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(54) REINFORCED FLEXIBLE LINES

(71) We, INSTITUT FRANCAIS DU PETROLE, a body corporate organised and existing under the laws of France, of 4, avenue de Bois-Preau, 92502 Rueil-Malmaison, France, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: 5

This invention relates to reinforced flexible lines.

Generally speaking, the invention is applicable to preventing a flexible line from being bent or locally deformed along a profile liable to damage it under the action of external forces applied thereto.

For a better understanding of the following description, reference is made, by way of non-limitative example only, to the case of a flexible pipe, formed by successive sections connected end to end by coupling members. The coupling members presently in use are rigid and, in spite of their being designed to be as short as possible, they locally affect the flexibility of the pipe. At the location of the coupling members, the flexibility of the pipe varies abruptly from a maximum value to zero. This results necessarily in a deterioration of the pipe at this location, for example when the pipe is reeled on a drum or passes over a pulley. This deterioration becomes generally greater with an increasing reeling or winding radius and an increasing pulling force during reeling or winding of the flexible pipe. 10 15

It is already known in the art to reduce this drawback by progressively varying the flexibility of the pipe over a portion which is immediately adjacent to the coupling member. To this end, the pipe is surrounded with a helical spring which may be of variable pitch. 20

Unfortunately, those helical springs which are almost satisfactory for this application substantially increase the outer diameter of the pipe at the location of the coupling members, thus resulting in other disadvantages well known to those skilled in the art, which require the use, for pulling the flexible pipe, of devices which can accommodate sudden and substantial variations in the outer diameter of the pipe. 25

Those helical springs which do not substantially increase the outer diameter of the flexible pipe, or at least which do not increase it by a greater extent than the rigid coupling members, are either ineffective or of very low efficiency.

According to the present invention there is provided a flexible line of which a portion that may be subjected to high bending stresses is locally reinforced by a reinforcing device comprising at least one end secured to one point of the flexible line, said at least one rod of selected length having one rod being located in the immediate vicinity of the portion of the flexible line to extend substantially axially thereof, so that, when the bending stresses are applied to the flexible line portion, the flexible line bears on said at least one rod and transmits the bending stresses thereto, said at least one rod being so designed as to be deformable along a profile which is not detrimental to the flexible line. 30 35

The local reinforcement of the flexible line is capable of preventing or at least reducing deterioration of the line which might result, for example, but not exclusively, from a sudden local variation in the flexibility of the line, from reeling the line on an inadequate support-member, and so forth. 40

The invention will now be further described, by way of example, with reference to the accompanying drawings, wherein:

- 45 *Figure 1* diagrammatically illustrates the operation of reeling a flexible pipe on a drum;
- Figure 2* diagrammatically shows the concept underlying embodiments of the invention;

Figure 3 shows an embodiment of the invention;

Figure 4 is a detail view of Figure 3, on a larger scale; and

Figure 5 to 12 are cross-sectional views of differently shaped rods and intermediate blades.

5 In the following description, reference is made to a flexible line, such as a flexible pipe 5 designated as a whole by reference 1 and formed of successive sections or portions such as 2 and 3 connected end to end by rigid couplings 4 of length 'b'. The flexible pipe 1 is wound or reeled on a drum 5 of radius R greater than the minimum winding or reeling radius of the flexible pipe.

10 Figure 1 illustrates the most unfavourable situation wherein, during reeling the flexible pipe 1, the section 2 thereof assumes over its whole length the profile of the drum 5. A cross-section A_o, which is common to the pipe section 2 and to the rigid coupling 4, is located in a diametral plane of the drum 5, which is not the case a cross-section B common to the rigid coupling 4 and to the pipe section 3. There is thus a gap 'a' between the drum 5 15 and the nearest point of cross-section B. The value of this gap is given by the equation:

$$e = -R + \sqrt{R^2 + b^2}$$

20 This value of 'e' is a maximum value which is rarely achieved in practice, since the contact point of the rigid coupling 4 with the drum 5 is located at the level of a cross-section A of the coupling between the cross-section A_o and B.

25 A further reeling of the flexible pipe 1 on the drum 5 results in a deformation of a portion 3a of the pipe section 3 between the cross-section 3 again continuously follows the outline of the drum 5. This deformation must be such that, at each point of the portion 3a of the flexible pipe, the radius of curvature is at least equal to the minimum radius of curvature which the flexible pipe can withstand without being damaged. As it is well known in practice, the length of the pipe portion 3a and the shape of its deformation during the flexible pipe reeling depend in particular on the gap 'e' to be compensated for, and 30 consequently depend on the drum diameter and on the coupling length, but also on the pipe characteristics, on the forces applied thereto during reeling of the pipe (pulling force, forces imparted by adjacent turns of the same pipe layer or by the upper pipe layer when the pipe is reeled in several layers) and so forth.

35 Deterioration of the pipe can be prevented by a local reinforcing device now to be described. Briefly speaking, this device comprises a guide member for guiding at least a part of the portion 3a of the flexible pipe adjacent the pipe coupling 4, the guide member being resiliently deformable under the action of the forces applied to the pipe, so as to assume a profile which is not detrimental to the flexible pipe. More precisely, through its deformation, the guide member guides the flexible pipe along such a profile that the 40 tangent thereto at the location of the cross-section A, which is common to the rigid coupling 4 and to the flexible pipe, is substantially parallel to the axis of the rigid coupling, and the radius of curvature at any point of this profile is at least equal to the minimum radius of curvature of the flexible pipe. The guide member is preferably selected to be as short as possible, but is sufficiently long that the unguided part of the flexible pipe portion 3a has a 45 substantially rectilinear profile, substantially tangential to the outline of the guide member.

50 Figure 2 shows a flexible pipe reeled on a drum 5 and formed by pipe sections such as 3 connected end to end by a rigid coupling 4 which contacts the drum 5 in the region of cross-section A. The pipe is provided with a device 6, as just briefly described for locally reinforcing the pipe. The device 6, diagrammatically shown as a flexible rod has one end 55 fast with pipe coupling 4. The connection of the rod 6 and coupling 4 may be achieved by any known means. When the flexible pipe is reeled on the drum 5, the rod 6, which is located between the portion 3 of the flexible pipe and the outer surface of the drum 5, will be deformed along a profile or contour P.

60 By choosing, as a function of the forces applied to the flexible pipe during reeling thereof, the size of the cross-section of the rod 6, the material from which the rod is made, and so forth, it is possible to have the rod subjected to a deformation of elastic character, to have the contour P such that at any point thereof its radius of curvature is at least equal to the minimum reeling radius of the flexible pipe, and to having in the cross-section B, common to the rigid coupling 4 and to the portion 3 of the flexible pipe, the tangent T_B to the profile P substantially parallel to the axis R'R of the coupling. Moreover, by suitably selecting the 65 length L_o of the rod 6, the tangent T_D to the profile P at the free end of the rod 6 will also be tangential to the drum 5. The result is that, after having been guided along the length L_o between the cross-sections B and D, the following section of the flexible pipe between the cross-sections D and C is substantially rectilinear and follows again the contour of drum 5 beyond cross-section C.

The length L_o is in particular dependent on the pulling force with which the flexible pipe is reeled. This length L_o decreases as the pulling force increases.

However, for given reeling conditions, the length of the guide rod 6 may be chosen to be either greater or smaller than L_o . In the first case, and for a sufficient length of the rod 6, the free end of the rod can bear on the drum 5, so that its deformation is limited. In the second case, which, for reasons of weight and cost of the assembly, will be more frequent, the cross-sections D and C, as hereinabove defined, will become respectively sections D' and C' and the pipe portion between D' and C' will make the angle α with the tangent T_D , to the profile in the region of the cross-section D'.

The length L of rod 6 can be chosen to be smaller than L_o , for which the angle α does not cause any local deterioration of the flexible pipe. The maximum permissible value of α depends generally on the structure of the flexible pipe. This value may be determined experimentally or through any other means by those skilled in the art. By way of example, in the case of a flexible pipe having an armouring formed by successive rings, the angle α may be close to the angular displacement of two adjacent rings which respect to each other.

Figures 3 and 4 shows a first embodiment of the invention comprising a sleeve 7 surrounding a portion of a flexible pipe to be reinforced, the sleeve being secured at one of its ends to a rigid coupling diagrammatically shown at 4 by any known means, such as, for example, threading 8. The sleeve 7 is positioned before securing the rigid coupling 4 to the end of a portion 3 of the flexible pipe. The sleeve 7 is provided with a plurality of longitudinal slots 9 of length L measured from the free end of the sleeve. The slots 9 delimit between each other rods 10. One or more rings 11, housed in slots 12 provided at the periphery of sleeve 7 with a substantial longitudinal clearance, connect the different rods 10 so that they co-operate to withstand the forces applied to the pipe which tend to bend at least one of the rods 10. It appears that the assembly of rods 10 behaves like the rod 6 of Figure 2 and can withstand high forces for a small thickness of the sleeve 7.

In order to form a homogenous assembly the slots 9 may be filled with a resilient material which sticks to the rods 10, this material being sufficiently elastic so as not to be destroyed by relative displacement of the rods 10.

The slots 9 may also receive intermediate rigid blades 13 which can be axially displaceable with respect to the rods 10. The intermediate blades 13 may be held in position by rings 11, or through a suitable cross-sectional shape as shown at 15 in Figure 4. Optionally, inner circular clips 14 may be used.

Such intermediate blades 13, whose purpose is mainly to fill the slots 10, so as to give a good homogeneity to the assembly, may be made of the same material as the rods 10 or of any other material, such as an elastomer, a plastomer, a fiber and resin conglomerate, etc.

Figures 5 to 12 illustrate different non-limitative examples of cross-sections which may be chosen for the rods 10 and the intermediate blades 13.

In the case of Figures 5 to 10, holding rings such as 11 (Figure 3), must be used so that the intermediate blades 13 remain in their slots 9. In the case of Figures 11 and 12, the complementary shapes of the cross-sections of the rods 10 and blades 13 provides for cohesion of the assembly, and circular clips 11 (Figure 4) are no longer necessary. The complementary shapes cause the rods 10 to co-operate with one another when at least one of the rods is subjected to a bending stress.

The size of the rod cross-sections, the profile selection, the number of slots, the nature of the material constituting the rods, the length of the rods and so forth will be determined by those skilled in the art in accordance with the reeling conditions of the flexible pipe (diameter of the reeling drum, pulling force applied to the pipe etc.).

Changes may be made without departing from the scope of the present invention. It is, for example, possible to use rods whose cross-sections progressively decrease towards their free ends. It is also possible to fill the space between the sleeve and the flexible pipe with a sealing or sealing improving material, such as a synthetic or natural rubber, etc.

WHAT WE CLAIM IS:

1. A flexible line of which a portion that may be subjected to high bending stresses is locally reinforced by a reinforcing device comprising at least one rod of selected length having one end secured to one point of the flexible line, said at least one rod being located in the immediate vicinity of the portion of the flexible line to extend substantially axially thereof, so that, when the bending stresses are applied to the flexible line portion of the flexible line bears on said at least one rod and transmits the bending stresses thereto, said at least one rod being so designed as to be deformable along a profile which is not detrimental to the flexible line.

2. A flexible line according to claim 1, wherein said device comprises a sleeve provided with a plurality of slots longitudinally extending from one end of the sleeve over a length which is shorter than the sleeve so as to define a slotted portion and a non-slotted portion of the sleeve, said slots delimiting between each other a plurality of said rods, said sleeve

having an inner diameter at least equal to the external diameter of the flexible line, which is inserted in said sleeve, and said non-slotted tubular portion of the sleeve forming said end of said rod secured to one point of the flexible line.

3. A flexible line according to claim 2, wherein said device comprises means associating 5
said rods with one another when one of said rods is subjected to a bending stress.

4. A flexible line according to claim 3, wherein said slots are regularly distributed
around the periphery of said sleeve.

5. A flexible line according to claim 4, wherein said slots are filled with a resilient
material which adheres to the walls of said slots.

6. A flexible line according to claim 4, wherein said device further comprises 10
intermediate blades which are axially slidable within said slots.

7. A flexible line according to claim 6, wherein said device comprises means for holding
said intermediate blades within said slots.

8. A flexible line according to claim 7, wherein said means for holding intermediate 15
blades within said slots comprise rings or clips.

9. A flexible line according to any one of claims 3 to 8, wherein said means associating
said rods with one another comprise rings or clips surrounding said sleeve on its slotted
portion.

10. A flexible line according to claim 6, wherein the cross-sections of said rods and of 20
said intermediate blades are of complementary shapes.

11. A flexible line according to claim 10, wherein said complementary shapes of the
cross-sections of said rods and of said intermediate blades are operative to hold said
intermediate blades in said slots.

12. A flexible line according to claim 11, wherein said complementary shapes of the 25
cross-sections of said rods and of said intermediate blades make said rods co-operate with
one another when at least one of said rods is subjected to a bending stress.

13. A flexible line according to any one of the preceding claims, which is formed of
successive sections connected end to end by rigid coupling means secured at the ends of
each line section, each line section being provided with a reinforcing device as set forth, said 30
reinforcing device being secured to said coupling means.

14. A flexible line of which a portion that may be subjected to high bending stresses is
reinforced by a reinforcing device, substantially as herein described with reference to
Figures 2, 3 and 4, or Figures 2, 3 and 4 as modified by any one of Figures 5 to 12, of the
accompanying drawings. 35

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FIG.3

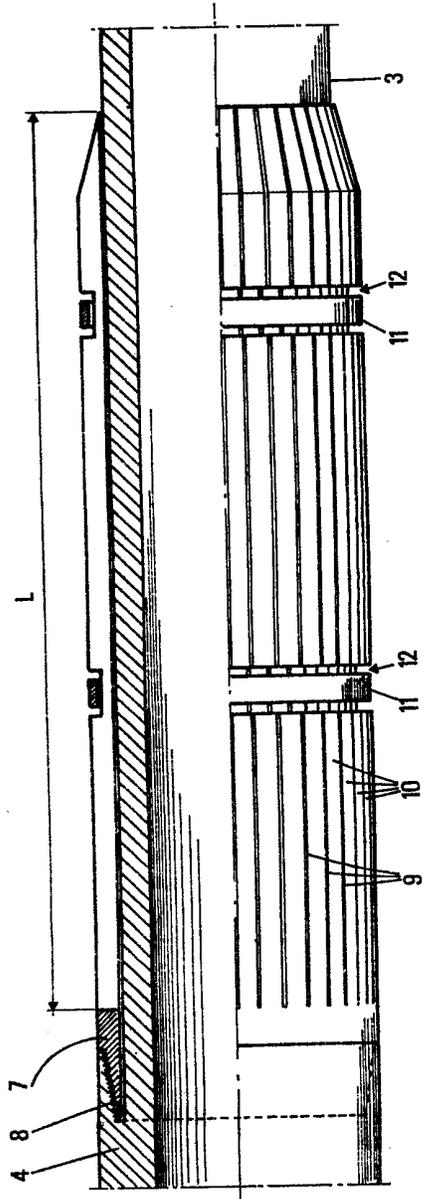


FIG.4

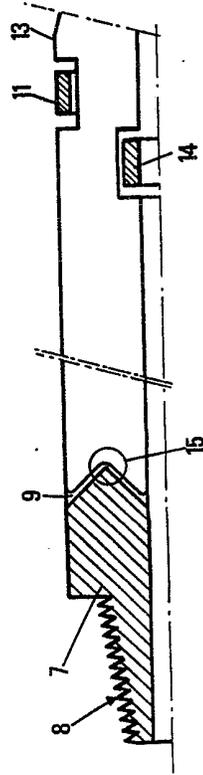


FIG.5

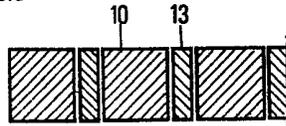


FIG.6

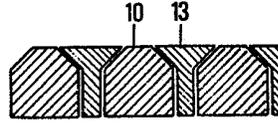


FIG.7

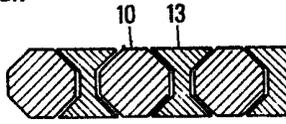


FIG.8

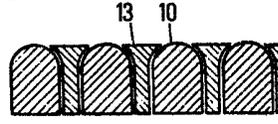


FIG.9

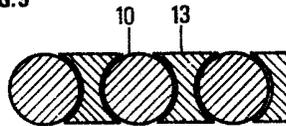


FIG.10

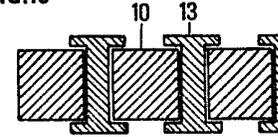


FIG.11

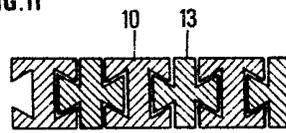


FIG.12

