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(54) **METHOD FOR FORMING A TUBULAR BODY, UNDULATING TUBULAR BODY AND USE OF SAME**

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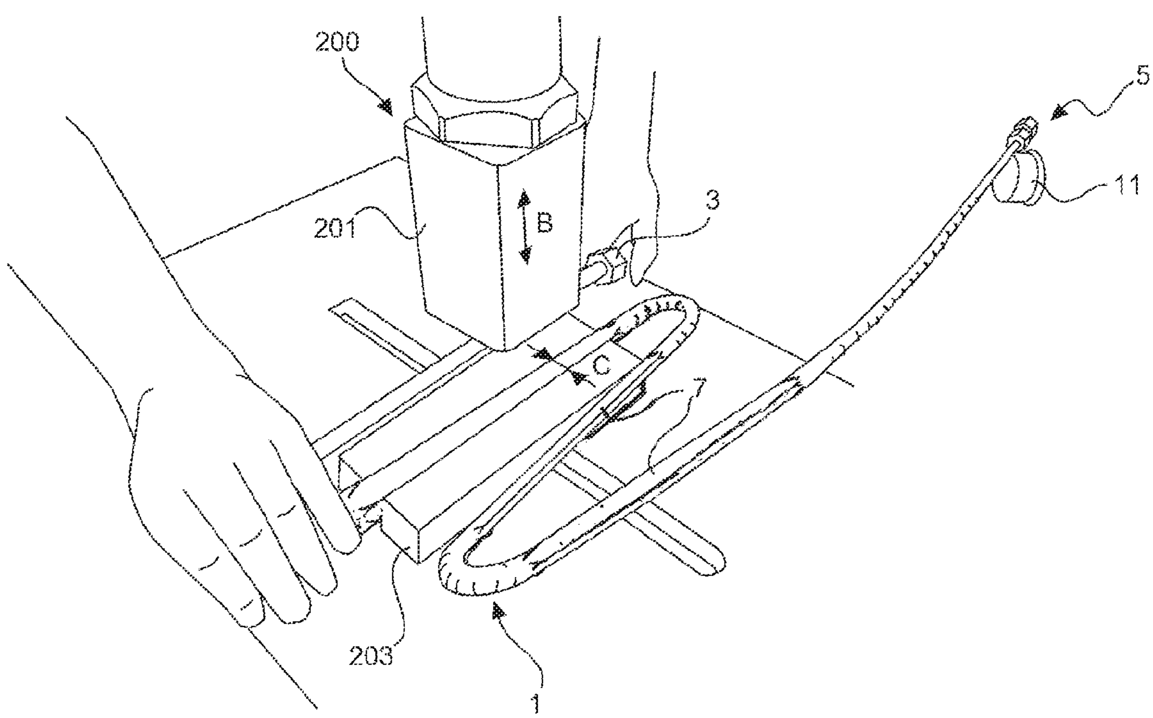
(57) **ABSTRACT**

A method for forming a tubular body, comprising the following steps: making available a tubular body having a first and a second tube end, filling the tubular body with a liquid, closing the tubular body, and forming the tubular body.



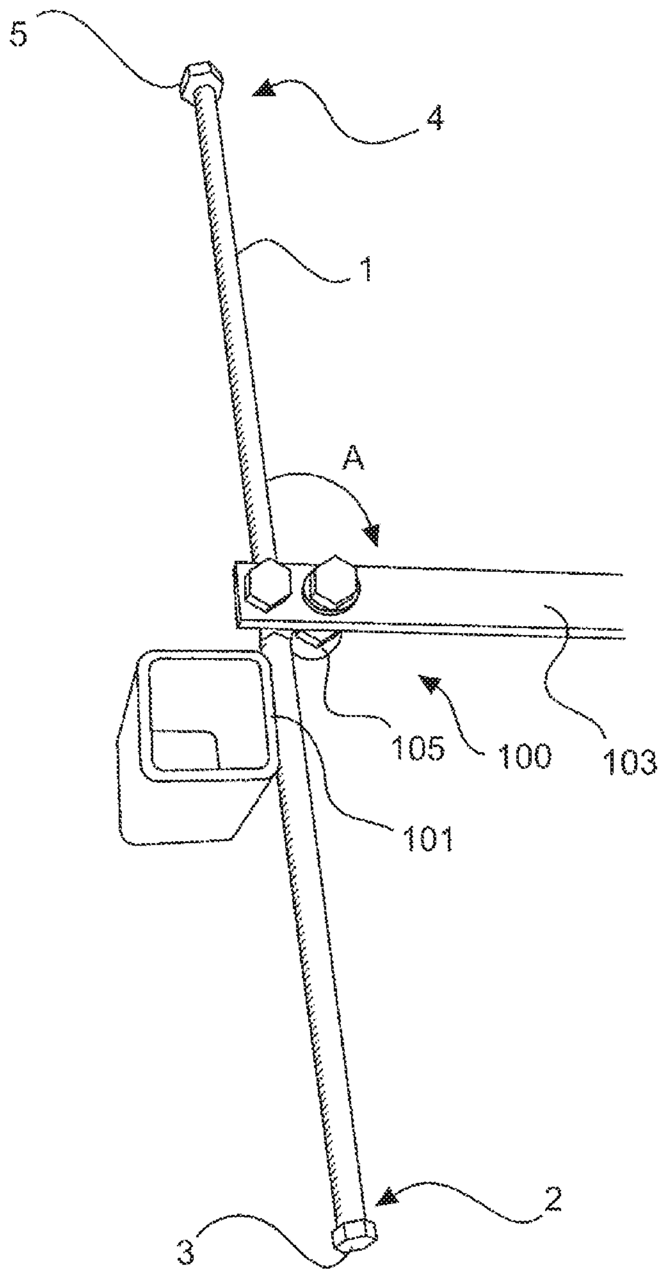


Fig. 1

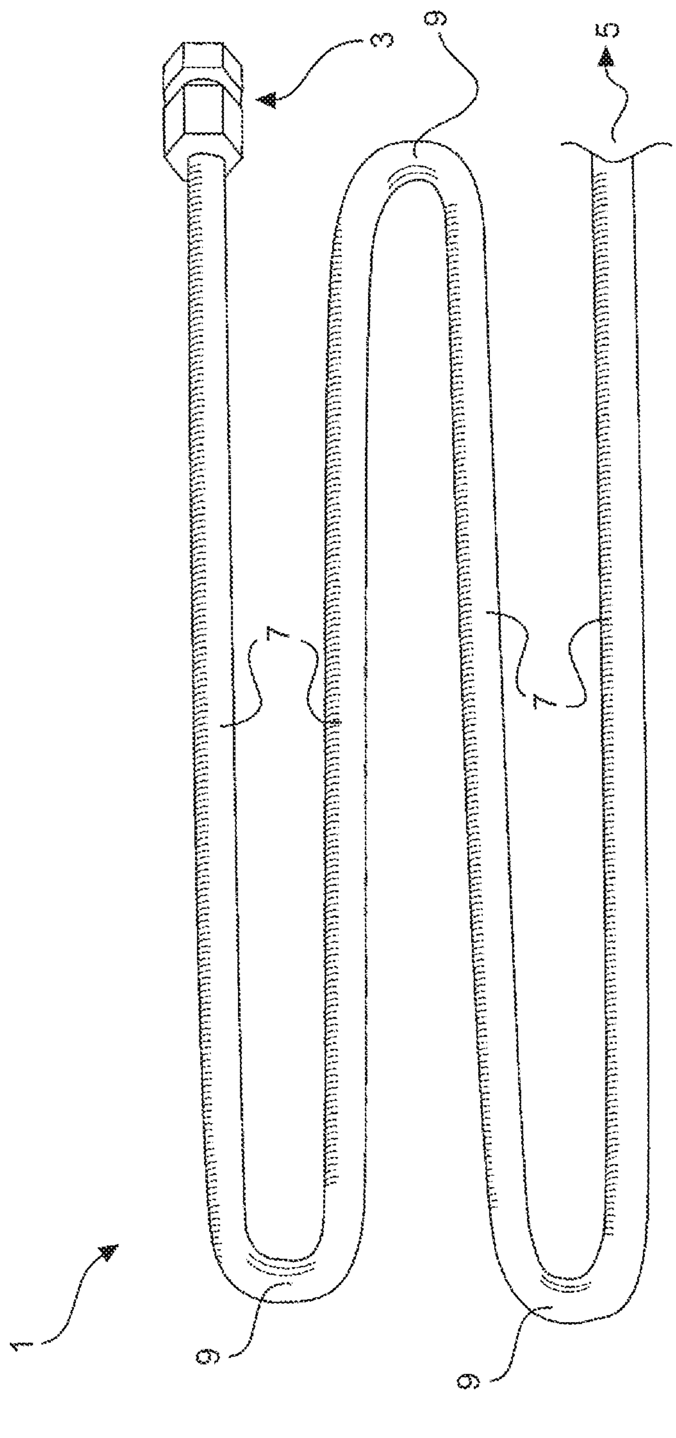


Fig. 2

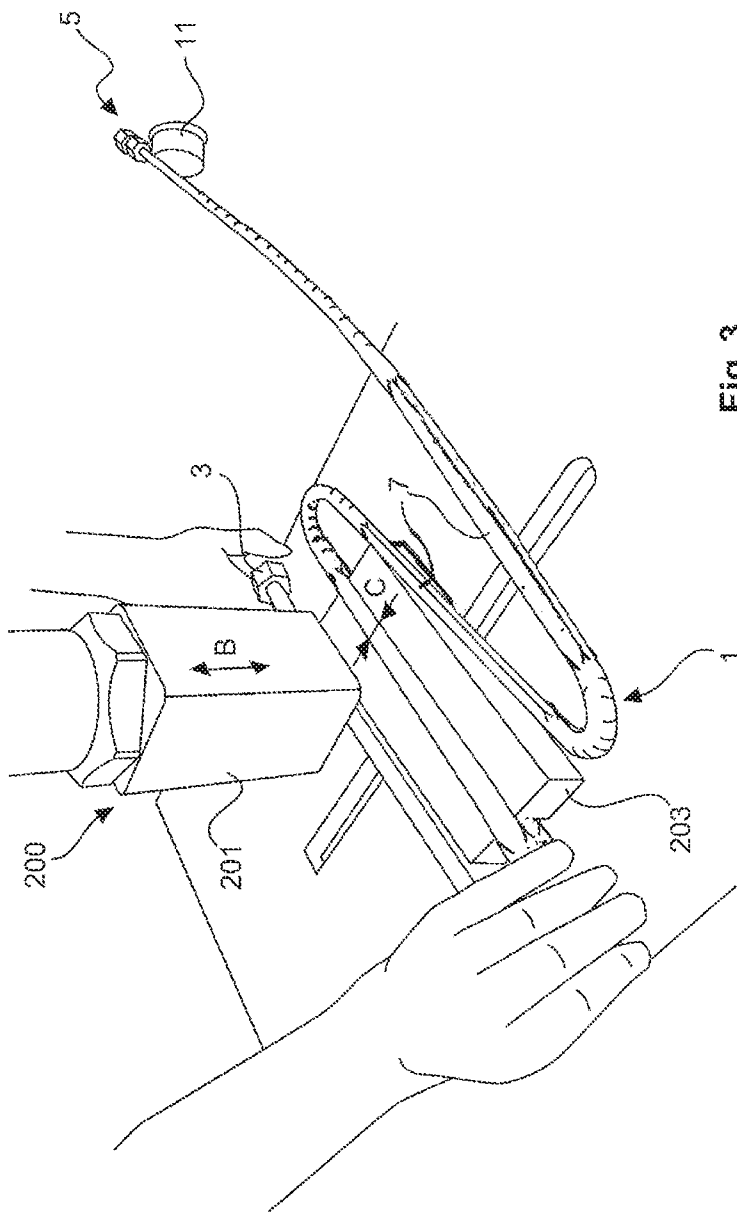


Fig. 3

METHOD FOR FORMING A TUBULAR BODY, UNDULATING TUBULAR BODY AND USE OF SAME

BACKGROUND

Technical Field

[0001] According to a first aspect, the present invention relates to a method for forming a tubular body. According to another aspect, the invention relates to a meandering tubular body produced by such a method. According to another aspect, the invention relates to the use of a tubular body of this kind.

Description of the Related Art

[0002] Forming tubular bodies is a widely known process. After being produced, tubular bodies are generally in an elongate, substantially uncurved form. However, since tubular bodies are not used only along straight delivery sections in practice, the installation locations may sometimes require fluids to be delivered along curved paths, e.g., around corners, by means of tubular bodies, and it is not always possible or desirable to use branch lines, flanged-on pipe elbows and the like in these situations, there is, on the one hand, the need to be able to bend tubular bodies, by means of forming for instance. On the other hand, there is a need to be able to form tubular bodies in respect of their cross-sectional shape in order to be able to lay them through predefined opening cross sections or to be able to shape the cross section of the tubular bodies as closely as possible to predetermined opening cross sections. The latter is significant especially when using the tubular bodies as cooling elements in order to be able to achieve the best possible heat transfer between the tubular body and the body to be cooled.

[0003] One particular challenge when forming tubular bodies is to prevent collapse or buckling of the tubular body or unwanted deformation of the tubular body in some other way and to obtain only the deformation which is intended in the forming process. To achieve this, sand is used as a filler in the prior art. The sand fills the internal cross section of the tubular body and prevents collapse or unwanted indentation of the tubular body during forming, given an adequate packing density.

[0004] Even if this method is feasible for simple forming processes, such as the production of individual bending radii or the production of non-circular cross sections of the tube, there is the problem, in the case of more complex forming processes, such as the production of meandering tubular bodies, that it may no longer be possible to remove the sand completely from the tubular body after the forming process. Consequently, it is not possible in the prior art to produce complex tubular body shapes, such as meandering tubular bodies, in one piece.

[0005] In the German patent application on which priority is based, the German Patent and Trademark Office identified the following documents: DE 694 02 051 T2, DE 196 16 484 A1, EP 0 099 714 A1, DE 199 52 508 A1 and DE 10 2010 018 162 B3.

BRIEF SUMMARY

[0006] Provided is a method for forming tubular bodies which allows higher flexibility for complexity in forming.

[0007] A method has the following steps: making available a tubular body having a first and a second tube end, filling the tubular body with a liquid, preferably water, closing the tubular body, and forming the tubular body. Water can be removed from the tubular body without leaving residues after the forming of said body, especially in the liquid or gaseous state, irrespective of the complexity of the tubular body, as long as one end or preferably both tube ends are opened again after forming. Moreover, liquids, such as water or suitable oils, can be compressed only with difficulty and therefore ensure adequate stabilization of the internal tube volume, despite being in the liquid state, if the tube is completely filled and closed.

[0008] In a particularly preferred development of the method, this method furthermore comprises the following step: pressurizing the liquid in the tubular body before the forming step. Through the pressurization of the liquid, the liquid is as it were preloaded. Physically speaking, liquids are not completely incompressible. However, it has been found that sufficient incompressibility or sufficiently low compressibility for the purposes of the method is available when using water, and this can be even further improved by subjecting the water to pressure before forming. Pressurization as it were provides an indicator of the complete filling of the tubular body. One particular advantage associated with pressurization is the following: if a leak, e.g., in the form of a crack, develops during the forming of the tubular body, the pressurized liquid would immediately escape from the interior of the tubular body. This escape would be easy to detect. Thus, pressure checking can simultaneously be performed during forming. If no liquid escapes until the forming process is complete, the operator knows immediately that the tube is pressure tight at least up to the pressure to which the tubular body has previously been subjected from the inside. This represents a significant economic advantage.

[0009] The liquid is preferably subjected to a pressure of 20 bar or more, particularly preferably in a range of from 50 bar to 200 bar.

[0010] In a preferred embodiment of the method, the forming step comprises introducing one or more bending radii into the tube. In brief, the advantage of using liquid as an internal stabilizer is all the more effective, the more complex is the geometry of the tubular body and consequently the more bending radii are introduced into the tube.

[0011] In another preferred embodiment, the bending radius or at least one of the plurality of bending radii, preferably a plurality of the bending radii or all of the bending radii, is/are less than three times the tube diameter. Whereas, in the case of conventional tube bending methods in the prior art, a minimum bending radius of about five times down to a maximum of easily three times the tube diameter is taken as a basis, the method allows significantly greater bending owing to the use of liquid, in particular pressurized liquid, as an internal stabilizer, and this results in significantly tighter possible bending radii. In preferred embodiments, the achievable bending radius is in a range of from less than three times the tube diameter to about twice the tube diameter, wherein, as before, the bending radius also depends, as is known, on the material used for the tubular body and especially on the wall thickness thereof. In the case of a tube with a diameter of 12 mm, a wall thickness of 1 mm and stainless steel as a material, the abovementioned bending radii can be achieved, for example.

[0012] In another preferred embodiment of the method, the forming step comprises: changing the tube cross section of one or more segments of the tubular body or of the entire tubular body, preferably to a substantially polygonal cross-sectional shape, particularly preferably to a substantially rectangular shape. A substantially polygonal or substantially rectangular shape is taken to mean that the angularity of the cross section is within the range of what is technically possible. If a tube cross section is deformed in such a way by means of forming that it has one or more edges which give the cross section a polygonal, in particular rectangular, shape overall, it must be expected that a small edge radius will remain on the inside and on the outside. This can be ignored for purposes of understanding the concept of the substantially polygonal or substantially rectangular cross-sectional shape.

[0013] Changing the tubular cross section into a substantially polygonal or substantially rectangular cross-sectional shape is preferably achieved by placing a segment or segments of the tubular body or the complete tubular body in a die and then forming it to match the die by the application of force. Force is applied either externally to the die or the tubular body and/or by means of the die itself, which acts in the manner of a punch, for example. There is a preference, for example, for deforming the tubular body by means of a punch or a roll, by means of levelling rolls for instance.

[0014] In another embodiment, the method is developed in that a plurality of bending radii is introduced into the tubular body and in that the forming step furthermore comprises: bending the tube into a meandering shape, wherein the meandering shape has one or more substantially uncurved tube segments, which each adjoin one or more of the bending radii.

[0015] As another preferred option, the method comprises the following step: discharging liquid from the tubular body, preferably by means of a pressure relief valve, if the pressure exceeds a predetermined value during forming. This is preferably carried out by closing at least one of the ends of the tubular body using an excess pressure limiter valve, which discharges liquid whenever the pressure rises significantly, preferably by 1 to 10% or more, owing to the progress of forming. The following is thereby achieved: when changing the tube cross section by applying force from the outside, the volume of the tubular body is sometimes reduced. To ensure that the liquid medium escaping from that segment of the tubular body which has just been deformed does not cause bulging or unwanted deformation of the tubular body at some other point, liquid is selectively discharged according to this embodiment in order to keep the pressure in the tubular body substantially constant. Depending on the design of the tubular body, different limit values can be defined here. At a wall thickness of 1 mm and with stainless steel as a material, a limit value for the pressure limit of about 50 bar has proven appropriate, for example.

[0016] In another preferred embodiment, said method furthermore comprises the following step: monitoring the liquid pressure during forming, preferably by means of a pressure sensor. Apart from the fact that visual monitoring of the liquid pressure can, of course, take place through observation of the pressure relief valve, there can also be a preference for quantitative detection of the pressure rise within the tubular body for the sake of more accurate control of the forming process, and a widely known pressure measuring transducer is preferably used for this purpose.

[0017] The method has proven itself especially also with tubular bodies which are formed by a steel material, in particular stainless steel or structural steel.

[0018] According to the second aspect of the invention, provided is a tubular body which is suitable for cooling a generator, wherein the generator is used for producing an electric current, in particular in the form of a multi-pole synchronous generator of a wind power plant.

[0019] The meandering tubular body has a plurality of bending radii, preferably with a bending radius of less than three times the tube diameter, and a plurality of substantially uncurved segments, which adjoin the bending radii, preferably without kinks, wherein at least one, preferably a plurality or all, of the substantially uncurved segments has/have a substantially rectangular cross section.

[0020] Where substantially uncurved segments of the tubular body are referred to above and below, this is to be taken to mean that the tubular body is designed to be free from curves, i.e., straight, in these segments or at least has so little curvature that it can be introduced into the groove of the generator and preferably rests there against the opposite walls of the groove in order to allow heat transfer. If there is a slight curvature in the direction of the depth of the groove, the curvature is insignificant here. Even if there is a slight curvature transversely to the depth of the groove, i.e., in a direction toward the groove walls or away from them, a substantially uncurved segment is assumed if the segment can be moved into the groove by elastic deformation.

[0021] The tubular body preferably has a wall thickness in a range between 0.5 and 3.5 mm, particularly preferably in a range of from 1-2 mm.

[0022] As another preferred option, the tubular body is formed by a steel material, in particular stainless steel or structural steel. Admittedly, there are materials which allow significantly greater changes in shape owing to higher ductility, e.g., copper tubes. However, the preference is to design the tubular body with the minimum possible electrical conductivity, especially for use in a generator for producing electric current. Fundamentally, the tubular body in its meandering shape also acts like a coil and, during the operation of the generator, when the pole shoes are moved past the grooves provided with the meander, can cause power losses or interference fields, it being possible to keep these low by a suitable choice of material.

[0023] Thus, according to the third aspect, the invention relates to the use of a meandering tubular body according to one of the embodiments described above in a generator.

[0024] In particular, the invention achieves implementing the cooling of the generator by means which are as economical as possible and of allowing coolant to be carried as far as possible without leakage.

[0025] Given the above considerations, the use of the meandering tubular body according to one of the preferred embodiments described above is particularly preferred because the tubular body has (implicitly) already been checked for pressure-tightness during the production thereof.

[0026] The meandering tubular body is particularly preferably used in a generator which is designed as a multi-pole synchronous generator of a wind power plant. The generator, particularly preferably the stator of the generator, has a multiplicity of grooves, in which a winding, which is preferably the stator winding, is arranged. The plurality of substantially uncurved tube segments of substantially rectangular cross section of the tubular body is introduced into the grooves. When cooling liquid then flows through the tubular body, the heat produced by the stator winding can be dissipated directly from the groove and, at the same time, the development of heat in the stator can be stemmed.

[0027] In the case of a synchronous ring generator of a gearless wind power plant, the term "multi-pole" is taken to refer to a multiplicity of stator poles, in particular a design having at least 48 stator teeth, often even with significantly more stator teeth, in particular 96 stator teeth or even more stator teeth. The magnetically active region of the generator, namely both of the rotor, which can also be referred to as an armature, and of the stator is arranged in an annular region around the axis of rotation of the synchronous generator. Thus, in particular, a range of from 0 to at least 50 percent of the radius of the air gap is free from materials which carry the electric current or electric field of the synchronous generator. In particular, this internal space is completely free and, in principle, can also be accessed. This region can often also make up more than 0 to 50 percent of the air gap radius, in particular up to 0 to 70 percent or even 0 to 80 percent of the air gap radius. Depending on the construction, there may be a supporting structure in this inner region, but this can be of axially offset design in some embodiments. By virtue of their functioning, such synchronous generators of a gearless wind power plant are slowly rotating generators. Here, the term "slowly rotating" is taken to mean a speed of less than 40 revolutions per minute, in particular of about 4 to 35 revolutions per minute, depending on the size of the plant.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0028] The invention is described in greater detail below by means of preferred illustrative embodiments with reference to the attached figures, of which:

[0029] FIG. **1** shows a first method state during the production of a meandering tubular body,

[0030] FIG. **2** shows a second method state of the method according to FIG. **1**, and

[0031] FIG. **3** shows a third method state of the method according to FIGS. **1** and **2**.

DETAILED DESCRIPTION

[0032] In its undeformed state, the tubular body **1** shown in FIGS. **1-3** has a substantially cylindrical cross section and is uncurved, as can be seen in FIG. **1**. To prepare the forming step, the tubular body **1** is closed pressure tightly in a first end segment **2** by means of a closure **3**, e.g., a blind plug. A second closure **5** is fitted in an opposite, second end segment **4**. The second closure **5** is designed as a check valve with an excess pressure limiter, for example.

[0033] The tubular body **1** is filled with liquid, preferably via the second closure **5**, and pressurized, e.g., with a pressure in a range of from 50 to 200 bar. The tubular body is then closed pressure tightly by means of the optionally provided check valve, wherein the optionally provided pressure limiter is designed to discharge liquid from the interior of the tubular body **1** if a predetermined pressure within the tubular body **1** is exceeded.

[0034] It is then possible to carry out the forming step with the filled and closed and preferably pressurized tubular body **1**. In the illustrative embodiment shown, the tubular body **1** is first of all placed in a tube bending device **100**, as shown in FIG. **1**. The tube bending device **100** holds a first leg of the tubular body **1** against a stop **101**. A lever **103** brings about the bending of the tubular body **1** around a retention pin **105** in the direction of the arrow A. Owing to the filling of the tubular body **1** with the liquid, tube bending takes place without the tube cross section collapsing, and a state as shown in FIG. **2** is achieved when the bending process is carried out several times.

[0035] The tubular body shown in FIG. **2**, which is bent in a meandering shape and represents an intermediate product of the method of the illustrative embodiment shown, has a plurality of substantially uncurved segments **7**, which are each arranged adjoining the bending radii **9** without kinks.

[0036] Starting from the state shown in FIG. **2**, the tube cross sections of the substantially uncurved segments **7** are then preferably changed. This is accomplished as shown in FIG. **3** by placing the substantially uncurved segments **7** successively in a die **203** of a punching device **200**. The die **203** consists of two parallel bars, for example, which between them define a gap of rectangular cross section, e.g., in the form of a square with the slot width C and preferably the same slot depth.

[0037] By moving a punch **201** repeatedly up and down in the direction of the arrows B, the tubular body **1** is subjected to an external force in the die **203**, said force leading to deformation in such a way that the tube cross section is shaped to match the cross section of the slot.

[0038] A pressure-measuring transducer **11**, which is designed to monitor the internal pressure of the liquid, is preferably arranged on the second closure **5**. If a predetermined pressure value is exceeded, there is the possibility either of discharging liquid manually or of automatic opening of a pressure relief valve if said pressure is exceeded in order to take account of the reduction in volume in the interior of the tubular body **1** due to the change in shape brought about by the punching device **200**.

[0039] As can be seen from the above illustrative embodiment, the method can be used for both the combined bending and the changing of the shape of the tube cross section. However, the advantages of stabilizing the volume of the tubular body **1** by means of, preferably pressurized, liquid also come into play in both individual processing steps, i.e., when only bending of the tube cross section is taking place or only a change in the shape of the tube cross section is taking place. It has been found that the use of water allows adequate stabilization, and the environmental compatibility of water is regarded as advantageous for the use thereof.

[0040] As an alternative, the use of oil or the like is likewise envisaged.

1. A method for forming a tubular body, the method comprising:

filling a tubular body with a liquid, the tubular body having a first end, a second tube end, and a cross-sectional shape;

closing the tubular body, and

forming the tubular body, wherein forming the tubular body includes changing the cross-sectional shape of at least a portion of the tubular body.

2. The method according to claim **1**, comprising pressurizing the liquid in the tubular body before forming the tubular body.

3. The method according to claim **2**, wherein the liquid is subjected to a pressure of 20 bar or more.

4. The method according to claim **1**, wherein forming comprises introducing one or more bending radii into the tubular body.

5. The method according to claim **4**, wherein the one or more bending radii is less than three times a diameter of the tubular body.

6. (canceled)

7. The method according to claim **1**, wherein changing the cross-sectional shape includes placing the tubular body in a die and forming the tubular body to match the die by applying force to the tubular body.

8. The method according to claim **1** further comprises:

bending the tubular body into a meandering shape, wherein the meandering shape has one or more substantially uncurved tube segments, each of the one or more substantially uncurved tube segments adjoin one or more of the bending radii.

9. The method according to claim **1**, comprising:

discharging the liquid from the tubular body when the pressure exceeds a predetermined value during forming.

10. The method according to claim **1**, comprising monitoring the liquid pressure during forming.

11. The method according to claim **1**, wherein the tubular body is a steel material.

12. A meandering tubular body produced by a method according to claim **1**, the meandering tubular body comprising:

a plurality of bending radii with a bending radius of less than three times the tube diameter, and

a plurality of substantially uncurved segments that adjoin the bending radii,

wherein at least one of the uncurved segments has a substantially polygonal cross section.

13. The meandering tubular body according to claim **12** in a generator, wherein the generator is configured to produce an electric current in a multi-pole synchronous generator of a wind power plant, wherein:

the generator has a plurality of grooves, in which a winding is arranged,

the tubular body has a plurality of substantially uncurved tube segments having a substantially polygonal cross section, wherein the substantially uncurved segments of the tubular body are arranged in the grooves, the tubular body including a cooling liquid flowing through said segments.

14. The meandering tubular body according to claim **12**, wherein a stator of the generator has the plurality of grooves and the winding is a stator winding.

15. The method according to claim **1**, wherein changing the cross-sectional shape of at least the portion of the tubular body includes changing the cross-sectional shape of at least the portion of the tubular body to a substantially polygonal cross-sectional shape.

16. The method according to claim **15**, wherein the polygonal cross-sectional shape is a substantially rectangular cross-sectional shape.

17. The method according to claim **7**, wherein applying force to the tubular body includes using a punch or a roll.

18. The method according to claim **9** wherein discharging the liquid from the tubular body comprises using a pressure relief valve, if the pressure exceeds a predetermined value during forming.

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