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(54) **Title** : METHOD FOR MANUFACTURING A FLEXIBLE TUBULAR PIPE

(54) **Titre** : PROCÉDÉ DE FABRICATION D'UNE CONDUITE TUBULAIRE FLEXIBLE

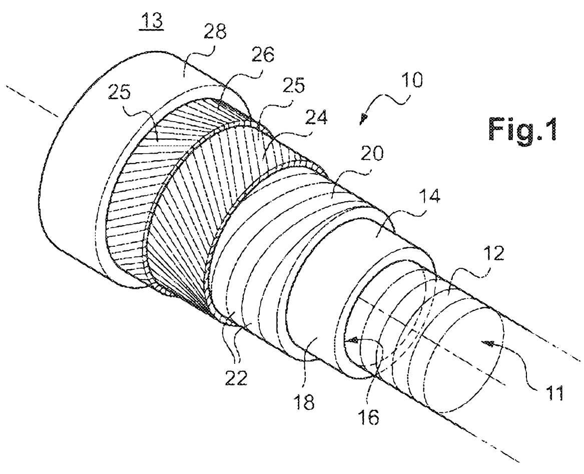

Fig.1

(57) **Abstract** : The invention relates to a method for manufacturing a tubular pipe for transporting hydrocarbons, wherein said method comprises a) forming a polymer material pressure sheath (14), having an outer surface (18) and an inner surface (16) defining an inner flow space (11); b) winding a metal wire at a short pitch around said tubular pressure sheath (14) such as to form turns (22) defining consecutive intervals (30) therebetween; c) winding a plurality of armoring pull wires (25) at a long pitch around said turns (22); and d) bringing said inner flow space (11) to a pressure P greater than a given pressure P_d, while simultaneously bringing said pressure sheath (14) to a temperature T greater than a given temperature T_d such as to obtain a low amplitude for the radial deformations at said intervals (30).

(57) **Abrégé** : L'invention concerne un procédé de fabrication d'une

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conduite tubulaire destinée au transport des hydrocarbures. Selon le procédé: a) on forme une gaine de pression (14) en matériau polymère présentant une surface externe (18) et une surface interne (16) définissant un espace d'écoulement interne (11);b) on enroule à pas court un fil métallique autour de ladite gaine de pression tubulaire (14) de manière à former des spires (22) définissant entre elles des intervalles successifs (30);c) on enroule à pas long une pluralité de fils d'armures de traction (25) autour desdites spires (22); et,d) on porte ledit espace d'écoulement interne (11) à une pression P supérieure à une pression donnée P_d, tandis qu'on porte simultanément ladite gaine de pression (14) à une température T supérieure à une température donnée T_d, de manière à obtenir une faible amplitude des déformations radiales audit niveau desdits intervalles (30).

Method for manufacturing a flexible tubular pipe

The present invention relates to a method for manufacturing a flexible tubular pipe intended for transporting hydrocarbons and to a flexible tubular pipe produced by such a method.

Such pipes are used in particular for the offshore transportation of hydrocarbons between a submarine installation and a surface installation.

They are constituted of a plurality of superposed metal and plastic layers that confer on them their mechanical properties and their properties that seal them against the hydrocarbon that they transport and the surrounding environment. Also, the flexible tubular pipes generally comprise, from the interior toward the exterior, a metal carcass made from a clipped spiral tape, a polymer material pressure sheath, a helicoidal winding with a short pitch of a metal wire forming a pressure vault, at least one layer of pull armoring wires wound with a long pitch around said pressure vault, and an external protection sheath.

The metal carcass makes it possible to prevent the overlying pressure sheath collapsing inward if the pipe is depressurized. During the manufacture of the flexible tubular pipe, the pressure sheath is directly extruded coaxially around the metal carcass that is driven in translation through an extrusion head. The pressure sheath is usually made from thermoplastic polymers and notably polymers based on polyvinylidene fluoride. After the pressure sheath has been cooled, at least one metal wire is wound helicoidally around it with a short pitch, forming non-contiguous turns. The pressure vault formed in this way will make it possible to protect the pressure sheath from the radial stresses exerted by the external hydrostatic pressure at the seabed and that exerted by the hydrocarbon fluid circulating inside the metal carcass. Moreover, by virtue of its construction, it allows bending of the pipe.

The turns define between them intervals or spaces commonly referred to as “butt gaps”. The width and the depth of these butt gaps are a function of the shape of the metal wire, its thickness and also the helical pitch. There is then wound helicoidally around the pressure vault with a long pitch at least one layer comprising a plurality of armoring pull wires, specifically to make it possible to absorb the traction forces that are exerted on the pipe. Finally, the armoring pull wires are covered with an external protection sheath that is extruded directly via an extrusion head.

The flexible tubular pipe is then type approved and tested by bringing the interior to a particular pressure for a particular period. The pressure imposed on the pipe is then predefined as a function of the internal pressure to which it will be liable to be subjected when it will enter service. In accordance with the documents API 17J and API 16C respectively relating to unbonded flexible pipes and to Kill & Choke systems, drawn up by the American Petroleum Institute, and the applicable standards to which it refers, this pressure is 1.3 or 1.5 times the service pressure, as appropriate. The latter may be as high as around one thousand bar, or even tens of thousands of bar.

When the pipe is pressurized, for example by injecting water into the interior, the pressure sheath will not only be pressed against the internal face of the pressure vault but will also be locally deformed at the level of the butt gaps. The external surface of the pressure sheath will therefore tend to creep inside the butt gaps while shrinkage occurs on each side of the creep area within the thickness of the pressure sheath. Moreover, on the opposite side, toward the internal surface of the pressure sheath in contact with the carcass, the results of cavitation phenomena are observed.

The pressurization of the pipe, in particular during the test phase, therefore weakens the pressure sheath by deforming it locally both externally at the level of the butt gaps of the pressure vault and internally at the level of the carcass. At the level of the butt gaps, the polymer material is deformed radially and internal stresses that can lead to delamination of the material appear. Also, aging of the pipe in service is accelerated, notably for applications at great depth where the temperature and pressure are high.

To remedy the problem of the creep of the pressure sheath into the butt gaps of the vault, applying an anti-creep layer between the pressure sheath and the pressure vault has been envisaged. This anti-creep layer is produced by helicoidally winding a polymer tape around the pressure sheath before winding the metal wire of the pressure vault, for example.

However, using this anti-creep layer necessitates a supplementary operation and even if it solves the problems linked to cavitation, by preventing the creep of the pressure sheath into the butt gaps, it represents an additional cost. Moreover, this also involves ensuring that the integrity of this layer is maintained over at least twenty years if it is required that the pressure sheath does not creep.

Preferred embodiments of the present invention seek to manufacture a flexible tubular pipe, not only such that its pressure sheath retains its integrity when the pipe is pressurized but also such that it can be produced at an advantageous cost.

According to an aspect of the present invention, there is provided a method of manufacturing a flexible tubular pipe intended for transporting hydrocarbons, said method being of the type including the following steps: a) forming a thermoplastic polymer material deformable tubular pressure sheath, said sheath having an external surface and an opposite internal surface defining an internal flow space for the hydrocarbons; b) helicoidally winding a metal wire at a short pitch around said pressure sheath so as to form turns resting on said external surface, said turns defining successive intervals therebetween; c) helicoidally winding a plurality of armoring pull wires at a long pitch around said turns; and finally d) bringing said internal flow space to a pressure P greater than a given pressure P_d so that said external surface of said pressure sheath is deformed radially at the level of said intervals, wherein in the step d) said pressure sheath is simultaneously brought to a temperature T greater than a given temperature T_d so as to be able to relieve the internal stresses of said polymer material of said deformed external surface to obtain a small amplitude of the radial deformations at the level of said intervals, wherein in the step d) said internal flow space is brought to a first pressure P_1 during a first time period t_1 and to a second pressure P_2 during a second time period t_2, and wherein said second time period t_2 is greater than or equal to said first time period t_1.

One feature of the invention therefore resides in the use of thermal energy for bringing the pressure sheath to a given temperature T_d while it is subjected to an internal pressure. As the result, the internal stresses of the polymer material are not only relieved but also minimized. Accordingly, it is seen that the excursion of the external surface of the pressure sheath into the butt gaps that occurs during creep significantly reduces the amplitude of the shrinkage on either side of the creep area. Also, the stress level associated with the deformation of the external surface of the pressure sheath, which generates an area of loss of cohesion, is lower at the level of the creep area. It is then possible to dispense with the relatively costly use of a screen film, liable to degrade over time, between the pressure sheath and the pressure vault. Additionally, the results of the cavitation phenomena more on the side of the internal surface of the pressure sheath and the areas of loss of cohesion initially present in the excursions of the external surface of the pressure sheath no longer occur.

It will be seen that said thermoplastic polymer material has a glass transition temperature T_g and a secondary transition temperature $T_{g'}$ greater than said first glass transition temperature T_g. The thermoplastic polymers used to produce the pressure sheaths are semi-crystalline polymers. Also, they have two principal phases, a crystalline phase and an amorphous phase. The crystalline phase corresponds to polymer areas organized into crystalline lamellas, which are grouped together in spherolites.

The glass transition temperature, characteristic of the polymer, results from the transformation of this amorphous phase between a vitreous state in which the polymer is relatively rigid and a rubbery state. Two type of amorphous phase exist in the material, however, a first type in which the amorphous phase is totally free vis à vis the spherolites, and a second type in which the amorphous phase is trapped in the spherolites between crystalline lamellas. A distinction is therefore made between the free amorphous phase type and the confined amorphous phase type. Also, the quantity of thermal energy necessary for the transformation of this second type amorphous phase from a vitreous state to a rubbery state is inherently greater than the quantity of thermal energy enabling transformation of the amorphous phase of the first type. Consequently, there are seen for this type of material two distinct transition temperatures, a glass transition temperature T_g determined by differential scanning calorimetry (DSC) or by dynamic mechanical analysis (DMA), and a secondary transition temperature $T_{g'}$ determined by dynamic mechanical analysis. Accordingly, in accordance with a particularly advantageous embodiment of the invention, said given temperature T_d is between T_g and $T_{g'}$. T_d may be equal to or greater than $T_{g'}$ but for cost reasons it is preferred to set the temperature T_d between T_g and $T_{g'}$.

Said given temperature T_d is preferably close to said secondary transition temperature $T_{g'}$. Said given temperature T_d is advantageously greater than the ambient temperature T_0, which averages 18°C. Obviously, the ambient temperature varies as a function of the geographical location. This given temperature T_d is between 40° and 80°C, for example, or even greater than 80°C, depending on the nature of the thermoplastic polymer material extruded around the metal carcass.

In accordance with an advantageous embodiment of the invention, in the step d), said given pressure P_d is greater than the atmospheric pressure P_0. In actual fact, the given pressure P_d must necessarily be greater than the service pressure of the flexible tubular pipe so as to anticipate any defect that could cause it to deteriorate. It is therefore considered that, if the pressure sheath of the pipe resists an internal pressure greater than the service pressure, it can resist the service pressure over a sufficiently long time period.

In the step d), said internal flow space is preferably brought to a first pressure P_1 during a first time period t_1 and to a second pressure P_2 during a second time period t_2. As a result, the residual stresses induced in the material after the steps of extruding and cooling the pressure sheath and caused by the temperature and the pressure variations will be attenuated thanks to stress relief mechanisms and the levels of stress in the pressure sheath, generated by the pressurization of said internal flow space during the step d), are limited. Also, the cavitation phenomena are further attenuated. Moreover, the mechanical characteristics of the polymer material of the pressure sheath are less impacted by the effect of the pressure.

Said internal flow space is advantageously brought to a pressure P less than said given pressure P_d between said first and second time periods t_1 and t_2. For example, between said first and second time periods t_1 et t_2, said internal flow space is brought to a pressure P close to the atmospheric pressure P_0.

Moreover, said first time period t_1 is preferably greater than the time period recommended by the standards documents of the American Petroleum Institute. Moreover, said second time period t_2 is greater than or equal to said

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first time period t_1. For example, said second time period t_2 is between said first time period t_1 and three times said first time period t_1. In accordance with a particularly advantageous embodiment, the first time period t_1 has a duration greater than or equal to 12 hours and the second time period t_2 has a duration close to 24 hours.

In accordance with a particularly advantageous feature of the invention, said thermoplastic polymer material is chosen from the materials of the fluorinated polymer family. For example, the polymer material is vinylidene polyfluoride, or a material chosen from the copolymers of vinylidene fluoride, that is to say from the polymers in which the principal chain is constituted of two or three monomers of different chemical kind, one of the principal monomers being vinylidene fluoride, and the other monomers being chosen from the following monomers: hexafluoropropylene, perfluoromethyl vinyl ether, perfluoroethyl vinyl ether, perfluoropropyl vinyl ether, tetrafluoroethylene, perfluorobutyl ethylene, fluoropropylene, chlorotrifluoroethylene, chlorodifluoroethylene, chlorofluoroethylene, trifluoroethylene, poly(ethylene-co-tetrafluoroethylene), poly(perfluoroalkoxy ethylene), poly(perfluoromethoxyethylene), poly(perfluorinated ethylene-propylene), polychlorotrifluoroethylene, poly(ethylene-co-chlorotrifluoroethylene), or a mixture of these polymers taken in combination.

Also, and in a nonlimiting manner, the polymer material is chosen from the family of polysulfones such as phenylene polysulfide or it is chosen from the polyaryletherketone family such as polyether ether ketone (PEEK).

Moreover, and in accordance with another particularly advantageous feature, between the step c) and the step d), a tubular protection sheath is formed around said plurality of armoring pull wires. This sheath makes it possible to protect the interior of the flexible tubular pipe and in particular the metal wires against the water of the marine environment.

In accordance with another aspect of the present invention, there is provided a flexible tubular pipe intended for transporting hydrocarbons produced by a method of manufacture as described above.

Other particular features and advantages of the invention will emerge on reading the following description of one particular embodiment of the invention given by way of nonlimiting example and with reference to the appended drawings, in which:

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- Figure 1 is a diagrammatic cutaway partial perspective view of a flexible tubular pipe produced by a method of manufacture in accordance with the invention;

- Figure 2 is a diagrammatic partial view in axial section of the flexible tubular pipe shown in figure 1 in accordance with a first configuration;

- Figure 3 is a graph representing the pressure profile applied to the flexible tubular pipe shown in figure 1 in accordance with the method of manufacture in accordance with the invention; and

- Figure 4 is a diagrammatic partial view in axial section of the flexible tubular pipe shown in figure 1 in accordance with a second configuration.

Preferred embodiments of the present invention seek to provide a method for manufacturing a flexible tubular pipe intended for transporting hydrocarbons in a marine environment. Figure 1, showing in cutaway view a flexible tubular pipe 10, will be referred to first in order to describe the first successive steps of the manufacture of the pipe. It shows the various superposed layers that form the pipe and that are successively formed on one another, from the interior 11 of the pipe to the exterior 13. The interior 11 forms an internal flow space for the hydrocarbon.

Figure 1 shows a carcass 12 that is the first layer of the flexible tubular pipe 10. It is optional, and in some circumstances the flexible tubular pipe 10 does not include it. It is produced by shaping a metal strip or tape by bending the two opposite edges into a U-shape in two opposite directions and winding it in a spiral to engage the edges in one another. This operation constitutes a clipping connection.

After this carcass 12 with a given length has been produced and then wound onto an appropriate drum, it is engaged through a circular extrusion head and paid out continuously so as to extrude a polymer material pressure sheath 14 coaxially onto the carcass 12. To do this, the polymer material is hot-extruded. The pressure sheath 14 has a thickness that extends between an internal surface 16 and an opposite external surface 18. The internal surface 16 of the pressure sheath 14 is then in contact with the carcass 12.

The polymer material used is a semicrystalline thermoplastic material and in the example described is a material based on vinylidene polyfluoride. Other semicrystalline fluorinated polymers can be used for this application, notably poly(perfluoroalkoxyethylene) (PFA) that will be described in detail hereinafter. The material is based on vinylidene polyfluoride in the sense that it essentially contains that substance with additionally usual additives, notably to facilitate extrusion or to resist deterioration. It also contains plasticizers, for example in a proportion by weight less than 15%, preferably less than 5%.

This polymer material has two distinct transition temperatures, its glass transition temperature T_g and its secondary transition temperature $T_{g'}$ representative of two amorphous phase types, one in which the amorphous phase is free between the spherolites, the other in which it is trapped in crystalline lamellas that precisely constitute the spherolites. To be specific, for this polymer material, the first or main glass transition temperature T_g is substantially between -30°C and -40°C, measured at atmospheric pressure. For its part, the secondary transition temperature $T_{g'}$ is between 40°C and 80°C measured at atmospheric pressure. The behaviors of the polymer material during the process of manufacturing the pipe in relation to these two parameters T_g and $T_{g'}$ will be explained in more detail hereinafter.

After forming the pressure sheath 14 on the carcass 12, the latter is cooled to a temperature in the vicinity of ambient temperature, i.e. around 18°C.

The pressure sheath 14 is then covered with a pressure vault 20 made of metal wire of substantially rectangular section wound in a spiral with a short pitch to form non-contiguous turns 22. The adjacent turns 22 are spaced from one another, forming intervals, or butt gaps, and come to be applied radially to the external surface 18 of the pressure sheath 14. The pressure vault 20 makes it possible to absorb radial external forces exerted by the hydrostatic pressure on the flexible tubular pipe in the marine environment and the radial internal forces exerted by the circulation of the hydrocarbon fluid inside the internal flow space. This protects the pressure sheath 14.

It will also be seen that the pressure vault 20 is not necessarily produced by winding a single wire and that, moreover, this wire is not necessarily of rectangular section. It may have a particular section, for example a Z-shape, 22T-shape, U-shape or K-shape geometry, enabling the turns to be clipped to one another. The butt gaps are still present, however.

The pressure vault 20 is then covered with at least two layers 24, 26 consisting of a plurality of armoring wires 25 wound with a long pitch and in two directions opposite one another. The armoring wires of these layers 24, 26 are called armoring pull wires because they make it possible to absorb traction forces exerted on the pipe in service.

Finally, the two layers 24, 26 of armoring pull wires are covered with an external sealing sheath 28 made from a plastic material, for example a material identical to that of the pressure sheath 14. This external sealing sheath 28 makes it possible to protect the internal structure of the flexible pipe 10, and notably the metal wires of the layers 24, 26 of armoring wires and also the pressure vault 20, from the marine environment.

The flexible tubular pipe 10 produced in this way then undergoes other manufacturing steps. The interior of the flexible tubular pipe 10 is usually pressurized so as to be able to test in particular its sealing and its integrity. Figure 2 shows partly in semi-axial section the flexible tubular pipe 10 after this pressure test has been carried out.

There is seen in figure 2 the external sealing sheath 28 covering the two layers 24, 26 of armoring wires that in turn cover the pressure vault 20. The latter has in section the non-contiguous turns 22 that are spaced from one another to form the butt gaps 30. Also seen in this figure 2 is the pressure sheath 14 pressing on the carcass 12 and having its internal surface 16 and its opposite external surface 18.

It will be seen that the external surface 18 has local deformations at the level of the butt gaps 30, and notably radial deformations. Thus the surface 18 has, in line with the butt gaps 30, a massive excursion 32 of the polymer material into the butt gaps 30 and on each side of the massive excursions 32, substantially in line with the internal edges 31, 33 of the turns 22, a shrinkage 34 of the polymer material. In actual fact, by virtue of the action of the pressure, the pressure sheath comes to be forced against the turns 22 of the pressure vault 20 and the polymer material creeps into the butt gaps 30. However, when application of the pressure ceases, the material shrinks at the level of the

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internal edges 31, 33. This creep into the butt gaps 30 may lead to loss of cohesion of the polymer material inside the massive excursions 32 and to shrinkage of and damage to the material at the level of the external surface 18 of the pressure sheath 14. These phenomena are manifested either during the pressure test for testing and type approval of the flexible tubular pipe or subsequently when it is in use on the hydrocarbons production site. Moreover, opposite the internal surface 16 of the pressure sheath 14, there are seen defects 36 caused by the cavitation phenomenon. These phenomena are linked to the pressurization of the interior of the flexible tubular pipe 10. In actual fact, this pressurization may be of the order of 1500 bar, or 2172 bar in one embodiment.

Against all expectations, it is found that the pressurization of the interior of the flexible tubular pipe 10 concomitantly with the input of thermal energy to the pressure sheath 14 make it possible to reduce not only the phenomena damaging the external surface 18 at the level of the butt gaps 30 but also the consequences of the cavitation phenomena. In actual fact, as explained hereinafter with reference to figure 4, on increasing the temperature of the pressure sheath 14 its viscosity decreases and, accordingly, the shrinkage at the level of the internal edges 31, 33 of the butt gaps 30 as well as the propagation of the defects 36 present in the excursions 32 and at the level of the internal face 16 of the pressure sheath 14 are minimized.

There will now be described, with reference to figure 3, the pressure profile P applied to the flexible tubular pipe 10 as a function of time. Accordingly, figure 3 shows a diagram 40 plotting on an abscissa axis 42 the time factor and on an ordinate axis 44 the pressure. The interior of the flexible tubular pipe 10 is then pressurized by injecting a fluid under pressure, for example water. In a first pressurization phase 46, the pressure P is brought to a pressure value P_1, for example 1500 bar, in 4 hours. This pressure P_1 is then maintained for a time period t_1 of 12 hours, for example. Then, during a depressurization phase 48, the pressure is rapidly reduced to a value P_i close to the atmospheric pressure P_0 and then raised during a second pressurization phase 50 to a second pressure value P_2 lower than P_1. The pipe is then maintained at the pressure P_2 for a second time period t_2 of 24 hours, for example.

In accordance with another aspect of the invention, in order to input thermal energy to the pressure sheath 14, a hot fluid is injected into the interior of the flexible tubular pipe 10. The hot fluid is water heated to a temperature significantly greater than 80°C, for example. As a result, the temperature of the pressure sheath 14 progressively reaches a temperature close to 80°C. That temperature is then maintained throughout the period of the pressurization/ depressurization/pressurization cycle, which period may extend over approximately 40 hours.

A tank disposed longitudinally around the structure of the flexible tubular pipe 10 is advantageously used to limit the dissipation of thermal energy fed in to heat the latter.

In accordance with a variant, the flexible tubular pipe 10 is placed inside a temperature-regulated hermetically-sealed enclosure. The circulation of a hot fluid in the enclosure makes it possible to input thermal energy to the pressure sheath 14.

In accordance with another variant, a temperature-regulated tank comprising metal tubes or elements is arranged around and along the structure of the flexible tubular pipe 10 to input thermal energy to the pressure sheath 14. Accordingly, a hot fluid such as water or an oil is caused to circulate inside the metal tubes to heat said sheath while an electrical current is caused to flow in the elements to heat said sheath.

The injection of a hot fluid into the interior of the flexible pipe 10 is advantageously combined with the arrangement of a temperature-regulated tank.

Reference will now be made to figure 4 showing the results of heating the pressure sheath 14 during the internal pressurization testing of the flexible tubular pipe 10.

The flexible tubular pipe 10 is seen in semi-axial section in figure 4, as in figure 2. There is seen in particular the pressure sheath 14 situated between the carcass 12 and the pressure vault 20. It will be seen that on each side of the butt gaps 30 the external surface 18 of the pressure sheath 14 tangential to the internal edges 31, 33 of the turns 22 and the shrinkage areas, as shown in figure 2, have disappeared. Moreover, inside the excursions 32 and on the side of the internal surface 16 of the pressure sheath 14 there are no longer seen any traces of the cavitation phenomena or the areas of loss of cohesion seen previously.

The reduction of the viscosity of the material makes it possible to fill the interior of the butt gaps 30 with minimum internal stresses in the material. This minimization of the stresses makes it possible not to generate cavitation.

Thus it appears that the pressurization of the flexible tubular pipe 10 conjointly with input of heat to the pressure sheath 14 at a temperature close to the secondary transition temperature $T_{g'}$ of the polymer material makes it possible to obtain improved integrity of this pressure sheath 14 without having recourse to a screen film. By proceeding in this way, it is certain that the integrity of the pressure sheath is preserved throughout the service life of the flexible tubular pipe, the latter being subjected to multiple pressure rise/descent cycles and temperature cycles and because of this to aging.

When the polymer material is brought to a temperature close to or greater than the secondary transition temperature $T_{g'}$ all the amorphous phase areas, whether free or confined, pass through a rubbery state and, accordingly, the stresses induced in the polymer material at the level of the deformations generated by the latter creeping into the butt gaps 30 are dissipated by a stress relief mechanism in an extensive area of the polymer material.

Moreover, it proves that in the vicinity of the secondary transition temperature $T_{g'}$ the polymer material suffers large deformations without the phenomenon of cavitation occurring.

In accordance with a variant execution of the invention, the polymer material used to produce the pressure sheath 14 is poly(perfluoroalkoxyethylene) or PFA. The glass transition temperature T_g of this thermoplastic material is approximately -80°C and the secondary transition temperature $T_{g'}$ is approximately 90°C. It is possible, by applying the same process as described above, to produce a PFA sheath the integrity of which is maintained for at least 20 years.

The pressurization of the interior of the pipe 10 at a pressure P_d at least equal to 1500 bar combined with input of thermal energy at a temperature close to the secondary transition temperature $T_{g'}$ of PFA, i.e. around 80°C, makes it possible to prevent the occurrence of a defect 36 on the internal surface 16 of the pressure sheath 14 caused by the cavitation phenomenon.

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not by way of limitation. It will be apparent to a person skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the present invention should not be limited by any of the above described exemplary embodiments.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of manufacturing a flexible tubular pipe intended for transporting hydrocarbons, said method being of the type including the following steps:

a) forming a thermoplastic polymer material deformable tubular pressure sheath, said tubular pressure sheath having an external surface and an opposite internal surface defining an internal flow space for the hydrocarbons;

b) helicoidally winding a metal wire at a short pitch around said tubular pressure sheath so as to form turns resting on said external surface, said turns defining successive intervals therebetween;

c) helicoidally winding a plurality of armoring pull wires at a long pitch around said turns; and

d) bringing said internal flow space to a pressure P greater than a given pressure P_d so that said external surface of said pressure sheath is deformed radially at the level of said intervals;

wherein in the step d) said tubular pressure sheath is simultaneously brought to a temperature T greater than a given temperature T_d so as to be able to relieve the internal stresses of said polymer material of said external surface deformed at the level of said intervals,

wherein in the step d) said internal flow space is brought to a first pressure P_1 during a first time period t_1 and to a second pressure P_2 during a second time period t_2, and wherein said second time period t_2 is greater than or equal to said first time period t_1.

2. The method as claimed in claim 1, wherein said thermoplastic polymer material having a glass transition temperature T_g and a secondary transition temperature $T_{g'}$ greater than said glass transition temperature T_g, said given temperature T_d is between T_g and $T_{g'}$.

3. The method as claimed in claim 2, wherein said given temperature T_d is close to said secondary transition temperature $T_{g'}$.

4. The method as claimed in any one of the preceding claims, wherein said given temperature T_d is greater than the ambient temperature T_0.

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5. The method as claimed in any one of the preceding claims, wherein in the step d) said given pressure P_d is greater than the atmospheric pressure P_0.

6. The method as claimed in any one of the preceding claims, wherein said internal flow space is brought to a pressure P less than said given pressure P_d between said first and second time periods t_1 and t_2.

7. The method as claimed in any one of the preceding claims, wherein said internal flow space is brought to a pressure P close to the atmospheric pressure P_0 between said first and second time periods t_1 and t_2.

8. The method as claimed in any one of the preceding claims, wherein said first time period t_1 has a duration greater than or equal to 12 hours.

9. The method as claimed in any one of the preceding claims, wherein said thermoplastic polymer material is chosen from the materials of the fluorinated polymer family.

10. The method as claimed in any one of claims 1 to 8, wherein said thermoplastic polymer material is chosen from the materials of the sulfonic polymer family or the aryletherketone polymer family.

11. The method as claimed in any one of the preceding claims, wherein between the step c) and the step d) a tubular protection sheet is formed around said plurality of armoring pull wires.

12. A flexible tubular pipe intended for transporting hydrocarbons, produced by a method of manufacture as claimed in any one of the preceding claims.

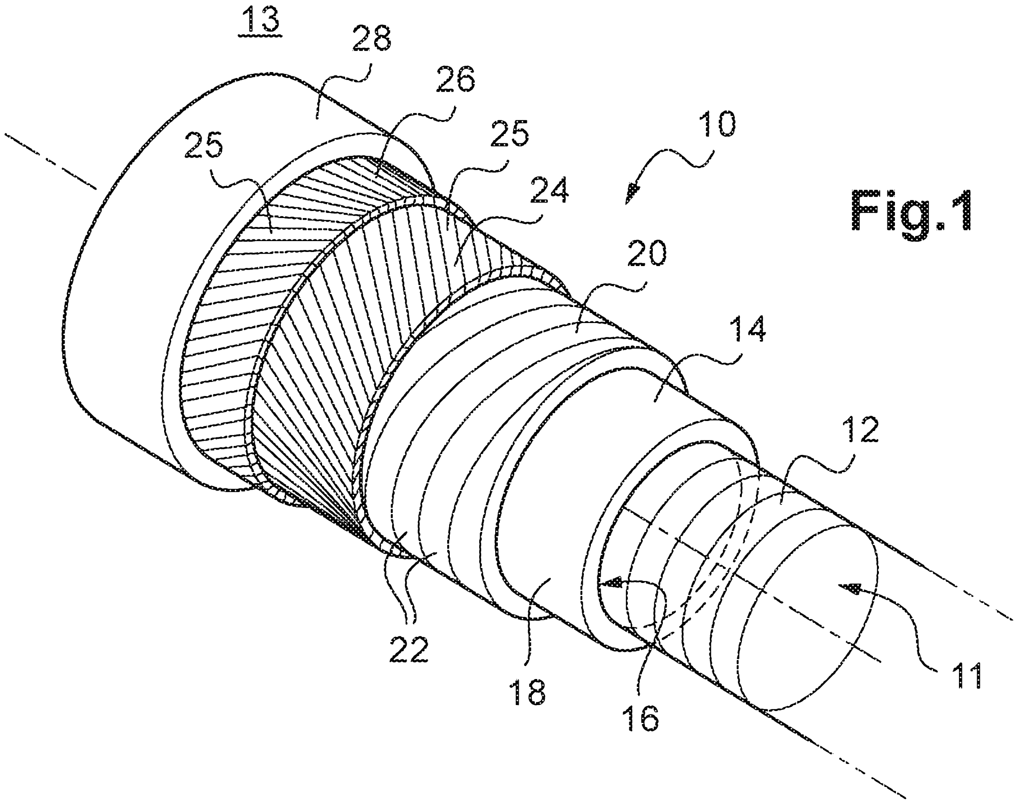
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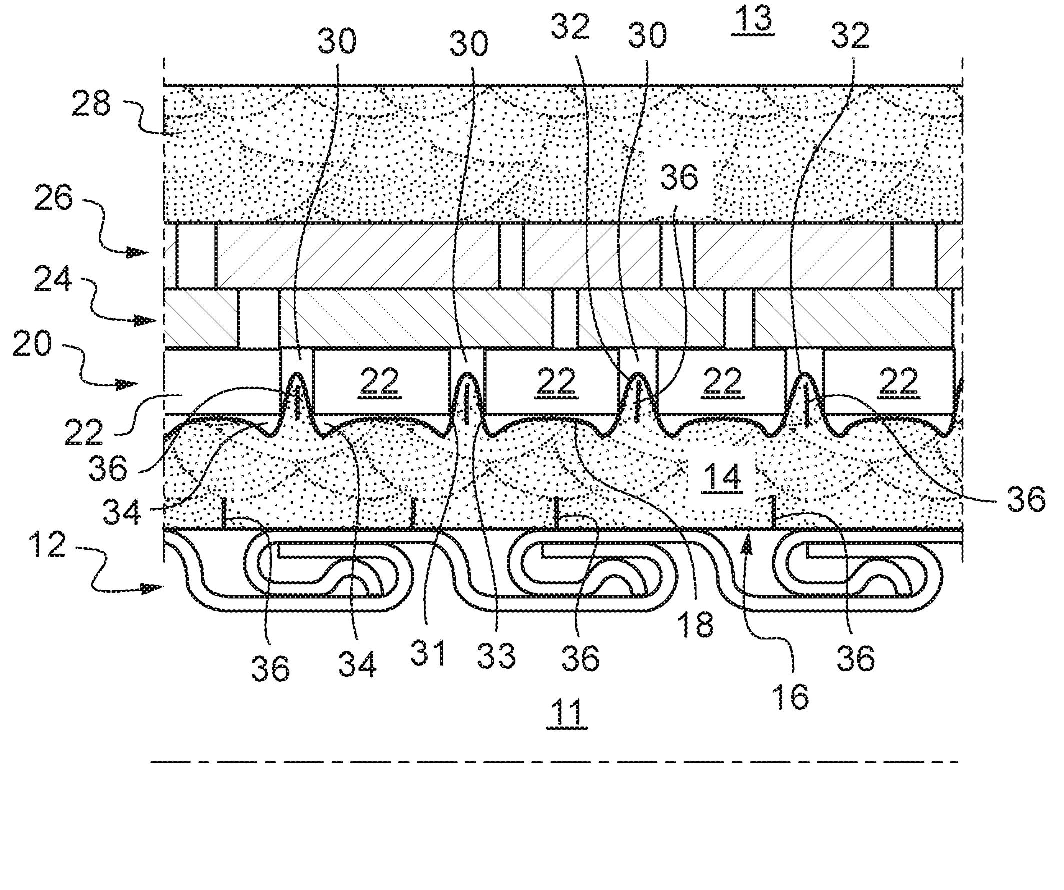
Fig.1

Fig.2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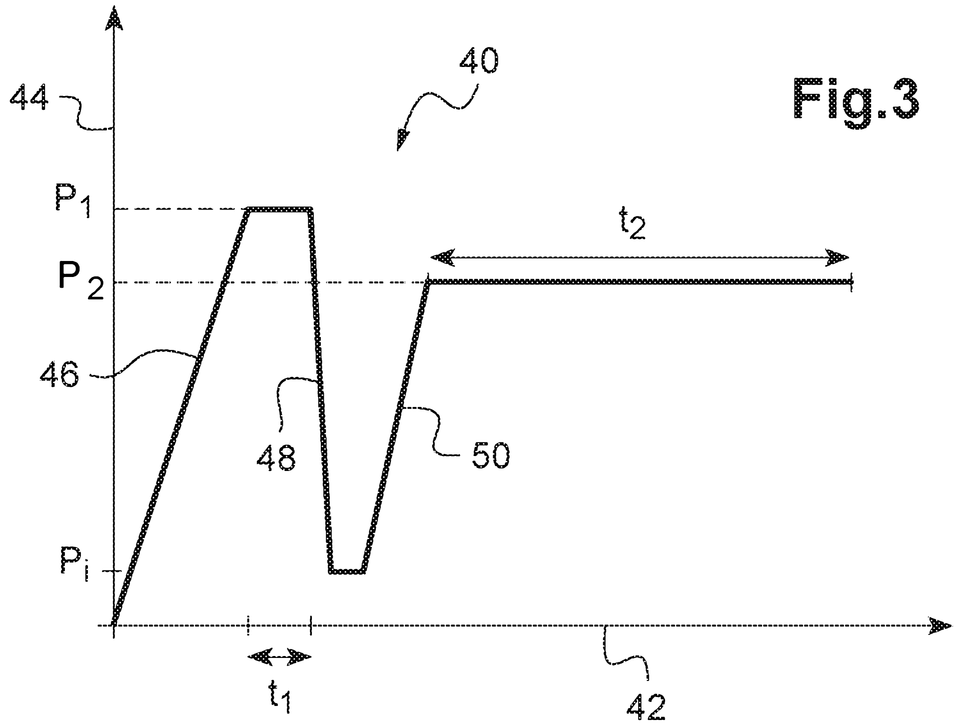
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t2
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Fig.3

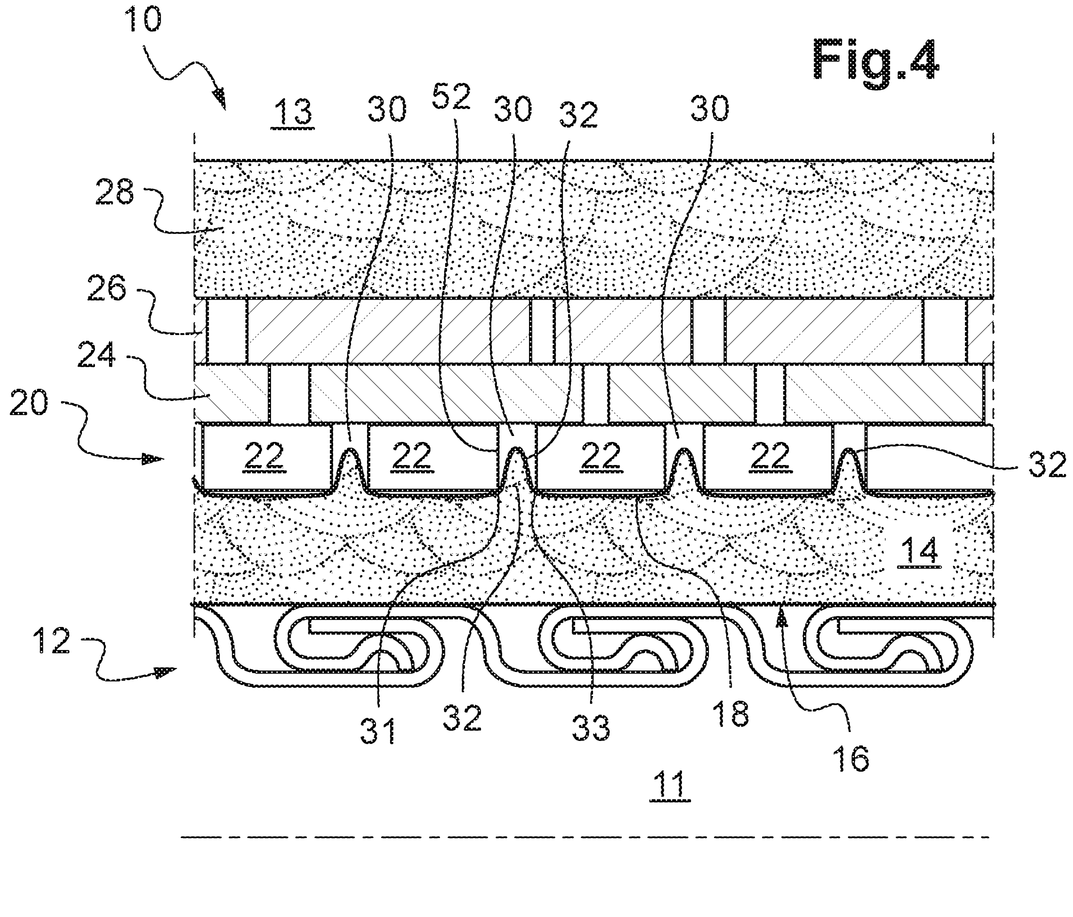
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Fig.4