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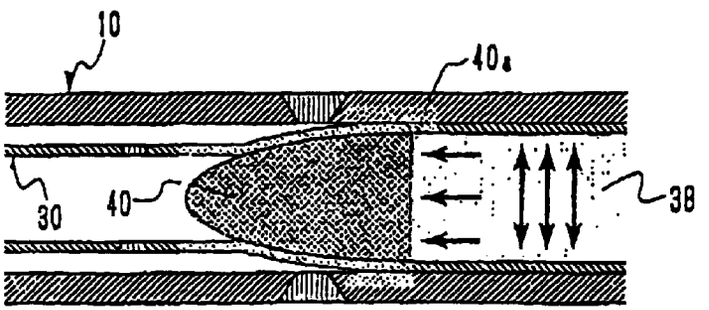
(54) Method of manufacturing long dual layer metal pipe

(57) The present invention relates to a method for manufacturing a long dual layer metal pipe (50) which comprises the following steps. Namely, a joined body (30) of inner metal pipes is inserted into a joined body (10) of outer metal pipes. The joined body (30) of inner metal pipes has an outer diameter smaller than an inner diameter of the joined body (10) of outer metal pipes. The joined body (30) of inner metal pipes has one or more joining portions. The joined body of outer metal pipes has one or more joining or clamping portions. Then the joined body of inner metal pipes is expanded to manufacture a dual layer metal pipe (50).

Fig.3D



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Description

[0001] The present invention relates to a method of manufacturing a long dual layer metal pipe.

[0002] Corrosive fluid has been conveyed through pipes in the chemical industrial field and a petrochemistry industrial field. The pipes for use in the foregoing purpose has to have excellent corrosion resistance against the corrosive fluid. As a means for improving the corrosion resistance of the pipes, a method using a material having excellent corrosion resistance to manufacture the pipes and another method using a dual layer metal pipe have been known.

[0003] The method using the material having excellent corrosion resistance is an ideal method because satisfactory corrosion resistance and reliability can be realized. However, the material having the excellent corrosion resistance usually contains expensive alloy elements such as Ni and Cr. As a result, there arises a problem in that the cost cannot be reduced. Therefore, in the chemical industrial field and the petrochemistry industrial field, a dual layer metal pipe has widely been used which has the structure that only the inner pipe having satisfactory corrosion resistance is made of the costly corrosion-resistant material and the outer pipe is made of a low-cost material.

[0004] The dual layer metal pipe required to have the satisfactory corrosion resistance has usually been a seamless pipe. The seamless pipes being arranged to be industrially manufactured usually have lengths of 20 m to 30 m. Therefore, when an oil-well pipe or pipe line having a length of thousands of meters to tens of kilometers is installed, an on-site operation has to be performed for joining dual layer metal pipes which have previously been manufactured in a plant and each of which has ten to twelve meters in length.

[0005] Since a dual layer metal pipe incorporates the inner and outer pipes which are made of different materials, a special technique is required to join the dual layer metal pipes to one another. When dual layer metal pipes each having an inner pipe made of a corrosion-resistant material such as stainless steel, and an outer pipe made of a low-cost material such as carbon steel, are welded to one another by a circumferential welding method, the corrosion-resistant material which is employed to form the inner pipe is previously welded. Then, welding conditions are changed to weld the outer pipe made of the low-cost material.

[0006] When the dual layer metal pipes are welded to each other by the circumferential welding method, the inner corrosion-resistant materials are welded to each other. Then, the outer low-cost materials are welded to each other. In the foregoing case, the welded portion of the corrosion-resistant material is sometimes again melted and the corrosion-resistant material is diluted with the low-cost material. Therefore, problems arise in that the corrosion resistance of the welded portion deteriorates and that the hardened welded portion causes cracks which occur easily.

[0007] To solve the above-mentioned problems, a joint welding method has been disclosed in Unexamined Japanese Patent Publication (kokai) No. 58-167094. In this publication, an inner layer containing alloy elements of the same types as those of a mixed material, an intermediate layer and an outer layer containing alloy elements of the same types as those of a base metal are sequentially formed in a direction from the mixed material to the base metal.

[0008] However, the method disclosed in Unexamined Japanese Patent Publication No. 58-167094 requires to sequentially change the materials for use in the welding operations and the welding conditions for the inner layer, intermediate layer and the outer layer. Thus, a complicated welding operation has to be performed. Further, the quality of the welded joint depends on the skill level of an operator of the welding operation. Therefore, there arises a problem in that the quality becomes unstable as the welding operation becomes complex. To prevent a weld defect, also a restraint of the welding speed is required, causing a problem to arise in that a satisfactory joining efficiency cannot be obtained.

[0009] On the other hand, a method has been disclosed in Examined Japanese Patent Publication (kokoku) No. 8-13428 in which an insert member having a predetermined composition is inserted into an end surface of a clad steel pipe. When inside-clad steel pipes each having the inner pipe made of a corrosion-resistant material are joined to each other, waves having high frequencies of 100 kHz to 400 kHz are used to induction-heat the clad steel pipes. When outside-clad steel pipes each having the outer pipe made of the corrosion-resistant material are joined to each other, waves having high frequencies of 10 kHz or lower are used to induction-heat the clad steel pipe.

[0010] The method disclosed in Examined Japanese Patent Publication (kokoku) No. 8-13428 is adapted to the diffusion welding method to join the dual layer metal pipes to one another. Therefore, the joining operation can be simplified as compared with the welding method, thus causing an advantage to be obtained in that an excellent working efficiency can be realized. When the inside clad steel pipes are joined by the method disclosed as described above, the induction heating using the high frequencies of 100 kHz to 400 kHz has to be performed to prevent separation of the inner pipe. Therefore, an excessive skin effect is undesirably produced. Thus, there arises a problem in that the above-mentioned method cannot be applied to join dual layer metal pipes each having a large thickness.

[0011] The above-mentioned problem can be overcome when dual layer metal pipes each having a sufficiently long length can be manufactured. However, the length of the seamless pipe which can be manufactured at present is about 100 m. A long dual layer metal pipe having a length longer than the above-mentioned value cannot easily be manufactured from a technical viewpoint. Moreover, the dual layer metal pipe, a small-diameter dual layer metal pipe and a large-diameter dual layer metal pipe cannot easily be manufactured. Therefore, the conventional method of forming a long dual layer metal pipe by joining dual layer metal pipes to one another encountered a limitation.

[0012] It is, therefore, the object of the present invention to provide a method of manufacturing long dual layer metal pipes which overcomes the drawbacks of the prior art products. This object is solved by the method according to independent claim 1. Further advantageous features, aspects and details of the invention are evident from the dependent claims, the description and the drawings. The claims are to be understood as a first non-limiting approach to define the invention in general terms.

[0013] The present invention relates to a method of manufacturing a long dual layer metal pipe to serve as a pipe for a plant, a line pipe, an oil-well pipe and the like for use in a chemical industry field, a petroleum industry field and the like.

[0014] It is an aspect of the present invention to provide a method of manufacturing a long dual layer metal pipe having a length which is not limited when manufactured, free from deterioration in the corrosion resistance, occurrence of a crack and instable quality and permitting a thick-wall long dual layer metal pipe, a small-diameter long dual layer metal pipe and a large-diameter long dual layer metal pipe to be easily manufactured.

[0015] To achieve the above-mentioned object and aspect, a method of manufacturing a long dual layer metal pipe according to the present invention comprises the steps of: inserting, into a joined body of outer metal pipes, a joined body of inner metal pipes which has an outer diameter smaller than an inner diameter of the joined body of outer metal pipes with the joined body of outer metal pipes having one or more joining portions or clamping portions and which has one or more joining portions; and expanding the joined body of inner metal pipes so that a long dual layer metal pipe is manufactured.

[0016] The joined body of the outer metal pipes can be obtained by joining or clamping metal pipes each having a predetermined length to each other at the end surfaces of the metal pipes. Therefore, the joined body has to have one or more joining portions or clamping portions. The joining method and the clamping method are not limited particularly. For example, a mechanical joining method, such as flange joining or screw joining, may be employed. Also a metallurgy joining method, such as a welding method, a friction welding method or a diffusion welding method, may be employed. Each metal pipe for constituting the joined body of the outer metal pipes may be an electro-resistance welded pipe or a seamless pipe.

[0017] The joined body of the inner metal pipes can be obtained by joining metal pipes each having a predetermined length at the end surfaces of the metal pipes. Therefore, the joined body of the inner metal pipes has to have one or more joining portions. Since the joined body of the inner metal pipes has to have gas tightness, the joining method should preferably be the metallurgy method such as e.g. the welding method, the friction welding method or the diffusion welding method. Although each metal pipe for constituting the joined body of the inner metal pipes may be an electro-resistance welded pipe, it is preferable that the seamless pipe is employed from a viewpoint of improving the corrosion resistance and realizing uniform expansion of the pipes.

[0018] It is preferable that at least the joined body of the inner metal pipes and the joined body of the outer metal pipes is obtained by a liquid phase diffusion welding method.

[0019] As compared with the other metallurgy methods, the liquid phase diffusion welding method is able to prevent burrs in the joining portion and deformation of the joining portion with an excellent joining efficiency. Therefore, the foregoing method is able to satisfactorily manufacture oil-well pipes and line pines having a length of thousands of meters and tens of km. When both of the inner and outer metal pipes are joined by the liquid phase diffusion welding method, an operation for removing burrs is not required when adequate joining conditions are employed. Therefore, the process for manufacturing the dual layer metal pipe can be simplified.

[0020] The joined body of the inner metal pipes have an outer diameter smaller than the inner diameter of the joined body of the outer metal pipes. The difference between the inner diameter of the joined body of the outer metal pipes and the outer diameter of the joined body of the inner metal pipes has to arbitrarily be selected in accordance with the workability of the inner pipe.

[0021] The method of expanding the joined body of the inner metal pipes is not limited to a particular method. For example, an expanding method using a mandrel or a plug, an expanding method using liquid pressures or an expancing method using a plunger which is inserted may be employed. In particular, the expanding method using the liquid pressures and the expanding method using the plunger which is inserted have an advantage in that the length and the diameter of the pipe which can be manufactured are not substantially limited.

[0022] According to the present invention, the joined body of the inner metal pipes, which has been joined to one another, having a predetermined length is initially inserted into the joined body of the outer metal pipes, which has been joined to one another, having a predetermined length. Then, the joined body of the inner metal pipes is expanded, and then the joined body of the inner metal pipes is brought into intimate contact with the joined body of the outer metal pipes. Thus, the long dual layer metal pipe can be manufactured. Therefore, the length of the dual layer metal pipe which can be manufactured is not substantially limited. Moreover, a small-diameter long dual layer metal pipe and a large-diameter long dual layer metal pipe can be manufactured if a suitable joining method or an expanding method is employed.

[0023] Since the operation for joining the joined body of the outer metal pipes and that for joining the joined body of

the inner metal pipes are performed individually, optimum joining conditions suitable to the material of each metal pipe can advantageously be selected. Therefore, differently from the conventional method for obtaining a long dual layer metal pipe by joining dual layer metal pipes to one another, even a thick-wall long dual layer metal pipe can easily be manufactured. Moreover, deterioration in the corrosion resistance of the joint portion caused from dilution of the weld metal can be prevented. Also, the production of cracks caused from hardening which occurs as a result of thermal cycles during the welding process can be prevented.

[0024] The above mentioned and other features of the present invention and the invention itself will be better understood by reference to the following detailed description of preferred embodiments of the invention, when considered in conjunction with the accompanying drawings, in which:

Figs. 1A to 1C are partial cross sectional views showing a joined body of the outer metal pipes joined by a metallurgy method according to one embodiment of the present invention;

Figs. 2A and 2B are partial cross sectional views showing a joined body of the outer metal pipes joined by a mechanical joining method and its cross sectional view taken along line A-A' according to one embodiment of the present invention;

Figs. 3A to 3D are diagrams showing a method of expanding a joined body of the inner metal pipes according to one embodiment of the present invention; and

Figs. 4A to 4C are diagrams showing a process for manufacturing a long dual layer metal pipe according to one embodiment of the present invention, in which a left-hand diagram is a partial cross sectional view and a right-hand diagram is a cross sectional view taken along line A-A'.

[0025] Preferred embodiments of the present invention will now be described with reference to the drawings. A method of manufacturing a long dual layer metal pipe according to the present invention has a joining step, a step for inserting inner pipes and an expanding step.

[0026] The joining step has a step for joining outer metal pipes to one another to form the joined body of the outer metal pipes and a step for joining inner metal pipes to one another to form the joined body of the inner metal pipes. The present invention is characterized in that the operation for joining the outer metal pipes and that for joining the inner metal pipes are performed individually. A method of joining the outer metal pipe and the inner metal pipe employed to manufacture the long dual layer metal pipe according to the present invention may be a metallurgy method such as a welding method, a friction welding method and a diffusion welding method.

[0027] Fig. 1A shows an example in which a joined body 10 of the outer metal pipes is manufactured by the welding method. The welding method is a method with which grooves 14_N, 14_{N+1}, ..., formed at the end surfaces of outer metal pipes 12_N, 12_{N+1}, ..., are abutted against one another. Then, melted metal is padded from outside so that welded portions 16_N are formed to join the outer metal pipes 12_N, 12_{N+1}, ..., to one another. Thus, the joined body 10 of the outer metal pipes is obtained. The welding method realizes a state as indicated with dashed lines shown in Fig. 1A such that the inner and outer surfaces of the welded portions 16N, ..., are expanded after the welding operation has been completed. Therefore, at least the inner surfaces of the welded portions 16N, ..., has to be flattened after the welding operation has been completed.

[0028] The welding method is not limited particularly. Any one of the following welding methods may be preferably employed: consumable arc welding such as shielded arc welding, submerge arc welding, MIG welding and carbon dioxide arc welding; non-consumable electrode arc welding such as TIG welding; plasma welding; electron beam welding; and laser welding.

[0029] Fig. 1B shows an example in which the joined body 10 of the outer metal pipes is manufactured by the friction welding method. The friction welding method is performed such that pipe end surfaces 18_N, 18_{N+1}, ..., of outer metal pipes 12_N, 12_{N+1}, ..., are formed to be perpendicular to the axis of the pipes. Then, the outer metal pipes 12_N, 12_{N+1}, ..., are abutted against one another at the pipe end surfaces 18_N, 18_{N+1}, ..., and then the outer metal pipes 12_N, 12_{N+1}, ..., are relatively rotated under a pressure. Thus, generated frictional heat is used to join the pipes.

[0030] Since the friction welding method, as indicated by dashed lines shown in Fig. 1B, encounters burrs on the inner and outer surfaces adjacent to the friction-welded portions 20_N, ..., burrs at least on the inner surface of the friction-welded portions 20_N, ..., have to be removed. Note that the welding method may be any one of a variety of methods including a method of securing either pipe and rotating another pipe, a method of rotating pipes in opposite directions and a method of vertically vibrating the pipes.

[0031] Fig. 1C shows an example, in which the joined body 10 of the outer metal pipes has been manufactured by the diffusion welding method. The diffusion welding method is performed such that pipe end surfaces 18_N, 18_{N+1}, ..., of outer metal pipes 12_N, 12_{N+1}, ..., are formed perpendicular to the axis of the pipe. Then, the outer metal pipes 12_N, 12_{N+1}, ..., are brought into intimate contact with one another at pipe end surfaces 18_N, 18_{N+1} ...,. Then, the outer metal pipes 12_N, 12_{N+1}, ..., are heated at temperatures not higher than the melting point of the outer metal pipes 12_N, 12_{N+1}, ..., to diffuse elements so that the pipes are joined. The diffusion welding method includes a solid phase diffusion weld-

ing method and a liquid phase diffusion welding method using an insert member.

[0032] In particular, the liquid phase diffusion welding method has an advantage in that an intimate joined body can be obtained which has strength and corrosion resistance similar to those of the base metal. Moreover, the joining operation can be completed in a short time as compared with the solid phase diffusion welding method. When the thickness, the shape and so forth of the insert member are optimized, a joined body free from burrs in the weld portions 20_N, ..., thereof can be obtained differently from the welding method or the like. Moreover, another advantage can be obtained in that time required to complete the joining operation can be shortened.

[0033] The joined body 10 of the outer metal pipes can be obtained by joining the outer metal pipes 12_N, 12_{N+1}, ..., as described above. Similarly to the method of joining the outer metal pipes 12_N, 12_{N+1}, ..., a method (not shown) of joining the inner metal pipes to obtain the joined body of the inner metal pipes may be employed. If burrs are formed, burrs on at least the surface of the welded portion of the joined body of the inner metal pipes which is brought into contact with the joined body 10 of the outer metal pipes, that is, on the outer surface, have to be removed.

[0034] In general, the inner metal pipes of the dual layer metal pipes have the corrosion resistance and the gastightness and the outer metal pipes simply support the inner metal pipes. Therefore, when the joined body 10 of the outer metal pipes of the long dual layer metal pipe is joined, the joining method is not limited to the metallurgy method such as the welding method. For example, a mechanical clamping method may be employed.

[0035] For example, as shown in Fig. 2A, flanges 22_N, 22_{N+1}, ..., are welded to the two ends of outer metal pipes 12_N, 12_{N+1}, ..., which constitute a joined body 10 of the outer metal pipes. Then, flange joints formed by abutting the flanges 22_N, 22_{N+1}, ..., to each other and by joining the flanges 22_N, 22_{N+1}, ..., with bolts may be employed. As shown in Fig. 2B, a screwed joint method may be employed such that male thread 24N is formed at an end of the outer metal pipe 12_N which constitutes the joined body 10 of the outer metal pipes. Moreover, a female thread 24_{N+1} is formed at an end of the outer metal pipe 12_{N+1}. The two types of the threads are joined to each other.

[0036] The method of joining the outer metal pipes and the inner metal pipes may arbitrarily be selected in accordance with the usage purpose of the long dual layer metal pipe. In particular, the liquid phase diffusion welding method is a preferred method to join the inner metal pipes to one another. When the inner metal pipes are joined by the liquid phase diffusion welding method, the joined body of the inner metal pipes exhibiting excellent corrosion resistance and gastightness can easily be obtained as described above. Further, burrs cannot easily be produced. As a result, the foregoing method of forming the long dual layer metal pipe enables a long dual layer metal pipe having excellent quality to be manufactured.

[0037] When both of the outer metal pipes and the inner metal pipes are joined by the liquid phase diffusion welding method, an excellent joining efficiency can be realized. In addition, when the shape of the insert member and so forth are optimized, a joined body free from a burr can easily be obtained. Therefore, an advantage can be obtained in that even a long dual layer metal pipe having a small diameter, from which burrs cannot easily be removed, can easily be manufactured.

[0038] As described above, according to the present invention, the outer metal pipes and the inner metal pipes are individually joined to one another. Accordingly, even if the inner metal pipes and the outer metal pipes are made of different materials, optimum joining conditions can arbitrarily be selected for each material. Thus, even if each of the outer metal pipes has a large wall thickness, a complete joined body of the outer metal pipes can be obtained without melting of the inner metal pipes. When the outer metal pipes are joined after the inner metal pipes have been joined, re-melting of the joined portions of the joined body of the inner metal pipes can be prevented. Therefore, the problems experienced with the conventional method of joining the dual layer metal pipes which have arisen in that the corrosion resistance of the joined body or the inner metal pipes deteriorates and cracks are caused from hardening can be prevented.

[0039] In the following, the step of inserting the inner pipe will now be explained. The step of inserting the inner pipe is a step of inserting the joined body of the inner metal pipes into the joined body of the outer metal pipes. The inserting order is not limited particularly. The joined body of the outer metal pipes and the joined body of the inner metal pipes may be individually joined to one another, and then the manufactured joined body of the inner metal pipes may be inserted into the manufactured joined body of the outer metal pipes.

[0040] When the length of the dual layer metal pipe is longer than thousands of meters in a case of an oil-well pipe or a line pipe, insertion of the manufactured joined body of the inner metal pipes into the manufactured joined body of the outer metal pipes cannot be performed in actual. In such a case, joining of the inner metal pipes and that of the outer metal pipes may alternately be performed in a state in which the inner metal pipes has been inserted into the outer metal pipes. Since the joined body of the outer metal pipes and the joined body of the inner metal pipes are alternately be joined, even a dual layer metal pipe longer than thousands of meters can be manufactured.

[0041] The expanding step will now be described. Fig. 3A shows an example of expansion using a mandrel (hereinafter called a "mandrel method"). A joined body 30 of inner metal pipes formed by joining inner metal pipes 32_N, 32_{N+1}, ..., to one another through welded portions 33N, ..., is inserted into a joined body 10 of the outer metal pipes formed by joining, through welded portions 16N, ..., outer metal pipes 12_N, 12_{N+1}, ..., to one another. Then, a mandrel 34 is inserted into an end of the joined body 30 of inner metal pipes, and then the mandrel 34 is forcibly pushed toward

another end of the joined body 30 of inner metal pipes. Thus, the joined body 30 of inner metal pipes is expanded. The expansion using the mandrel has a limitation of the length of the pipe which is determined by the length of a shaft 34a of the mandrel 34.

[0042] Fig. 3B shows an example of expansion using a plug (hereinafter called a "plug method"). A plug 36 is inserted into a joined body 30 of inner metal pipes inserted into the joined body 10 of the outer metal pipes. Then, the plug 36 is drawn out to another end of the joined body 30 of inner metal pipes. Thus, the joined body 30 of inner metal pipes is expanded. The expansion using the plug has a limitation of the length of the pipe which is determined by the length of a shaft 36a of the plug 36.

[0043] Fig. 3C shows an example of expansion using liquid pressures (hereinafter called a "liquid pressure method"). An end of the joined body 30 of inner metal pipes inserted into the joined body 10 of the outer metal pipes is hermetically closed. Moreover, fluid 38 such as water is forcibly injected into the joined body 30 of inner metal pipes from another end by using a hydraulic pump or the like (not shown). Thus, the hydraulic pressures are used to expand the joined body 30 of inner metal pipes.

[0044] The liquid pressure method is only required to have a pipe structure which permits suspension of the hermetic closing of the end. Therefore, the length of the pipe which can be manufactured is not limited. Thus, the foregoing method is a preferred method to manufacture a long dual layer metal pipe for use as a pipe line having a length of tens of kilometers. Since the expanding unit, such as the mandrel, is not required, an advantage can be realized in that even a dual layer metal pipe having a large diameter can be manufactured.

[0045] Fig. 3D shows expansion using a plunger (hereinafter called a "plunger method"). A plunger 40 is inserted into an end of a joined body 30 of inner metal pipes inserted into a joined body 10 of the outer metal pipes. Moreover, a pressurizing device such as a hydraulic pump is operated to forcibly inject fluid 38 such as water into the joined body 30 of inner metal pipes. Thus, hydraulic pressure is applied to an end surface 40a of the plunger 40 so that the plunger 40 is inward pushed toward another end. Thus, the joined body 30 of inner metal pipes is expanded by the plunger 40.

[0046] The plunger method uses hydraulic pressures to inward push the plunger 40. Therefore, an advantage can be realized in that the length of the dual layer metal pipe which can be manufactured is not limited. The plunger 40 inserted into an end of the joined body 30 of inner metal pipes and inward pushed to another end is discharged from the other end by the hydraulic pressure. Therefore, the operations for hermetically closing the other end and that for suspending the hermetic closing are not required differently from the liquid pressure method. Thus, the foregoing method is a preferred method to manufacture a long dual layer metal pipe, such as an oil-well pipe, having an end which is deeply buried into the surface of the earth.

[0047] As a matter of course, the joined body 30 of inner metal pipes has to have an outer diameter smaller than the inner diameter of the joined body 10 of the outer metal pipes because the joined body 30 of inner metal pipes has to be inserted into the joined body 10 of the outer metal pipes. In consideration of the material of the joined body 30 of inner metal pipes, the outer diameter of the joined body 30 of inner metal pipes advantageously has to have an expansion ratio (= (outer diameter of expanded pipe - outer diameter of pipe before expansion) / (outer diameter or pipe before expansion × 100 (%)) which is not higher than a predetermined value.

[0048] If the pipe has an excessively high expansion ratio, there is apprehension that a multiplicity of microcracks are formed in the lengthwise direction of the joined body 30 of inner metal pipes after the joined body 30 of inner metal pipes has been expanded. Because the microcracks enlarge the surface area of the inner surface of the joined body 30 of inner metal pipes, the corrosion resistance is deteriorated. If SUS329J1 which is a dual-phase stainless steel is used as the joined body 30 of inner metal pipes, the expansion ratio has, advantageously, to be 30% or lower. Generally, it is preferably about 20% to 30%.

[0049] A process of manufacturing the dual layer metal pipe by the manufacturing method according to the present invention will now be described with reference to Figs. 4A to 4C. Fig. 4A shows the step of inserting the inner pipe in which the joined body 30 of inner metal pipes has been inserted into the joined body 10 of the outer metal pipes in the joining step (not shown).

[0050] In the example shown in Figs. 4A to 4B, the joined body 10 of the outer metal pipes is formed by joining the outer metal pipes 12_N, 12_{N+1}, ..., through the welded portions 16N. The joined body 30 of inner metal pipes is formed by joining the inner metal pipes 32_N, 32_{N+1}, ..., to one another through the welded portions 33N. In this case, both of the inner and outer surfaces of the joined body 10 of the outer metal pipes and the joined body 30 of inner metal pipes are subjected to a burr removal process.

[0051] Fig. 4B shows an expansion step, in which the joined body 30 of inner metal pipes inserted into the joined body 10 of the outer metal pipes in the step for inserting the inner pipe is expanded in a stroke. The outer diameter of the joined body 30 of inner metal pipes is enlarged by plastic deformation. Thus, the inner surface of the joined body 10 of the outer metal pipes and the outer surface of the joined body 20 of inner metal pipes are brought into completely intimately contact with each other. Thus, a long dual layer metal pipe 50 structured as shown in Fig. 4C can be obtained.

Example 1

[0052] As the outer metal pipe, a carbon steel pipe for high pressure piping, made of STS480 (JIS G3455) and having an outer diameter of 216.3mm, an inner diameter of 190.9 mm and a length of 5 m was employed. The inner metal pipe was a dual-phase stainless steel pipe made of SUS329J1 (JIS G3459) and having an outer diameter of 165.2 mm, an inner diameter of 159.6 mm and a length of 5 m was employed. In the foregoing case, the expansion ratio was 15.6 %.

[0053] Ten outer metal pipes were welded to one another by a TIG welding method so that a joined body of the outer metal pipes having a length of 50 m was manufactured. Eleven inner metal pipe were welded to one another by the TIG welding method so that a joined body of the inner metal pipes having a length of 55 m was manufactured. Then, burrs were removed, and then the obtained joined body of the inner metal pipes was inserted into the joined body of the outer metal pipes. A plug method was employed to expand the joined body of the inner metal pipes so that a long dual layer metal pipe having a length of 50 m was manufactured.

Example 2

[0054] A similar procedure to that according to Example 1 was employed except that the flange joint method is employed to join the outer metal pipes to one another, liquid phase diffusion welding method is employed to join the inner metal pipes to one anther and the liquid pressure method is employed to expand the joined body of the inner metal pipes. Thus, a long dual layer metal pipe having a length of 50 m was manufactured.

[0055] The inner metal pipes were joined to one another by the liquid phase diffusion welding method such that annular Ni alloy foil having a composition corresponding to JIS Z3265 BNi-5, a thickness of 40 μm and the outer and inner diameters which were 98 % of the outer diameter of the inner metal pipe and 100 % of the inner diameter of the inner metal pipe was employed as the insert member. The roughness Rmax of each of the joint surfaces of the inner metal pipes was 25 μm or smaller (according to the present invention, Rmax is 50μm or sumaller, preferably, 25μm or smaller), the joining temperature was 1300°C, the duration was 60 seconds, the pressure was 4 MPa and the atmosphere in which the joining process was performed was Ar. Since no burr was formed in the joint portion, the operation for removing burrs was not performed.

Example 3

[0056] A similar procedure to that according to Example 1 was employed except that the liquid phase diffusion welding method is employed to join the outer metal pipes and the inner metal pipes to one another and the plunger is employed to expand the joined body of the inner metal pipes. Thus, a long dual layer metal pipe having a length of 50 m was manufactured.

[0057] The outer metal pipes were joined to one another by the liquid phase diffusion welding method such that annular Ni alloy foil having a composition corresponding to JIS Z3265 BNi-5, a thickness of 30 μm and the outer and inner diameters. The foil were 98 % of the outer diameter of the outer metal pipe and 99 % of the inner diameter of the outer metal pipe. The outer annular Ni alloy foil was employed as the insert member. The roughness Rmax of each of the joint surfaces of the inner metal pipes was 50 μm or smaller, the joining temperature was 1300°C, the duration was 60 seconds, the pressure was 4 MPa and the atmosphere in which the joining process was performed was Ar. The liquid phase diffusion welding operation of the inner metal pipes was performed under the same conditions as those according to Example 2. Since no burr was formed in the joined body of the inner metal pipes and the joined body of the outer metal pipes, the operation for removing burrs was not performed.

Comparative Example 1

[0058] No inner metal pipe was used and dual-phase stainless steel pipes made of SUS329J1 (JIS G3459) and having an outer diameter of 216.3mm, an inner diameter of 190.9 mm and a length of 5 m were welded to one another by the TIG welding method. Thus, a long metal pipe having a length of 50 m was manufactured.

Comparative Example 2

[0059] Clad steel pipes each having a length of 5 m and obtained by cladding a dual-phase stainless steel pipe SUS329J1 (JIS G3459) having an outer diameter of 165.2 mm and an inner diameter of 159.6 mm to the inner surface of a carbon steel pipe having an outer diameter of 216.3 mm and an inner diameter of 190.9 mm and made of STS480 (JIS G3455) for high-pressure piping were welded to one another by the TIG welding method. Thus, a long dual layer metal pipe having a length of 50 m was manufactured.

[0060] Table 1 shows results of evaluation of costs of materials, joining efficiencies and results of corrosion tests of

the steel pipes obtained in Examples 1 to 3 and comparative Examples 1 and 2. The corrosion tests were performed in the following manner. Namely, samples each having a length of 100mm and a width of 12.5mm, which was provided with the joint portion in the central portion thereof, were cut from the long steel pipes (or steel pipes which was TIG-welded) after the elongation. Then, the samples were immersed in 10 % FeCl + N/20HCl solution maintained at 50°C for 24 hours. The corrosion resistance was evaluated in accordance with an amount of reduction caused from corrosion per unit area and unit time.

Table 1

	Metal Pipe Joined Body				Expansion Method	Cost
	Outer		Inner			
	Material	Joining Method	Material	Joining Method		
Comp. Ex. 1	SUS329J1	TIG Welding	-	-	-	D
Ex. 1	STS480	TIG Welding	SUS329J1	TIG Welding	Plug Method	A
Ex. 2	STS480	Flange Joint	SUS239J1	Flange Joint	Liquid Pressure Method	A
Ex. 3	STS480	Liquid Diffusion Welding	SUS329J1	Liquid Diffusion Welding	Plunger Method	A
Comp. Ex. 1	Clad Steel	TIG Welding	-	-	-	B
	Joining Efficiency		Results of Corrosion Test			Total Evaluation
	Outer Pipe	Inner Pipe	Reduction Amount due to Corrosion (g/m2 • hr)	Corrosion Hole	Evaluation	
Comp. Ex. 1	C		2.0	No	B	D
Ex. 1	C	C	2.1	No	B	B
Ex. 2	B	A	2.0	No	B	A
Ex. 3	A	A	1.9	No	B	A
Comp. Ex. 1	D		2.3	No	B	D
A: Very Good, B: Good, C: Acceptable, D: Bad						

[0061] In Examples 1 to 3, the outer metal pipes were carbon steel pipes for high-pressure piping and the inner metal pipes were dual-phase stainless steel pipes. The two types of the pipes were individually joined to one another, and then expansion was performed at a stretch so that dual layer metal pipes were formed. Therefore, the costs of the materials were lowest. In Comparative Example 1, the dual-phase stainless steel pipes each containing Cr in a large quantity were use to produce the long pipe. Therefore, the cost of the material was highest. In Comparative Example 2 using the clad steel pipe, the materials and thicknesses of the outer and inner pipes were the same as those in examples 1 to 3. Since the joining step was performed when the clad steel pipe was manufactured, the cost of the material was raised as compared with Examples 1 to 3.

[0062] The joining efficiency was highest in Example 3 in which both of the outer metal pipes and the inner metal pipes were joined by the liquid phase diffusion welding method. The reason for this lies in that time required to complete the liquid phase diffusion welding process was half or shorter than that required to complete the welding method. Moreover, the joined body free from a burr was obtained because the shape of the insert member and so forth were optimized. Thus, the operation for removing burrs was not required.

[0063] Example 2 using the liquid phase diffusion welding method for joining the inner metal pipes and the flange joint for joining the outer metal pipes resulted in a secondary joining efficiency. Example 1 and Comparative Example 1 in each of which both of the outer metal pipes and the inner metal pipes were joined to one another by the TIG welding method encountered reduction in the efficiency as compared with Example 2. Comparative Example 2 in which the clad

steel pipes were joined by the TIG welding method has to change the welding conditions between the inner pipes and the outer pipes. Therefore, Comparative Example 2 resulted in a lowest joining efficiency.

[0064] No corrosion was found in the inner surface of each of the long dual layer metal pipes obtained in examples 1 to 3. The amounts of reduction caused from corrosion were similar to that resulted in Comparative Example 1 in which the dual-phase stainless steel pipes SUS329J1 was as it is TIG-welded. No reduction in the corrosion resistance caused from the expansion process was observed. On the other hand, Comparative Example 2 in which the clad steel pipes were TIG-welded to one another was free from corrosion. However, corrosion resistance of the welded portion deteriorated and, therefore, the amount of reduction caused from corrosion was somewhat enlarged.

[0065] As a result, Example 2 or 3 in which the inner metal pipes were joined to one another by the liquid phase diffusion welding method exhibited most excellent results. Example 1 in which both of the inner metal pipes and the outer metal pipes were TIG-welded exhibited a secondary result.

Example 4

[0066] As the outer metal pipes, stainless steel pipes SUS316TP (JIS G3459) for use as pipes and each having an outer diameter of 165.2 mm, an inner diameter of 143.2 mm and a length of 5 m were employed. As the inner metal pipes, piping-purpose titanium pipes TTP270WC (JIS H4630) and each having an outer diameter of 114.3 mm, an inner diameter of 110.1 mm and a length of 5 m were employed. In this case, the expansion ratio was 25.3 %.

[0067] Ten outer metal pipes were welded to one another by the TIG welding method so that a joined body of the outer metal pipes having a length of 50 m was manufactured. Moreover, eleven inner metal pipes were welded to one another by the TIG welding method so that a joined body of the inner metal pipes having a length of 55 m was manufactured. Then, burrs were removed, and then the obtained joined body of the inner metal pipes was inserted into the joined body of the outer metal pipes. The plunger method was employed to expand the joined body of the inner metal pipes. Thus, a long dual layer metal pipe having a length of 50 m was manufactured.

Example 5

[0068] A similar procedure to chat according to Example 1 was employed except that the flange joint method is employed to join the outer metal pipes to one another, liquid phase diffusion welding method is employed to join the inner metal pipes to one anther and the liquid pressure method is employed to expand the joined body of the inner metal pipes. Thus, a long dual layer metal pipe having a length of 50 m was manufactured.

[0069] The inner metal pipes were joined to one another by the liquid phase diffusion welding method such that annular Ti-Zr-Cu-Ni alloy foil having a thickness of 30 μm and the outer and inner diameters which were 99 % of the outer diameter of the inner metal pipe and 100 % of the inner diameter of the inner metal pipe was employed as the insert member. The roughness Rmax of each of the joint surfaces of the inner metal pipes was 25 μm or smaller, the joining temperature was 900°C, the duration was 180 seconds, the pressure was 3 MPa and the atmosphere in which the joining process was performed was He. Since no burr was formed in the joint portion, the operation for removing burrs was not performed.

Example 6

[0070] A similar procedure to that according to Example 1 was employed except that the liquid phase diffusion welding method is employed to join both of the outer metal pipes and the inner metal pipes to one another and the plug method is employed to expand the joined body of the inner metal pipes. As a result, a long dual layer metal pipe having a length of 50 m was manufactured:

[0071] The outer metal pipes were joined to one another by the liquid phase diffusion welding method such that annular Ni alloy foil having a composition corresponding to JIS Z3265 BNi-2, a thickness of 25 μm and the outer and inner diameters which were 100 % of the outer diameter of the outer metal pipe and 99.5 % of the inner diameter of the outer metal pipe was employed as the insert member. The roughness Rmax of each of the joint surfaces of the outer metal pipes was 50 μm or smaller, the joining temperature was 1290°C, the duration was 60 seconds, the pressure was 3.5 MPa and the atmosphere in which the joining process was performed was Ar. The liquid phase diffusion welding operation of the inner metal pipes was performed under the same conditions as those according to Example 5. Since no burr was formed in the joined body of the inner metal pipes and the joined body of the outer metal pipes, the operation for removing burrs was not performed.

Comparative Example 3

[0072] No inner metal pipe was used and piping-purpose titanium pipes TTP270WC (JIS H4630) each having an

outer diameter of 165.2 mm, an inner diameter of 143.2 mm and a length of 5 m were welded to one another by the TIG welding method. Thus, an elongated metal pipe having a length or 50 m was manufactured.

Comparative Example 4

[0073] Clad steel pipes each having a length of 5 m and obtained by cladding a piping-purpose titanium pipe TTP270WC (JIS H4630) having an outer diameter of 114.3 mm and an inner diameter of 110.1 mm to the inner surface of a stainless steel pipe SUS316TP (JIS G3459) for use as a pipe and having an outer diameter of 165.2 mm and an inner diameter of 143.2 mm were welded to one another by the TIG welding method. Thus, a long dual layer metal pipe having a length of 50 m was manufactured.

[0074] Table 2 shows results of evaluation of costs of materials, joining efficiencies and results of corrosion tests of the steel pipes obtained in Examples 4 to 6 and Comparative Examples 3 and 4. The corrosion tests were performed by using elongated samples each of which had a length of 100 mm and a width of 12.5 mm and each of which was provided with the joint portion in the central portion thereof from the expanded steel pipes (or steel pipes which was TIG-welded). Then, the samples were immersed in 5 % HCl solution, temperature of which was 25°C, for 720 hours. The corrosion resistance was evaluated in accordance with a depth of corrosion per unit time.

Table 2

	Metal Pipe Joined Body				Expansion Method	Cost
	Outer		Inner			
	Material	Joining Method	Material	Joining Method		
Comp. Ex. 3	TTP270WC	TIG Welding	-	-	-	D
Ex. 4	SUS316TP	TIG Welding	TTP270WC	TIG Welding	Plunger Method	A
Ex. 5	SUS316TP	Flange Joint	TTP270WC	Liquid Diffusion Welding	Liquid Pressure Method	A
Ex. 6	SUS316TP	Liquid Diffusion Welding	TTP270WC	Liquid Diffusion Welding	Plug Method	A
Comp. Ex. 4	Clad Steel	TIG Welding	-	-	C	

	Joining Efficiency		Results of Corrosion Test		Total Evaluation
	Outer Pipe	Inner Pipe	Corrosion Depth (mm/year)	Evaluation	
Comp. Ex. 1	C		0.07	B	D
Ex. 1	C	C	0.08	B	B
Ex. 2	B	A	0.07	B	A
Ex. 3	A	A	0.07	B	A
Comp. Ex. 1	D		0.10	B	D

A: Very Good, B: Good, C: Acceptable, D: Bad

[0075] In Examples 4 to 6, the outer metal pipes, which were the stainless steel pipes for forming pipes, and inner metal pipes which were the piping-purpose titanium pipes, were prepared. The two types of the pipes were individually joined to one another, and then expansion was performed at a stretch so that dual layer metal pipes were formed. Therefore, the costs of the materials were lowest. In Comparative Example 3, the piping-purpose titanium pipes each containing Ti in a large quantity were as it is employed as the elongated pipe. Therefore, the cost of the material was highest. In Comparative Example 4 using the clad steel pipes, the materials and thicknesses of the outer and inner pipes were the same as those in Examples 4 to 6. Since the joining step was performed when the clad steel pipe was manufactured, the cost of the material was raised as compared with Examples 4 to 6.

[0076] The joining efficiency was highest in Example 6 in which both of the outer metal pipes and the inner metal pipes

were joined to one another by the liquid phase diffusion welding method. Example 5 exhibited secondary efficiency because the inner metal pipes were joined to one another by the liquid phase diffusion welding method and the outer metal pipes were joined by the flange joints. Example 4 and Comparative Example 3 in each of which the TIG welding method was employed resulted in reduction in the efficiency as compared with Example 5. Comparative Example 4 in which clad steel pipes were TIG-welded has to change the welding conditions between the inner pipes and the outer pipes. Therefore, Comparative Example resulted in a lowest joining efficiency.

[0077] The depth of corrosion in the inner surface of the long dual layer metal pipe obtained in each of Examples 4 to 6 was similar to that resulted in Comparative Example 3 in which the piping-purpose titanium pipes TTP270WC were as it is TIG-welded to one another. Thus, deterioration in the corrosion resistance caused from the expansion was not observed. On the other hand, Comparative Example 4 in which the clad steel pipes were TIG-welded to one another encountered deterioration in the corrosion resistance of the welded portions. Therefore, the depth of corrosion was somewhat enlarged.

[0078] As a result, Examples 4 and 5, in which the inner metal pipes were joined to one another by the liquid phase diffusion welding method, exhibited most excellent total results. Example 1, in which both of the inner metal pipes and the outer metal pipes were TIG-welded to one another, resulted secondarily satisfactory results.

[0079] Although the invention has been described in its preferred form and structure with a certain degree of particularity, it is understood that the present disclosure of the preferred form can be changed in the details of construction and in the Combination and arrangement of parts without departing from the spirit and the scope of the invention.

[0080] If the long dual layer metal pipe 50 has to have only corrosion resistance and high strength is not required, the joined body 30 of inner metal pipes and the joined body 10 of the outer metal pipes brought into intimate contact with each other by the expansion step may be used as it is. If the long dual layer metal pipe 50 has to have high strength, the joined body 30 of inner metal pipes and the joined body 10 of the outer metal pipes may be joined to each other after the expansion step has been performed.

[0081] Specifically, an induction coil may be advantageously operated to join the outer surface of the joined body 30 of inner metal pipes and the inner surface of the joined body 10 of the outer metal pipes to each other by a solid-phase diffusion welding method after the joined body 30 of inner metal pipes has been expanded. As an alternative, a method may be advantageously employed in which a tape-shape insert member is spirally wound around the outer surface of the joined body 30 of inner metal pipes so as to be inserted into the joined body 10 of the outer metal pipes. Then, the joined body 30 of inner metal pipes is expanded. Next, an induction coil is operated to heat the joined body 30 of inner metal pipes so that the joined body 30 of inner metal pipes and the joined body 10 of the outer metal pipes are joined to each other by the liquid phase diffusion welding method.

[0082] If the inner metal pipe is made of a thin-wall material or a soft metal material, a pressurizing device such as a compressor may be advantageously employed in place of applying liquid pressures to the joined body 30 of inner metal pipes by using a hydraulic pump or the like so as to apply pressure by using gas, such as air. In the foregoing case, an effect similar to that obtainable from the above-mentioned embodiment can be obtained.

[0083] The method of manufacturing a long dual layer metal pipe according to the present invention has the steps of inserting the joined body of the inner metal pipes having one or more joined portions into the joined body of the outer metal pipes having one or more joined portions and expanding the joined body of the inner metal pipes so that a long dual layer metal pipe is manufactured. Therefore, an effect can be obtained in that the length of the pipe which can be manufactured is not limited by employing a suitable expanding method and thus a long dual layer metal pipe having a length of thousands of meters can be manufactured.

[0084] The outer metal pipes and the inner metal pipes are individually joined to one another. Therefore, an advantage can be obtained in that the problem experienced with the conventional method by which dual layer metal pipes manufactured previously are joined to one another can be prevented. The problem arises in that the corrosion resistance of the welded portions deteriorates because of re-melting of the inner metal pipe when the welding operation is performed and cracks are formed connected with the hardening. Since the joining conditions can individually be optimized in this embodiment, an advantage can be obtained in that a complete long dual layer metal pipe can be manufactured even if either of the inner metal pipe or the outer metal pipe is a thick-wall pipe.

[0085] When the liquid pressure method or the plunger method is applied as the expansion method, an advantage can be obtained in that the length of the pipe which can be manufactured is not limited. Another advantage can be obtained from the liquid pressure method in that a long dual layer metal pipe having a large diameter can easily be manufactured. When the liquid phase diffusion welding method is employed to join at least the inner metal pipes to one another, a long dual layer metal pipe having excellent corrosion resistance and gastightness can be manufactured at low cost. When both of the inner metal pipes and the outer metal pipes are joined to one another by the liquid phase diffusion welding method, the operation for removing burrs can be omitted. Therefore, a long dual layer metal pipe having a small diameter can be manufactured.

[0086] As described above, the method of manufacturing a long dual layer metal pipe according to the present invention is a method which is capable of efficiently manufacturing a long dual layer metal pipe having an excellent quality at

low cost. Therefore, when the method according to the present invention is applied to, for example, an oil-well pipe or a line pipe, the inner metal pipes and the outer metal pipes are individually joined to one another and the expansion process is performed in the field differently from the conventional method in which dual layer metal pipes previously manufactured in a plant are welded to one another in the field. Thus, time required to complete a digging operation and/or pipe arranging operation can significantly be shortened. Therefore, the present invention is an invention which enables a great industrial effect to be obtained.

Claims

1. A method of manufacturing a long dual layer metal pipe (50) comprising the steps of:

   inserting a joined body (30) of inner metal pipes into a joined body (10) of outer metal pipes, said joined body (30) of inner metal pipes having an outer diameter smaller than an inner diameter of said joined body (10) of outer metal pipes, said joined body (30) of inner metal pipes having one or more joining portions (33_N), said joined body (10) of outer metal pipes having one or more joining or clamping portions (14_N, 14_{N+1}, 18_N, 18_{N+1}, 20_N, 22_N, 22_{N+1}); and

   expanding said joined body (30) of inner metal pipes to manufacture a dual layer metal pipe (50).

2. A method of manufacturing a long dual layer metal pipe (50) according to claim 1, wherein at least said joined body (30) of inner metal pipes and said joined body (10) of outer metal pipes is joined by a liquid phase diffusion welding method.

3. A method of manufacturing a long dual layer metal pipe (50) according to any of the claims 1 or 2, wherein said inner metal pipe is a seamless pipe.

4. A method of manufacturing a long dual layer metal pipe (50) according to any of the preceding claims, wherein said joined body (30) of inner metal pipes is expanded by using liquid pressures.

5. A method of manufacturing a long dual layer metal pipe (50) according to any of the preceding claims 1 to 31, wherein said joined body (30) of inner metal pipes is expanded by using a plunger (40).

Fig. 1A

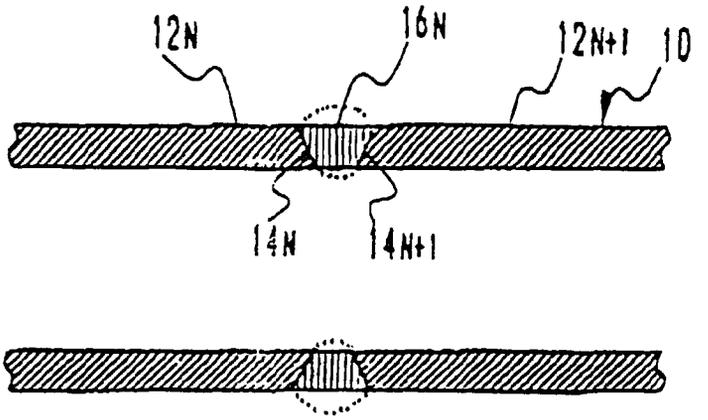

Fig. 1B

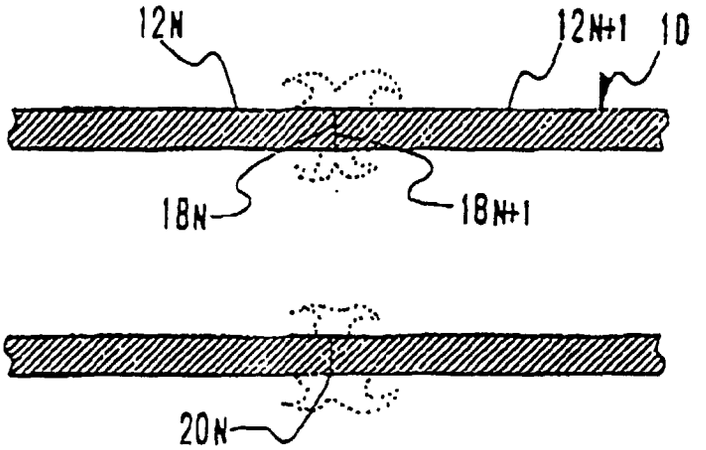

Fig. 1C

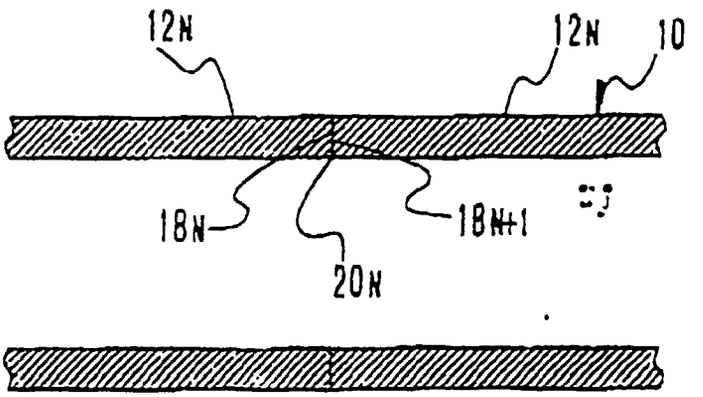

Fig. 2A

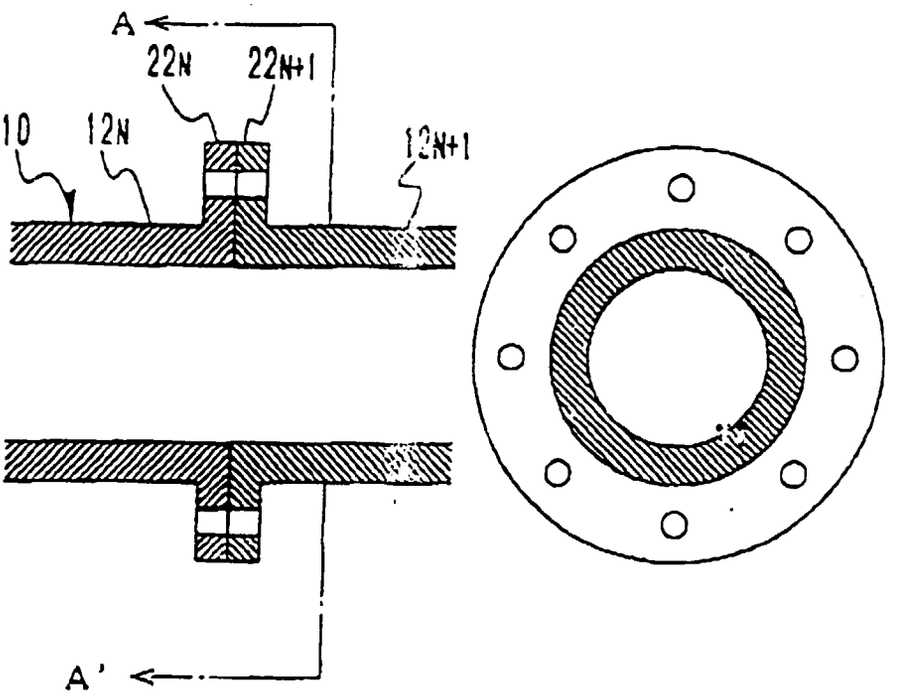

Fig. 2B

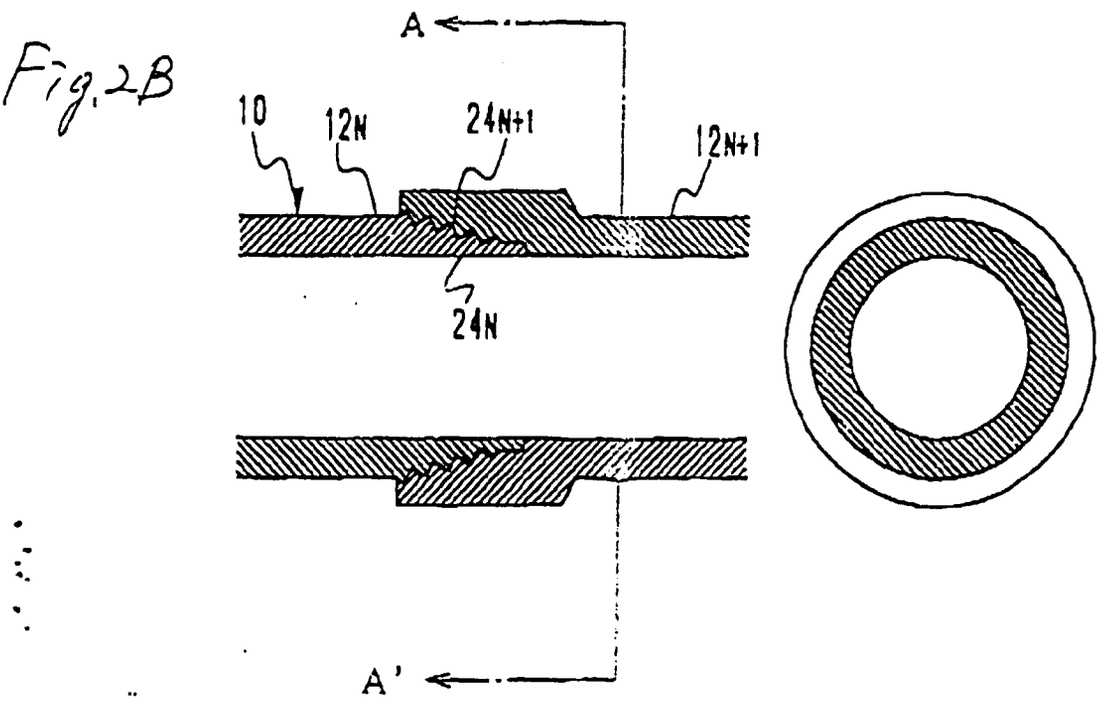

Fig.3A

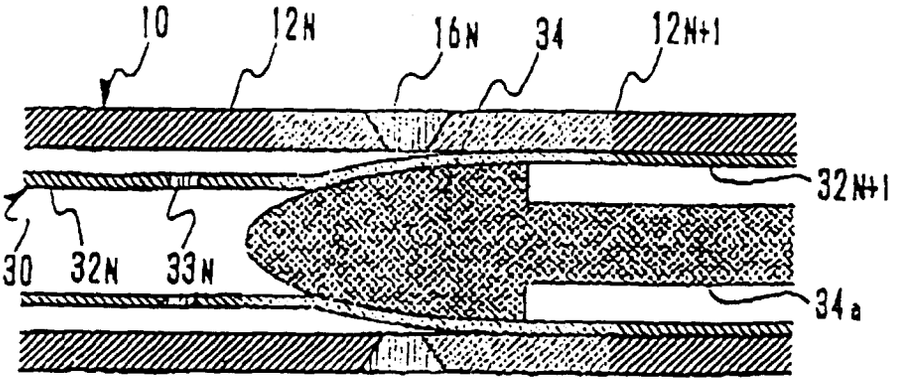

Fig.3B

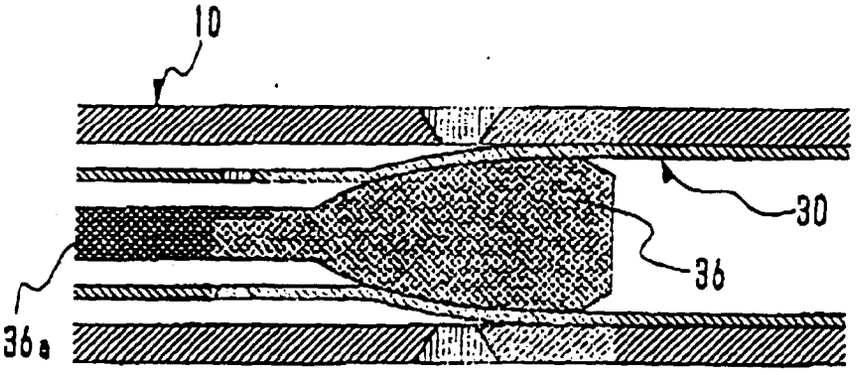

Fig.3C

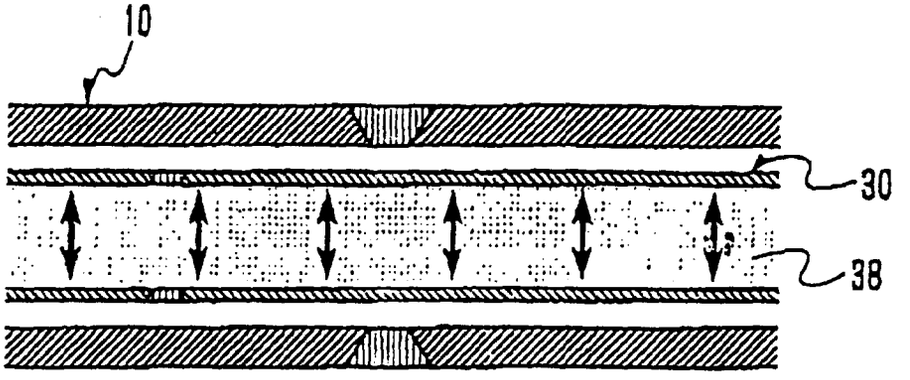

Fig.3D

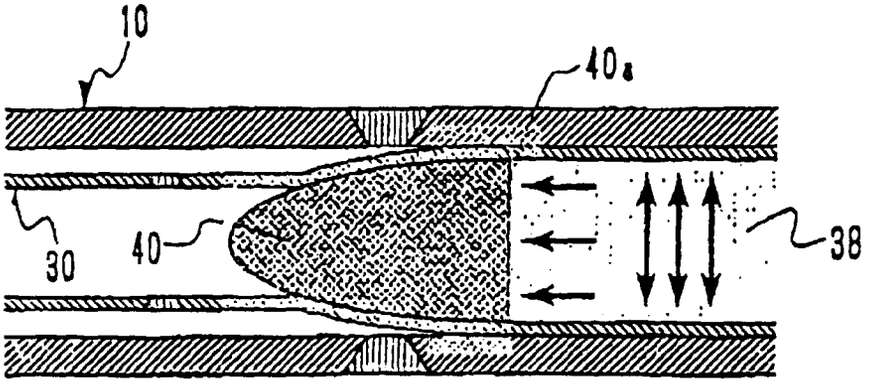

Fig.4A

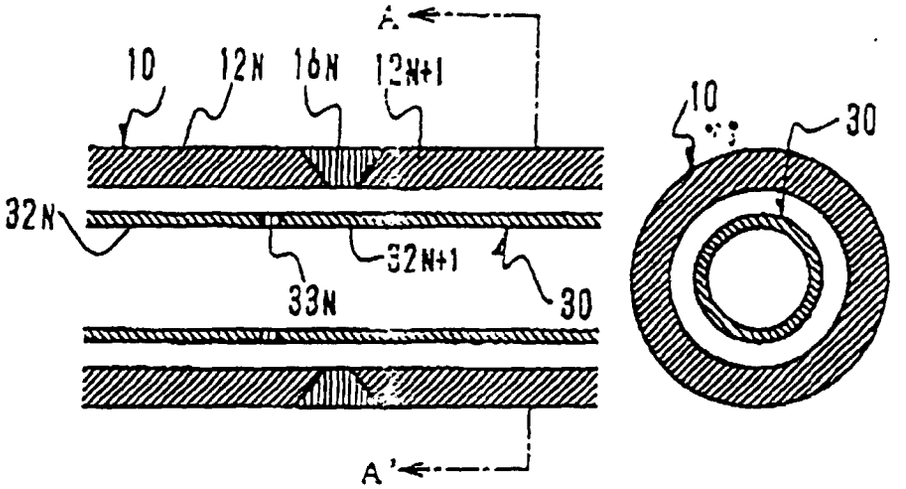

Fig.4B

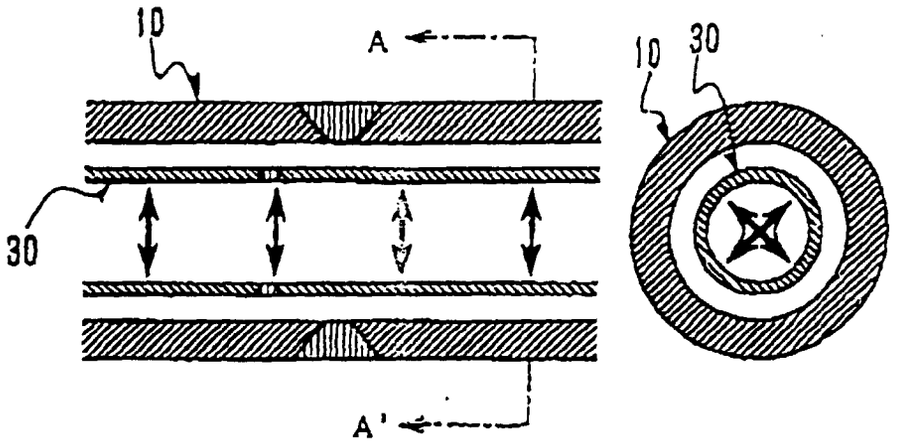

Fig.4C