpose is achieved by the method according to claim **1** and the tool according to claim **9**. Advantageous embodiments of the method and the tool are outlined in the corresponding dependent claims and are explained below.

[0010] According to the present invention, a method is proposed for manufacturing a coil assembly of an electric motor for a deep well vertical turbine pump with a stator assembly that has a stator bore to receive a rotor and slots radially open to the inside, which are respectively separated from each other by a stator tooth and in which electrical conductors, notably consisting of round wire, of coils of the coil assembly lie, forming distributed windings and, at one axial end of the coil assembly, a winding head. The coil assembly is manufactured by shaping and encapsulating the coils within the tool so that the winding head extends only between an inner diameter and an outer diameter that is smaller than the diameter of the stator bore in order to enable axial insertion of the coil assembly into the stator assembly leading with the winding head, in which the coils are respectively wound individually, drawn into the tool as wire bundles and encapsulated within it.

[0011] The electric motor can be manufactured with the following steps:—

- **[0012]** Providing a stator assembly that has a stator bore to hold a rotor and slots that are radially open to the inside, respectively separated from each other by a stator tooth,
- **[0013]** manufacturing a coil assembly by shaping and encapsulating coils created by winding electrical conductors, notably consisting of round wire, so that the coils form distributed windings and, at one axial end of the coil assembly, a winding head that extends only between an inner diameter and an outer diameter that is smaller than the diameter of the stator bore, and

[0014] axially inserting the coil assembly into the stator assembly, leading with the winding head, so that the coils are positioned to lie in the slots.

[0015] Thus the core of the invention consists of manufacturing the coil assembly ex situ and then inserting it axially into the stator as a whole. This means the coils are not inserted individually. To permit axial insertion, the winding head is radially offset to the inside into the stator bore relative to the stator slots, respectively relative to the stator teeth, so that the winding head is not aligned with the stator teeth or, in other words, so that the stator teeth and the winding head do not interfere with each other during axial joining. Thus the coil assembly can be easily inserted into the stator assembly. It can also be easily pulled out of the stator again and therefore can be changed in case of a defect.

[0016] The winding head comprises the whole of the segments of all coils of an electric motor with distributed windings that lie on one axial end of the stator and in which the axial-side coil segments of the individual coils lie axially above each other to extend from one slot to the next slot.

[0017] A distributed winding means the winding type of a coil of a phase whose windings are distributed across at least two stator slots that are separated by each other in space by more than one stator tooth. In other words, the at least two stator slots lie in angle segments at some distance from each other, in which additional angle segments with slots exist between the aforesaid angle segments with the windings of the coils of the other phases lying in them. For example, the two aforementioned stator slots in case of a two-pole, 3-phase machine lie in opposite angle segments of respectively 60°. Thus a distributed winding is differentiated from a concentrated winding that is wound around a single stator tooth or whose windings are arranged around it.

[0018] The coil assembly according to the invention has the advantage that it can be prefabricated with its encapsulated distributed windings and axially inserted into the stator assembly. This enables the straightforward, fast and cost-effective manufacturing and repair of electric motors for deep well vertical turbine pumps with distributed windings, respectively of deep well vertical turbine pumps as such.

[0019] The proposed new motor design with its coils manufactured and encapsulated outside the stator assembly combines the high power density of encapsulated systems with the ability to replace the stator winding and/or the coil assembly when needed. Due to the novel coil assembly, remaking the stator with the coils or the coil assembly is also faster than rewinding the stator assembly with submarine cables.

[0020] An unsheathed winding wire is logically used to manufacture the coils in order to fill the slot cross-section with the maximum of current conductors.

[0021] A copper winding wire coated with an insulating varnish can be used in the known manner. Alternatively a wire made of a different metal such as aluminium could be used as well.

[0022] To keep coil manufacturing simple, the winding wire is a round wire in the known manner, ideally with a diameter between 0.6 mm and 2 mm.

[0023] The winding wire is used to produce a number of individual coils with a number of windings by correspondingly winding the wire along a closed ring. Where applicable, the required coil shape can be formed simultaneously, at least approximately. Insofar as the coil shape produced during winding as such is not yet suitable for insertion into the stator assembly, a wound coil (raw coil) can be brought into the required final coil shape by a mechanical shaping process.

[0024] A self-adhesive winding wire can be used to make the wound coils inherently stable. The winding wire may be coated with a thermosetting varnish where required. Heating the coil after winding cements the windings with each other, also making the coils inherently stable.

[0025] The wound coils, shaped where required and made inherently stable where required, are subsequently encapsulated to meet the insulation requirements in the deep well vertical turbine pump.

[0026] According to the present invention, the coils are manufactured individually and subsequently encapsulated together, along with the winding head, namely within the same tool. Here all coils can be encapsulated together, producing a one-piece cast body that is axially inserted into the stator assembly. Alternatively, only some of the coils can be encapsulated, for example, all coils belonging to the same phase, producing a multi-part, for example, a three-part cast body. This multi-part cast body can be subsequently assembled and axially inserted into the stator assembly in this assembled form. Thus the coil assembly can also be formed by a multi-part cast body of cast body sections axially inserted into each other, in which all coils of a phase are preferably encapsulated together in each cast body section.

[0027] In all of the versions, the coils on the part of the winding head or the first winding head respectively have at least the following features:

[0028] a first radial segment that connects to a first longitudinal coil segment projecting from a first slot of the stator assembly,

[0029] one curved segment connected to the first radial segment and extending along an arc to a second slot of the stator assembly, in which a second longitudinal coil segment lies, and

[0030] a second radial segment that connects the curved segment to the second longitudinal coil segment.

[0031] The first radial segment turns the path of the coil from the axial direction coming out of the slot towards the motor axis, into the annular space between the inner diameter and the outer diameter, so that the winding head is not aligned with the stator teeth. The second radial segment turns the path of the coil from this annular space back into alignment with the second slot in order to continue in the axial direction.

[0032] The curved segment preferably lies on a circle around the stator axis.

[0033] For manufacturing the coil assembly as a one-part or multi-part cast body, an advantageous winding concept is obtained by the coils lying in the slots, distributed so that a second coil of a phase lies in a first slot and a second slot diametrically opposite the first slot, and a first and third coil of the phase respectively lie in two slots that lie in the same circumferential semi-circle relative to the second coil. This results in a minimal length of the winding head segments of the second and third coils in the winding head or the first winding head.

[0034] To obtain a symmetrical winding head, the second coil can consist of two coil sections or, at least in the winding head, divide into two coil sections that, in the winding head, extend in opposite circumferential directions from the first slot to the second slot. The two coil sections preferably have the same number of windings, notably half the number of windings of the two other coils. They are connected in series, preferably wound continuously with the same winding wire, so that the second coil has the same number of windings in total as the first and third coils.

[0035] The motor is preferably a three-phase motor. Alternatively it can be a five-phase motor.

[0036] Furthermore, the motor is preferably a two-pole motor. However, it may also be a four-pole or even an eight-pole motor.

[0037] Each phase preferably has three coils, but four or more coils per phase may be present as well.

[0038] The coils of the same phase are connected in parallel or series to form a coil group. The coil groups can be connected, for example, in a star or delta formation.

[0039] The coils can lie in the slots in one or two layers.

[0040] Overall a three-phase motor with three coils per phase thus has nine coils, so that the stator of such a motor has eighteen slots given a single-layer arrangement of the coils. In case of a two-layer arrangement, the stator only has nine slots since the longitudinal segments of two coils are arranged in each slot.

[0041] The number of windings of the coils can be chosen arbitrarily depending on the slot cross-section, for example, between 20 and 80, preferably between 40 and 60, and in particular can preferably be **50**.

[0042] According to the present invention, the coil assembly is manufactured by respectively winding the coils individually, drawing them into the tool as wire bundles and encapsulating them within it.

[0043] For the execution of the method, the tool for manufacturing the coil assembly of distributed windings for axial insertion into the stator assembly of an electric motor appropriately comprises a winding support having a central guide cylinder and fins arranged at a distance from it, corresponding in number to the stator teeth, so that there is an annular space between the guide cylinder and the fins that is open in the axial direction towards an insertion end to receive at least one coil wound in the form of a wire bundle and to form a winding head segment of the coil in the annular space, in which there is a longitudinal cavity respectively between two fins adjacent to each other in the circumferential direction in order to form respectively one longitudinal coil segment of the coil.

[0044] It can then be provided that

[0045] a. a coil is inserted from the insertion end into the annular space so that it extends radially through a first of the longitudinal cavities into the annular space, extends in a curve to a second longitudinal cavity and emerges from it again radially,

[0046] b. the coil is subsequently pushed away from the insertion end towards the opposite axial end by a heading tool in the form of a hollow cylinder guided on the guide cylinder, where it forms the winding head segment of the coil lying in the winding head,

[0047] c. subsequently, a drawing device is moved from the second axial end radially outside along the fins to the insertion end in order to fold up the coil and press it into the first and second longitudinal cavities until the insertion end is reached, where it wraps around the outer circumference of the fins with increasing tension, forming a second winding head segment of the coil that forms part of the second winding head.

[0048] The curved segment lies on a circle around the tool axis.

[0049] For the execution of step b. the tool can have a heading tool in the form of a hollow cylinder that can be inserted into the annular space and is guided on the guide cylinder, in order to push the coil(s) to the second axial end opposite the insertion end, and to there form a first winding head segment of the coil(s) forming part of a first winding head of the coil assembly.

[0050] For the execution of step c, the tool can have a drawing device that is movable to the insertion end, sliding radially along the outside of the fins, in order to fold up the coil(s). In this process, the coil is also pressed to a minor extent into the first and second longitudinal cavities.

[0051] Ideally the drawing device has a drawing cone that can preferably be hyperbolic viewed in the axial cross-section. During the movement of the drawing cone to the insertion end, the section of the coil(s) lying outside the fins slides along the inside of the drawing cone, aligning the coil parallel to the first and second longitudinal cavities. Preferably the hyperbolic section of the drawing cone transitions to a cylindrical section that is in contact with the outside of the fins. This causes the coil(s) or more precisely the longitudinal segment of the coil(s) to be pressed into the first and second longitudinal cavities.

[0052] Steps a. through c. can be performed sequentially for the remaining coils. Alternatively, step a. can be repeated directly for several or even all coils, and steps b. and c. can be subsequently performed for all coils simultaneously.

[0053] After drawing in and folding up the coils, a sleeve can be put axially over the fins, sliding to the insertion end starting from the second axial end, radially delimiting the second winding head in an end position in order to form a casting mould for the same.

[0054] Consequently, the tool can have a sleeve that can be put over the outside of the fins, sliding toward the insertion end to an end position, in order to encompass a second winding head segment of the coil(s) forming part of a second winding head in this position, forming a casting mould.

[0055] Subsequently or simultaneously, a locking mechanism with a number of locking rods corresponding to the number of longitudinal cavities can be inserted into the longitudinal cavities, preferably axially, in order to close them to form a casting mould.

[0056] Consequently, the tool can have a locking mechanism, with a number of locking rods corresponding to the number of longitudinal cavities that can be moved into the longitudinal cavities, notably axially, in order to close these to form a casting mould.

[0057] The locking mechanism can have at least one locking ring in order to jointly push the locking rods radially into the longitudinal cavities. For this purpose, the locking ring can surround the locking rods along an outer circumference. To exert a consistent radial compressive force on the locking rods, a means to reduce the diameter of the locking ring can be provided. The locking mechanism can also comprise two or more locking rings arranged at intervals from each other at different axial heights of the tool.

[0058] After the longitudinal cavities are closed, the coils can be encapsulated in the tool.

[0059] Preferably the guide cylinder can have a rotatable eccentric cone at the insertion end. The eccentric cone has a shell surface that is steeper on one side than on the opposite side. This facilitates receiving a coil at the insertion end, or more precisely, the arrangement of its winding head segment in the annular space. For insertion of the coil into the winding support, the eccentric cone can be rotated to a position where the less steep side of the eccentric cone faces the desired curved course of the coil in the annular space from the first to the second longitudinal cavity. This generally facilitates the insertion of the coil from above into the annular space and shaping the curved segment of the coil. The coil slides along the eccentric cone into the annular space.

[0060] In particular, the eccentric cone facilitates the insertion and shaping of the curved segment of a coil or coil section that, according to the present invention, is to be arranged in two diametrically opposite longitudinal cavities, because the tip of the eccentric cone is offset relative to a diameter at the insertion end on which the two longitudinal cavities lie. If the head of the guide cylinder were a cone, its tip would lie on the diameter, so that an additional measure would be required to bring the coil onto the right or left side of the cone. If the curved segment of the coil or coil section is to extend along the left semicircle in reference to the aforementioned diameter, the eccentric cone can be rotated to a position where its tip is offset to the right relative to the diameter. Consequently the less steep side of the eccentric cone then faces to the left. If the curved segment of the coil or coil section is to extend along the right semicircle in reference to the aforementioned diameter, the eccentric cone can be rotated to a position where its tip is offset to the left relative to the diameter. Consequently the less steep side of the eccentric cone then faces to the right.

[0061] For the purpose of automation, it is advantageous for the coil to be wound into the wire bundle above the tool, notably the insertion end, using a flyer winder, and to be subsequently dropped into the tool, notably the winding support. This is done so the coil drops into the aforesaid first and second longitudinal cavities at the insertion end. The coil segment between the first and second longitudinal cavities, in contrast, falls onto the eccentric cone and slides down its less steep side into the annular space.

[0062] According to an advantageous embodiment, the drawing device can include a press ring actuating element that can slide along the winding support to the insertion end, having a number of sliding dies in an annular arrangement corresponding to the number of longitudinal cavities, so that each sliding die projects into one of the longitudinal cavities in order to press the coil(s) radially into the first and second longitudinal cavities. The press ring actuating element is preferably arranged below the drawing cone and ideally can be moved to the insertion end together with it.

[0063] In the process, each sliding die can support itself on a shock resistant block, relative to which it is radially moveable, in which the sliding dies can be pushed into the shock resistant blocks against a restoring force. The shock resistant blocks push the sliding dies radially toward the tool axis, thereby exerting the force required to press the coil(s) into the longitudinal cavities.

[0064] Additional characteristics, advantages and properties of the invention are described in more detail below with the help of embodiments of the invention and the included figures. Identical reference numbers or reference marks in the figures identify components, parts, surfaces or directions that are identical or at least have the equivalent effect.

[0065] Please note that the terms "have", "comprise" or "contain" in no way exclude the existence of additional characteristics within the scope of the present description. Furthermore, the use of the indefinite article for an object does not exclude its plural.

[0066] The terms or word elements "radial", "axial", "circumferential" or "in circumferential direction" used in the present description generally refer to the longitudinal axis of the stator or the tool, unless otherwise specified.

[0067] Characteristics of an embodiment of the invention may also exist in another embodiment unless this is technically excluded. Furthermore, process features described for one of the fixtures and fixture characteristics described here may exist in the method described here.

LIST OF FIGURES

[0068] FIG. **1**: Cross-section of a stator assembly of an electric motor according to the state of the art

[0069] FIG. **1***a*: Illustration of the assignment of the slots of the stator assembly to the phases

[0070] FIG. **1***b*: Schematic view of the electric motor in an exploded view

[0071] FIG. **1***c*: Schematic view of a coil winding pattern according to the present invention

[0072] FIG. **2**: Perspective view of a two-layer coil assembly made of encapsulated single coils with a view of the shaped first winding head

[0073] FIG. **3***a*-**3***c*: Various views of a single coil of the coil assembly according to FIG. **2**

[0074] FIG. **4**: Perspective view of another two-layer coil assembly made of encapsulated single coils

[0075] FIG. **5***a*-**5***b*: Two different views of a single coil of the coil assembly according to FIG. **4**.

[0076] FIG. **6***a*-**6***b*: Snapshots during the joining of single coils according to FIG. **5***a*, **5***b* to make the coil assembly according to FIG. **4**

[0077] FIG. **7***a*-**7***d*: Snapshots during the axial joining of the stator assembly and coil assembly according to FIG. **4**

[0078] FIG. **8***a*-**8***c*: Various perspective views of a one-layer coil assembly made of encapsulated single coils according to another embodiment

[0079] FIG. **9***a*-**9***c*: A tool for drawing in and encapsulating coils in a radial cross-section

[0080] (FIG. **9***a*), an axial cross-section (FIG. **9***b*) along the section boundary A-A according to FIG. **9***a* and in an exploded view (FIG. **9***c*)

[0081] FIG. **10***a*: View of a test tool according to FIG. **9***a*-*c* with coils drawn in

[0082] FIG. **10***b*: View of the test tool according to FIG. **9***a*-*c* with the first sleeve in place

[0083] FIG. **11***a*-**1***b*: Views of the coil assembly as a cast body before (FIG. **11***a*) and after axially sliding on the stator (FIG. **11***b*)

[0084] FIG. **11***c*-**11***d*: Views of the cast body according to FIG. **11***a* with view of the radially inner first winding head (FIG. **11***c*) and radially outer second winding head (FIG. **11***d*)

[0085] FIG. **12***a*-**12***f*: Various snapshots of a tool during execution of the method according to the present invention for manufacturing the stator assembly by drawing in and folding over the coils

[0086] FIG. **13***a*-**13***b*: Longitudinal sections through the tool for drawing in and folding over the coils at the point in time shown in FIG. **12***d* (FIG. **13***a*) and the point in time shown in FIG. **12***f* (FIG. **13***b*)

[0087] FIG. **13***c*: Perspective view of the press ring actuating element from FIG. **12***c* FIG. **13***d*: Individual depiction of a guiding and folding element arrangement of the press ring actuating element from FIG. **12***c*

[0088] FIG. **13***e*: Encapsulated coil assembly manufactured according to the present invention by drawing in and folding over using the tool in FIG. **12***c*

[0089] FIG. **13***f*: Top view of the locking mechanism of the tool in FIG. **12***c*

[0090] FIG. **13***g*: Top view of the tool in FIG. **12***c* with three coils of a phase

[0091] FIG. **14***a*-**14***c*: Tool for needle winding and encapsulating the coils of a single phase in a first (FIG. **14***a*) and second (FIG. **14***b*) perspective view and in a top view (FIG. **14***c*)

[0092] FIG. **14***d*-**14***e*: Enlarged views of the axial ends of the tool according to FIG. **14***a*-**14***c*

[0093] FIG. **15***a*: Perspective view of the tool for needle winding and encapsulating the coils with insulated longitudinal cavities

[0094] FIG. **15***b*-**15***c*: Views of the tool according to FIG. **15***a* with a view of the interconnected second winding head with a first coil drawn in (FIG. **15***b*) and two coils drawn in (FIG. **15***c*).

[0095] Embodiments of the invention for the composition of an electric motor for a deep well vertical turbine pump with a coil assembly **5** according to the present invention are described below.

[0096] The electric motor has a stator made of a mechanical stator assembly **1** and an electric coil assembly **5**. The stator assembly **1** has a stator bore **9** with a diameter db to receive a rotor **13** mounted on a motor shaft **14** and slots **4** that are open radially to the inside, more precisely towards the stator bore **9**, delimited in the circumferential direction on both sides by respectively one stator tooth **3**, so that the stator teeth **3** and the stator slots **4** alternate along the inner circumference of the stator assembly **1**. One such stator assembly **1** is shown in FIG. **1** and is commonly known. It consists of a number of plates insulated against each other in the axial direction. The stator teeth **3** transition to a stator ring **2**. The stator teeth **3** can be of one piece with the stator ring **2** or attached to it, for example, with positive locking such as a dovetail joint. Merely by way of example, the stator assembly **1** in FIG. **1** has eighteen slots **4**; however, the number of slots **4** may be higher or lower.

[0097] For the composition of the electric motor as an induction motor, in the simplest case a three-phase motor supplied by three phases U, V, W, the electric motor has a coil assembly **5** with coils **6** made of electrical conductors **11** formed by what are called distributed windings. In a distributed winding, the corresponding coil **6** of a phase U, respectively its electrical conductor **11**, extends within a first slot **4***a* and a second slot **4***b*, separated from each other by several stator teeth **3**, so that additional slots **3** lie between the first and second slots **4***a*, **4***b* in which the coils **6** of other phases V, W are arranged. In case of a two-pole electric motor, the first slot **4***a* and second slot **4***b* lie opposite each in the simplest case or are at least arranged within opposite angle segments $\alpha 1$, $\alpha 2$ of the stator circumference assigned to the same phase U, V, W; see FIG. **1***a*. In case of a four-pole electric motor, these angle segments are offset relative to each other by 90°.

[0098] FIG. **1***a* shows the assignment of the coils **6** to the phases U, V, W and slots for a two-pole motor. A number X/2 of coils **6** are arranged in the X slots **4**, i.e. there are nine coils **6** in the present example with X=18 slots. Respectively three of these coils are assigned to a phase U, V, W, connected in parallel and thus forming a group. The groups are electrically interconnected, for example, in a star or delta formation. Each group or phase U, V, W is distributed over two opposite angle segments $\alpha 1$, $\alpha 2$.

[0099] The stator assembly **1** has a first axial end and a second axial end. It can have a length between 30 cm and 1.50 m. In the embodiments shown here, the coils **6** respectively form a winding head **7**, **8** on the two axial ends of the stator assembly **1** respectively the coil assembly **5** in order to transition from the first slot **4***a* to the second slot **4***b*. Thus a winding head **7**, **8** is formed by the coil segments **6***c*, **6***d* of different coils **6** at an axial end of the coil assembly **5** lying against each other, or more precisely lying over each other axially at least in part.

[0100] The central idea according to the present invention is to form the coil assembly **5** from encapsulated single coils or as a cast body with coils embedded in it, however in a manner independent of the stator assembly **1** as opposed to the state of the art. Thus the coil assembly, i.e. the electrical part of the stator, is manufactured outside the stator assembly. Subsequently the coil assembly **5** is axially inserted into the slots **4** of the stator assembly **1**. In order to accomplish this, the intent according to the present invention is for a first of the two winding heads **7**, also called the shaped winding head **7** in the following, to extend only between an inner diameter di and an outer diameter d_a, in which the outer diameter d_a is smaller than the diameter D_b of the stator bore **9**. Thus the shaped winding head **7** is offset radially to the inside towards the motor axis **10** relative to the stator teeth **3**, creating the clearance required to slide the stator teeth **3** between the encapsulated coils **6** during axial joining, as illustrated in FIG. **1***b* and described in more detail below.

[0101] Accordingly, a method for manufacturing an electric motor comprises the steps:—

- **[0102]** providing a stator assembly **1** that has a stator bore **9** to hold a rotor and slots **4** that are radially open to the inside, respectively separated from each other by a stator tooth **3**,
- **[0103]** manufacturing a coil assembly **5** of encapsulated coils **6** or by encapsulating coils made by winding round wire (winding wire) electrical conductors **11** so that the coils **6** form distributed windings and, at one axial end of the coil assembly **5**, a winding head **7** that extends only between an inner diameter di and an outer diameter d_a, in which the outer diameter d_a is smaller than the diameter d_b of the stator bore **9**, and
- **[0104]** axially inserting the coil assembly **5** into the stator assembly **1**, leading with the winding head **7**, so that the coils **6** are positioned to lie in the slots **4**.

[0105] A coil **6** is made of a winding wire continuously wound N times. Thus each coil **6** is a wire bundle consisting of N windings, for instance **50** windings, so that N single wires form the coil **6** viewed in cross-section but are actually segments of the continuous winding wire. The single wires, respectively wire segments, are the electrical conductors of the coil **6**. The winding wire is usually a copper round wire coated with an insulating varnish, with a diameter between 0.6 mm and 2 mm.

[0106] Four different methods for manufacturing the coil assembly **5** as a cast body are described below, in which the coil assemblies **5** themselves also differ from each other with regard to the winding heads **7**, **8**. The third method, hereinafter referred to as “drawing in/folding technique”, including the tool shown in FIGS. **12***a-f* and **13***a-g*, is the object of the claims.

[0107] Encapsulated Single Coils

[0108] According to a first method, the coil assembly **5** is made of individually encapsulated coils **6** that are subsequently nested inside each other to form the coil assembly **5**.

[0109] FIG. **2** shows a section of a coil assembly **5** produced in this manner with a view of the first winding head **7**, also called the shaped winding head **7** in the present description. Here the coil assembly **5** comprises 18 coils **6** so that each coil **6** lies in two slots **4** but each slot **4** holds two coils **6**, lying in an upper winding and a lower winding when viewed radially. In other words, the coil assembly has a two-layer structure. A coil **6** of this coil assembly is shown in various views in FIG. **3***a* through **3***c*. The coils **6** are all formed the same in this embodiment.

[0110] Each coil essentially consists of four coil segments, namely a first and second longitudinal coil segment **6***a* and a first and second winding head segment **6***c*, **6***d*. The two longitudinal coil segments **6***a*, **6***b* run parallel and lie radially opposite each other. The two winding head segments **6***c*, **6***d* lie axially opposite each other.

[0111] The first longitudinal coil segment **6***a* extends within the first slot **4***a* axially from the second winding head **8** to the first winding head **7**, while the second longitudinal coil segment **6***b* extends within the second slot **4***b* axially from the first winding head **7** back to the second winding head **8**. However, the two longitudinal coil segments **6***a*, **6***b* lie on different circumferences in reference to the motor axis **10**, since the first longitudinal coil segment **6***a* forms the lower winding in the first slot **4***a* and the second longitudinal coil segment **6***b* forms the upper winding in the second slot **4***b* and therefore lies farther out radially than the first longitudinal coil segment **6***a*.

[0112] The first winding head segment **6***c* is part of the first winding head **7** and connects the end of the first longitudinal coil segment **6***a* of the coil **6** emerging from the first slot **4***a* with the end of the second longitudinal coil segment **6***b* entering the second slot **4***b*. Correspondingly the second winding head segment **6***d* is part of the second winding head **8** and connects the end of the second longitudinal coil segment **6***b* of the coil **6** emerging from the second slot **4***b* with the end of the first longitudinal coil segment **6***b* entering the first slot **4***a*.

[0113] The shape of the first winding head segment **6***c* is significant here; it can be seen in FIG. **3***a*-**3***c* and is carried out in the form of an “offset end winding”. It consists of five segments that transition to each other, comprising a first S-shaped segment **6***ca*, which connects to the first longitudinal coil segment **6***a*, a first curved segment **6***cb*, a central U-shaped segment **6***cc*, a second curved segment **6***cd* and a second S-shaped segment **6***ce* that connects to the second longitudinal coil segment **6***b*.

[0114] The first S-shaped segment **6***ca* turns the path of the coil coming from the axial direction of the first longitudinal coil segment **6***a* radially inward, so that the coil **6** is brought out of alignment with the corresponding stator slot **4**, or viewed differently, projects radially over the stator teeth **3** flanking the slot. In this embodiment, the path is subsequently changed again from the radial direction back to the axial direction, but on a circumference with a diameter d_a that is smaller than the diameter d_b of the stator bore **9**.

[0115] The first curved segment **6***cb* connecting to the first S-shaped segment **6***ca* extends along an arc in the circumferential direction around the motor axis **10**, in which it also rises in the axial direction away from the stator body **1**, creating space for the winding head segments **6***c* of the other coils **6**. The U-shaped segment **6***cc* with its legs extending axially away from the stator body **1** connects the two curved segments **6***cb*, **6***cd* approximately in the middle section of the winding head segment **6***c*. Here the leg connecting to the first curved segment **6***cb* lies radially on the outside and the second leg connecting to the second curved segment **6***cd* lies radially further inward in reference to the motor axis **10**; see FIGS. **3***b* and **3***c*. Thus the U-shaped segment **6***cc* lies in an axial plane intersecting the motor axis **10**.

[0116] The second curved segment **6***cd* and the second S-shaped segment **6***ce* are essentially symmetrical counterparts of the first curved segment **6***cb* and first S-shaped segment **6***ca*. However, the second curved segment **6***cd* extends along an arc around the motor axis **10** with a smaller diameter or radius than the arc of the first curved segment **6***cb*. Furthermore, the second curved segment **6***cd* ends axially in the direction of the stator assembly **1**, offset relative to the first curved segment **6***cb*; see FIG. **3***b*.

[0117] The second winding head segment **6***d* consists of three segments transitioning to each other, comprising a first curved segment **6***da* that connects to the first longitudinal coil segment **6***a*, a central U-shaped segment **6***db* and a second curved segment **6***dc* that connects to the second longitudinal coil segment **6***b*. Thus the second winding head segment is also carried out in the form of an offset end winding. Compared to the first winding head segment **6***c*, the second winding head segment **6***d* omits changing the path of the coil radially inward, so that the second winding head segment **6***d*, or more precisely the curved segments **6***da* and **6***dc*, lies/lie axially in front of the stator teeth **3**. Thus the U-shaped segment **6***db* lies radially farther out, so that the inside diameter of the second winding head **8** is larger than the outer diameter of the rotor **13**, allowing it to pass by the second winding head **8** during axial joining.

[0118] All coils **6** are shaped identically so that the same forming and casting tool can be used, and so that no special sequence of the coils needs to be considered while assembling the single coils into the coil assembly.

[0119] After winding the coil, the resulting wire bundle is wrapped with an insulating material and shaped as shown in FIGS. **3***a*, **3***b* and **3***c*, notably bent. Alternatively the wire can also be shaped first and subsequently wrapped with the insulating material. In this case a binding, tape, cord or spiral coiled tube can be used as the insulating material, in which the insulating material is wrapped around the wire bundle in a spiral. According to another version, the coil **6** can also be wound directly in the required shape, eliminating the need for a separate shaping step.

[0120] The wound wire bundle wrapped with the insulating material is subsequently placed into a casting mould, where it is encapsulated with a sealant. The insulating material ensures that the coil **6** is covered by a sufficient thickness of the sealant on all sides since it serves as a spacer element to the casting mould. A casting resin, for example, can be used as the sealant.

[0121] As an alternative to wrapping the wire bundle with the insulating material as described above, the casting mould can be lined with such an insulating material, for example, in the form of an insulating paper. The wire bundle can be placed on the paper, which is folded over the wire bundle so that it fully encloses the wire bundle.

[0122] According to a different manufacturing method, it is also possible to simultaneously use the casting mould to produce the required shape of the coil **6**. Thus shaping the wire bundle is realised directly through insertion and adaptation to the casting mould. Furthermore, it is possible for winding or laying the windings of the winding wire to take place directly in the casting mould, eliminating a separate shaping step.

[0123] FIG. **4** shows an embodiment of a coil assembly **5** as an alternative to FIG. **2**. Here the coil assembly **5** also has a two-layer structure and comprises 18 coils, so that two coils **6** lie in each slot **4** in the form of an upper winding and a lower winding.

[0124] The shape of the single coils **6** in this alternative embodiment is shown in FIGS. ***5**a* and ***5**b*. It differs from the first version in FIGS. **2** and ***3**a*-***3**c* to the effect that, on the part of the first winding head **7**, a U-shaped segment lies radially on the outside, so that the first S-shaped segment ***6**ca* on the part of the winding head **7** of the first version can be omitted. Here the coil assembly **5** has a torpedo-like overall shape. Once again the coil **6** essentially consists of four coil segments, namely a first and second longitudinal coil segment ***6**a* and a first and second winding head segment ***6**c*', ***6**d*. Only the differences of the second version compared to first version are pointed out in the following.

[0125] The first winding head segment ***6**c*' consists of four segments transitioning to each other, comprising a straight segment ***6**a*' that forms an extension of the first longitudinal coil segment ***6**a*, a U-shaped segment ***6**ca*' that connects to the straight segment ***6**a*', a curved segment ***6**cbr* and an S-shaped segment ***6**ccr* that connects to the second longitudinal coil segment ***6**b*; see FIG. ***5**a*, ***5**b*. Due to the straight segment ***6**a*', the U-shaped segment ***6**ca*' projects axially beyond the S-shaped segment ***6**ccr*. The straight segment ***6**a*' transitions to a leg of the U-shaped segment ***6**ca*', whose other leg lies radially further inward so that the U-shaped segment ***6**ca*' lies in an axial plane encompassing the motor axis **10**. The second leg of the U-shaped segment ***6**ca*' turns the path of the coil back in the axial direction towards the stator assembly **1** and then transitions to the curved segment ***6**cbr*, which extends in the circumferential direction along an arc, overcoming the axial offset between the U-shaped segment ***6**ca*' and the S-shaped segment ***6**ccr*. Thus the curved segment ***6**cbr* also takes a helical path here. The arc lies on a diameter d_a that is smaller than the diameter d_b of the stator bore **9**. Thus the curved segment ***6**cbr* is not aligned with any stator slots **4** or stator teeth **3**, ensuring that the coil assembly **5** can be joined axially relative to the stator assembly **1**. Furthermore, the curved segment ***6**cbr* therefore ends at a radial distance from the second longitudinal coil segment ***6**b*. This distance is bridged by the S-shaped segment ***6**ccr*.

[0126] The shape of the second winding head segment ***6**d* is essentially identical to the first embodiment and consists of a first curved segment ***6**dar*, a U-shaped segment ***6**dbr* and a second curved segment ***6**dcr*, in which the U-shaped segment ***6**dbr* lies approximately in the centre between the curved segments ***6**dar*, ***6**dcr* and extends through the motor axis **10** within an axial plane with its legs. This axial plane is offset by approximately 90° relative to the axial plane in which the U-shaped segment ***6**car* of the first winding head segment ***6**c*' extends. The first curved segment ***6**dar* extends along a first arc and the second curved segment ***6**dcr* extends along a second arc that runs radially farther inward compared to the first arc.

[0127] FIGS. ***6**a* and ***6**b* show two snapshots of the arrangement of coils **6** to form the coil assembly **5** by nesting the single coils **6** inside each other. Two coils **6** lie next to each other in FIG. ***6**a* and six coils **6** lie next to each other in FIG. ***6**b*. It is clear that the curved segments ***6**cbr* of the coils **6** lie axially above each other, or more precisely lie against each other axially.

[0128] FIG. ***7**a* through ***7**d* illustrate the joining process of the coil assembly **5** relative to the stator assembly **1**, in which the coil assembly **5** is inserted axially into the stator assembly **1** in the direction of the arrow A in FIG. ***7**a*, leading with the first winding head **7**. In FIG. ***7**b* the first winding head ***7**b* already slightly protrudes axially from the stator assembly **1**. FIG. ***7**b* shows how the stator teeth **3** engage in the spaces between adjacent coils **6** of the stator assembly **5**. In FIG. ***7**c*, the stator assembly **1** is positioned almost in its final position relative to the coil assembly **5**. The end position is reached in FIG. ***7**d*. FIGS. ***7**c* and ***7**d* show that the first winding head **7** has a considerable axial length.

[0129] A third embodiment of a coil assembly **5** with individually encapsulated coils **6** is illustrated in FIG. ***8**a* through ***8**c*. Here the coil assembly **5** comprises nine coils **6**, so that each coil **6** lies in two slots **4** and exactly one coil **6** lies in each slot **4**. Thus the coil assembly **5** has one layer. In this third embodiment, the coils **6** are all different from each other, having different axial lengths, and the second winding head **7** is asymmetrical.

[0130] With each of the coils **6**, the first winding head segment ***6**c* is formed by three segments that transition to each other, namely a first radial segment ***6**ca*", a curved segment ***6**cb*" and a second radial segment ***6**cc*". The first radial segment ***6**ca*" connects to the first longitudinal coil segment ***6**a* and turns the path of the coil, coming from the axial direction, radially inward towards the motor axis **10** and subsequently in the circumferential direction. Connected to the first radial segment ***6**ca*" is the curved segment ***6**cb*", extending along an arc with a diameter d_a that is smaller than the diameter d_b of the stator bore **9**. The curved segment ***6**cb*" differs from the curved segments ***6**cb*, ***6**cd*, ***6**db*' of versions **1** and **2** in that its path is not helical, i.e. it does not extend in the axial direction but remains within the same radial plane. This ultimately results in the different axial lengths of the coils **6**. The second radial segment ***6**ca*" connects to the curved segment ***6**cb*" and turns the path of the coil, coming from the circumferential direction, to the radial direction and then to the axial direction before transitioning to the second longitudinal coil segment ***6**b*.

[0131] In the second winding head **8** of the third version, the second winding head segments ***6**d* of the coils **6** are also formed by three segments ***6**da*", *6db*", ***6**dc*", namely a first curved segment ***6**da*", a transition segment ***6**db*" and a second curved segment ***6**dc*", in which the transition segment ***6**db*" lies between the first and second curved segments ***6**da*", ***6**dc*". The first curved segment ***6**da*" connects to the first longitudinal coil segment ***6**a* and extends helically along an arc on a first circumference around the motor axis **10** to the transition segment ***6**db*", which forms a flat transition to a smaller diameter lying radially farther inward on a circumference around the motor axis **10**. Along an arc on this second circumference, the second curved segment ***6**dc*" extends helically or axially back in the direction of the stator assembly **1** and connects to the second longitudinal coil segment **6***b*; see FIG. **8***c*.

[0132] While the coil shapes differ between the two illustrated versions, the method for manufacturing the wound and individually encapsulated coils is identical; therefore, please refer to the explanations of the first version in this regard.

[0133] Drawing Technique

[0134] A second method proposes winding the coils **6** individually, i.e. laying the N windings and inserting the resulting wire bundles into a drawing tool. Through this insertion as such, the wire bundles are brought into a shape that approximates the final shape of the coil **6**. Then the wire bundle can be brought into the final shape by means of the heading tool in the drawing tool. This can be done sequentially for each single coil, for a coil group—e.g. for all coils belonging to the same phase—or even for all coils **6** simultaneously.

[0135] A suitable drawing and casting tool **20** is shown in FIG. **9***a* through **9***c*. FIG. **9***a* through **9***c* show the drawing and casting tool **20** in a top view (FIG. **9***a*), a section (FIG. **9***b*) along the section boundary A-A according to FIG. **9***a* and in an exploded view (FIG. **9***c*).

[0136] The drawing and casting tool **20**, referred to simply as the tool **20** in the following, comprises an oblong winding support **21** as the central element with a front axial end **35** and a rear axial end **36**. The winding support **21** consists of a front winding support segment **22** and a rear winding support segment **23**, respectively formed by a circular cylinder. The front winding support segment **22** has a smaller diameter than the rear winding support segment **23**, so that the front winding support segment **22** is offset relative to the rear winding support segment **23**, forming an annular space to hold the first winding head **7**. There is a seamless transition **46** between the two segments **22**, **23** of the winding support **21**. While the front and rear winding support segments **22**, **23** are in one piece in the illustrated embodiment, they can be separate components attached to each other in a different embodiment.

[0137] At the front axial end **35**, the winding support **21** has a cone **24** in the form of a taper. This facilitates drawing the coils **6** into the tool **20** and shaping them in the area of the first winding head **7**. Alternatively the cone **24** can be a separate component attached to the front winding support segment **22**.

[0138] The rear winding support segment **23** has a pin **40** at its axial end formed by an offset of the rear winding support segment **23**. Thus the pin **40** is in one piece with the rear winding support segment **23**. However, it could also be a separate component mounted on the rear winding support segment **23**.

[0139] As shown in FIG. **9***c*, the outer circumference of the rear winding support segment **23** has longitudinal slots **39** extending axially and parallel to the tool axis **44**. A fin **29** lies in each of these longitudinal slots **39** with a positive fit; the fins as a whole protrude from the winding support **21** in a star shape. Overall the tool **20** has eighteen slots **39** for eighteen corresponding fins **29**. The fins **29** extend to the axial end of the cone **24**. They have a rectangular cross-section along their entire axial length. Their narrow longitudinal side is screwed to the rear winding support segment **23**. This is done using screws inserted into corresponding bore holes **33** in the fins **29**. The fins **29** have additional bore holes **34** at various locations along their length, extending through the fins **29** and having an internal thread. They are intended for the installation of a corresponding shoulder screw. When this is screwed in to the maximum extent, it first contacts the winding support **21**. Continuing to screw in the shoulder screw causes the corresponding fin to be pushed off the winding support **21**. This helps release the fins from the winding support **21** when they are embedded in the cast body.

[0140] There is a longitudinal cavity **28** respectively between two fins **29** adjacent to each other in the circumferential direction, which serves to hold a coil **6**, or more precisely a longitudinal coil segment **6***a*, **6***b* of a coil. The fins **29** of the tool **20** correspond to the stator teeth **3** of the stator assembly **1**, in which the longitudinal cavities **28** correspond to the stator slots **4**.

[0141] The fins **29** extend beyond the rear winding support segment **23** so that they lie at a radial distance from the front winding support segment **22**, forming the aforementioned annular space. The axial face ends **37** of the fins **29** have a radial inner flat area **38** angled relative to the cone **24**, forming a funnel-shaped insertion opening that also facilitates drawing the coils **6** into the tool **20**.

[0142] The tool **20** also comprises three dies **25**, **26**, **27** that are moveable radially relative to the winding support **21** and shape a coil **6** drawn into the tool **20** by axially exerting a compressive force. A first die **25** and a second die **26** jointly form a die formation to shape the first winding head **7**, pushing the coils **6** in the tool **20** axially downward in the direction of the rear winding support segment **23**. The two dies **25**, **26** are axially guided on the front winding support segment **22** for this purpose.

[0143] The first die **25** consists of a ring **42** mounted on the front winding support segment **22**, with radially projecting teeth **43** integrated on its outer circumference that also extend in the axial direction beyond the ring **42** to the rear winding support segment **23**. Two teeth **43** adjacent to each other in the circumferential direction respectively define a slot-like space in which one of the fins **29** lies with a positive fit according to the present invention. Correspondingly each of the teeth **43** extends with a positive fit into one of the longitudinal cavities **28** formed between two fins **29** adjacent to each other in the circumferential direction. Thus the first die **25** encompasses the fins **29** with a positive fit. Viewed in cross-section, the teeth are trapezoidal and their radially outer width is greater in the circumferential direction than their radially inner width.

[0144] The second die **26** is a sleeve in the form of a circular cylinder that is mounted on the front winding support segment **22**. Its axial face end is supported on the inside of the ring **42** so that the teeth **43** encompass the outside of the die **26** with a positive fit. A pressing force is thus exerted on the second die **26** by the first die **25** exerting a radial pressing force.

[0145] The third die **27** is also a sleeve in the form of a circular cylinder. It encompasses the fins **29** radially on the outside by contacting the radially outer longitudinal sides of the fins **29** with its inner circumference. The third die **27** can also be omitted. It is not shown in FIG. **9***c*.

[0146] Completing the drawing tool **20** with a first and second sleeve **30**, **31** as well as a cover **32** forms a complete casting tool **20** in which the coils **6** can be encapsulated without pressure.

[0147] The first sleeve **30** is a circular cylinder that, like the die **27**, encompasses all fins **29** radially on the outside by contacting the radially outer longitudinal sides of the fins **29** with its inner circumference. Along the inner circumference, the sleeve **30** has axially extending longitudinal slots **41** in which the fins lie with their radially outer longitudinal sides with a positive fit. Thus the first sleeve **30** delimits the longitudinal cavity **28** in the radial direction to the outside and therefore forms part of the casting mould. Consequently, the coils **6** are encapsulated within the first sleeve **30**.

[0148] The longitudinal cavities **28** are closed in the axial direction by the cover **32**. It forms an annular disk **32** that, in the installed state, lies with its opening **45** on the pin **40** and is moved up to the offset between the pin **40** and the rear winding support segment **23** so that it contacts the axial face end of the rear winding support segment **23**. The second sleeve **31** is also a circular cylinder. It encompasses the outer circumference of both the annular disk **32** and the end of the first sleeve **30** facing it axially. The second sleeve **31** delimits the space holding the second winding head **8** to be encapsulated radially to the outside.

[0149] The tool **20** is used as follows:

[0150] The two sleeves **30**, **31** and the three dies **25**, **26**, **27** are initially removed so the tool **20** serves as a drawing tool. The longitudinal cavities **28** are open radially to the outside and towards the front axial end **35**.

[0151] A coil is initially wound, forming an annular wire bundle by laying the winding wire in N loops that form the N windings of the coil. Then the wire bundle is insulated with an insulating material, as previously explained for the embodiment with the encapsulated single windings. However, the longitudinal cavities **28** may also be lined with an insulating material, for example, a folded insulating paper, so that insulating the wire bundle outside the tool **20** can be omitted. Then the wire bundle is inserted into the tool **20**.

[0152] The wire bundle is drawn in at the front axial end **35** by pressing the wire bundle extending radially on the face end between the first two fins **29**, which delimit the first longitudinal cavity **28** that is to receive the coil **6**. Then the wire bundle is guided over the front axial end **35** to the second two fins **29**, which delimit the second longitudinal cavity **28** that is to receive the coil **6**. In case of a two-pole electric motor, the first two fins **29** and the second two fins **29** lie in diametrically opposite angle segments α1, α2; see FIG. **1***a*. In doing so, the wire bundle is moved past the cone **24** and extending radially on the face end, is pressed between the second two fins **29**.

[0153] During this process, the remainder of the wire bundle hangs outside in front of the fins **29**.

[0154] Subsequently the wire bundle is drawn down in the direction of the rear axial end **36**, in which it contacts the cone **24**. In doing so, the first and second die **25**, **26** are used to press the wire bundle axially into the tool **20** until it contacts the stepped transition **46**. Here the second die **26** is guided on the front winding support segment **22**. At the stepped transition **46** coming from the first longitudinal cavity **28**, the wire bundle radially enters the annular space formed between the fins **29** and the front winding support segment **22**, occupied in FIG. **9***b* by the second die **26**, and then extends in a curve within this annular space in a radial plane to the second longitudinal cavity **28**, which it enters radially coming out of the annular space. The segment of the wire bundle lying in the annular space corresponds to the first winding head segment **6***c* in FIG. **3***a*-**3***c*, **5***a*, **5***b*.

[0155] Then the wire bundle is pressed into the first and second longitudinal cavity **28** so that it extends axially within the longitudinal cavities **28** to the rear axial end **36**. The segments of the wire bundle lying in the longitudinal cavities **28** correspond to the longitudinal coil segments **6***a*, **6***b* in FIG. **3***a*-**3***c*, **5***a*, **5***b*.

[0156] Since the wire bundle forms a closed ring, the segment of the wire bundle forming the second winding head segment **6***d* in FIG. **3***a*-**3***c*, **5***a*, **5***b* remains radially outside the fins **39** during this step. This stays that way during the remainder of the process as well, so that the second winding head does not lie axially in front of the stator teeth **3**, as in versions **1** through **3**, but is radially offset relative to it and lies axially in front of the stator ring **2**.

[0157] Consequently, the wire bundle emerges radially from the two longitudinal cavities **28** at the rear axial end **36** and then extends in the circumferential direction radially outside in front of the fins from the first to the second longitudinal cavity **28**. With the third die **27**, the wire bundle or more precisely its second winding head segment lying radially outside the fins **29** can be pushed in the direction of the cover **32** until it contacts the cover **32**. Here the third die **27** is guided by the outer longitudinal side of the fins **29**. The wire bundle is stretched overall during this pressing step. The second winding head segment lies in a second annular space that is occupied by the third die **27** in FIG. **9***b*.

[0158] The described method is repeated for all coils/wire bundles.

[0159] As described above, the tool **20** comprises eighteen fins **29** so that eighteen longitudinal cavities **28** can also be formed. Thus the tool **20** is intended for manufacturing a coil assembly **5** for a two-pole motor with three coils **6** per phase U, V, W (see FIG. **1***a*), so that nine coils have to wound in total and drawn into the tool **20**. Naturally the tool **20** can also have a different number of fins **29**, respectively cavities **28**, in other embodiments.

[0160] In order to draw the three coils **6** per phase into the tool **20**, there is a special assignment of the longitudinal cavities **28** to the three coils **6**. FIG. **1***c* illustrates this assignment. Insofar the method uses a special winding concept.

[0161] As illustrated in FIG. **1***c*, the coils of each phase U, V, W are distributed over two opposite angle segments α1, α2, β1, β2, and γ1, γ2 of the inner circumference of the stator, in which each angle segment comprises three adjacent slots **4** to hold the three coils of a phase U, V, W. The first phase U is examined in the following, comprising a first coil **6.1**, a second coil **6.2** and a third coil **6.3**, whose first longitudinal coil segments **6***a* lie in the three adjacent slots **4.1**, **4.2** and **4.3** of the first angle segment α**1**, and whose second longitudinal coil segments **6***b* lie in the three adjacent slots **4.10**, **4.11** and **4.12** of the second angle segment α2.

[0162] To obtain symmetrical winding heads **7**, **8**, the intent is for a coil **6** to respectively lie in those two slots **4** of opposite angle segments that are nearest each other viewed in the circumferential direction, i.e. that have the shortest distance between them on the face end of the stator assembly **1** in the circumferential direction.

[0163] In order to realise this, the intent is for the third coil **6.3**, which lies in the far right slot **4.3** of the first angle range α1 in order to get from the second winding head **8** to the first winding head **7**, to also use the far right slot **4.10** of the second angle range α2 to get from the first winding head **7** back to the second winding head **8**. Correspondingly the first coil **6.1**, which lies in the far left slot **4.1** of the first angle range α1 to get from the second winding head **8** to the first winding head **7**, also uses the far left slot **4.12** of the second angle range α2 to get from the first winding head **7** back to the second winding head **8**. Thus the first and third coils **6.1**, **6.3** do not use any slots **4** that are opposite each other. This is however necessary for the second coil **6.2** because it lies in the middle between the first and third coils **6.1**, **6.3**. To obtain a symmetrical winding head **7**, **8**, the wire bundle of the second coil **6.2** is divided in half, forming two partial bundles **6.2***a*, **6.2***b* that are routed in circumferential directions opposite to each other.

[0164] In reference to the drawing tool **20**, whose longitudinal cavities **28** correspond to the slots **4** of the stator assembly **1**, this means that a first coil **6** of a phase that is inserted into a first longitudinal cavity **28** is not routed to the diametrically opposite longitudinal cavity **28**, but to the one that lies two longitudinal cavities **28** closer in the anticlockwise direction. Subsequently the second longitudinal cavity **28** that is adjacent to the first longitudinal cavity **28** in the clockwise direction is left empty and the third coil of the phase is drawn into the third longitudinal cavity **28** adjacent to that; this too is not routed to the diametrically opposite longitudinal cavity **28** but to the one that lies two longitudinal cavities **28** closer in the clockwise direction. Then the middle, second coil **6** is drawn in with its first two and second two partial bundles **6.2***a*, **6.2***b*. The partial bundles **6.2***a*, **6.2***b* are laid around the cone **24** or the front winding support segment **22** in opposite circumferential directions to each other on the part of the first winding head **7**. Furthermore, the partial bundles **6.2***a*, **6.2***b* are laid around the fins **29** in circumferential directions opposite to each other on the part of the second winding head **7**.

[0165] Contrary to the procedure that has been described, the second coil of a phase can also be drawn into the tool **20** first, followed by drawing in the first and third coils.

[0166] FIG. **10***a* shows the drawing tool **20** with coils **6** made of wire bundles wrapped with insulating material **15** drawn into the longitudinal cavities **28**. It clearly shows the first winding head **8** lying radially in front of the fins **29** and the division of the centre, second coil **6.2** into two partial bundles **6.2***a*, **6.2***b* realised within that, into which the coil **6.2** branches in the first winding head **8** in order to encompass the fins **29** respectively to the right and left. The two partial bundles **6.2***a*, **6.2***b* lie axially above the winding head segments of the first and third coils **6.1** and **6.3**, which makes it clear that the second coil **6.2** was drawn into the tool **20** after drawing in the first and third coils **6.1**, **6.3**.

[0167] Naturally, instead of dividing the second coil **6.2** of a phase in the winding heads **7**, **8**, two coil sections with N/2 windings can be produced directly as the second coil and drawn into the tool **20**. These coil sections with their corresponding longitudinal coil segments **6***a*, **6***b* are then inserted into the same longitudinal cavities **28**. The longitudinal coil segments **6***a*, **6***b* adjacent to each other can be wrapped individually with the insulating material **15** so that two wire bundles lie in the longitudinal cavities **28** of the second coil **6.2**, or jointly so that only one wire bundle lies in the longitudinal cavities **28** of the second coil **6.2**.

[0168] As previously described as well, the longitudinal cavities can be lined with an insulating material, for example, a folded insulating paper, instead of wrapping the wire bundles with the insulating material **15** outside the tool **20**.

[0169] To encapsulate the coils **6**, the three dies **25**, **26**, **27** are removed from the tool **20** and the first and second sleeves **30**, **31** are put over the tool. Then the sealant is poured into the tool **20** so that all coils **6** are encapsulated together, forming a monolithic cast body.

[0170] The cast body is demoulded after the sealant has hardened. To do so, the sleeves **30**, **31** are first pulled off; the first sleeve **30** is moved in the direction of the front axial end **35** and the second sleeve **31** in the direction of the rear axial end **36** relative to the cast body. Subsequently the fins **29** are released from the winding support **21**, notably unscrewed, and removed by pulling them out towards the front axial end **35**. Finally, the winding support **21** is pulled out of the cast body axially in the direction of the rear axial end **36**.

[0171] Various views of the demoulded cast body are shown in FIG. **11***a* through **11***d*. In FIG. **11***b*, a stator body **1** has been put axially over the cast body for illustrative purposes. The cast body forms the coil assembly **5**. It essentially consists of three segments, a first ring cylinder in which the first winding head **8** is encapsulated, a number of rods extending in parallel in which the longitudinal coil segments of the coils **6** are encapsulated, and a second ring cylinder in which the second winding head **7** is encapsulated.

[0172] On one end, the rods project radially to the inside in the form of teeth from the inner surface of the first ring cylinder, see FIG. **11***d*, and extend axially away from it. On the other end, they transition to the second ring cylinder and project radially away from its outer surface; see FIG. **11***c*. In other words, the second ring cylinder lies within the space framed by the rods. The clearances between the rods are provided to receive the stator teeth, as illustrated in FIG. **11***b* by means of the stator assembly **1** that has been put on.

[0173] Drawing/Folding Technique

[0174] According to a third method for manufacturing the coil assembly **5**, the coils **6** are folded starting from the first winding head **7** towards the second winding head **8** while drawing them into a corresponding winding support **51**. This procedure is called the drawing/folding technique here. The tool **50**, **51** that is used is shown in FIGS. **12***a-f* and **13***a-g*. FIG. **12***a*-**12***f* illustrates the state of the tool **50** with the winding support **51** at different points in time.

[0175] FIG. **12***a* shows the winding support **51** with three coils **6** of a first phase U, namely a first coil **6.1**, a second coil **6.2** and a third coil **6.3**, whose winding head segments **6***c* forming the first winding head **7** have already been drawn into the winding support **51**. Here the coils **6** are shown as having a rectangular cross-section and being massive, merely for illustrative purposes. However, as with the previous embodiments, these are bendable wire bundles consisting of winding wire, more precisely round wire, laid in a number N of windings.

[0176] The winding support **51** has a central guide cylinder **52** that is exposed at a first axial end **65** that forms an insertion end of the winding support **51** to receive the coils **6**. At the opposite second axial end **66**, an annular base plate **74** is integrated in one piece with the guide cylinder **52**; see FIG. **13***b*. However, the base plate **74** could also be a separate component. From the base plate **74**, a number of parallel fins **59** also rise in the axial direction, arranged equidistant along the periphery of the base plate **74** and partly projecting radially from the base plate **74**. This creates a guide for the locking rods **91** that are explained below. There is respectively one longitudinal cavity **58** between two fins **59** adjacent to each other in the circumferential direction, into which a longitudinal segment **6***a*, **6***b* of a coil is drawn. Furthermore, there is an annular space **71** between the central guide cylinder **52** and the fins **59** to guide each of the first winding head segments **6***c* of the coils **6** from a longitudinal cavity **58** along an arc around the guide cylinder **52** to another longitudinal cavity **58**, and to enable pushing this first winding head segment **6***c* within the winding support **51** in the axial direction to the second axial end **66** or in the direction of the base plate **74**.

[0177] The guide cylinder **52** has a head in the form of an asymmetrical cone **54** at the first end **65**, which serves as a deflecting eccentric and is referred to as the eccentric cone in the following. The eccentric cone **54** has a shell surface that is steeper on one side than on the opposite side. The eccentric cone **54** is connected to a rotatable pin **55** extending through the guide cylinder **52** and projecting from the underside of the base **74**. The eccentric cone **54** can be rotated around the central pin **55** to position the less steep shell surface so that it faces towards the curved segment **6***cb* to be formed on the coil **6** that is to be drawn in. The coil **6** then slides along the less steep side of the eccentric cone **54** down into the annular space **71**.

[0178] The annular space **71** is open in the axial direction at the first axial end **65** for insertion of the coils **6.1**, **6.2**, **6.3**. To facilitate insertion, the face ends **67** of the fins **59** are rounded. The fins **59** end at the same level as the guide cylinder **52** so that the eccentric cone **54** projects axially relative to the face ends **67** of the fins **59**.

[0179] As shown in FIG. **12***a*, the first and third coils **6.1**, **6.3** lie in the same radial plane and axially above the second coil **6.2**, i.e. on the side of the first axial end **65** (insertion end) of the second coil **6.2**. Consequently they were inserted into the winding support **51** after the second coil **6.2**. FIG. **13***g* shows the winding support **51** and the coils **6.1**, **6.2**, **6.3** with their arrangement in a top view. As already explained for the second embodiment, the second coil **6.2** consists of two coil sections **6.2***a*, **6.2***b* in order to obtain symmetrical winding heads **7**, **8**. The two coil sections **6,2***a*, **6.2***b* form common longitudinal coil segments **6***a*, **6***b* and are thus drawn into the same longitudinal cavities **58**.

[0180] The assignment of the longitudinal cavities **58** to the individual coils **6.1**, **6.2**, **6.3** is as explained in reference to FIG. **1***c*. Thus only the two longitudinal cavities **58** assigned to the second coil **6.2** lie diametrically opposite each other, while the two longitudinal cavities **58** respectively assigned to the second and third coils **6.1**, **6.3**, in reference to the second coil **6.2**, lie on the same side in the right or left half-space, or put differently, within the same circumferential semi-circle; see FIG. **13***g*.

[0181] The fins **59** have a rectangular cross-section. Their radial width is larger on the second axial end **66** than on the first axial end **65**, in which there is a linear transition **68** opposite the guide cylinder **52** between a first fin segment with the smaller radial width and the second fin segment with the larger radial width. The linear transitions **68** of the fins **59** respectively form part of an inner cone surface that serves as a support for a heading tool **56**, which has a corresponding outer cone **57**. Due to the different radial widths of the fin segments, the annular space **71** is radially wider in the area of the first fin segments than in the area of the second fin segments.

[0182] In FIG. **12***b* the aforesaid heading tool **56** has been moved into the winding support **51** in the axial direction of the arrow B, filling the annular space **71**, and has pushed the coils **6.1**, **6.2**, **6.3** to the second axial end **66** or in the direction of the base plate **74**. The heading tool **56** is carried out as a hollow cylinder, in which the central guide cylinder **52** extends into its inner cavity **73**; see FIG. **13***a*. The shell surface of the pressing cylinder **56** is formed by flat areas (facets) to fit flush against the radial inner face ends of the fins **59**. Given a number n of fins **59**, the outside cross-section of the heading tool **56** consequently forms an n-sided polygon.

[0183] The head **69** facing towards the second axial end **66** of the winding support **51** has a smaller outer diameter than the remainder of the heading tool **56**, in which there is a conical segment between the head **69** and the aforesaid remainder, forming the aforementioned outer cone **57**. FIG. **12***b* shows that the heading tool **56** contacts the linear transitions **68** of the fins **59** with its outer cone **57** so that these linear transitions **68** form stops for the heading tool **56** and thus define the maximum insertion depth for the heading tool **56**, which has been reached in FIG. **12***b*. Here the coils **6.1**, **6.2**, **6.3** lie axially in front of the head **69** with their first winding head segments **6***c*.

[0184] FIG. **12***c* now shows the tool **50**, **51** with the winding support **51** and the fixture **50** for drawing in and folding the coils **6**, which is also used for encapsulating them. The fixture **50** is moveable in the axial direction relative to the winding support **51**.

[0185] The fixture **50** comprises a drawing device **70**, **80** that is configured to fold up the coils **6** and press them into the longitudinal cavities **58**. The drawing device has a hyperbolic drawing cone **70** that is pushed axially over the winding support **51** starting from the second axial end **66** in the direction of the arrow C. The drawing cone **70** has a radial collar **75** in the form of an annular disk on which the individual coils **6** rest prior to folding. A hyperbolic segment **76** of the drawing cone **70**, see FIG. **13***a*, connects the collar **75** with a cylindrical segment **77** that encompasses the fins **59** radially on the outside and moves along them. During the axial movement of the drawing cone **70** to the first axial end **65** relative to the winding support **51**, the hyperbolic segment **76** progressively folds up the coils **6** so they line up in the axial direction parallel to the winding support **51**, whereby the longitudinal coil segments **6***a*, **6***b* are automatically pressed into the corresponding longitudinal cavities **58** from which they originally emerged radially starting from the first winding head **7**. The folding movement is illustrated in FIG. **12***d*, for which FIG. **13***a* shows a cross-sectional view along an axial section through the tool axis **60**. The section passes through the first coil **6.1** while the third coil **6.3** is not shown. In these figures the drawing device **70**, respectively the insertion cone **70**, has already been pushed partly over the winding support **51**.

[0186] Note that FIG. **13***a* shows the sectioned first coil **6.1** near the base plate **74**, i.e. much deeper than the heading tool **52** can push the first winding head segment **6***c* of the first coil **6.1**. This is because the coils **6** of the other phases have already been inserted into the winding support **51** as well, but are not shown in FIG. **13***a*. The first winding head segments **6***c* of these other coils **6** are between the winding head segment **6***c* of the first coil **6.1** and the heading tool **52**, which has consequently pushed all first winding head segments together ahead of it in the direction of the base plate. According to the present invention, the first winding head segment **6***c* of the second coil **6.2***m* lies between the first coil **6.1** and the base plate **74**, i.e. under the first coil **6.1**; see FIG. **12***a*, **12***b*.

[0187] On the side of the insertion cone **70** axially opposite the winding support **51**, there is a sleeve **72** that is moved together with the insertion cone **70** on the outside over the winding support **51** toward the first axial end **65** to an end position, where it forms a radial outer delimiter for encapsulating the second winding head **8**; see FIGS. **12***f* and **13***b*. A ring **88** is attached to the sleeve **72** for sealing and fully encompasses its outer circumference from the underside. It has an inner land for this purpose so that the inner radius of the ring **88** is larger on the side of the sleeve **72** than on the side facing away from it. The land forms a step **89** with which the ring **88** lies against the face end of the sleeve **72**.

[0188] Furthermore, the drawing device **70**, **80** comprises a press ring actuating element **80** shown by itself in FIG. **13***d*. It has a number of sliding dies **84** arranged in an annular shape, corresponding to the number of the longitudinal cavities **58**, which are pushed onto the winding support **51** following the sleeve **72** so that each sliding die **83** projects into one of the longitudinal cavities **58** in order to press the corresponding longitudinal coil segment **6***a*, **6***b* of the respective coil **6** deeper into the corresponding longitudinal cavity **58**. All sliding dies **84** collectively form a press ring. FIG. **13***a* shows that the radial face end of a sliding die **83** lies against the longitudinal coil segment **6***a* of the coil **6.3** and presses it radially inward. The sliding dies **83** move in this radial position between the fins **59** along the winding support **51** to the second winding head **8** at the first axial end **65**.

[0189] In order to perform the aforementioned task, the sliding dies **83** are approximately trapezoidal in their radial cross-section, projecting into a longitudinal cavity **58**, essentially form-fitting. The radially outer reverse side of the sliding dies **83** is extended towards the two circumferential sides by respectively one protrusion **83***a*, **83***b* so that a sliding die **83** is approximately T-shaped. FIG. **13***c* also shows that the top edge **83***c* of the sliding dies **83** facing the drawing cone **70** is rounded. This facilitates sliding along the longitudinal coil segments **6***a*, **6***b* as well as moving over coil segments projecting radially from the longitudinal cavity **58** and pushing them radially back into the longitudinal cavity **58**.

[0190] Each sliding die **83** is held in a respective shock resistant block **81** by a shaft **82**. The shock resistant blocks **81** are mounted on a mounting ring **84** in an annular arrangement so that the sliding dies **83** extend radially to the tool axis **60**. The sliding dies **83** are radially moveable relative to the shock resistant blocks **81** and can be pressed into the shock resistant blocks **81** against a restoring force. To this end, the shock resistant blocks **81** can be made of an elastic material or be filled with one, or contain a mechanical energy storage device such as a spring, in which the material or spring in its stress-free state pushes the shaft **82** with sliding die **83** away from itself and is compressed by a radial movement of the sliding die **83** to the outside.

[0191] The press ring actuating element **80**, as previously explained, is moved in the direction of the first axial end **65** to the second winding head **8**. Here the longitudinal coil segments **6***a*, **6***b* necessarily project radially from the longitudinal cavities **58** in order to then be curved to the right or left around the fins **59**. Due to the radial projection of the longitudinal coil segments **6***a*, **6***b* from the longitudinal cavities **58** toward the second winding head **8**, the sliding dies **83** are pushed radially outward into the shock resistant blocks **83** with the progressive axial movement toward the first axial end **65**. This in turn facilitates the movement of the press ring actuating element **80** over the sleeve **72**.

[0192] As shown in FIG. **12***e*, the press ring actuating element **80** in the end position of the sleeve **72** is moved farther up relative to the winding support **51**, namely to the outside over the sleeve **72**. To do so, the sliding dies **83** are also pushed into the shock resistant blocks **81** by the radial thickness of the sleeve **72** so that the press ring actuating element **80** can be moved over the sleeve **72**. The drawing device **70**, **80**, i.e. the drawing cone **70** and the press ring actuating element **80**, can be subsequently removed upward.

[0193] FIG. **13***d* illustrates a guiding and folding element **85** on its own, which has the press ring actuating element **80** below each sliding die **83**. The effect of the guiding and folding element **85** is also shown, which is intended for folding an insulation **15** in the form of an insulating paper during the movement of the press ring actuating element **80** around the electrical conductor **11** so that it is fully encased by the insulation **15**.

[0194] Here the electrical conductor **11** is shown as rectangular, merely by way of example, although it is a round or oval wire bundle in practice.

[0195] The longitudinal cavities **58** are lined with the insulation **15** prior to the insertion of the coils **6**. The insulation **15** has a U-shaped cross-section, in which a right side flank **15***a* and a left side flank **15***b* project radially from each of the longitudinal cavities **58**.

[0196] A guiding and folding element **85** consists of a back part **85***b*, here in the form of a right-angled triangle, with a first front end in the movement direction E that has a first folding blade **86***b* integrated on the right side and a rear end in the movement direction E that has a second folding blade **87***c* integrated on the left side. Thus the first and second folding blades **86***b*, **87***c* on the one hand are at a distance from each other axially, in which the first folding blade **86***b* leads, and on the other hand arranged opposite each other in reference to a longitudinal cavity **58**. Here the first folding blade **86***b* is intended for folding the right side flank **15***a* of the insulation **15** over the electrical conductor **11** and the second folding blade **87***c* is intended for folding the left side flank **15***b* of the insulation **15** over the electrical conductor **11**. The folding blades **86***b*, **87***c* essentially project at a right angle from the back part **85***b* in the direction of the longitudinal cavity **58**.

[0197] Each of the folding blades **86***b*, **87***c* is defined by a rectangular basic shape with a greater length than width. Both folding blades **86***b*, **87***c* extend opposite to the movement direction E with their longitudinal axis or, more simply put, to the rear.

[0198] The first folding blade **86***b* is twisted by 90° along its longitudinal axis so that its width from a radial alignment with the longitudinal cavity **58** at the proximal end **86***bo* transitions continuously to a parallel alignment with the longitudinal cavity **58** at the distal end **86***bu*, and the distal end **86***bu* simultaneously lies close to the cavity in order to contact the electrical conductor **11** as a tongue. As shown in FIG. **13***d*, the right side flank **15***a* of the insulation **15** is guided long the inner side of the first folding blade **86***b* facing the left side flank **15***b* and increasingly turned over or folded over the electrical conductor **11** due to the twist of its longitudinal axis during the movement of the guiding and folding element **85** in the direction E.

[0199] The second folding blade **87***c* is folded by 90° along its diagonal so that a first segment **87***co* on the right side of the diagonal folding line is positioned radially to the longitudinal cavity **58** and a second segment **87***cu* on the left side of the folding line lies parallel to the longitudinal cavity **58** and close to it in order to contact the electrical conductor **11** as a tongue. As shown in FIG. **13***d*, the left side flank **15***b* of the insulation **15** is guided along the inside of the second folding blade **87***c* facing the right side flank **15***a* and turned over or folded over the electrical conductor **11** due to the diagonal fold during the movement of the guiding and folding element **85** in the direction E.

[0200] Since the first folding blade **86***b* leads, the right side flank **15***a* of the insulation **15** is folded first, so that the second folding blade **87***c* folds the left side flank **15***b* of the insulation **15** over the previously folded first side flank **15***a*.

[0201] The first folding blade **86***b* is connected to the front end of the guiding and folding element **85** only on its longitudinal side at its proximal end **86***bo*, so quasi with a point connection. The guiding and folding element **85** at the same level opposite the first folding blade **86***b* has a side wall **87***b* that is integrated with the back part **85***b*. The left side flank **15***b* of the insulation **15** is guided along this side wall **87***b* as well. The second folding blade **87***c* projects from the side wall **87***b* with the first segment **87***co* integrated into the side wall **87***c*.

[0202] As illustrated in particular by FIGS. **13***a* and **13***c*, there is a guiding and folding element **85** of the type described above underneath each sliding die **83**. FIG. **13***a* shows that the sliding dies **83** have an axial extension **85***a*, **85***b* on their radially outer reverse side, pointing down or against the intended movement direction E of the drawing device **70**, **80**. The extension **85***a*, **85***b* is of one piece with the respective sliding die **83**. The extension **85***a*, **85***b* forms the guiding and folding element **85** and consists of a first extension segment **85***a*, **86***a*, **87***a*, axially connected directly to one of the sliding dies **83**, and a second extension segment **85***b*, **86***b*, **87***b* connected below that.

[0203] FIG. **13***c* shows that the first extension segment consists of a back part **85***a* and two guide walls **86***a*, **87***a* that are integrated on the sides of the back part **85***a* in the circumferential direction and project approximately radially to the fixture axis **60**. They ensure that the right and left side flanks **15***a*, **15***b* of the insulation **15** stay aligned with the longitudinal cavity **58** and do not project from it. The side flanks **15***a*, **15***b* of the insulation **15** are held between the guide walls **86***a*, **87***a*.

[0204] The second extension segment **85***b*, **86***b*, **87***b* is formed by the part of the guiding and folding element **85** shown in FIG. **13***d*, namely by the back part **85***b*, the first folding blade **86***b* and the side wall **87***b*, as well as the second folding blade **87***c*.

[0205] As shown further in FIG. **12***c*, the ring **88** with the land, which forms a step **89** in the transition from the side of the ring **88** facing the press ring actuating element **80** with a smaller radial thickness to the side of the ring **88** facing away from the press ring actuating element **80** with a larger radial thickness, lies axially below the press ring actuating element **80**.

[0206] The fixture **50** further comprises a locking mechanism **90** that, in the initial state of the method, is also located below the winding support **51** in order to move axially into the winding support **51** from the direction of the second axial end **66** up to an end position, which is shown in FIG. **12***e*, in order to radially close the longitudinal cavities **58** so the coils **6** can be encapsulated.

[0207] The locking mechanism **90** has a number of locking rods **91** corresponding to the number of longitudinal cavities **58** that are intended for form-fitting insertion into the longitudinal cavities **58**. For this purpose, the locking rods **91** are positioned equidistant in an annular arrangement and, on their end opposite the winding support **51**, joined together as one piece with a common supporting ring **92**. Approximately in the middle in reference to their axial overall length and in the middle of the lower half, the locking rods **91** have respectively one locking ring **93**, **94** that pushes the locking rods **91**, or more precisely all locking rods simultaneously, radially inward. FIG. **13***f* shows the upper locking ring **93** in a top view of the locking mechanism **90**. The structure of the second locking ring **94** is identical.

[0208] Each of the locking rings **93**, **94** is formed by an annular arrangement of track blocks **97** mounted on the radial outer side of the locking rods **91** at the same axial height so that all track blocks **97** lie in the same radial plane. The track blocks **97** on their reverse side facing away from the corresponding locking rod **91** have a track **97***a* that is bordered by two axially opposite side flanks **97***b*, **97***c*; see FIG. **13***b*. A tensioning belt **96** passing around the locking rods **91** and connecting the track blocks **97** lies in the track **97***a*, held in position by the side flanks **97***b*, **97***c* so it cannot slip out of place.

[0209] A holder **98** is arranged on one of the locking rods **91** respectively at the height of the first and second locking rings **93**, **94** for a torque rod **95** that passes through these holders **98** and is held within them so it can rotate. As shown in FIGS. **13***b* and **13***f*, each of the holders **98** bears a cylindrical pin **99**, on the circumference of which the corresponding tensioning belt **96** is routed tangentially and on which the tensioning belt **96** is attached with one of its ends. The other end of the tensioning belt **96** is routed tangentially to the torque rod **95** and attached to this. By rotating the torque rod **95** in the circumferential direction in which the tensioning belt **96** lies tangentially against the torque rod **95**, i.e. in the direction of the arrow E in FIG. **13***f*, the tensioning belt **96** is increasingly wrapped around the torque rod **95** so that its length decreases and thus the diameter of the tensioning belt **93**, **94** decreases. This in turn causes the locking rods **91** to be moved radially inward towards the tool axis **60** to close the longitudinal cavities **58**.

[0210] In the state where the locking mechanism **90** has been axially inserted into the winding support **51**, as shown in FIG. **12***e*, the aforementioned rotation of the torque rod **95** and thus the tensioning of the locking rings **93**, **94** is realised so that the locking rods **91** are pressed between the fins **59**, thereby closing the longitudinal cavities **58** of the winding support **51** in the radial direction.

[0211] Simultaneously the sleeve **72** on the first axial end **65** lies at the level of the second winding head **8** and delimits it radially to the outside. The drawing device **70**, **80** or more precisely the drawing cone **70** and the press ring actuating element **80** can be removed in the end position or moved axially to a non-interfering distance from the winding support **51**, resulting in the state shown in FIG. **12***f*. For simplicity, the second winding head **8** is shown here only as a massive ring, even though it consists of single wire bundles lying axially above each other with numerous clearances between them and to the sleeve **72**. These are filled when the coils **6** are encapsulated.

[0212] The sealant is poured without pressure from the first axial end **65**, i.e. the end of the second winding head **8**. It flows through the clearances and cavities between the wire bundles of the coils **6** in the second winding head **8** and the longitudinal cavities **58** to the first winding head **7**, fully encapsulating all coils along with the winding heads **7**, **8**. The encapsulated coil body **5** is shown in FIG. **13***e*.

[0213] Needle Winding Technique

[0214] Another method for manufacturing the coil body **5** consists of winding the single coils with a needle winding device within a winding support and then encapsulating them inside this winding support. A tool **20'** forming this winding support is shown in FIG. **14***a*-**14***e*. FIG. **15***a*-**15***c* shows the tool **20'** in practice.

[0215] The layout of the tool **20'** essentially corresponds to that of the drawing and casting tool **20** in FIG. **9***a* through **9***c*. Therefore, please refer to the explanations for those figures. Only the differences are described below. Unlike the drawing tool **20**, the winding tool **20'** does not have the first, second and third dies **25**, **26**, **27** due to the method. The winding tool **20'** also comprises a winding support **21** with a front winding support segment **22** and a rear winding support segment **23**, in which the front winding support segment **22** has a smaller diameter than the rear winding support segment **23**, so that the front winding support segment **22** is offset relative to the rear winding support segment **23**, forming an annular space to receive the first winding head **7**. The front axial end **35** of the winding support **21** has a cone **24** and the rear axial end **36** has a pin **40**. A mounting sleeve **47** is attached form-fitting on the pin **40** and the second winding head **8** is wound on that. The mounting sleeve **47** projects radially relative to the rear winding support segment **23**.

[0216] The rear winding support segment **23** has parallel longitudinal slots **39** distributed equidistant over the circumference to receive fins **29**, of which only those required for winding a single phase are mounted in FIG. **14***a*-**14***e*. In greater detail, eight fins **29** are mounted here in groups of four fins **29** each, opposite each other in angle segments $\alpha1$, $\alpha2$. As before, there is a longitudinal cavity **28** respectively between two fins **29** adjacent to each other in the circumferential direction. The fins **29** extend toward the front axial end **35** beyond the rear winding support segment **23** so that they lie at a distance from the front winding support segment **22**, forming the aforementioned annular space.

[0217] In contrast to the illustrated drawing tool **20**, the fins **29** have a T-shaped cross-section so that the slot opening is narrower than the slot width on the inside of the longitudinal cavities **28**. This reduces the risk of the winding wire emerging from a longitudinal cavity **28**. The longitudinal edges of the fins **29** that face each other have been bevelled, so that a wire that may have been wound inaccurately nevertheless slides into the longitudinal cavity **28** along the flat area tilted toward the longitudinal cavity. All other edges of the fins **29** on their face end opposite the cone **24** are bevelled as well.

[0218] On the part of the rear axial end **36**, a retaining element **48** is mounted radially outside on each fin **29**, notably screwed. Each retaining element **48** comprises a finger **49** that extends in the axial direction and lies radially farther out than the corresponding fin **29**.

[0219] Winding the winding support **21** is carried out with a needle winding device that continuously feeds the winding wire under tension, in which the needle winding device and the winding support **21** are moveable relative to each other, bidirectionally in at least 3 spatial directions, namely axial, radial and in the circumferential direction.

[0220] The longitudinal cavities **28** are lined with an insulating paper **15** prior to winding. As shown in FIG. **15***a*, this insulating paper **15** is folded in a U shape and projects at the rear axial end **36** of the longitudinal cavities **28** to prevent lateral contact of the winding wire with the fins **29**. The T shape of the fins **29** keeps the insulating paper **15**, which contacts the protrusions of the T-fins **29** projecting in the circumferential direction with its longitudinal sides, from sliding out. FIG. **15***a* also shows that the mounting sleeve **47** is sheathed with an insulating material **15**.

[0221] Winding a coil **6** is now carried out in the tool **20'** in a manner that is known as such, for example, by repeatedly

[0222] a) drawing in the winding wire through an axial linear movement of the needle winding device from the rear axial end **36** in the longitudinal direction of the winding support **21** parallel to the fixture axis **44** to the front axial end **35** into a first longitudinal cavity **28** that is radially open to the outside, from which the wire emerges axially at the end of the first axial movement,

[0223] b) rotating the winding support **21** around the axis **44** with a first rotational movement until the needle winding device is aligned with a certain second longitudinal cavity, into which the winding wire is to be drawn,

[0224] c) drawing the winding wire, with a second linear movement of the needle winding device, back from the front axial end **35** in the longitudinal direction of the winding support **21** parallel to the fixture axis **44** to the rear axial end **35** into the second longitudinal cavity **28** that is radially open to the outside, from which the wire emerges axially at the end of the second axial movement, and

[0225] d) rotating the winding support **21** back around the axis **44** with a second rotational movement until the needle winding device is once again aligned with the first longitudinal cavity, into which the winding wire is to be drawn.

[0226] Prior to the first rotational movement in step b), a linear movement of the needle winding device in the direction of the tool axis can be performed if necessary to draw the winding wire radially inward. Correspondingly a linear movement of the needle winding device in the direction away from the tool axis can be performed if necessary after the first rotational movement in step b) in order to draw the winding wire radially outward. The two radial movements are required if the rotational movement in step b) is performed with a comparatively small angle, so that the alignment of one or more fins **29** lies on a connecting line between the start point and end point of the rotational movement. In this case, there is a risk that the winding wire may not be positioned correctly in the annular space during the first rotational movement and second linear movement.

[0227] The aforementioned movements are repeated according to the N windings to be drawn in to form a coil **6**. Naturally the aforementioned movements can also be performed by the respective other component in the sense of a kinematic inversion of the direction.

[0228] The first longitudinal coil segment **6***a* of a coil **6** is laid by the sum of the first axial movements, the second longitudinal coil segment **6***b* by the sum of the second axial movements. Furthermore, the first winding head segment **6***c* of the coil **6** is laid by the sum of the first rotational movements and the second winding head segment **6***d* by the sum of the second rotational movements.

[0229] Due to the cone **24** on the head of the winding support **21** with the fins **29**, the first winding head segment **6***c* is automatically formed within the annular space between the fins **29** and the front winding support segment **22**, i.e. offset radially inward relative to the teeth **3** of the stator assembly to which the fins **29** quasi correspond. The second winding head segment **6***d* on the other hand is formed axially in front of the fins **29** so that it later lies axially in front of the stator teeth **3**.

[0230] The winding concept, or more precisely the assignment of the longitudinal cavities **28** to the individual coils, is carried out as previously explained in reference to FIG. **1***c* and FIG. **12***a*, **13***f*. Thus the second coil **6**.**2** of a phase is wound in diametrically opposite longitudinal cavities **28** and divided into two coil sections **6**.**2***a*, **6**.**2***b* that are routed in different circumferential directions from one longitudinal cavity to the other in order to obtain symmetrical winding heads **7**, **8**. This is shown in FIG. **15***b* with a view of the second winding head **8**, which however initially consists only of this second coil **6**.**2** here.

[0231] The end and the start of the winding wire **11** of the second coil can be seen as well. The second coil **6**.**2** can be wound by fully winding the first coil section **6**.**2***a* completely and then winding the second coil section **6**.**2***b* completely, i.e. by initially producing all N/2 windings in the same direction sequence. Alternatively one winding of the first coil section **6**.**2***a* and one winding of the second coil section **6**.**2***b* can be wound alternately.

[0232] The two other coils **6**.**1**, **6**.**3** of the phase are then wound one after the other, respectively in the two longitudinal cavities **28** that are adjacent to the longitudinal cavities **28** of the second coil **6**.**2** within the same circumferential semi-circle; see FIG. **1***a*, **13***f*. FIG. **15***c* shows the fixture **20'** with wound first and second coils **6**.**1**, **6**.**2**, in which the first coil **6**.**1** lies radially on the first coil section **6**.**2***a* of the second coil **6**.**2** in the area of the second winding head segment **6***d* that is visible here.

[0233] All coils **6** of all phases can be initially wound in the illustrated manner and subsequently encapsulated together. With this full encapsulation, the coil assembly **5** forms a monolithic cast body (full cast body). As with the fixture **20** according to FIG. **9***a*-**9***c*, a cover **32** is put over the mounting sleeve **47** for this purpose, a cylindrical first sleeve **30** encompassing the fins **29** is put over the fins **29** and the cylindrical second sleeve **31** is put over the cover **32** and the second winding head **8**. Subsequently the winding tool **20'** completed in this way is filled with sealant.

[0234] According to an alternative, only the coils **6** for a single phase U, V, W are wound and then encapsulated, and this is repeated for each phase, forming one cast body section per phase. With this partial encapsulation, the coil assembly **5** thus forms a multi-part cast body. The individual cast body sections are pushed together axially to form the coil assembly **5**. This embodiment has the advantage that less force is required for demoulding the cast body sections compared to demoulding the full cast body and that the stress on the components is reduced overall. The same tool **20'** can be used for all cast body sections.

[0235] However, the embodiment with cast body sections results in an axially larger constructed size of the winding heads **7**, **8** by several millimetres, since each winding head **7**, **8** has an insulating layer of sealant with a thickness of 1-2 mm respectively on its two axial face ends, and these are added up when stacking the cast body sections. The monolithic (one-piece) cast body on the other hand has a smaller axial constructed size of the winding heads for the same output or power density (up to 1.6 cm in total), because the coils lie closely against each other there without intermediate insulation. The performance of a coil assembly **5** produced as a full cast body is therefore better.

[0236] Note that the preceding description is merely exemplary for the purpose of illustration and in no way limits the scope of protection of the invention. Characteristics of the invention designated as "can", "exemplary", "preferred", "optional", "ideal", "advantageous", "where applicable", "appropriate" or the like are merely elective and in no way limit the scope of protection, which is established exclusively by the claims. Insofar as elements, components, process steps, values or information are cited in the preceding description that have known, obvious or foreseeable equivalents, these equivalents are also covered by the invention. Furthermore, the invention encompasses all changes, variations or modifications of embodiments of the invention that involve the exchange, addition, change or omission of elements, components, process steps, values or information, as long as the fundamental concept according to the present invention is preserved, regardless of whether the changes, variations or modifications result in an improvement or an impairment of an embodiment.

[0237] Although the preceding description of the present invention identifies numerous material/immaterial characteristics or characteristics pertaining to the subject matter of the proceedings in reference to one or more concrete embodiment(s) of the invention, these characteristics can also be used in isolation from the concrete embodiment of the invention, at least insofar as they do not require the mandatory presence of additional characteristics. Conversely, these characteristics mentioned in reference to one or more concrete embodiment(s) of the invention can be combined at will with each other and with additional disclosed or undisclosed characteristics or embodiments of the invention that are not shown, at least to the extent that these characteristics do not mutually exclude each other or result in technical incompatibilities.

1. A method for manufacturing a coil assembly of an electric motor for a deep well vertical turbine pump having a stator assembly that has a stator bore configured to receive a rotor and slots radially open to inside the stator bore, and separated from each other by respective stator teeth, electrical conductors of coils of the coil assembly lying in the slots, forming distributed windings and, at one axial end of the coil assembly, a winding head, wherein the coil assembly, by shaping and encapsulating of the coils within a tool, is manufactured so that the winding head extends only between an inner diameter and an outer diameter that is smaller than a diameter of the stator bore thereby enabling axial insertion of the coil assembly into the stator assembly leading with the winding head, in which the coils are respectively wound individually, drawn into the tool and encapsulated within it.

2. The method according to claim **1**, wherein the tool comprises a winding support having a central guide cylinder and fins, corresponding in number to the stator teeth, arranged at a distance from the central guide cylinder so that there is an annular space between the central guide cylinder and the fins that is open in the axial direction towards an insertion end and configured to receive at least one coil wound in a form of a wire bundle and to form a winding head segment of the coil in the annular space, a respective longitudinal cavity being situated between each two fins adjacent to each other in a circumferential direction in order to form a respective one longitudinal coil segment of the coil, and

a. one of the coils is inserted into the annular space from the insertion end so that it extends radially through a first of the longitudinal cavities into the annular space, extends in a curve to a second of the longitudinal cavities and emerges from this again radially,
b. the coil is subsequently pushed away from the insertion end towards an opposite second axial end using a heading tool having a shape of a hollow cylinder that is inserted into the annular space and guided on the guide cylinder, where it forms a winding head segment of the coil lying in the winding head,
c. a drawing device, comprising a drawing cone is subsequently moved from the second axial end radially along an outside of the fins to the insertion end in order to fold up the coil and press it into the first and second longitudinal cavities until the insertion end is reached, where the coil wraps around the outer circumference of the fins with increasing tension, forming a second winding head segment of the coil that forms part of a second winding head.

3. The method according to claim **2**, wherein step a Is initially repeated for several or all the coils and steps b and c are performed subsequently for all the coils together.

4. The method according to claim **3**, wherein a sleeve is put axially over the fins from the second axial end to the insertion end, radially delimiting the second winding head in an end position to form a casting mould for it.

5. The method according to claim wherein by locking rods of a locking mechanism having a number of locking rods corresponding to the number of longitudinal cavities are moved into the longitudinal cavities, axially, thereby to close the longitudinal cavities to form a casting mould.

6. The method according to claim **5**, wherein at least one locking ring of the locking mechanism radially pushes the locking rods jointly into the longitudinal cavities.

7. The method according to claim **6**, wherein the guide cylinder has a rotatable eccentric cone on the insertion end with a shell surface and that is steeper on one side than on a side opposite thereto, and the eccentric cone, for insertion of the coil into the winding support, is rotated to a position where the less steep side of the eccentric cone faces a desired curved course of the coil in the annular space from the first to the second longitudinal cavity.

8. The method according to claim **1**, wherein the coil is wound to form wire bundles above the tool using a flyer winder and subsequently dropped into the tool.

9. A tool for manufacturing a coil assembly of distributed windings configured for axial insertion into a stator assembly of an electric motor, the stator assembly having slots radially open to inside the bore, and separated from each other by respective a stator teeth, comprising a winding support having a central guide cylinder and fins, corresponding in number to the stator teeth, arranged at a distance from the central guide cylinder so that there is an annular space between the central guide cylinder and the fins that is open in an axial direction towards an insertion end to receive at least one coil wound in a form of a wire bundle and to form a winding head segment of the coil in the annular space, a respective longitudinal cavity being situated between each two fins adjacent to each other in a circumferential direction in order to form a respective one longitudinal coil segment of the coil.

10. The tool according to claim **9**, wherein a heading tool in a form of a hollow cylinder configured to be inserted into the annular space is guided on the guide cylinder, to push the at least one coil to a second axial end opposite the insertion end and to form at the second axial end a first winding head segment of the at least one coil forming part of a first winding head of the coil assembly.

11. The tool according to claim **10**, further comprising a drawing device that is movable to the insertion end, sliding radially along the outside of the fins, thereby to fold up the at least one coil.

12. The tool according to claim **11**, wherein the drawing device comprises a drawing cone.

13. The tool according to claim **12**, further comprising a sleeve configured to be put over the outside of the fins, and slide toward the insertion end to an end position thereby to encompass a second winding head segment of the at least one coil forming part of a second winding head and form a casting mould.

14. The tool according to claim **13**, further comprising a locking mechanism having a number of locking rods corresponding to the number of longitudinal cavities and configured to be moved axially into the longitudinal cavities thereby to close the longitudinal cavities to form a casting mould.

15. The tool according to claim **14**, wherein the locking mechanism has at least one locking ring configured to jointly push the locking rods radially into the longitudinal cavities.

16. The tool according to claim **15**, wherein the guide cylinder has a rotatable eccentric cone on the insertion end with a shell surface that is steeper on one side than on a side opposite thereto.

17. The tool according to claim **16**, wherein the drawing device comprises a press ring actuating element configured to slide along the winding support to the insertion end, having a number of sliding dies in an annular arrangement corresponding to the number of longitudinal cavities so that each sliding die projects into a respective one of the longitudinal cavities thereby to press the at least one coil radially into the first and second longitudinal cavities.

18. The tool according to claim **17**, wherein each sliding die is supported on a shock resistant block relative to which the sliding die it is radially moveable, the sliding dies being configured to be pushed into the shock resistant blocks against a restoring force.

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