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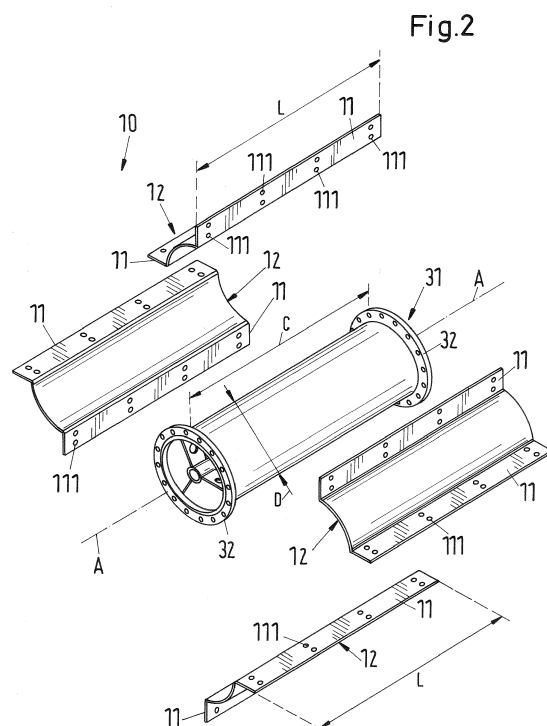
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(54)

DEVICE FOR MODIFYING THE NATURAL FREQUENCY OF A VERTICAL PUMP, VERTICAL PUMP AND METHOD FOR RETROFITTING A VERTICAL PUMP

(57) A suppressing device is proposed for shifting a structural natural frequency of a vertical pump, said pump (1) comprising a pumping unit (2) with an inlet (21) and an impeller (22) for conveying a fluid, a discharge unit (4) with an outlet (41) for the fluid, a drive unit (5) for rotating the impeller (22), a column pipe (3) extending in an axial direction (A) and having at least one column element (31) with an axial length (C), said column pipe (3) connecting the pumping unit (2) with the discharge unit (4), as well as a line shaft (6) extending within the column pipe (3) and operatively connecting the drive unit (5) with the pumping unit (2), said suppressing device (10) being designed and adapted for closely fitting around the entire circumference of the column element (31), and having an extension (L) in the axial direction (A) which is at least half the axial length (C) of the column element (31) and comprising at least one rib (11) extending essentially in a radial direction being perpendicular to the axial direction (A). In addition, a vertical pump is proposed comprising such a suppressing device (10) as well as a method of retrofitting a vertical pump.



Description

[0001] The invention relates to a suppressing device for shifting a structural natural frequency of a vertical pump as well as to a vertical pump in accordance with the preamble of the independent device claim. The invention further relates to a method of retrofitting a vertical pump.

[0002] Vertical pumps, in particular large vertical pumps have been used successfully in a plurality of applications for a very long time. Vertical pumps for specific applications are not infrequently manufactured in accordance with the specifications of the users or are matched in detail to specific requirements.

[0003] Important fields of application for the use of vertical pumps are, amongst other things, cooling towers, applications in cooling water systems, for example in nuclear or other types of power plants, for the drainage of waste water pools, or overflow basins for the prevention of flooding, or vertical pumps are also successfully used for the drainage of large areas of land. Vertical pumps are also widely used in the supply of water, in particular in the supply of drinking water, or as main pumps or as auxiliary pumps in open or closed systems. Other applications are firefighting in the offshore area (production of oil and gas), for example on oil platforms or floating production storage and offloading units (FPSO). Moreover, a whole series of further applications for vertical pumps are well known to the person of ordinary skill in the art.

[0004] Vertical pumps may be designed both as single stage and multistage pumps. They are typically immersed into the liquid reservoir to be pumped, so that at least the intake or suction bell with the adjoining pump rotor is immersed into the fluid to be pumped, so that the pump is directly ready for operation.

[0005] One typical and well-known setup of a vertical pump (see for example Fig. 1) comprises a pumping unit with an inlet and an impeller for conveying the fluid and being immersed into the reservoir. The pumping unit is connected by a vertically upwards extending column pipe to a discharge unit having an outlet for the fluid. On top of the discharge unit a drive unit is provided for driving the impeller. The drive unit is operatively connected to the impeller by means of a line shaft extending within the column pipe. In some applications the line shaft is surrounded by an additional tube extending coaxially in the interior of the column shaft. Usually the vertical pump is supported by a supporting structure being arranged beneath and in the proximity of the discharge unit, such that the pumping unit and the main part of the column pipe are hanging without further support.

[0006] One of the problems with vertical pumps is caused by the structural natural frequencies of the pump installation. In former times, vertical pumps were mostly designed by rule of thumb. Due to a lack of reliable analytical methods many of these pumps were designed with structural natural frequencies at or near the running

speed of the pump or multiples or half-integral multiples thereof. For example, when the pump is running at 1800 rpm this corresponds to a frequency of 30 Hertz. Thus, if 30 Hertz corresponds or is close to a structural natural frequency of the system the pump is running at a speed corresponding to a structural natural frequency of the pump system. When such a matching occurs a considerable load results especially on the bearings, which causes for example a premature failure of the bearings or the line shaft. In addition, an enhanced wear or other negative degradation effects may occur.

[0007] In many cases, for example in power plants or nuclear installations the user is not willing to replace an entire existing pump or the user is not interested in a complete redesign of its pumps. Rather, the user favors a retrofit and an aftermarket solution to solve the problems caused by said resonance effects.

[0008] To address these issues it is a known measure to attach a point mass at a specific location of the pump, for example at a specific location on the column pipe. The point mass lowers the structural natural frequency of the system. To be effective it is essential to provide as much weight as possible concentrated at a specific location, for example at a node of the oscillation, because the more the weight is spread out and away from the point of interest the less effect it has on lowering the natural frequency.

[0009] Although this method has proven successful in many applications there are some restrictions or drawbacks. It is possible that the required point mass for effectively lowering the natural frequency is as large that the pump cannot support it structurally. In other applications the spatial circumstances do not allow for the installation of a point mass at the required location. Furthermore, in some applications it turned out that the method with the point mass did not at all yield to the desired result.

[0010] Based on that prior art it is an object of the invention to propose a suppressing device for shifting a structural natural frequency of a vertical pump in such an effective manner that the described resonance effects may be avoided. The suppressing device should be easy to construct and easy to be installed. Specifically, the suppressing device shall be suited for retrofitting existing vertical pumps in a simple and cost-efficient manner. In addition, it is an object of the invention to propose a vertical pump that allows for a shifting of its structural natural frequency in a simple and cost-efficient manner. Furthermore, it is an object of the invention to propose a method of retrofitting an existing vertical pump which method allows for shifting the structural natural frequency of the pump.

[0011] The subject matter of the invention satisfying these objects is characterized by the features of the independent claims.

[0012] Thus, according to the invention a suppressing device is proposed for shifting a structural natural frequency of a vertical pump, said pump comprising a pump-

ing unit with an inlet and an impeller for conveying a fluid, a discharge unit with an outlet for the fluid, a drive unit for rotating the impeller, a column pipe extending in an axial direction and having at least one column element with an axial length, said column pipe connecting the pumping unit with the discharge unit, as well as a line shaft extending within the column pipe and operatively connecting the drive unit with the pumping unit, said suppressing device being designed and adapted for closely fitting around the entire circumference of the column element, and having an extension in the axial direction which is at least half the axial length of the column element and comprising at least one rib extending essentially in a radial direction being perpendicular to the axial direction.

[0013] By providing the suppressing device for closely fitting around the entire circumference of the column element a stiffening effect results that shifts the structural natural frequency of the pump to a higher frequency. The close fit around the column element generates a compression that ensures a transfer of stiffness to the column element. This clamping effect is comparable to an increase of the thickness of the wall of the column element. In addition, the at least one rib extending essentially in the radial direction increases the moment of inertia what in turn raises the natural frequency of the pump. Therefore the rib preferably extends with respect to the axial direction along the entire lengths of the stiffening device. By this means the original structural natural frequency can be shifted away from a critical value to a higher value.

[0014] According to a preferred embodiment the extension of the suppressing device in the axial direction is equal to the axial length of the column element around which the suppressing device is fitting in the assembled state. By this measure a particularly efficient stiffening effect is realized.

[0015] In order to provide for a very simple mounting of the suppressing device it is preferred that the suppressing device comprises a plurality of stiffening members being curved in a circumferential direction and being connectable to each other and complementing one another in the assembled state to a tubular structure for closely fitting around the entire circumference of the column element. This renders possible to put the stiffening members around the column member and to fix them with respect to each other, for example by means of screws.

[0016] In order to increase the moment of inertia it is advantageous, when each stiffening member has two lateral ribs extending in the radial direction, each rib forming an end of the stiffening member with respect to the circumferential direction.

[0017] According to a particularly preferred embodiment the suppressing device comprises four stiffening members, each of which has a middle part with a quadrant shaped cross section, said middle part extending between the two lateral ribs. This embodiment provides for an especially simple and fast mounting of the sup-

pressing device. Preferably, the four stiffening members are at least essentially identical.

[0018] For fixing the suppressing device closely around the column element to achieve the desired clamping effect it is advantageous when each lateral rib is provided with a plurality of holes for receiving fixing means to rigidly connect adjacent stiffening members. The fixing means are preferably screws and screw nuts.

[0019] In order to realize the desired shift of the structural natural frequency and depending on the respective application it might be advantageous that at least one stiffening member has an intermediate rib extending in the radial direction and being arranged between the two lateral ribs.

[0020] Furthermore, in accordance with the invention a vertical pump for conveying a fluid is proposed, comprising a pumping unit with an inlet and an impeller for conveying the fluid, a discharge unit with an outlet for the fluid, a drive unit for rotating the impeller, a column pipe extending in an axial direction and having at least one column element with an axial length, said column pipe connecting the pumping unit with the discharge unit, as well as a line shaft extending within the column pipe and operatively connecting the drive unit with the pumping unit, wherein at least one column element of the column pipe is provided with a suppressing device designed according to the invention said suppressing device closely fitting around the entire circumference of the column element, and having an extension in the axial direction which is at least half the axial length of the column element.

[0021] As already explained in connection with the suppressing device, a vertical pump being provided with a suppressing device according to the invention renders possible to easily suppress critical structural natural frequencies of the pump by shifting these critical frequencies to higher values.

[0022] It is preferred, when the suppressing device is releasably connected to the column element because by this measure it is also possible to modify already existing pumps in such a manner that they become vertical pumps according to the invention. Furthermore, this measure is advantageous from the constructural point of view.

[0023] In order to realize a particularly efficient shift of the structural natural frequency it is preferred that the extension of the suppressing device in the axial direction is equal to the axial length of the column element, i.e. the suppressing device covers the column element along its entire axial extension.

[0024] In case the column pipe comprises a plurality of column elements it is an advantageous measure when at least two column elements are provided with a respective suppressing device. In many applications it might be preferred when each of the individual column elements is provided with a respective suppressing device.

[0025] Furthermore, in accordance with the invention a method of retrofitting a vertical pump is proposed, the pump comprising a pumping unit with an inlet and an

impeller for conveying a fluid, a discharge unit with an outlet for the fluid, a drive unit for rotating the impeller, a column pipe extending in an axial direction and having at least one column element with an axial length, said column pipe connecting the pumping unit with the discharge unit, as well as a line shaft extending within the column pipe and operatively connecting the drive unit with the pumping unit, said method comprising the steps of:

- providing a suppressing device for shifting a structural natural frequency of the vertical pump, said suppressing device being designed in accordance with the invention
- selecting at least one of the column elements
- mounting the suppressing device to the column element in a closely fitting manner around the entire circumference of the column element.

[0026] The suppressing device according to the invention is particularly suited for retrofitting already existing vertical pumps. If there is a resonance issue at a specific vertical pump, e.g. because a structural natural frequency of the pump installation is equal or very close to the running speed of the pump the method according to the invention provides for an efficient, very simple and cost-efficient solution for suppressing said natural frequency by shifting the structural natural frequency to higher values. Thus, there is no need for a complete redesign of the pump. The resonance issue may be solved by providing a suited suppressing device to the column pipe of the pump.

[0027] By the same reasons as already herein before mentioned it is preferred that the suppressing device is provided with an extension in the axial direction being equal to the axial lengths of the column element.

[0028] In order to facilitate the mounting of the suppressing device it is preferred when the suppressing device comprises a plurality of stiffening members, preferably four stiffening members, and when the stiffening members are laid around the column element and fixed to each other to closely fit around the entire circumference of the column element.

[0029] For applications where the column pipe comprises more than one column element it is preferred that a plurality of column elements is selected and each of the selected column elements is provided with a separate suppressing device.

[0030] Further advantageous measures and embodiments of the invention will become apparent from the dependent claims.

[0031] The invention will be explained in more detail hereinafter with reference to the drawings. There are shown in a schematic representation:

Fig. 1: is a cross-sectional view of a vertical pump known from the prior art,

Fig. 2: is an exploded perspective view of a first embodiment of a suppressing device according to the invention together with an column element of a vertical pump,

Fig. 3: is a perspective view of a stiffening member of the first embodiment shown in Fig. 2,

Fig. 4: is a cross-sectional view of the stiffening member shown in Fig. 3 in a section perpendicular to the axial direction,

Fig. 5: is a perspective view of a column element with the first embodiment of the suppressing device mounted on it,

Fig. 6: is schematic, cross-sectional view of an embodiment of a vertical pump according to the invention,

Fig. 7: like Fig. 4, but for a variant of the stiffening member, and

Fig. 8: is a cross-sectional view of a second embodiment of a suppressing device according to the invention.

[0032] In the drawings of the different embodiments identical parts or parts having the same function or an analogously same function are designated with the same reference numerals.

[0033] Fig. 1 shows a cross-sectional view of a vertical pump which is designated in its entity with reference numeral 1. The vertical pump 1 as such is known from the prior art. However the general description given with reference to Fig. 1 is also valid for an embodiment of a vertical pump 1 according to the invention as illustrated in Fig. 6.

[0034] Fig. 1 shows the vertical pump 1 in its usual operating position, i.e. in a vertical orientation. Hereinafter relative terms regarding the location like "above" or "below" refer to this operating position shown in Fig. 1.

[0035] The vertical pump 1 (Fig. 1) comprises a pumping unit 2 located at the lower end of the pump 1. The pumping unit 2 is provided with an inlet 21 and an impeller 22 for conveying a fluid, for example water. From the upper end of the pumping unit 2 a tubular column pipe 3 is vertically extending upwards to connect the pumping unit 2 to a discharge unit 4 having an outlet 41 for discharging the pumped fluid. The column pipe 3 extends in an axial direction A which is defined by the axis of the column pipe 3 and coincides with the vertical direction when the pump 1 is in its usual operating position. The column pipe 3 consists of a plurality - in this embodiment five - column elements 31 being arranged one after the other with respect to the axial direction A. Each of the tubular column elements 31 is provided at its axial ends with a flange 32 for connecting the column element 31

to the adjacent column element 31 or the pumping unit 2 or the discharge unit 4, respectively.

[0036] On top of the discharge unit 4 a drive unit 5 is arranged for driving the impeller 22 of the pump 1. The drive unit 5 may be for example an electric motor or any other motor. The drive unit 5 is operatively connected to the impeller 22 by means of a line shaft 6 extending in the center of the column pipe 3 and coaxially therewith. The line shaft 6 is supported by a plurality of shaft bearings 61. Usually adjacent to each connection of two neighboring column elements 31 a shaft bearing 61 is arranged for supporting and guiding the line shaft 6 along its entire axial extension. Depending on the specific application it is possible that an additional tube is arranged around the line shaft 6 extending coaxially with the column pipe 3 and delimiting the line shaft 6 from the remainder of the interior of the column pipe 3. This measure can be used for example if a contact of the fluid to be conveyed with the line shaft 6 should be avoided.

[0037] During operation the vertical pump 1 is supported by a supporting structure (not shown in Fig. 1) which is usually supporting the pump 1 in the vicinity and below the discharge unit 4, for example at a level indicated by arrow B in Fig. 1. The lower part of the pump beneath the supporting structure is freely hanging, i.e. without additional support, into the reservoir of the fluid to be pumped. If the fluid is water the reservoir may be a river, a lake, a sea, a sump or a cooling water pool. The sump level which is the level of the fluid surrounding the vertical pump is usually at a given level located between the upper end of the pumping unit 2 and the lower end of the discharge unit 4. Thus, during operation of the pump at least the pumping unit 2 is completely immersed into the fluid to be conveyed. The impeller 22 driven by the drive unit 5 and the line shaft 6 sucks the fluid through the inlet 21 and conveys it through the column pipe 3 to the discharge unit 4 and to the outlet 41.

[0038] In known vertical pumps 1 resonance effects can occur which are detrimental for the pump 1. In particular, a premature failure of the bearings like the shaft bearings 61 and of the line shaft 6 may be caused by resonance effects. These effects arise for example when the running speed of the pump 1 or the rotational speed of the impeller 22 corresponds to a frequency which is equal or very close to a structural natural frequency. These resonance effects may occur both in already existing and operating pumps 1 and in newly constructed pumps 1.

[0039] In order to resolve these resonance problems the present invention proposes a suppressing device for shifting a structural natural frequency of a vertical pump 1 and thus suppressing the original natural frequency.

[0040] Fig. 2 shows in an exploded perspective view a first preferred embodiment of a suppressing device according to the invention which is designated in its entity with the reference numeral 10. For a better understanding Fig. 2 additionally shows a perspective view of a column element 31 of the column pipe 3. The suppressing

device 10 is designed and adapted for closely fitting around the entire circumference of the column element 31. The suppressing device has an extension L in the axial direction A which is at least half the axial length C of the column element 31 the suppressing device 10 is surrounding. It is preferred as shown by the first embodiment of the suppressing device 10 if the extension L in the axial direction A is equal to the axial length C of the column element 31, i.e. in the mounted state the suppressing device 10 covers the entire lateral surface of the column element 31 (see Fig. 5).

[0041] The expression "axial length" with regard to the column element 31 means the distance between the two flanges 32 delimiting the column element 31, that is the distance between the lower edge of the upper flange 32 and the upper edge of the lower flange 32 of the respective column element 31.

[0042] The suppressing device 10 comprises at least one rib 11 extending essentially in a radial direction being perpendicular to the axial direction A.

[0043] The first preferred embodiment of the suppressing device 10 comprises a plurality and more specifically four stiffening members 12. The four stiffening members 12 are essentially identical. For a better understanding Fig. 3 shows one of the stiffening members 12 in a perspective view and Fig. 4 a cross-sectional view of one of the stiffening members 12 in a section perpendicular to the axial direction A. In addition, Fig. 5 shows a perspective view of the column element 31 with the suppressing device 10 being mounted on it.

[0044] Each of the stiffening members 12 is curved in a circumferential direction and connectable to its adjacent stiffening members 12. The four stiffening members 12 are complementing one another in the assembled state to form a tubular structure having an inner diameter which corresponds or is slightly smaller than the outer diameter D of the column element 31. Thus, in the assembled and mounted state the four stiffening members 12 are closely fitting around the entire circumference of the column element 31 and generating a clamping effect. By this close fit around the entire circumference of the column element 31 the suppressing device 10 provides for an increase of the thickness of the wall of the column element 31 which in turn stiffens the column element 31 and thus shifts the structural natural frequency to a higher value.

[0045] As can be best seen in Fig. 3 and Fig. 4 each stiffening member 12 has a middle part 121 having a quadrant shaped cross-section as well as two lateral ribs 11 extending in the radial direction. Each of the lateral ribs 11 forms an end of the stiffening member 12 with respect to the circumferential direction. The middle part 121 of each stiffening member 12 extends between the two lateral ribs 11.

[0046] The stiffening member 12 may be manufactured by selecting a material, preferably a metallic material, which is compatible with the material of the column element 31. Starting with a rectangular sheet of the ma-

terial two parallel end edges of the rectangular sheet are bent until each of them extends perpendicular to the remainder of the sheet. After that the rectangular sheet is bent until the middle part 121 is curved such that it has a quadrant shaped cross section.

[0047] As best seen in Fig. 4 the middle part 121 has a curvature that corresponds to a radius R which is pre-defined by the outer diameter D of the column element 31. As already said the radius R is most preferred equal to half the outer diameter D of the column element 31. The stiffening member 12 has a thickness T which is preferably -but not necessarily- uniform over the entire stiffening member 12. The extension RL of the lateral ribs 11 in the radial direction is preferably the same for both lateral ribs 11. However it is also possible that the two lateral ribs 11 have different extensions RL in the radial direction.

[0048] With respect to the axial direction A it is preferred that both lateral ribs 11 have the same axial length AL (Fig. 3) and that the axial length AL is equal to the extension L of the suppressing device 10 in the axial direction L. Thus, it is preferred that each lateral rib 11 extends in the axial direction A over the entire length of the stiffening member 12. However, depending on the specific application it is also possible that the axial length AL of the lateral ribs 11 is smaller than the extension L of the suppressing device 10 in the axial direction A. Thus, the middle part 121 of the stiffening member 12 may be longer in the axial direction A than the lateral ribs 11. This might be advantageous for example in such applications where the spatial circumstances are not sufficient for lateral ribs 11 extending over the entire extension L of the suppressing device 10.

[0049] In order to mount the suppressing device 10 to the column element 31 each lateral rib 11 is provided with a plurality of holes 111 for receiving fixing means to rigidly connect adjacent stiffening members 12. Most preferred the suppressing device 10 is bolt on the column element 31 (see Fig. 5). The holes 111 in adjacent ribs 11 of the stiffening members 12 are aligned such that they can receive screws 13 as fixing members which are secured by means of screw nuts 14. This measure renders possible a very simple and reliable mounting of the suppressing device 10. In addition, by bolting the suppressing device 10 on the column element 31 there is no need to weld additional parts to the column pipe 3. Welding something to the column pipe 3 always includes the danger to distort the column pipe 3 or parts thereof and render these parts unusable. Furthermore, using screws 13 and screw nuts 14 renders possible to tightly fit the suppressing device 10 around the circumference of the column element 31 thus providing the desired clamping effect that stiffens the column element 31.

[0050] Whereas the closely fitting stiffening members 12 correspond to an increase in the wall thickness of the column element 31 the lateral ribs 11 extending in the radial direction have the additional effect to change and especially to increase the moment of inertia of the column

element 31. The increase of the moment of inertia shifts the natural frequency of the structure to higher values.

[0051] The respective dimensions of the suppressing device 10 or the stiffening members 12 for generating the stiffening effect and the increase in the moment of inertia depend on the specific application and have to be determined for the respective application.

[0052] A preferred method for the determination of appropriate dimensions and locations of the suppressing device 10 is a finite element analysis (FEA). This well-known method is especially suited for the determination of structural natural frequencies of given structures. Thus, by means of a FEA the original structural natural frequencies of a vertical pump can be determined. After that the FEA renders possible to find appropriate parameters for the dimensions of the suppressing device 10 which results in an efficient increase of the structural natural frequency to move it away from critical values - like the running speed of the pump 1 - thus, suppressing detrimental resonance effects.

[0053] Of course there are also other suited methods for the investigation and the determination of structural natural frequencies, for example methods based upon simulations or other analytical methods which are as such known to a person skilled in the art. Furthermore, it is possible to use empiric data, historical data of vertical pumps or general knowledge or know-how both alone and in combination with analytical methods or simulations in order to determine appropriate dimensions for the design of the suppressing device 10. The parameters that can be varied in order to find appropriate dimensions and/or locations for the suppressing device 10 include: the extension L of the suppressing device in the axial direction A, the axial length AL of the stiffening members 12, the thickness T of the stiffening members 12, the extension RL of the ribs 11 in the radial direction, the number of the ribs 11, the number of the suppressing devices 10, the location of the suppressing device 10, i. e. to which column element 31 or column elements 31 a suppressing device 10 is mounted.

[0054] According to the invention also a vertical pump 1 having at least one suppressing device 10 is proposed. The suppressing device 10 is suited both for already existing pumps 1 to shift structural natural frequencies away from critical values and for newly constructed vertical pumps 1. Fig. 6 shows in a more schematic, cross-sectional view a preferred embodiment of a vertical pump 1 according to the invention. In Fig. 6 the same reference numerals are used as in Fig. 1 to Fig. 5 and they have the same meaning as already explained herein before.

[0055] The vertical pump 1 for conveying a fluid, for example water, comprises the pumping unit 2 with the impeller 22 (not shown in Fig. 6) and the inlet 21 (not shown in Fig. 6) and the discharge unit 4 with the outlet 41. On top of the discharge unit 4 the drive unit 5 is arranged. The column pipe 3 is vertically extending and connects the pumping unit 2 with the discharge unit 4. The line shaft 6 extends within the column pipe 3 and

operatively connects the drive unit 5 with the impeller 22 in the pumping unit 2.

[0056] The column pipe 3 comprises a plurality, here four, column elements 31 being arranged one after another in the axial direction A.

[0057] According to the invention at least one column element 31 of the column pipe 3 is provided with a suppressing device 10 which is designed in accordance with the invention. The suppressing device 10 is closely fitting around the entire circumference of the column element 31 and has the extension L in the axial direction A which is at least half the axial length C of the column element 31.

[0058] In the preferred embodiment shown in Fig. 6 each of the four column elements 31 is provided with a respective suppressing device 10. Each suppressing device 10 is designed in the same manner as explained herein before with reference to Fig. 2 to Fig. 5. Each suppressing device 10 is adapted to the axial length C of the column element 31 it is surrounding, i.e. the extension L of the suppressing device 10 in the axial direction A and the axial length AL of the stiffening members 12 is equal to the axial length C of the column element 31. The suppressing devices 10 are bolt on the respective column element 31 as already explained and thus the suppressing devices 10 are releasably connected to the column element 31. The connection between the suppressing device 10 and the respective column element 31 is a tight fit that provides for a clamping effect which stiffens the respective column element 31.

[0059] In vertical pumps 1 having a column pipe 3 comprising a plurality of column elements 31 it is not necessary that each column element 31 is provided with a suppressing device 10. It is also possible that only one or two or any other number of column elements 31 is provided with a suppressing device 10. The number of column elements 31 and the choice of the specific column element 31 or elements 31 that are provided with a suppressing device 10 are depending on the specific vertical pump 1 and/or the specific application. The appropriate number and location of the suppressing device 10 or the suppressing devices 10 may be determined by way of a FEA method or any other method herein before mentioned. It may also be the case that the circumstances, especially the spatial circumstances at the location where the vertical pump is operating, require some restrictions regarding the number and the location of the suppressing devices 10 mounted to the column pipe 3 of the pump 1.

[0060] Fig. 7 shows a variant of the stiffening member 12 in a like representation as Fig. 4. The variant is illustrated in a cross-sectional view wherein the section is taken perpendicular to the axial direction A. The variant of the stiffening member 12 differs from the stiffening member 12 shown in Fig. 4 by an additional intermediate rib 15 extending in the radial direction and being arranged on the middle part 121 of the stiffening member 12 between the lateral ribs 11. The intermediate rib has an extension RL in the radial direction which may be the same as or different from the extension of the lateral ribs

11 in the radial direction. Regarding the extension of the intermediate rib 15 in axial direction A it is preferred that this extension is the same as the corresponding extension of the lateral ribs 11. It is preferred when the extension of the intermediate rib 15 in the axial direction A is equal to the axial length AL of the stiffening member 12. The intermediate rib 15 is preferably fixed to the stiffening member 12 by means of welding.

[0061] Of course it is also possible to provide more than one intermediate rib 15 on a stiffening member 12 and to combine stiffening members 12 having at least one intermediate rib 15 with stiffening members 12 having no intermediate rib 15.

[0062] Fig. 8 is a cross-sectional view of a second embodiment of a suppressing device 12 according to the invention. In the following description only the differences to the first embodiment are explained. The explanations with respect to the first embodiment are also valid in analogously the same way for the second embodiment shown in Fig. 8.

[0063] The second embodiment of the suppressing device 10 is designed as a single part for closely fitting around the entire circumference of the column element 31. The suppressing device 10 comprises two essentially identical stiffening members 12, each being designed in a similar matter as the stiffening member 12 discussed with reference to Fig. 4. However, in the second embodiment each stiffening member 12 has a middle part 121 having a semicircular cross-section in a section perpendicular to the axial direction A. Analogously to the first embodiment the middle part 121 of each stiffening member 12 extends between the two respective lateral ribs 11. The two stiffening members 12 are connected to each other in an articulated manner. This is realized by providing a hinge 16 that connects two adjacent lateral ribs 11 belonging to different stiffening members 12. Thus, the suppressing device can be moved from an open position as shown in Fig. 8 to a closed position, in which the two lateral ribs 11 that are not connected by the hinge 16 are contacting each other. The lateral ribs 11 are provided with a plurality of holes 111 for receiving fixing means. Preferably the fixing means are screws and screw bolts.

[0064] In order to mount the suppressing device 10 to the column element 31 (not shown in Fig. 8) the suppressing device is brought into the open position, laid around the column element 31 and afterwards moved to the closed position. Then, the screws 13 (not shown in Fig. 8) are put through the holes 111 and secured by the screw nuts 14 (not shown in Fig. 8) such that the suppressing device 10 is closely fitting around the entire circumference of the column element 31.

[0065] As an optional measure the two lateral ribs 11 that are connected by the hinge 16 may also be provided with holes 111 to receive screws 13 that are secured by screw bolts 14. This measure may improve the clamping effect of the suppressing device 10 and release the hinge 16 from its load.

[0066] According to a variant of the second embodiment the two stiffening members 12 are not connected in a hinged manner but separate parts. Thus, the hinge 16 is dispensed with. The two separate stiffening members 12 are then mounted on the column element 31 in an analogous manner as described with respect to the first embodiment.

[0067] Of course, there are other embodiments possible with a different number of stiffening members 12 complementing one another to a tubular structure in the assembled state, for example the number of stiffening members 12 may be three or more than four.

[0068] The suppressing device 10 according to the invention is especially suited for retrofitting vertical pumps 1.

[0069] According to the invention, the method of retrofitting a vertical pump 1 comprises the steps of providing a suppressing device 10 for shifting a structural natural frequency of the vertical pump 1, said suppressing device being designed in accordance with the invention, selecting at least one of the column elements 31 of the column pipe 3 and mounting the suppressing device 10 to the column element 31 in a closely fitting manner around the entire circumference of the column element 31.

[0070] The tight fitting of the suppressing device 10 provides for a clamping effect that results in a stiffening of the column member 31 or the column pipe 3, respectively.

[0071] Also when retrofitting existing axial pumps it is preferred that the suppressing device 10 comprises a plurality of stiffening members 12 and most preferred four stiffening members 12. Furthermore, it is preferred that the axial length AL of the stiffening members 12 or the extension L of the suppressing device 10 in axial direction A, respectively, is equal to the axial length C of the column element 31. The stiffening members 12 are laid around the column element 31 and fixed to each other. The preferred means for fixing the stiffening members 12 to each other and to the column element 31 are screws 13 and screw nuts 14. Thus, the method provides for a very simple, safe and efficient bolt-on solution to resolve resonance problems in vertical pumps.

[0072] When the column pipe 3 of the axial pump 1 comprises more than one column element 31, for example four or seven column elements, it is preferred to select a plurality of column elements 31, for example all column elements 31, each of which is provided with a separate suppressing device 10.

[0073] In order to select the appropriate column element 31 or column elements 31 that shall be provided with a suppressing device 10 as well as to determine appropriate dimensions and designs for the individual suppressing devices 10 it is preferred to use an analytical method and preferably the method of a FEA. As already herein before mentioned, the determination of the specific dimensions and locations of the suppressing device 10 may be based upon other methods, e.g. simulations or other analytical methods which are as such known to

a person skilled in the art. Furthermore, it is possible to use empiric data, historical data of vertical pumps or know-how for said determination.

[0074] The method according to the invention is suited both for resolving resonance problems in already existing and operating pumps and for avoiding resonance problems in newly manufactured pumps. Especially in view of retrofitting existing axial pumps it is advantageous that there is no need for a complete redesign of the vertical pump to overcome resonance issues. The invention provides a solution with a very simple and effective design. This method is very flexible and can be applied to all vertical pumps 1 having a column pipe 3. The installation of the suppressing devices 10 is very fast and easy. In addition, there is no need for welding parts to the vertical pump 1. Thus, welding related distortions or other detrimental effects are avoided.

[0075] Furthermore, the installation of the suppressing device 10 may be performed on site at the location where the vertical pump is running. Since the proposed method comprises a very simple bolt on solution, it is not necessary to disassemble the entire vertical pump or to disassemble the column pipe 3 of the vertical pump 1. This drastically reduces the costs and the required time for resolving existing resonance problems in vertical pumps.

[0076] In a specific example where a resonance problem occurred in a vertical pump already in operation because the running speed of the pump was very close to a structural natural frequency of the pump the method according to the invention successfully suppressed the original natural frequency by increasing the natural frequency to a value that is now 15% away from the running speed of the vertical pump.

Claims

1. A suppressing device for shifting a structural natural frequency of a vertical pump, said pump (1) comprising a pumping unit (2) with an inlet (21) and an impeller (22) for conveying a fluid, a discharge unit (4) with an outlet (41) for the fluid, a drive unit (5) for rotating the impeller (22), a column pipe (3) extending in an axial direction (A) and having at least one column element (31) with an axial length (C), said column pipe (3) connecting the pumping unit (2) with the discharge unit (4), as well as a line shaft (6) extending within the column pipe (3) and operatively connecting the drive unit (5) with the pumping unit (2), said suppressing device (10) being designed and adapted for closely fitting around the entire circumference of the column element (31), and having an extension (L) in the axial direction (A) which is at least half the axial length (C) of the column element (31) and comprising at least one rib (11) extending essentially in a radial direction being perpendicular to the axial direction (A).

2. A suppressing device in accordance with claim 1 wherein the extension (L) in the axial direction (A) is equal to the axial length (C) of the column element (31) around which the suppressing device (10) is fitting in the assembled state.
3. A suppressing device in accordance with anyone of the preceding claims comprising a plurality of stiffening members (12) being curved in a circumferential direction and being connectable to each other and complementing one another in the assembled state to a tubular structure for closely fitting around the entire circumference of the column element (31).
4. A suppressing device in accordance with claim 3 wherein each stiffening member (12) has two lateral ribs (11) extending in the radial direction, each rib (11) forming an end of the stiffening member (12) with respect to the circumferential direction.
5. A suppressing device in accordance with claim 4, comprising four stiffening members (12), each of which has a middle part (121) with a quadrant shaped cross section, said middle part (121) extending between the two lateral ribs (11).
6. A suppressing device in accordance with claim 4 or claim 5, wherein each lateral rib (11) is provided with a plurality of holes (111) for receiving fixing means to rigidly connect adjacent stiffening members (12).
7. A suppressing device in accordance with anyone of claims 4 to 6 wherein at least one stiffening member (11) has an intermediate rib (15) extending in the radial direction and being arranged between the two lateral ribs (11).
8. A vertical pump for conveying a fluid comprising a pumping unit (2) with an inlet (21) and an impeller (22) for conveying the fluid, a discharge unit (4) with an outlet (41) for the fluid, a drive unit (5) for rotating the impeller (22), a column pipe (3) extending in an axial direction (A) and having at least one column element (31) with an axial length (C), said column pipe (3) connecting the pumping unit (2) with the discharge unit (4), as well as a line shaft (6) extending within the column pipe (3) and operatively connecting the drive unit (5) with the pumping unit (2), **characterized in that** at least one column element (31) of the column pipe (3) is provided with a suppressing device (10) designed according to any one of the preceding claims said suppressing device (10) closely fitting around the entire circumference of the column element (31), and having an extension (L) in the axial direction (A) which is at least half the axial length (C) of the column element (31).
9. A vertical pump in accordance with claim 8, wherein the suppressing device (10) is releasably connected to the column element (31).
10. A vertical pump in accordance with claim 8 or claim 9, wherein the extension (L) of the suppressing device in the axial direction (A) is equal to the axial length (C) of the column element (31).
11. A vertical pump in accordance with anyone of claims 8 to 10, wherein the column pipe (3) comprises a plurality of column elements (31) and wherein at least two column elements (31) are provided with a respective suppressing device (10).
12. A method of retrofitting a vertical pump comprising a pumping unit (2) with an inlet (21) and an impeller (22) for conveying a fluid, a discharge unit (4) with an outlet (41) for the fluid, a drive unit (5) for rotating the impeller (22), a column pipe (3) extending in an axial direction (A) and having at least one column element (31) with an axial length (L), said column pipe (3) connecting the pumping unit (2) with the discharge unit (4), as well as a line shaft (6) extending within the column pipe (3) and operatively connecting the drive unit (5) with the pumping unit (2), said method comprising the steps of:
 - providing a suppressing device (10) for shifting a structural natural frequency of the vertical pump, said suppressing device (10) being designed in accordance with anyone of claims 1 to 7,
 - selecting at least one of the column elements (31),
 - mounting the suppressing device (10) to the column element (31) in a closely fitting manner around the entire circumference of the column element (31).
13. A method in accordance with claim 12 wherein the suppressing device (10) is provided with an extension (L) in the axial direction being equal to the axial lengths (C) of the column element (31).
14. A method in accordance with claim 12 or claim 13, wherein the suppressing device (10) comprises a plurality of stiffening members (12), preferably four stiffening members (12), and wherein the stiffening members (12) are laid around the column element (31) and fixed to each other to closely fit around the entire circumference of the column element (31).
15. A method in accordance with anyone of claims 12 to 14, wherein a plurality of column elements (31) is selected and each of the selected column elements (31) is provided with a separate suppressing device (10).

Fig.1

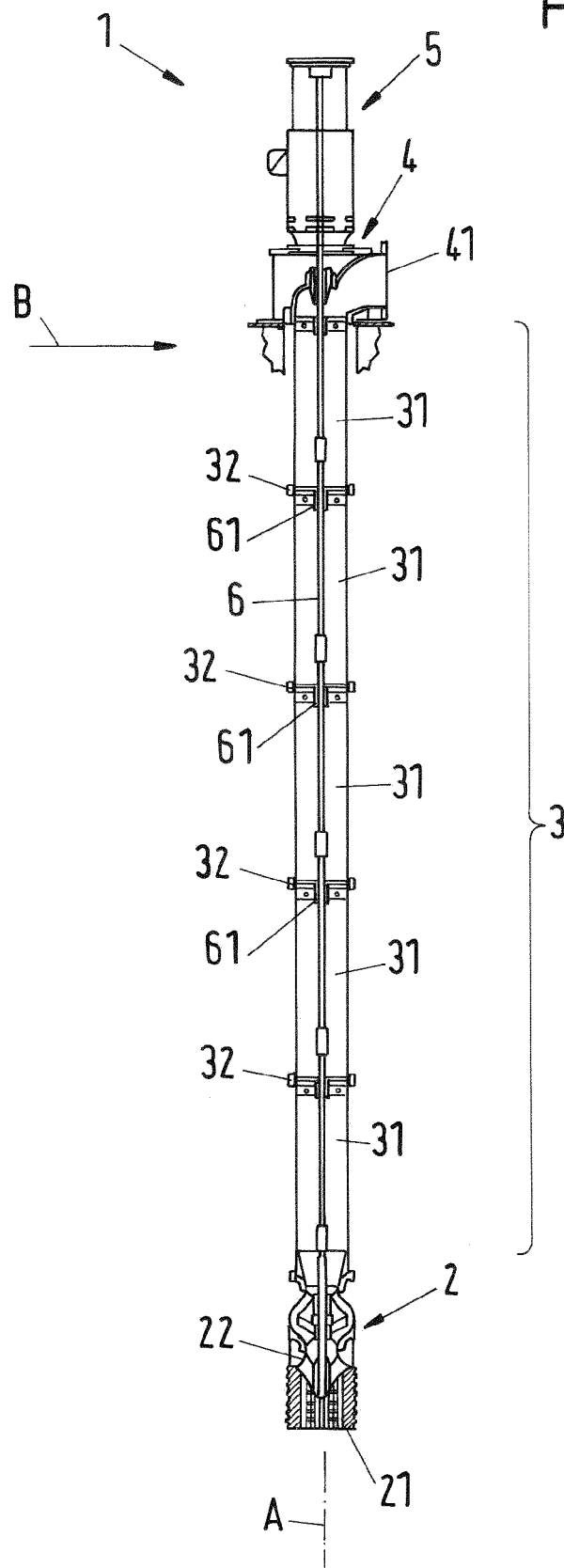


Fig.2

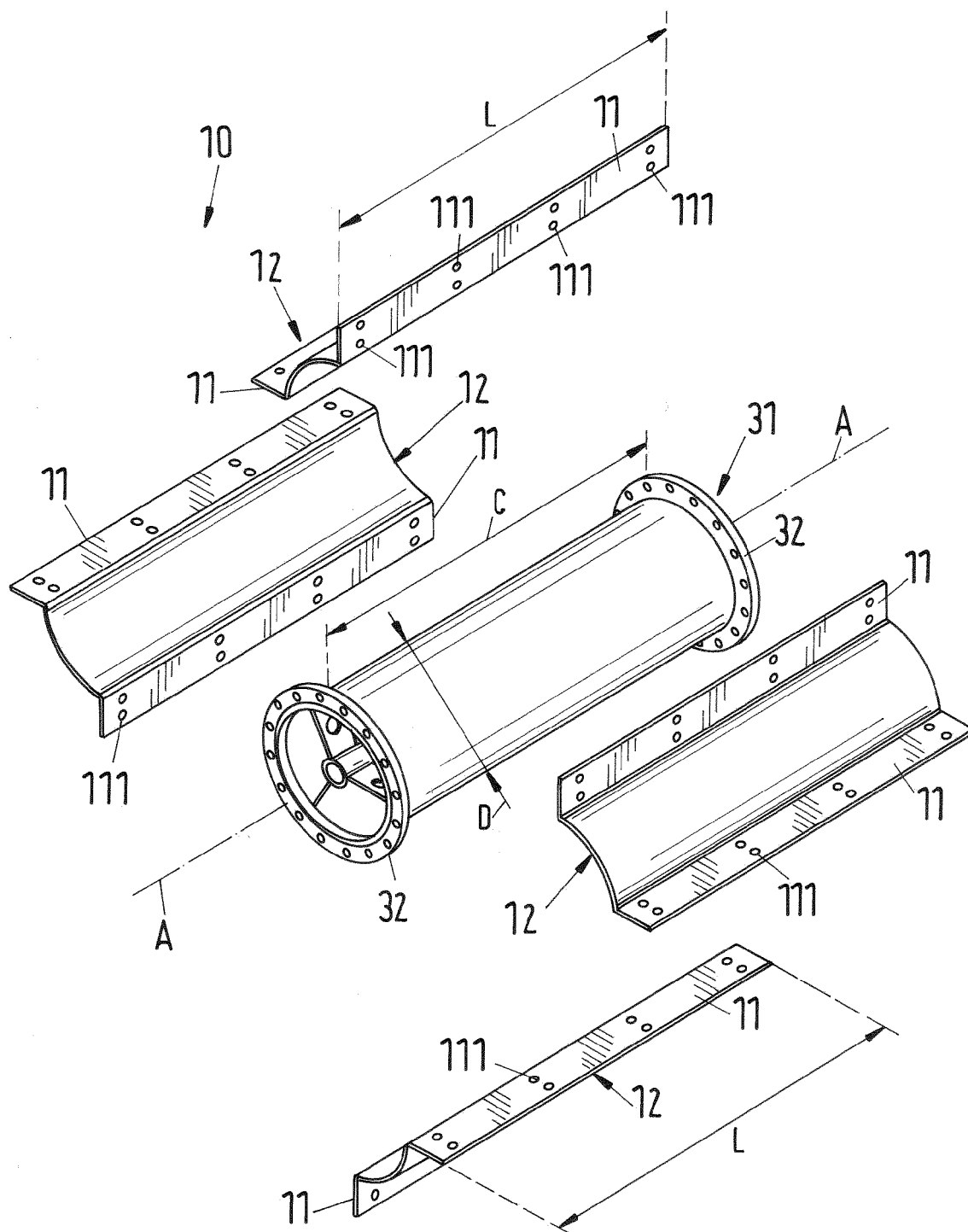


Fig.3

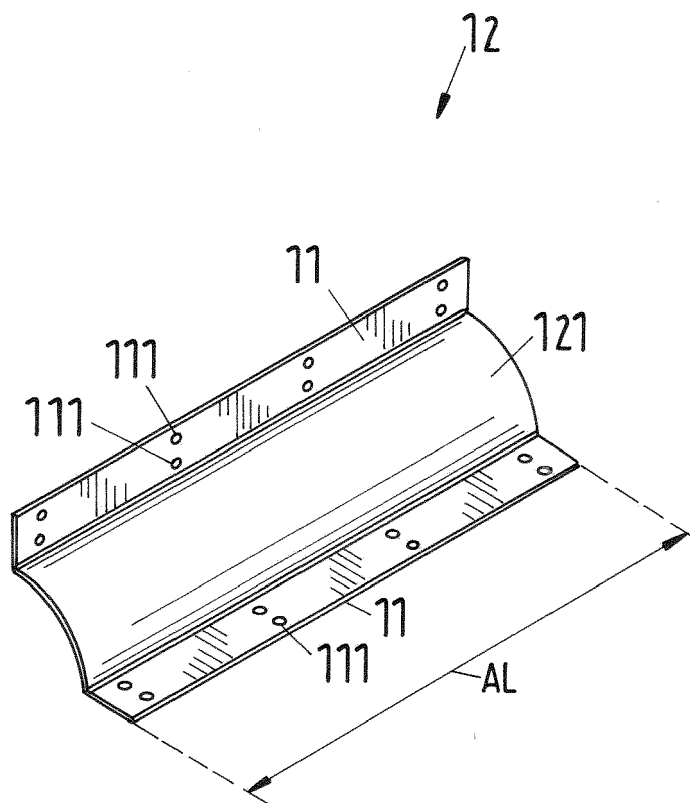


Fig.4

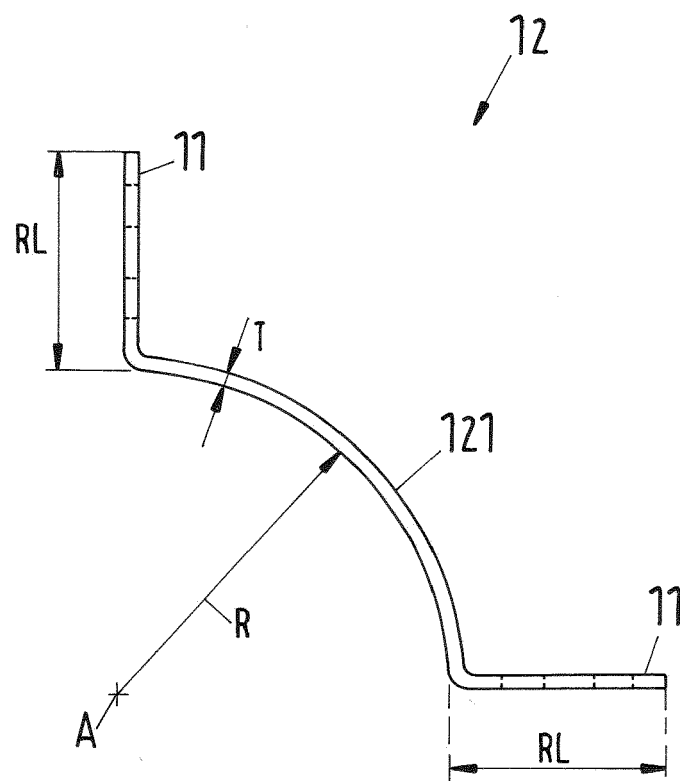


Fig.5

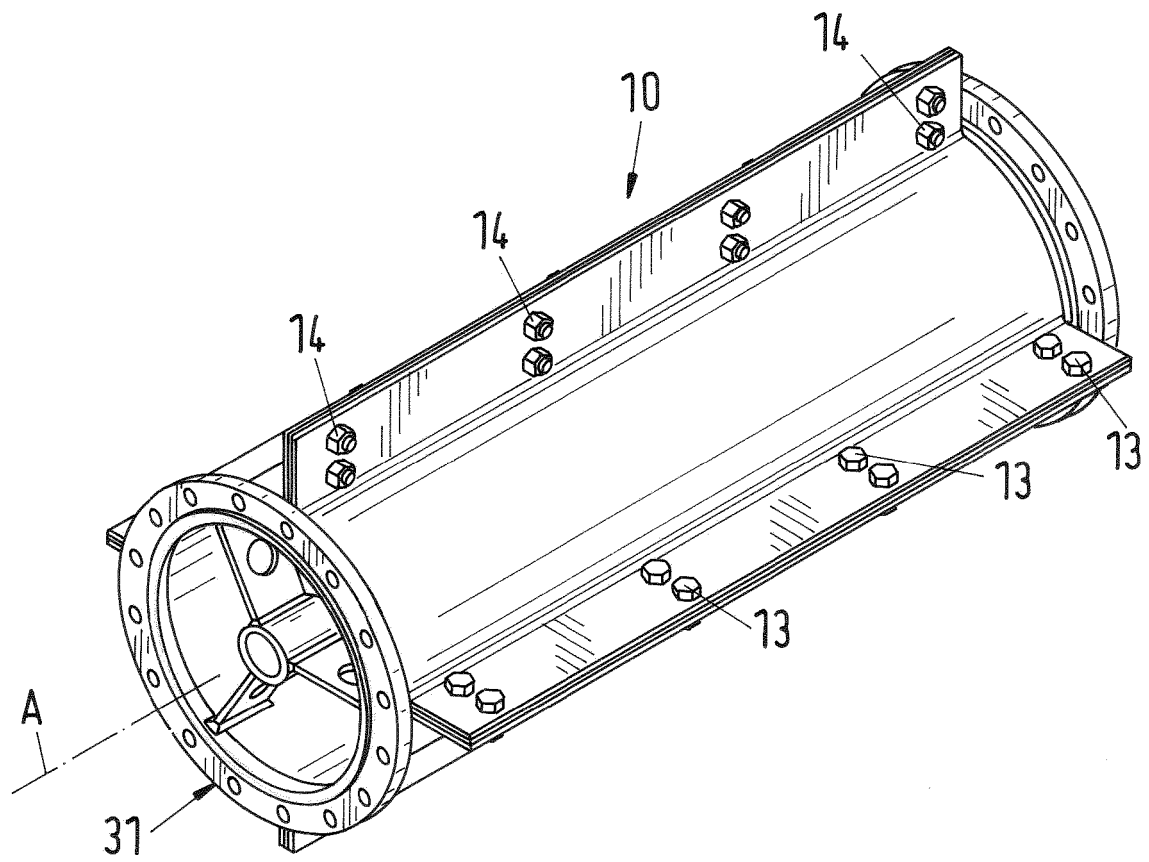


Fig.6

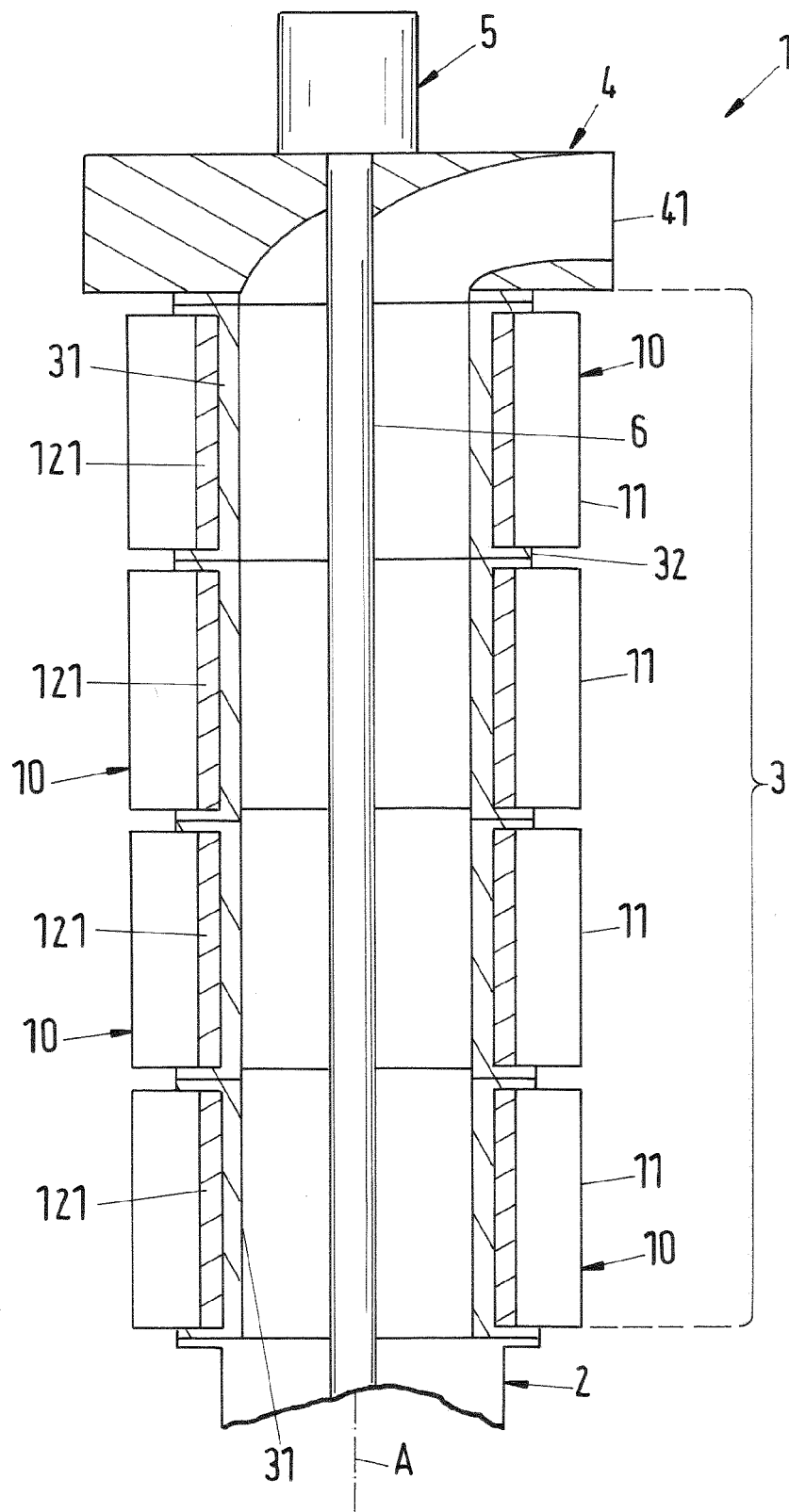


Fig.7

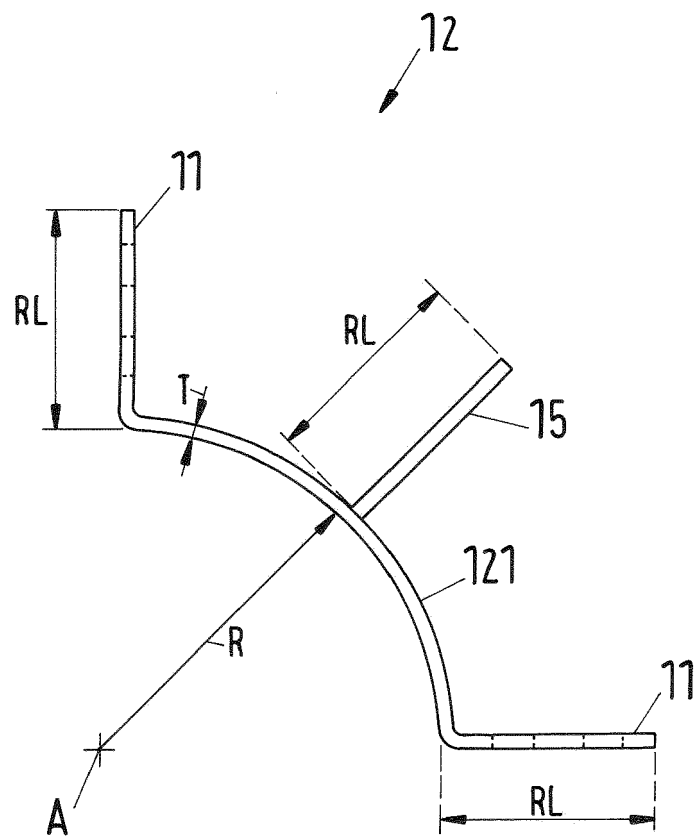
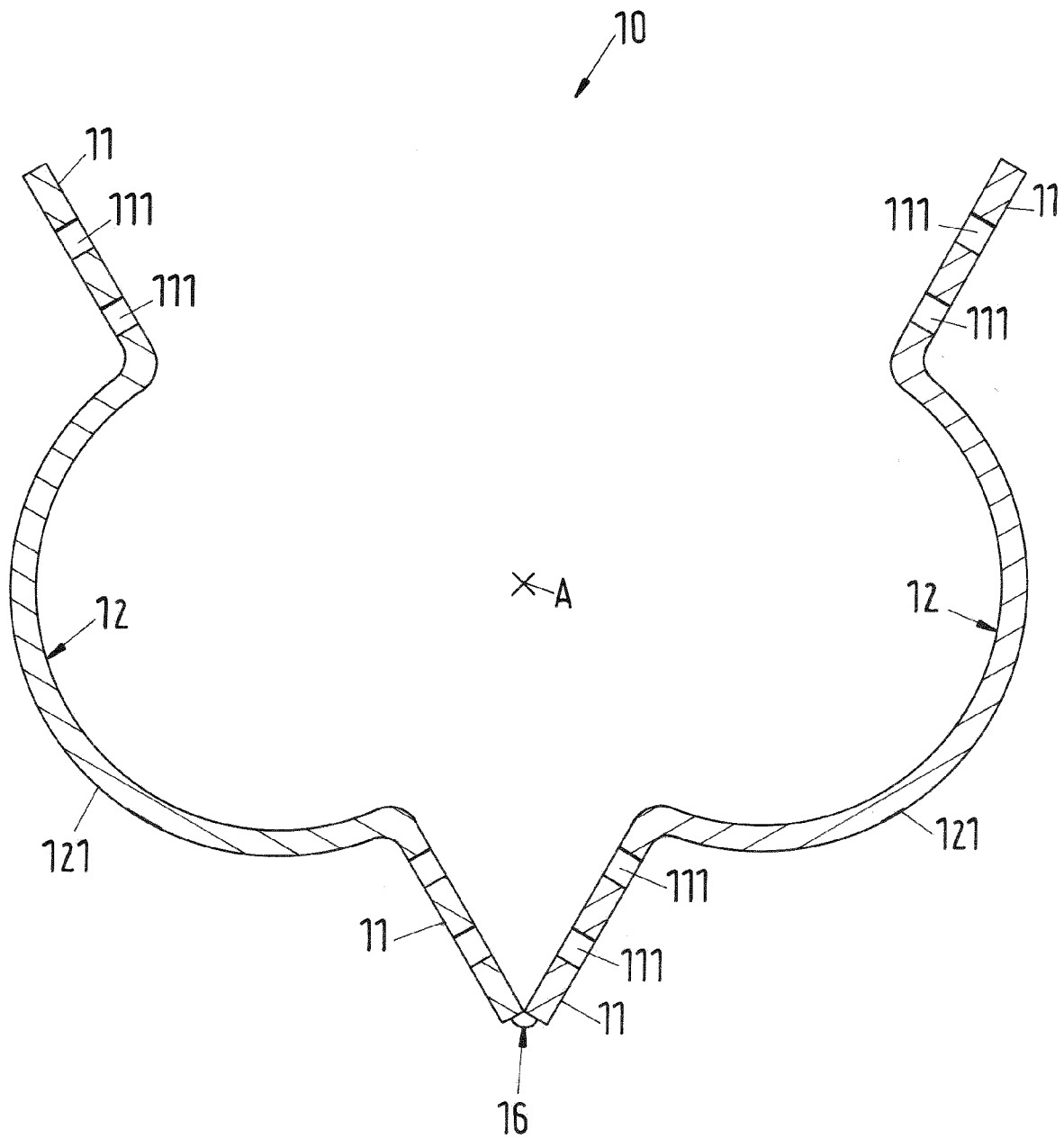


Fig.8





EUROPEAN SEARCH REPORT

Application Number
EP 15 18 9335

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X	US 2012/067449 A1 (PESEK TOMAS [CH]) 22 March 2012 (2012-03-22) * paragraphs [0002], [0003], [0019], [0030] - [0033], [0037], [0045] - [0047] * figures 1,2,4A *	1-4,6-15	
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CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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