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(54) METHOD FOR MANUFACTURING A STEEL-MADE YANKEE CYLINDER

(57) The invention relates to a method for manufacturing a steel-made Yankee cylinder. According to the invention is the Yankee cylinder divided into several cylindrical shell sections (2a,2b,2x) and these cylindrical shell sections are welded together in an aligned relation to each other, maintaining the roundness of the Yankee, by applying shorter mutually opposed weld seams in pairs along a circumferentially running weld joint. Each weld in a subsequently applied weld pair is preferably applied furthest away from the last weld in a precedingly applied weld pair in a sequential weld pattern. By this welding method is the roundness in the fast-revolving pressure vessel maintained, improving structural rigidity of the Yankee during operation.

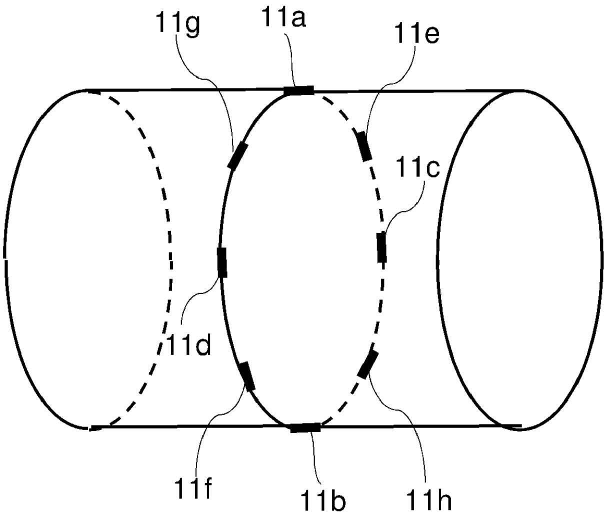

Fig. 8a

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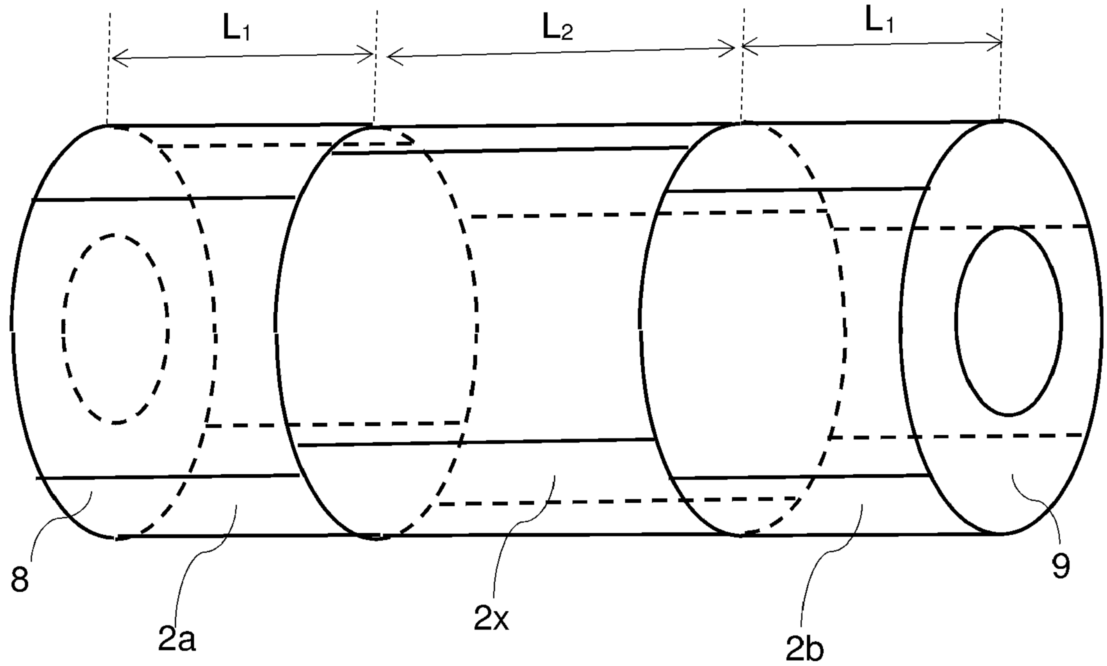


Fig. 8b

Description

BACKGROUND OF THE INVENTION

[0001] The invention relates to a method for manufacturing a steel-made Yankee drying cylinder for paper or tissue machines.

PRIOR ART

[0002] Yankee cylinders have been used frequently as the main drying step in especially tissue machines. On a Yankee cylinder the paper is subjected to drying where the dryness increases from about 40% dryness to about 90% dryness. The Yankee cylinder is a fast-rotating pressure vessel, as it is heated by steam at a pressure above 5 bars and must meet all requirements for such a pressure vessel. The speed of the outer surface of the cylindrical shell is up to 1000 m/min. Such pressure vessels need to be manufactured with high precision. Some Yankee cylinders have even exploded due to deficiencies in manufacturing or due to uneven heating of the Yankee.

[0003] These Yankee cylinders have traditionally been made of cast iron and with a diameter up to 6 meters and a cylinder length of up to 8 meter, and with a gross weight of up to 140 ton. These huge cylinders previously had to be cast in foundries having a capacity to cast such heavy and bulky products, and then shipped in finally machined state to final customer sites at different locations all over the world. Not that many countries have foundries with this capacity and the ones in operation today make casted Yankee cylinders for customer all over the world and some may for instance be shipped from Sweden to Asian markets. The transportation costs become excessive, especially if the final paper mill is located inland at quite some distance from harbors, needing transportation also at common roads.

[0004] Steel-made Yankees has therefore been considered and used during the latest decades, and these steel-made Yankees gain market, as they may be made with reduced gross weight and may be easier to transport, especially if the Yankee could be transported in several modules with only a part weight of the final gross weight of the Yankee. The gains are obvious if a Yankee cylinder with a final gross weight of 140 ton may be transported in three or more modules weighing less than 50 ton a piece.

[0005] An example of a steel-made Yankee may be seen in US 9.452.498, where a steel-made Yankee may be made in modules and wherein the modules may be shipped to a final customer residing in a distant location to the manufacturing site. In this patented process a specific welding technique is used where the modules of the Yankee are welded together at the site of the customer using a specific narrow gap welding process with a mobile welding robot guided by a track system inside of the modules. Now, this narrow gap welding process conventionally requires strict alignment of the modules together and creating a narrow gap between the end faces to be welded together, and the welding robot gradually fills the narrow gap with multiple weld seams The narrow gap may typically be filled by passing the robot at least 4-5 times over the weld seam to be made, but in some cases more than 10-20 passes needs to be made with the welding robot, applying sequential weld layers on top of each other in the narrow gap.

[0006] Even though the concept of steel-made Yankee cylinders is known per se and steel-made cylinders are shipped in modules to end users at different locations, welding techniques used for these modules still need development to improve the final quality of the weld seams, to decrease the need for complex and expensive welding equipment at end user locations to reduce potential deformation of the huge Yankee during welding and to maintain the manufactured roundness of the modules also in the finally assembled Yankee needed for proper operation of the Yankee.

SUMMARY OF THE INVENTION

[0007] The invention is related to an improved way of manufacturing a steel-made Yankee cylinder, that may enable shipment of smaller Yankee modules from one location in the world to another end user location in the world where less complicated welding machines and well-trained operators for these complex welding machines may not be readily available. Licensed welders are difficult to find as the need for these licensed welders is in high demand, especially from gas- and oil pipeline builders. More complex welding methods involving narrow gap welding also need special welding equipment and welders well acquainted with this kind of welding equipment, which not all licensed welders are.

[0008] Even though narrow gap welding is supposed to reduce local heat load around the weld applied, and instead apply the weld in multiple passes of the welding head, most often 10-20 passes over the weld joint, substantial heat deformation may occur that can affect the roundness of the final Yankee.

[0009] Hence, the inventive method could obtain a final steel-made Yankee, delivered in modules and finally welded together at an end user location, requiring less skills in welding, less advanced welding machines, and may provide a finally assembled steel-made Yankee with as good or even better roundness in the Yankee that is classified as a pressure vessel rotating at high speeds.

[0010] In order to solve these objectives, the inventive method is applied for manufacturing a steel-made Yankee cylinder used for drying a fibrous web in a paper or tissue machine and classified as a pressure vessel capable of being pressurized to at least 4 bar(e), wherein the Yankee cylinder comprises a cylindrical outer shell and at least two circular disc-shaped gables.

[0011] The method comprising the steps of:

manufacturing the disc-shaped gables from steel plates, and machining the outer circumference to a circular shape congruent to the outer circumference of the Yankee cylinder;

manufacturing a first cylindrical shell section from rolled steel plates by welding a rolled steel plate together with another rolled steel plate along a weld seam running in the axial direction of the Yankee and welding the first cylindrical shell section to a first circular disc shaped gable, forming a first sub-section of the Yankee cylinder, and manufacturing a second cylindrical shell section from rolled steel plates by welding a rolled steel plate together with another rolled steel plate along a weld seam running in the axial direction of the Yankee and welding the second cylindrical shell section to a second circular disc shaped gable, forming a second sub-section of the Yankee cylinder;

manufacturing an optional number of additional cylindrical shell sections from rolled steel plates by welding a rolled steel plate together with another rolled steel plate along a weld seam running in the axial direction of the Yankee;

characterized in that at least one cylindrical shell section is welded together with another cylindrical shell section along a circumferentially running weld seam that is applied in at least two layers, and wherein at least one layer of the weld seam is applied in a sequential application of a circumferentially running partial weld seam that is applied in mutually diametrically opposing pairs of weld seams with a circumferential extension of each weld in this pair is less than 30° of the total circumference of the Yankee cylinder, and where a subsequent pair of welds are applied in mutually diametrically opposing pairs of weld seams and applied 60-90° angularly offset from the preceding weld pair, and this application of weld pairs is continued until at least 4 pairs of welds have been applied evenly around the circumference of the cylindrical shell section.

Hence, the specified inventive welding technique enable a minimum of one sided heat exposure from the welding process until the cylindrical shell sections has been fixed in relation to each other, which guarantee that the roundness of the Yankee cylinder is not negatively affected during welding of pre-fabricated cylindrical shell sections. This welding technique needs only normal welding skills to be applied from a licensed welder.

[0012] In a preferred embodiment of the invention are at least 8 pairs of welds are also applied evenly around the circumference of the cylindrical shell section. The inventive application of numerous weld pairs further fixates the cylindrical shell sections to each other,

If the Yankee cylinder has a larger diameter, let's say 6-8 meter or more, at least 16 pairs of welds may also be applied evenly around the circumference of the cylindrical shell section.

[0013] In yet a preferred embodiment a weld in a subsequent weld pair may be welded in a position furthest away from the last weld in a preceding weld pair, thus distributing the heat load from welding even better.

[0014] In a further preferred embodiment of the invention, each weld in a weld pair has a circumferential first length less than 30° of the circumference and non-welded slots between these weld pairs are filled with complementary welds having a circumferential second length forming a continuous welded layer around the entire Yankee cylinder. The limited length of each weld also reduces the heat load from welding further. The subsequent filling of complementary welds assures that a continuous weld is developed around the circumference, but only after all first weld pairs have been applied and secure the cylindrical shell sections to each other, and preventing deformation during subsequent welding of the complementary welds.

[0015] In a subsequent step of the inventive method at least one additional layer of weld seam may also be applied as a continuously applied weld seam around the entire circumference. The continuous application of a subsequent weld seams is welded first after the application of the weld pairs that prevent the local heating from the continuous weld head to deform the roundness of the Yankee. The additional continuous weld may be applied in a number of layers in the range from 2-20 layers if requested, but first after application of the weld pairs distributed over the circumference.

[0016] The inventive method may also be complemented with physical guides that assure an alignment of the cylindrical shell sections during welding of the weld pairs. Hence, the abutting surfaces of the cylindrical shell sections at the location of circumferential running weld may be equipped with complementary protruding guides along at least a part of the circumference of the cylindrical shell section, wherein said protruding guides align the cylindrical shell sections around a common axis of the Yankee cylinder when the cylindrical shell sections are brought together ahead of welding.

[0017] Further, during application of the weld pairs the cylindrical shell sections may also be stacked on top of each other in the vertical direction when aligning the cylindrical shell sections ahead of welding, whereby the abutting surfaces of the cylindrical shell sections are subject to weight of the uppermost cylindrical shell section and that welding of at least one layer of weld is applied over the entire circumference while maintaining this weight load on the abutting surfaces of the cylindrical shell sections.

[0018] The inventive method is used for a prefabrication of Yankee modules at one location and final assembly at a distant end user site, wherein the manufacturing of the cylindrical shell sections takes place at a manufacturing site, while the assembly of the cylindrical shell sections into a complete Yankee cylinder takes place at the final assembly location at a paper mill, needing less advanced aligning and welding equipment at the paper mill and allowing transport of several individual shell sections with reduced part shipping volume.

LIST OF DRAWINGS

[0019] In the following schematic drawings are details numbered alike in figures, and details identified and numbered in one figure may not be numbered in other figures in order to simplify figures.

FIG. 1; shows a schematic representation of a Yankee drying cylinder in operation.

FIG. 2; .show a schematic cross-sectional view of a finally assembled Yankee drying cylinder;

FIG. 3a-3b; shows prior art welding technique using narrow gap welding;.

FIG. 4; shows a cross-sectional partial view of a gable end and a part of a cylindrical shell section before being welded together.

FIG. 5; shows the details of figure 4 being put together ahead of welding;

FIG. 6 show the details of figure 5 after having been welded together;

FIG. 7 shows two cylindrical shell sections before being brought together:

Fig.8a; shows the two cylindrical shell sections in figure 7 after being welded together;

Fig8b; shows a Yankee cylinder with three cylinder sections welded togheter;

FIG. 9a-9c; Shows a partial cross-section view of a first embodiment where two cylindrical shell sections with gables are pushed togheter (9a), welded by a first weld layer(9b) and finally welded with an additional weld layer (9c);

FIG. 10a-10c; Shows a partial cross-section view of a second embodiment where two cylindrical shell sections with gables are pushed togheter (10a), welded by a first weld layer(10b) and finally welded with an additional weld layer (10c);

FIG.11; is a side of the cylindrical shell and indicates a possible distribution of weld seams distributed over the circumference of the cylindrical shell section;

FIG. 12; is a schematic representation of how the welding layers may be formed in the final weld seam;

FIG. 13a-13d; show in a side view how the welds may be applied in a first embodiment to two cylindrical shell sections brought together (13a) by first small weld seams (13b) and complemented by intermediate weld seams (13c), and finally with a covering weld seam (13d); and finally

FIG. 14a-14d; show in a side view how the welds may be applied in a second embodiment to two cylindrical shell sections brought together (14a) by first small weld seams (14b) and complemented by intermediate weld seams (14c), and a cross section view XII-XII (14d) over the seld seam in figure 14c.

DETAILED DESCRIPTION OF THE INVENTION

[0020] With reference to FIG. 1 is a typical Yankee drying cylinder 1 shown in operation. The Yankee cylinder 1 rotates around an axis A in the direction of arrow R, supported by journals 24 and bearings 25 that allow rotation. The Yankee is heated from the inside by hot pressurized steam kept at a pressure typically above 5 bar, and when the steam condenses at the inside surface the cylinder is heated. A wet fibrous web W travels on a fabric 30 that may be, for example, an endless water absorbing felt that runs in a loop around guide rolls (not shown) or, in some cases, a fabric that does not absorb water but is textured such that it may imprint a three-dimensional pattern into the fibrous web W. The direction of travel of the fabric 30 is indicated by arrows C. A roll 31 is placed inside the loop of the fabric 30 and arranged to form a nip with the outer surface of the Yankee cylinder 1. In the nip between the roll 31 and the Yankee cylinder 1, the fibrous web W is transferred to the outer surface of the Yankee drying cylinder 1. The outer surface of the Yankee drying cylinder 1 is normally much smoother than the surface of the fabric 30 and this makes it easier to achieve transfer of the web W to the Yankee drying cylinder 1 since the wet fibrous web W tends to follow/adhere to the surface that is smoothest. The fibrous web W will then travel over the outer surface of the Yankee drying cylinder 1 as the Yankee drying cylinder 1 rotates in the direction of arrow R. As the fibrous web W is in contact with the outer surface of the Yankee drying cylinder 1, the fibrous web W is dried since the Yankee drying cylinder is very hot due to the heating from inside by steam. The fibrous web W which is initially quite wet will thus be dried by evaporation. The fibrous web W that has been dried on the Yankee drying cylinder 1 can then be creped off from the Yankee drying cylinder 1 by a doctor 29. It should be understood that the fibrous web W that has been creped off from the Yankee drying cylinder will normally be passed on and eventually wound to a roll in a reel-up, for example such a reel-up as disclosed in US5,816, 528 or US9,511,968.

[0021] As can be seen in Figure 2, the cylindrical shell 2 has two axial gable ends 3, 4 and an inner surface 5 in which circumferential grooves 6 are formed. When the Yankee drying cylinder 1 is used to produce paper, hot steam will condensate in the grooves 6 and heat will be transferred to the outer surface of the circular cylindrical shell 2 such that the fibrous web W which is initially wet will be dried by evaporation due to contact with the hot shell 2. Condensate may then be evacuated from the inside of the Yankee drying cylinder, for example by an arrangement as disclosed in US 8,959,790 or US 5,537,756.

For each axial end 3, 4 of the circular cylindrical shell 2, a gable wall 8, 9 is connected to the respective axial end 3, 4 by a weld seam 11 such that the cylindrical shell 2 and the gable walls

8, 9 define an enclosed space V within the Yankee drying cylinder 1.

With further reference to Figure 2, the Yankee drying cylinder 1 may be provided with a tubular structure 22 interposed between and connecting the gable walls 8, 9 to each other. The tubular structure 22 may be arranged to receive hot steam coming from a conduit that goes through one of the journals 24 (not shown in the figures). The hot steam may then exit through openings 23 in the tubular structure 22 and reach the inner surface 5 of the cylindrical shell 2 and heat the cylindrical shell 2.

Figure 2 is only a schematic representation of a Yankee drying cylinder 1 and the exact shape and relative dimensions of all details shown in Figure 2 do not necessarily correspond to the actual Yankee drying cylinder.

[0022] In figures 3a and 3b conventional welding techniques associated with so called narrow gap welding are disclosed, which technique has been put in use when manufacturing steel-made Yankees as disclosed in US 9.452.498, when welding cylindrical shell sections of a Yankee together.

As shown in figure 3a is narrow gap welding starting with the formation of a narrow gap NG between the end faces to be welded together. A welding head WH, in figure 3a an oscillating welding head, is inserted into the narrow gap and multiple welding layers are applied on top of each other in sequence, starting with a first fillet weld PI, and then in sequence additional layers P2-P3-P4-P5 on top of each other, and each layer in a continuous weld seam along the narrow gap NG. As disclosed in figure 3b is a welding carriage WE typically used equipped with at least one welding head WH1/WH2 protruding down towards the bottom of the narrow gap, using guides G1/G2 following the narrow gap that centers the welding head in the narrow gap. The welding carriage WE needs to be precisely guided and is therefore mounted on some kind of rail system that allows multiple passes and formation of the multiple weld layers P2-P3-P4-P5 and further until the narrow gap is completely filled.

[0023] Reference will now be made to Figure 4 which illustrates a part of the manufacturing process of a Yankee drying cylinder as explained previously with regard to Figure 1 and Figure 2. Figure 4 represents a stage in the manufacturing process in which the cylindrical shell 2 has not yet been connected to the gable walls 8, 9. In Figure 4, only one gable wall 8 and only one axial end 3 of the cylindrical shell 2 are shown but it should be understood that everything that is described with reference to the gable wall 8 and the axial end 3 is also applicable to the other gable wall 9 at the other axial end 4 of the cylindrical shell 2. As can be seen in Figure 4, the cylindrical shell 2 has a protruding guide 12 that is located in connection to the inner surface 5 of the cylindrical shell 2, i.e. away from the outer surface 43 of the cylindrical shell 2 and the gable wall 8 has a protruding guide 13 that is located at a distance from the outer circumference of the gable wall 8 such that it can meet and engage the protruding guide 12 of the cylindrical shell 2.

In the embodiment shown in Figure 4, the protruding guide 12 of the cylindrical shell 2 has an axial surface 15 facing outwards and is parallel to the central axis A of the cylindrical shell 2. The protruding guide 13 of the gable wall 8 has a corresponding axial surface 14 which is designed to match the surface 15 such that the surfaces 14, 15 can cooperate with each other and define the radial position of the gable wall 8 in relation the cylindrical shell 2. The protruding guide 12 of the cylindrical shell 2 also has a surface 17 that is perpendicular to the central axis A of the cylindrical shell 2 and the protruding guide 13 of the gable wall 8 has a corresponding surface 16 that is parallel to the surface 17 on the protruding guide 12 on the cylindrical shell 2. The surfaces 15 and 17 can cooperate with each other to define an end position of the gable wall 8 and the cylindrical shell 2 in the axial direction.

The cylindrical shell 2 and the gable wall 8 have opposing slanted surfaces 26 that serve to define a groove 28 (see Figure 5) between the cylindrical shell 2 and the gable wall 8 when the cylindrical shell 2 and the gable wall 8 have been brought together. The groove 28 will have a shape that is generally V-shaped. In relation to the central axis A of the cylindrical shell 2, the slanted surfaces have an angle that is relatively high and may be, for example, in the range of 60° - 85°.

In embodiments of the invention, the slanted surfaces 26 may be followed, closer to the bottom of the groove 28, by slanted surfaces 27 that have an angle in relation to the central axis A that is smaller than the angle of the slanted surfaces 26, for example 5°-25°smaller. For example, if the slanted surfaces 26 have an angle in relation to the central axis A that is 70°, the slanted surfaces 27 may have an angle in relation to the central axis A that is 45°. In this way, there is a smoother transition to the bottom of the groove 28.

[0024] Figure 5 shows the situation where the gable wall 8 has been brought against the cylindrical shell 2 such that the protruding guides 12, 13 engage with and cooperate with each other to define the position of the gable wall 8 in relation to the cylindrical shell 2, both axially and radially.

In advantageous embodiments, the protruding guides 12, 13 may be ring-shaped segments that are designed such that, in a pair of cooperating protruding guides, one has an outer radius which is smaller than the inner radius of the other. In this way, the protruding guide with the smaller radius can be placed radially inside the protruding guide with the greater radius such that the protruding guides 12, 13 can determine/define the radial position of an gable wall 8, 9 in relation to the cylindrical shell 2. The protruding guides 12, 13 may then serve to determine the relative position of the end wall 8, 9 in relation to the cylindrical shell 2 in both a radial and an axial direction.

[0025] In Figure 6, it can then be seen how the gable wall 8 has been connected to the cylindrical shell 2 by at least one weld seam 11. The weld seam 11 may be a circumferential weld seam 11 that goes all the way around the circumference of the cylindrical shell 2 to connect the cylindrical shell 2 to the gable wall 8. However, the weld seam 11 in Figure 6 does not necessarily have to be interpreted as a continuous circumferential weld seam but it could be understood as a number of weld seams separated from each other along the circumference of the cylindrical shell 2 or it could be understood as a weld seam that is continuous but does not extend over the entire circumference of the cylindrical shell 2. What has here been said about the gable wall 8 and the axial end 3 of the cylindrical shell 2 is also applicable to the other gable wall 9 at the other axial end 4 of the cylindrical shell 2.

[0026] Figure 7 schematically shows two cylindrical shell sections 2 and 2' respectively that are to be welded together after pushing the shell sections together in the direction of the bidirectional arrow indicated. The cylindrical shell sections may of course have one gable end already welded to the cylindrical shell section. When the end surfaces of the two cylindrical shell sections have been brought together, several shorter welds are applied in a sequential manner around the circumference of the cylindrical shells between the abutting end surfaces as shown in figure 8a. The left hand cylindrical shell section 2a is welded together with the right hand cylindrical shell section 2b using a sequential application of weld pairs. Each weld pair is welded in sequential order in mutually diametrically opposing pairs of weld seams, for example weld pair 11a and 11b, with a circumferential extension of each weld in this pair less than 30° of the total circumference of the Yankee cylinder. Subsequent pair of welds, for example weld pair 11c and 11d, are applied in mutually diametrically opposing pairs of weld seams and applied 60-120°, preferably 90°, angularly offset from the preceding weld pair, and this application of weld pairs is continued until at least 4 pairs of welds have been applied evenly around the circumference of the cylindrical shell section. Hence the weld pairs are welded in this sequence: 11a-11b, 11c-11d, 11e-11f and finally 11g-11h. Once the two first weld pairs, i.e. 11a-11b and 11c-11d, has been applied is the cylindrical shells locked in position and could not deflect further due to heating from welds. In the same manner may optionally additional cylindrical shell sections be welded to the first two welded cylindrical shell sections depending upon the total length of the Yankee cylinder to be made.

[0027] Figure 8b shows an embodiment where the Yankee cylinder is welded together with three cylindrical shell sections 2a, 2b and 2c. In this embodiment, the intermediate cylindrical shell section 2b may have a slighter longer axial length L_2 than the length L1 of the other two cylindrical shell sections 2a and 2c, and advantageously to such an extent that the part weight of the left hand cylindrical shell section 2a with a gable end 8 welded to it, as well as the right hand cylindrical shell section 2c with a gable end 9 welded to it, has the same weight as the intermediate cylindrical shell section 2b. As indicated here, each cylindrical shell section is welded together from 4 curved steel plates along axially running weld seams, but these cylindrical shell sections may be welded together from any number of curved steel plates, for example a minimum of two curved steel plates to more than 10 curved steel plates.

[0028] In figures 9a-9c a first embodiment of the inventive method is disclosed. In this embodiment temporary support gables TSa and TSb may be used, as disclosed in figure 9a, in each cylindrical shell section 2a and 2b respectively which may be used to avoid any deformation of the open circular end of one shell section during transport. When the cylindrical shell sections have been brought together weld pairs may be applied as disclosed in relation to figure 8, and these weld pairs 11 may be part of one layer as disclosed in figure 9b, complemented later with additional intermediate welds 39 to be explained later. Once this layer of weld is made, at least one additional layer 40 may be applied as disclosed in figure 9c. The temporary support gables TSa and TSb may be removed once a first layer is completed, i.e. after figure 10b, or alternatively when the entire weld is finished, i.e. after figure 10c.

[0029] In figures 10a-10c a second embodiment of the inventive method is disclosed. In this embodiment a temporary protruding guide 12' may be used, as disclosed in figure 10a. In this embodiment only one end surface of the abutting end surfaces of the cylindrical shells is equipped with an additional protruding guide 12', as the inner surface of the other cylindrical shell provides with the complementary guide surface. When the cylindrical shell sections have been brought together may weld pairs be applied as disclosed in relation to figure 8, and these weld pairs 11 may be part of one layer as disclosed in figure 10b, complemented later with additional intermediate welds 39 to be explained later. Once this layer of weld is made, at least one additional layer 40 may be applied as disclosed in figure 10c, and the temporary protruding guide 12' may be removed. The temporary protruding guide 12' may be in form of a continuous or a slitted ring that may be attached to inner side of one cylindrical shell by distributed spot welds, or alternatively may be in the form of multiple segments distributed over the inner circumference.

[0030] The inventive way of performing the welding will now be explained in more detail compared with what has been disclosed in figure 8 with reference to Figure 11 and Figure 12.

As explained in figure 8, instead of making one continuous weld seam 11 that is circumferential and goes all the way 360°along the groove 28, a number of separate weld seams 11a, 11b, 11c, 11d, 11e, 11f, 11g, 11h (same number as shown in figure 8), 11i, 11j, 11k, 11l, 11m, 11n, 11o, 11p (additional weld beds besides those shown in figure 8) may be formed in such a pattern that each weld seam 11 belongs to a pair of weld seams that are separated from each other in the circumferential direction by an angle of 180° or close to 180°. For example, they can be separated from each other by 175°- 185°. Such separate weld seams are preferably made in a sequence where opposite weld seams in the same pair are made following each other. In this way, the effects of heat deformation can be more evenly distributed around the cylindrical shell 2 which is an advantage for further machining on the shell 2 if shell thickness is to be uniform over the final product, i.e. the Yankee drying cylinder.

With reference to Figure 11, a possible welding sequence may then be such that the weld seam

11a is made first. Thereafter, the second weld seam 11b is made at a point which is 180° away from the first weld seam 11a (or close to 180°). A third weld seam 11c is made at a point which is 90° away from the first weld seam 11a in the circumferential direction of the shell 2 (or close to 90°, for example 85°- 95°). A fourth weld seam 11d is then made opposite the third weld seam 11c, i.e. 180°or about 180° away from the third weld seam 11c. The following weld seams are then made in opposing pairs as indicated by Figure 11 and the alphabetical order (11a, 11b, 11c) may be seen as an indication of a possible order in which the weld seams 11 are made. In this way, heat deformation caused by the welding can be more evenly distributed, and more importantly with a minimum weld length at each weld bead applied.

When the cylindrical shell 2 has a diameter in the range of 2 m - 8 m, the number of such separate weld seams may suitably be 16 - 32. Each such separate weld seam 11a, 11b, 11c may suitably have a length of 100mm - 250 mm or 150 mm - 200 mm but other numerical values may be considered.

In advantageous embodiments of the invention, the angular distance α between adjacent weld seams (11a, 11b, 11c) is the same for all such separate weld seams 11. It should be understood that Figure 11 is intended as a schematic representation which has been made with reference to the

cylindrical shell 2 (or rather an axial end 3, 4 of the cylindrical shell 2) but that the weld seams 11a, 11b, 11c, 11d also connect the cylindrical shell 2 to an gable wall 8,9. In Figure 11, the weld seams 11a, 11b, 11c, 11d, 11e, 11f, 11g, 11h are shown as distributed along the circumference of the shell 2 but they are, of course, also distributed along the corresponding part of the circumference of the gable wall 8, 9.

With reference to Figure 12, the spaces between separate weld seams 11 may be filled by intermediate/interconnecting weld seams 39. Finally, at least one continuous weld seam 40 is applied, preferably from the outside.

It should be noted that a number of layers with shorter welds 11 and intermediate welds 39 may be welded on top of each other, preferably 1-2 layers, and a number of continuous welds 40 may be applied on top of eachother, preferably at least one such continuous layer but up to 8-10 layers continuous layers may be applied on top of each other.

[0031] FIG. 13a-13d; show in a side view how the welds as shown in figure 12 may be applied in a first embodiment to two cylindrical shell sections 2a and 2b brought together as shown in figure 13a. A number of first small weld seams 11 may be applied as shown in figure 13b. These are thereafter complemented by intermediate weld seams 39 as shown in figure 13c, and finally with a covering weld seam 40 as shown in figure 13d.

[0032] FIG. 14a-14d; show in a side view how the welds as shown in figure 12 may be applied in a second embodiment to two cylindrical shell sections brought together as shown in figure 14a. In this embodiment the abutting surfaces of the cylindrical shells 2a and 2b have axially protruding fingers in each shell, locking into corresponding recesses in the other shell. First small weld seams 11 may be applied on the end of each finger protrusion as shown in figure 14b, and thereafter may these be complemented by intermediate weld seams 39 as disclosed in figure 14c. The weld seam obtained is shown in figure 14d as a cross section view XII-XII in figure 14d. The axial slots between the abutting surfaces of the cylindrical shell sections may also preferably be welded (but not shown here).

[0033] The sequential application of smaller weld seams may of course be used both between a gable and a first cylindrical shell, as well as between optional shell sections needed to give the Yankee the total length. However, from a delivery point of view, preferably all gables are welded to one cylindrical shell as a gable module at the manufacturing site before shipment to a final end customer, and optional cylindrical shells needed may be shipped independently and first at final end customer site be welded together with the gable modules using the inventive method. Preferably are the modules manufactured with similar weight of each module, such that outer modules with a gable and a cylinder section, is shorter than any optional intermediate cylinder shell section without any gables.

Claims

1. A method for manufacturing a steel-made Yankee cylinder used for drying a fibrous web in a paper or tissue machine and classified as a pressure vessel capable of being pressurized to at least 4 bar(e), wherein the Yankee cylinder comprises a cylindrical outer shell (2/ 2a,2b) and at least two circular disc-shaped gables (8/8a,8b) the method comprising the steps of:

manufacturing the disc-shaped gables (8/8a,8b) from steel plates, and machining the outer circumference to a circular shape congruent to the outer circumference of the Yankee cylinder;
manufacturing a first cylindrical shell section (2a) from rolled steel plates by welding a rolled steel plate together with another rolled steel plate along a weld seam running in the axial direction of the Yankee and welding the first cylindrical shell section to a first circular disc shaped gable (8a), forming a first sub-section (2a, 8a) of the Yankee cylinder, and manufacturing a second cylindrical shell section (2b) from rolled steel plates by welding a rolled steel plate together with another rolled steel plate along a weld seam running in the axial direction of the Yankee and welding the second cylindrical shell section to a second circular disc shaped gable (8b), forming a second sub-section (2b, 8b) of the Yankee cylinder;
manufacturing an optional number of additional cylindrical shell sections (2x) from rolled steel plates by welding a rolled steel plate together with another rolled steel plate along a weld seam running in the axial direction of the Yankee;
characterized in that at least one cylindrical shell section (2a,2b,2x) is welded together with another cylindrical shell section (2b,2a,2x) along a circumferentially running weld seam that is applied in at least two layers, and wherein at least one layer of the weld seam is applied in a sequential application of a circumferentially running partial weld seam that is applied in mutually diametrically opposing pairs of weld seams (11a, 11b) with a circumferential extension of each weld in this pair is less than 30° of the total circumference of the Yankee cylinder, and where a subsequent pair of welds (11c, 11d) are applied in mutually diametrically opposing pairs of weld seams and applied 60-90° angularly offset from the preceding weld pair, and this application of weld pairs is continued until at least 4 pairs of welds have been applied evenly around the circumference of the cylindrical shell section.

2. A method according to claim 1, wherein at least 8 pairs of welds are applied evenly around the circumference of the cylindrical shell section.

3. A method according to claim 2, wherein at least 16 pairs of welds are applied evenly around the circumference of the cylindrical shell section.

4. A method according to claim 1, wherein a weld in a subsequent weld pair is welded in a position furthest away from the last weld in a preceding weld pair.

5. A method according to claim 1, wherein each weld (11) in a weld pair (11a, 11b) has a circumferential first length less than 30° of the circumference and non-welded slots between these weld pairs are filled with complementary welds (39) having a circumferential second length forming a continuous welded layer (11,39) around the entire Yankee cylinder.

6. A method according to claim 5, wherein at least one additional layer (40) of weld seam is applied as a continuously applied weld seam around the entire circumference.

7. A method according to claim 1, wherein the abutting surfaces of the cylindrical shell sections (2a,2b,2x) at the location of circumferential running weld are equipped with complementary protruding guides (12,12') along at least a part of the circumference of the cylindrical shell section, wherein said protruding guides align the cylindrical shell sections (2a,2b,2x) around a common axis of the Yankee cylinder when the cylindrical shell sections are brought together ahead of welding.

8. A method according to claim 7, wherein the cylindrical shell sections are stacked on top of each other in the vertical direction when aligning the cylindrical shell sections ahead of welding, whereby the abutting surfaces of the cylindrical shell sections are subject to weight of the uppermost cylindrical shell section and that welding of at least one layer of weld is applied over the entire circumference while maintaining this weight load on the abutting surfaces of the cylindrical shell sections.

9. A method according to claim 8, wherein the manufacturing of the cylindrical shell sections takes place at a manufacturing site, while the assembly of the cylindrical shell sections into a complete Yankee cylinder takes place at the final assembly location at a paper mill, needing less advanced aligning and welding equipment at the paper mill and allowing transport of several individual shell sections with reduced part shipping volume.

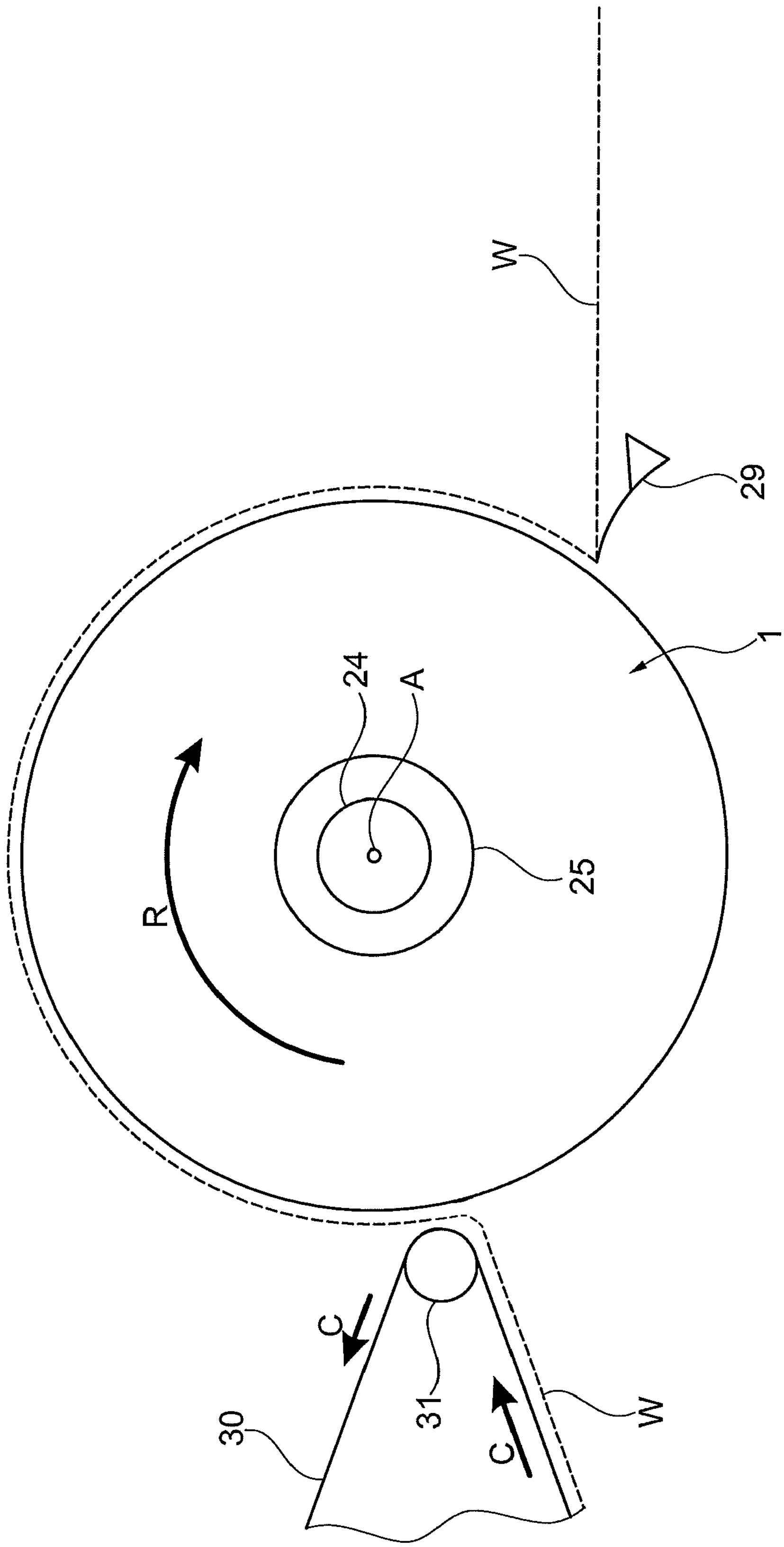


Fig. 1

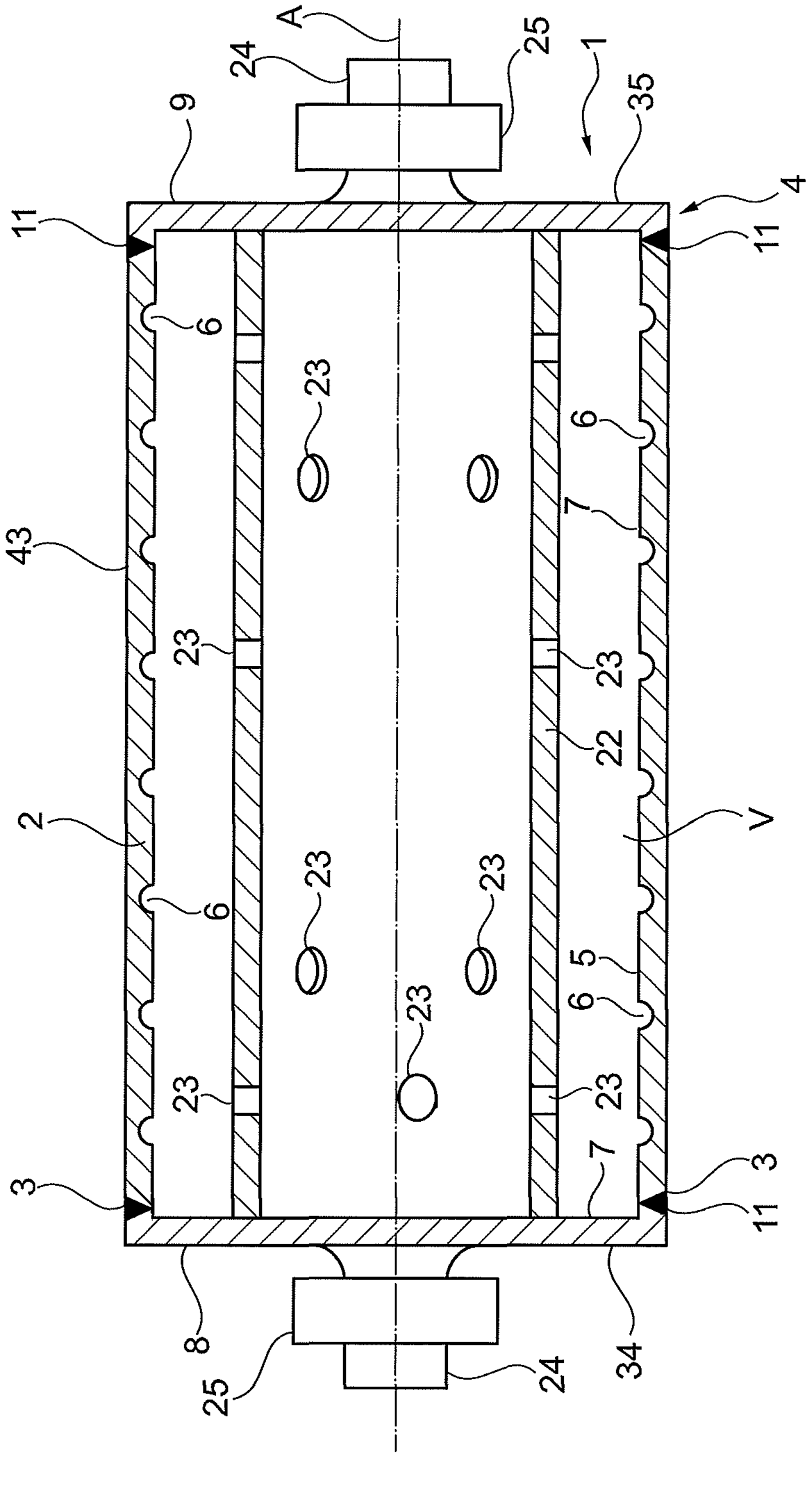


Fig. 2

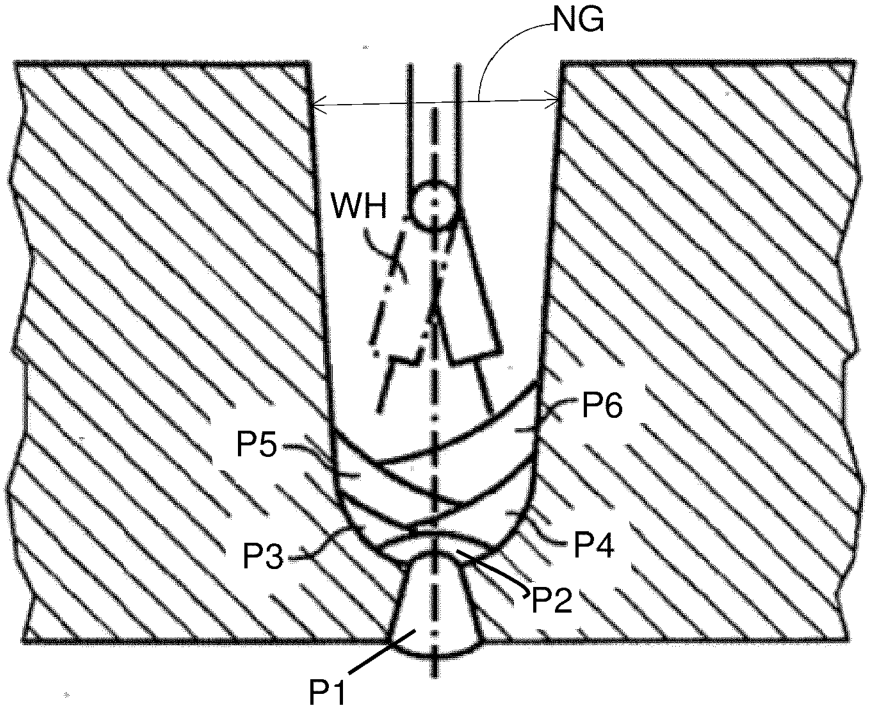


Fig. 3a

Prior Art

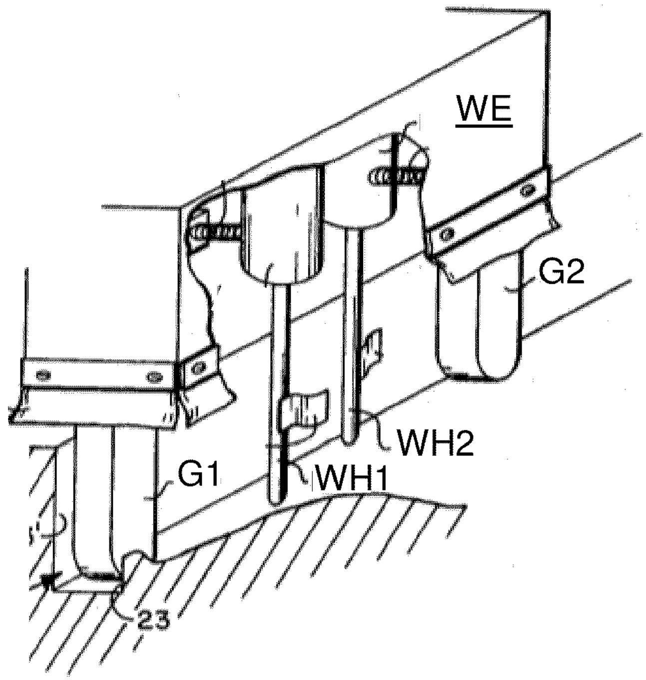


Fig. 3b

Prior Art 1967
US3328556

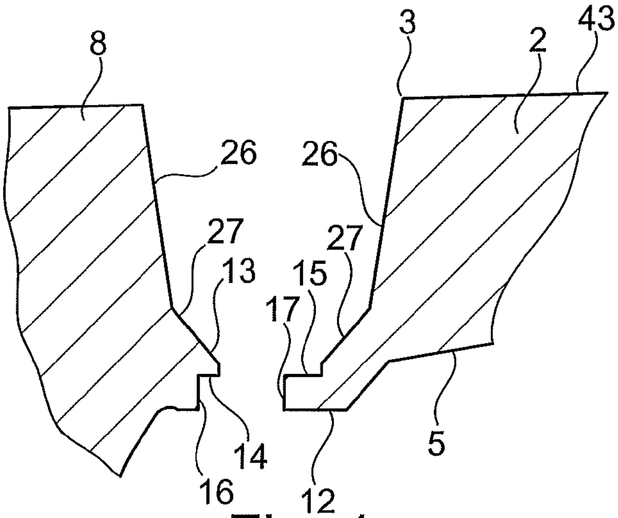


Fig. 4

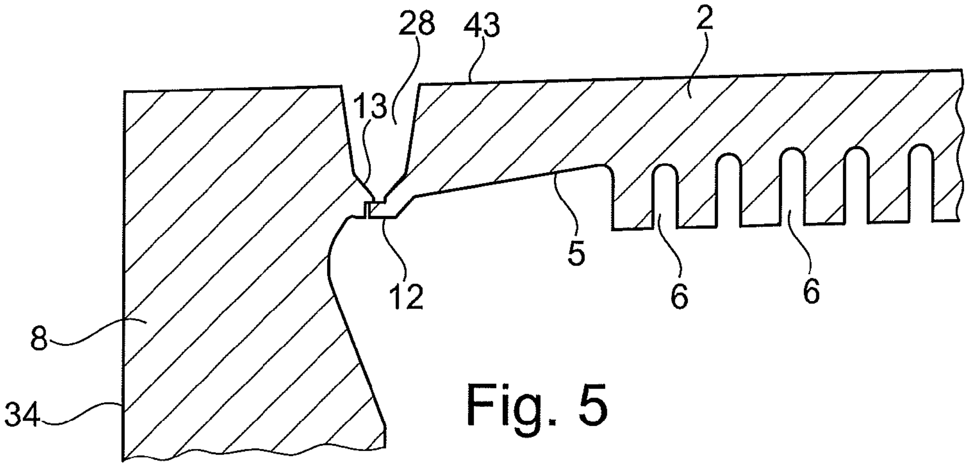


Fig. 5

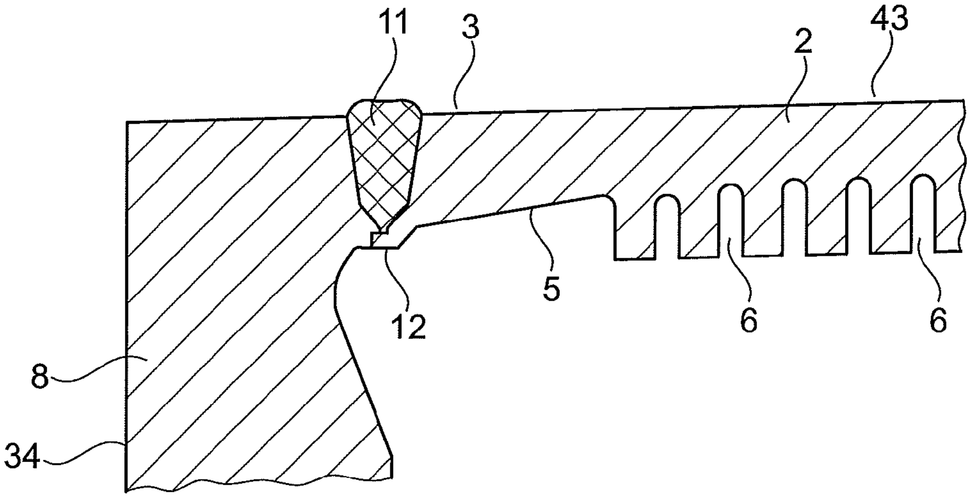


Fig. 6

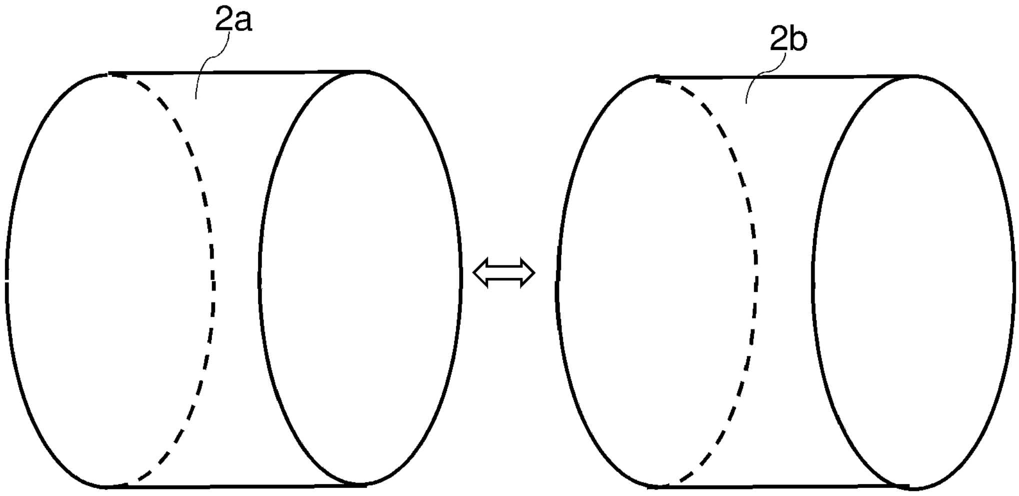


Fig. 7

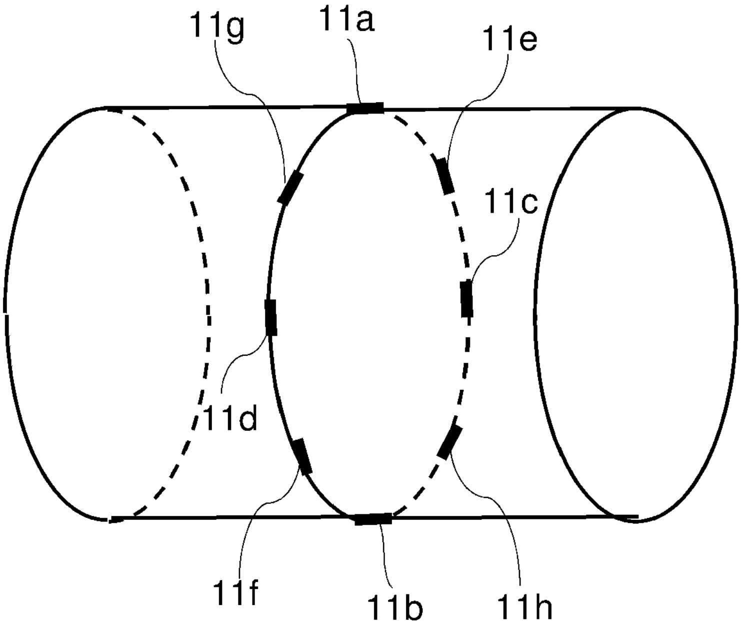


Fig. 8a

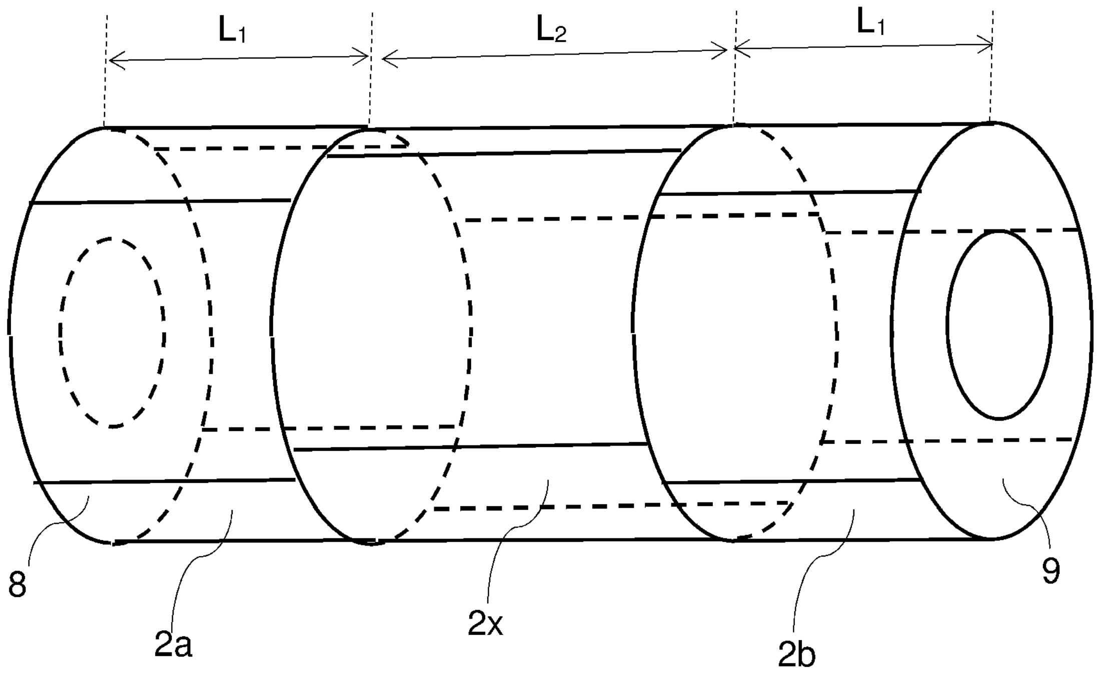


Fig. 8b

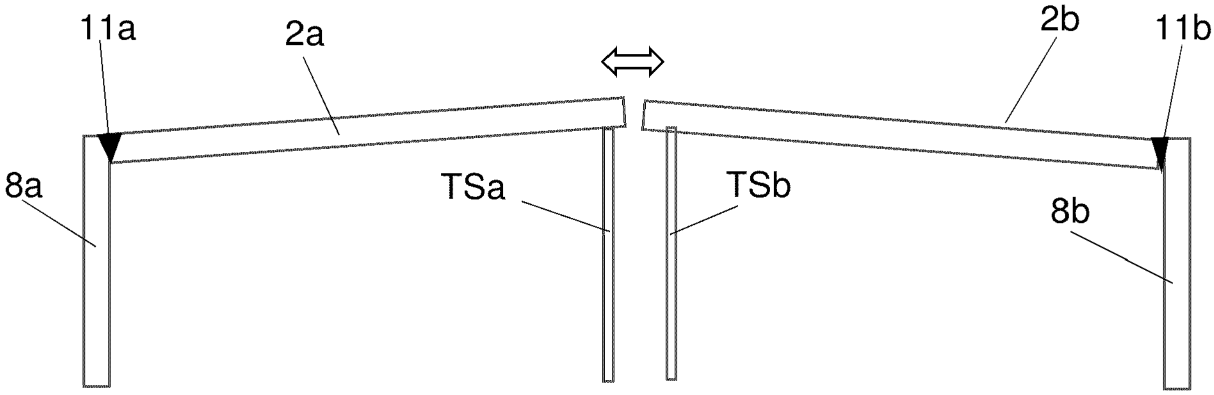


Fig. 9a

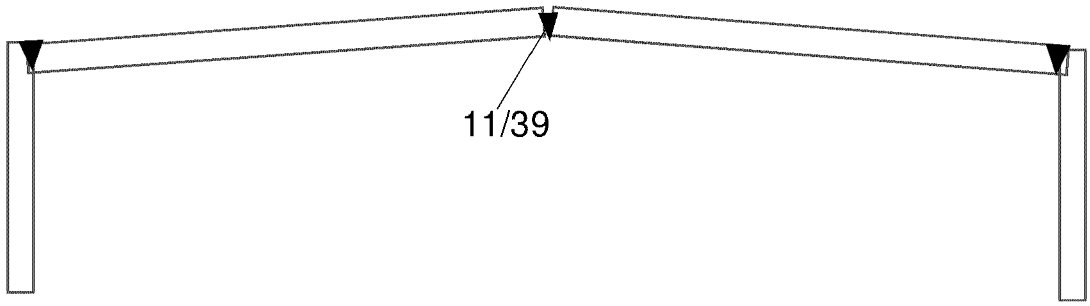


Fig. 9b

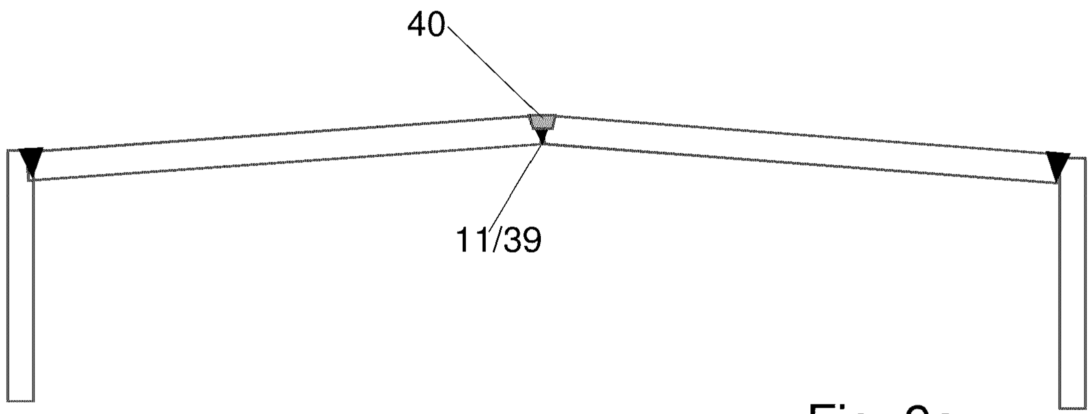


Fig. 9c

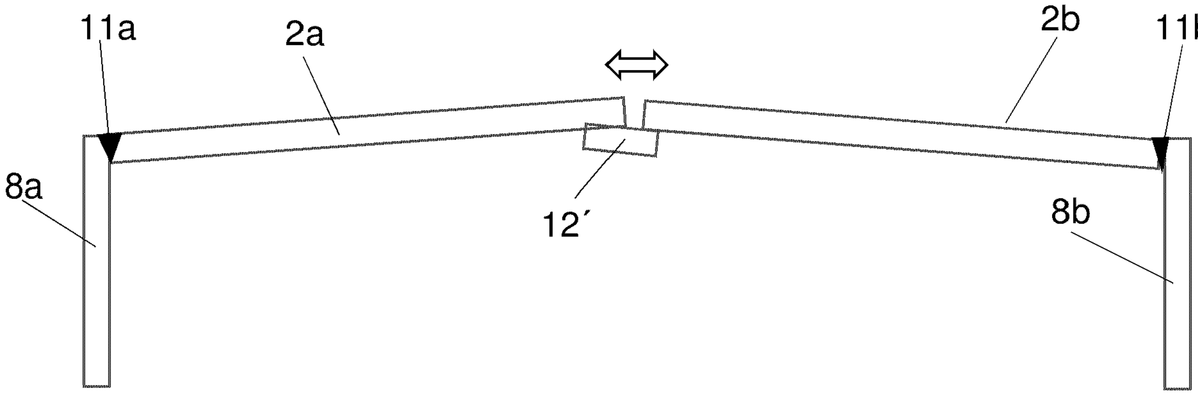


Fig. 10a

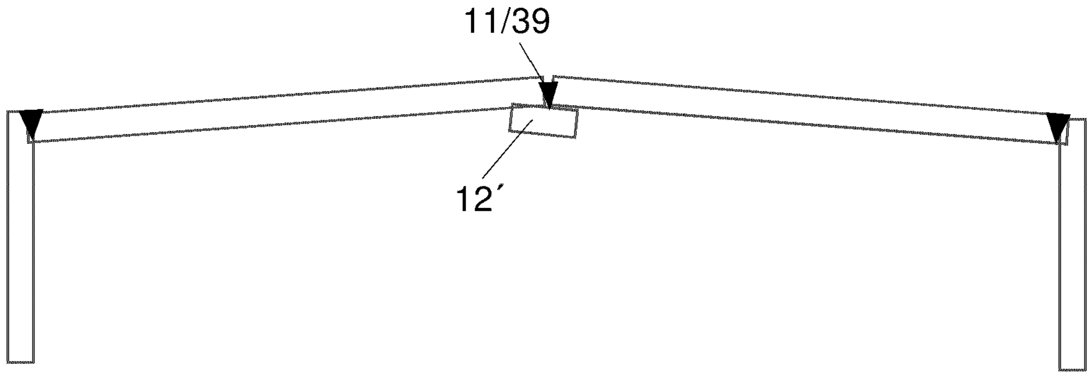


Fig. 10b

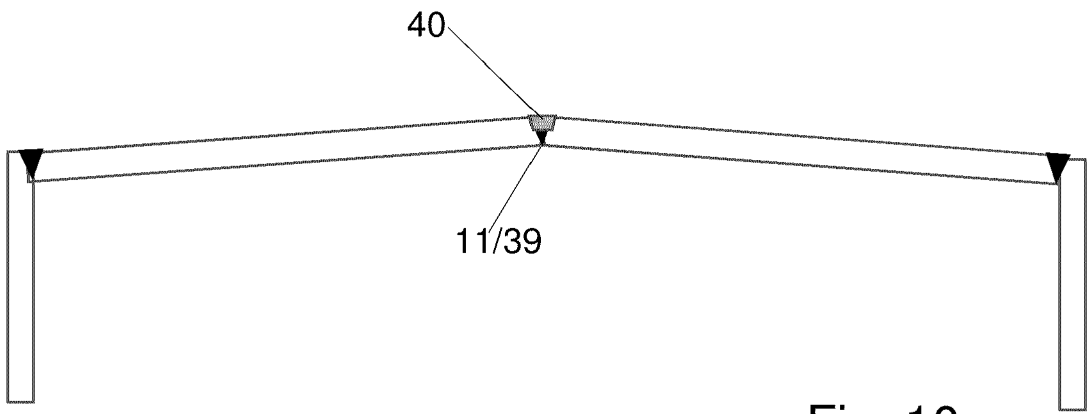
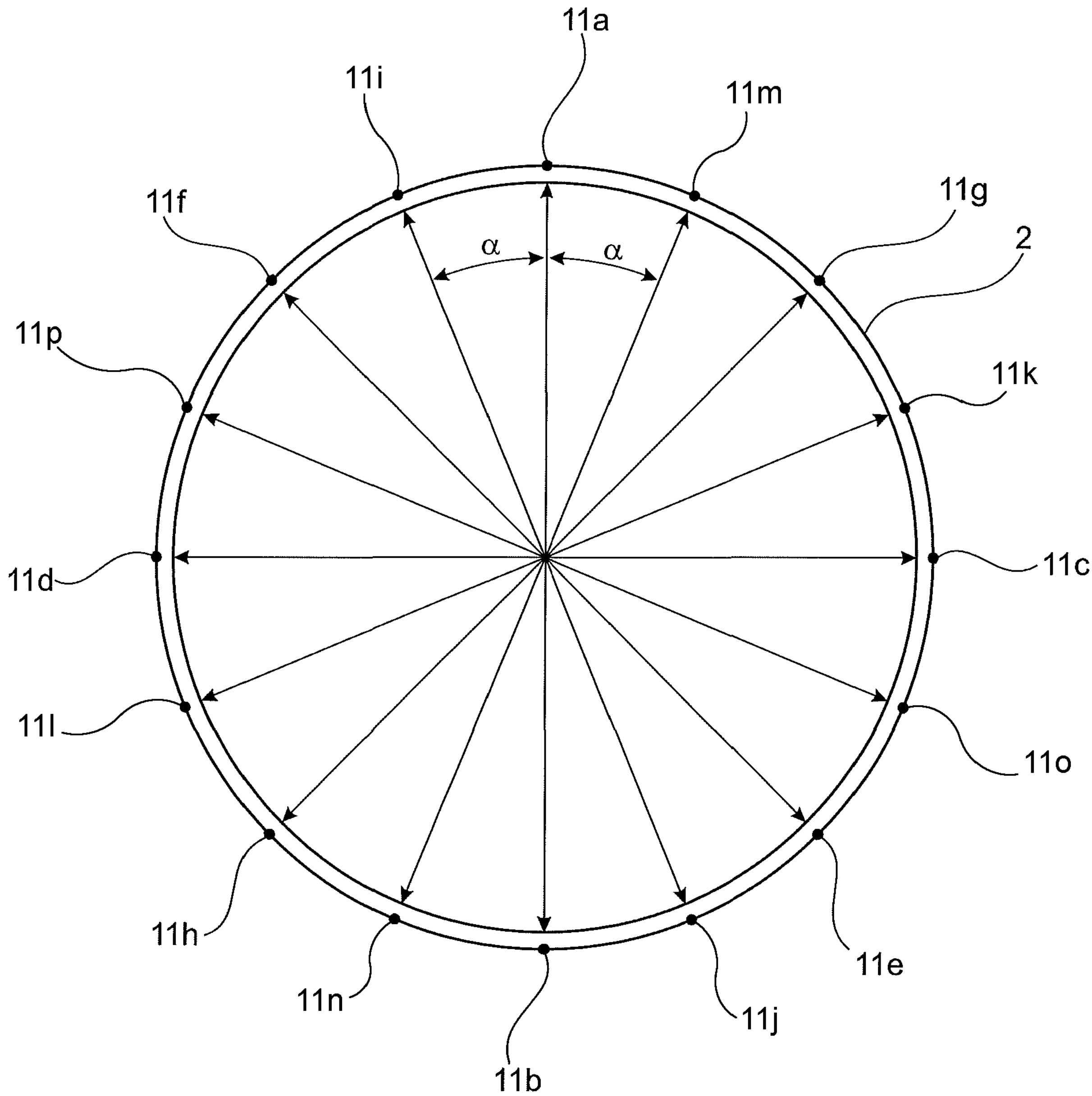


Fig. 10c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11i
11m
11g
11f
2
α
α
11p
11k
11d
11c
11l
11o
11h
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11n
11j
11b

Fig. 11

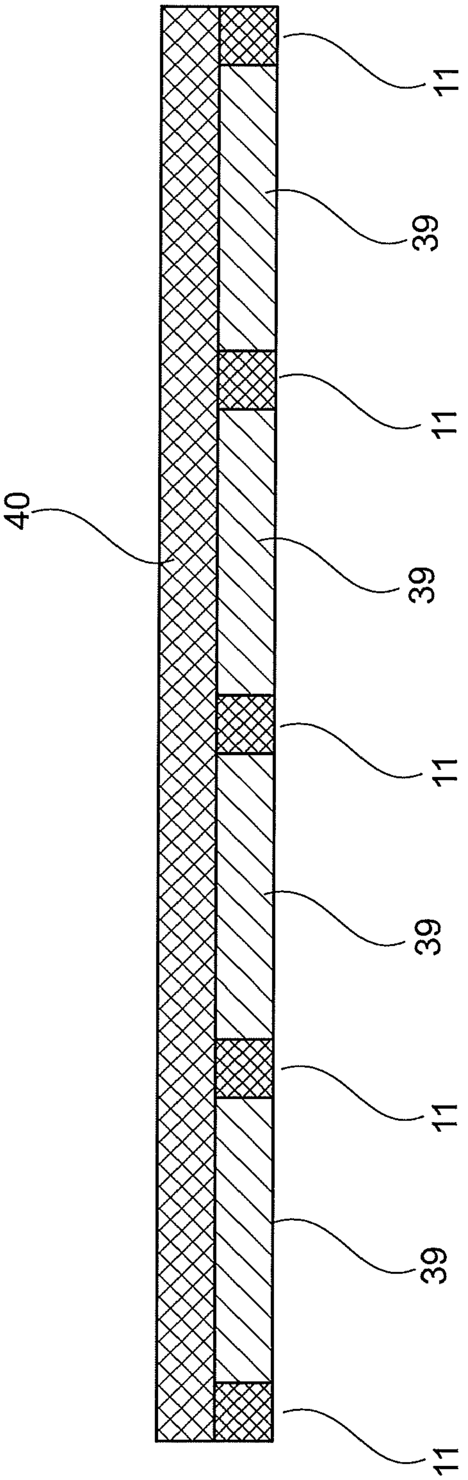

Fig. 12

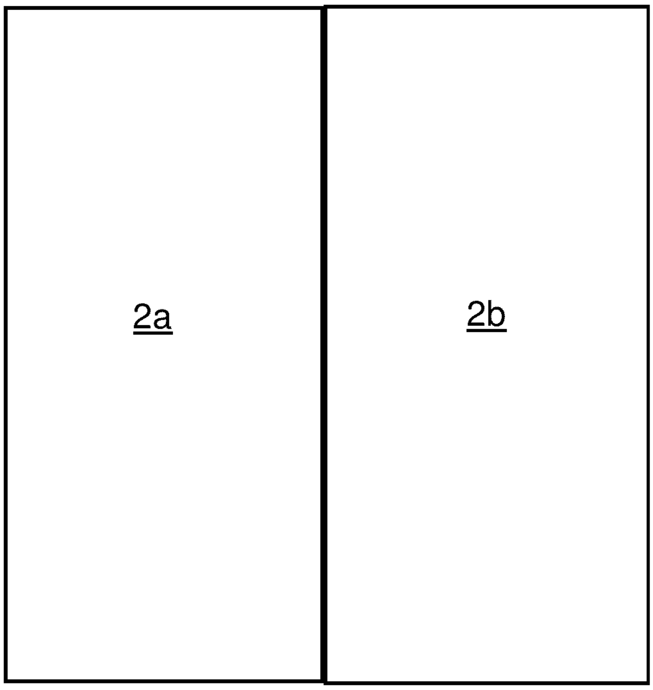

Fig. 13a

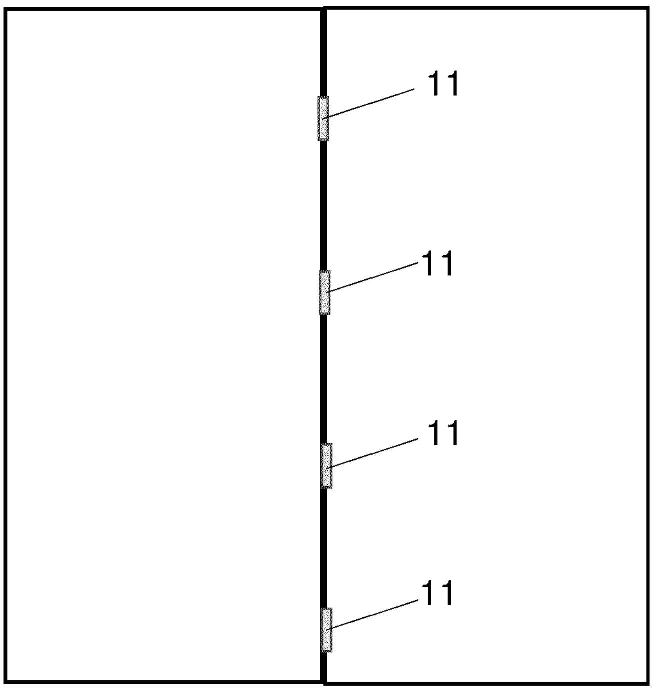

Fig. 13b

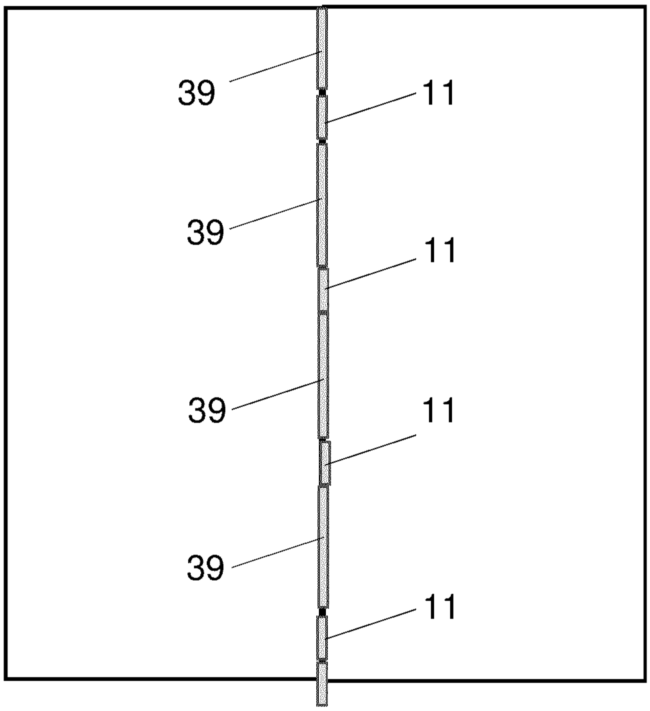

Fig. 13c

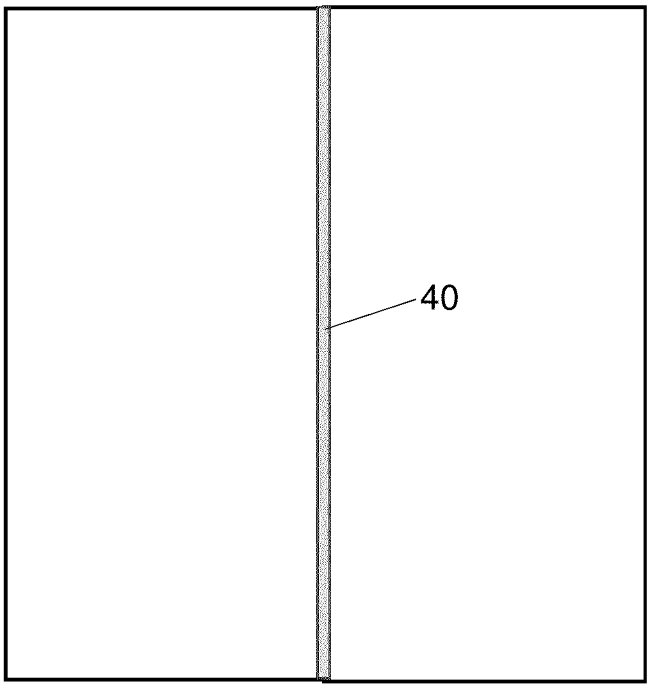

Fig. 13d

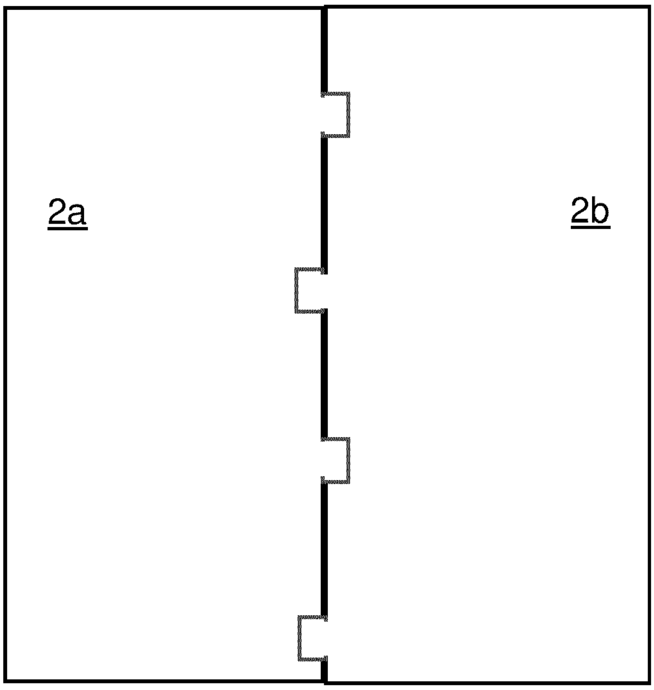

Fig. 14a

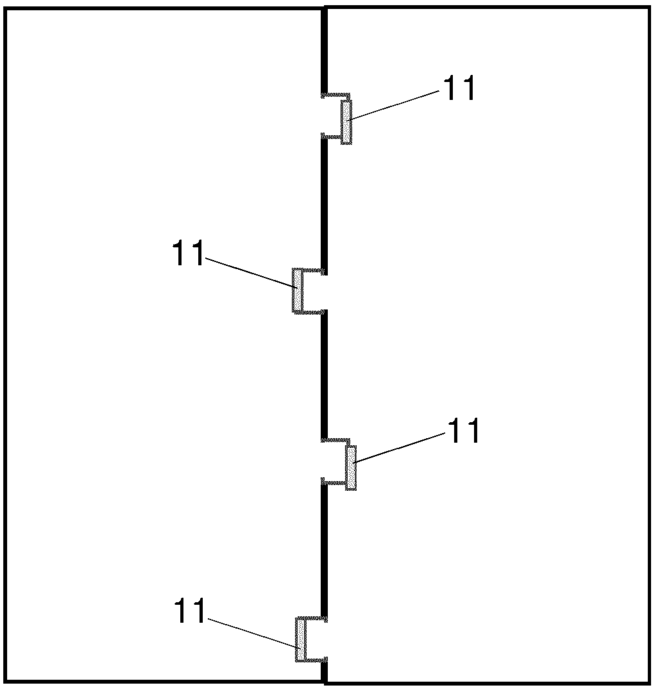

Fig. 14b

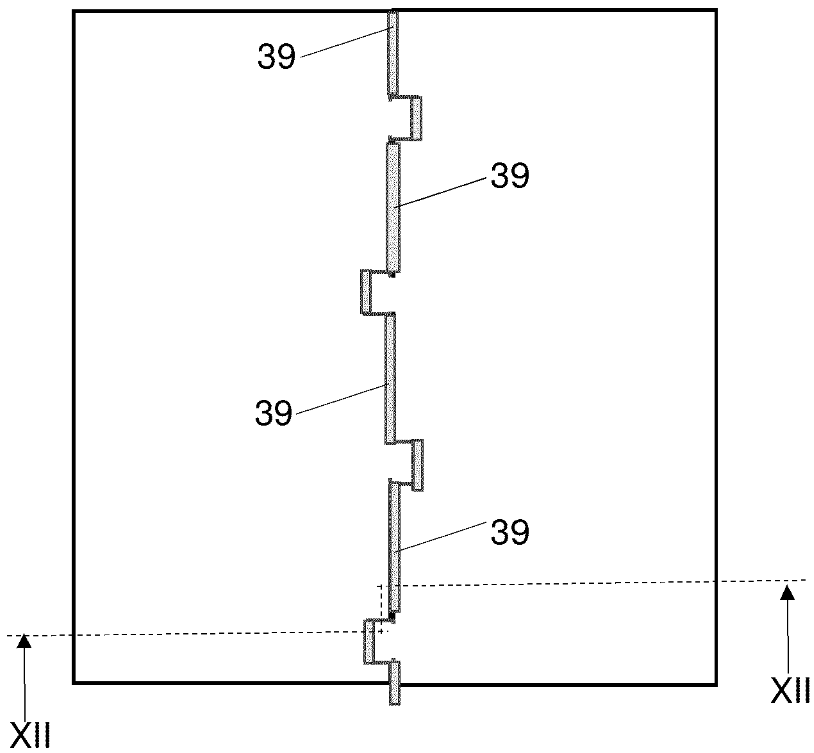

Fig. 14c

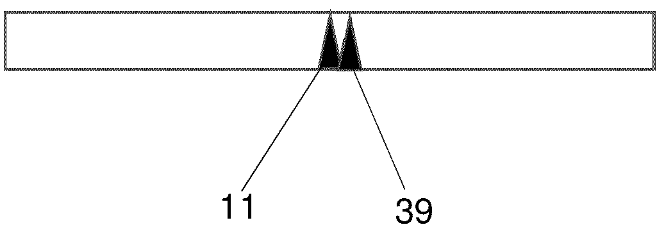

Fig. 14d

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EUROPEAN SEARCH REPORT

Application Number
EP 18 18 9484

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A	WO 2008/105005 A1 (TOSCOTEC S P A [IT]; MENNUCCI GIOVAN BATTISTA [IT]; PIERUCCINI SIMONE) 4 September 2008 (2008-09-04) * page 10, line 7 - page 11, line 1 * -----	1	
A	US 3 029 504 A (NIELSEN EINER S) 17 April 1962 (1962-04-17) * page 2, lines 47-68 * -----	1	
A	WO 2015/000647 A1 (VOITH PATENT GMBH [DE]) 8 January 2015 (2015-01-08) * paragraph [0021] * -----	1	
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			D21F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	8 February 2019	Pregetter, Mario

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