



(51) International Patent Classification:

*F16L 58/16* (2006.01) *D01F 11/14* (2006.01)  
*D01F 9/16* (2006.01) *F16L 11/08* (2006.01)

(21) International Application Number:

PCT/NL2016/050604

(22) International Filing Date:

30 August 2016 (30.08.2016)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2015434 14 September 2015 (14.09.2015) NL

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(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

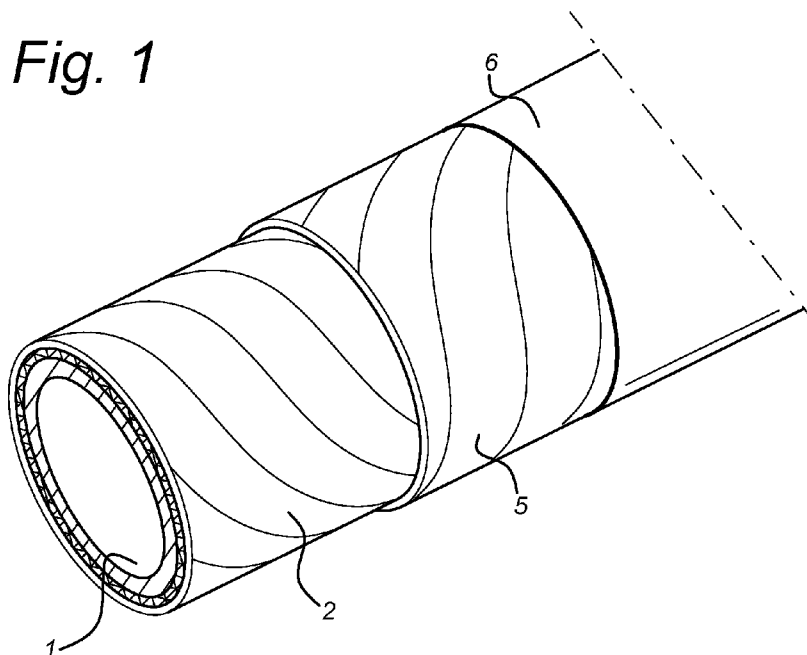
Published:

— with international search report (Art. 21(3))

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM,

(54) Title: HIGH PRESSURE PIPE AND METHOD FOR PRODUCING SUCH PIPE

Fig. 1



(57) Abstract: A high-pressure pipe comprises an inner liner (1), an outer coating layer (6) and a reinforcement layer (2, 5) positioned between the inner liner and the outer coating layer. The reinforcement layer has helically wound strips (2, 5) which each comprise a matrix and fibers embedded in the matrix; the fibers consist of a multitude of twisted high-strength filaments. With an aim of providing a relatively high bending flexibility, the filaments of a fiber are sized filaments obtained by subjecting the filaments to a sizing operation.

High pressure pipe and method for producing such pipe

The invention is related to a high-pressure pipe, comprising an inner liner, an outer coating layer and a reinforcement layer positioned between the inner liner and the outer coating layer, said reinforcement layer comprising helically wound strips which each comprise a matrix and fibers embedded in the matrix, said fibers comprising twisted high-strength filaments.

Such a high-pressure pipe is generally known, e.g. from WO-A-2013/131972. The helically wound reinforcing elements, in the form of strips of said prior art pipe may comprise carbon fibers, consisting of a large number of thin filaments. Carbon fibers have several advantages; for instance such fibers are largely invulnerable with respect to aggressive substances such as H<sub>2</sub>S as present in crude oil. Furthermore, the carbon fibers have a high tensile strength and a high modulus of elasticity. Such properties provide the pipes in question with the capacity to withstand high pressures, up to 200 bar or higher. Carbon fibers per se are however problematic with respect to handling. The filaments have a high stiffness and hardness, which makes it difficult to implement such fibers directly in the pipe wall. With the aim of facilitating the handling of the carbon fibers, they can be impregnated with a matrix material and then assembled so as to form carbon fiber reinforcing elements, for instance, in the form of strips

Due to the circumstance that the carbon filaments are embedded in, and thereby connected to each other by, the matrix material, the reinforcing elements exhibit a relatively high bending stiffness. This relatively high bending stiffness of the fibers is not conducive for carrying out winding operations, as are for instance applied in manufacturing high-pressure pipes. This means that in the process of manufacturing high-pressure pipes, the reinforcing elements in question should have a rather limited thickness so as to limit their bending stiffness and so as to be able to wind the fibers around the inner lining. In case the reinforcing strips are thin, this means that a relatively high number of strips are to be wound around the inner lining so as to achieve the required strength and stiffness of the pipe wall.

The process of winding multiple layers of strips with embedded fibers is however intricate and time-consuming. It would be preferable to complete the winding process with a limited number of strips, preferably two oppositely wound strips. The number

and the thickness of the fibers in each of those strips would then have to be increased. However, the stiffness of the strips thus obtained would severely limit the possibility to wind these around the inner lining. Moreover, the pipe itself would be rather stiff with respect to bending, making it almost impossible to wind the pipe onto a reel.

5           An object of the invention is therefore to provide a high-pressure pipe of the type mentioned before which can be manufactured from a limited number of strips, and which still has the advantages associated with high-strength fibers. A further object is to provide such pipe which can be wound onto a reel of limited radius. This object is achieved in that the filaments of a fiber are sized filaments obtained by subjecting the  
10   filaments to a sizing operation before twisting them together in the step of forming fibers.

          The sizing operation of the filaments has the advantage that it allows for some displacement between adjacent filaments, in contrast to filaments which are fixedly adhered to each other through a stiff matrix such as a solidified resin. The filaments are  
15   twisted so as to form a fiber, possibly in the presence of additional material which promotes the cohesion of the twisted filament bundle. The filaments should still be able to displace somewhat with respect to each other in the fiber, which makes it possible to bend the fiber even in case the thickness of the fiber, and thereby the number of twisted filaments in the fiber, is relatively high.

20           A sizing operation is well known per se in the field of textile material. A sizing operation entails for instance the use of sizing agents or chemicals, such as liquid resins, oil-type and wax-type materials.

          Preferably, the filaments are unimpregnated filaments. Typically, the filaments have a thickness of 4-100  $\mu\text{m}$ , or 4-50  $\mu\text{m}$ , or 4-10  $\mu\text{m}$ . Preferably, the filaments are  
25   carbon filaments. Optionally, the filaments are coated with a flexible coating, e.g. a rubber-like coating. Typically, the filaments have a length which is of the same order of magnitude as the length of the fiber containing said filaments.

          The invention is furthermore related to a method for producing a high-pressure pipe, comprising the steps of:

- 30           - providing high-strength filaments,  
          - sizing said high-strength filaments,  
          - twisting said sized high-strength filaments so as to form fibers,  
          - embedding the fibers in a matrix so as to form a strip,

- providing a tube-shaped inner lining,
- helically winding strips on top of each other and with opposite winding angle around the inner lining,

- providing an outer coating on top of the helically wound strips.

5           The filaments are preferably unimpregnated filaments, and preferably during the step of embedding the fibers in the matrix the unimpregnated state the filaments of the fibers is maintained. Unimpregnated fibers are fibers which are not impregnated with matrix material or other materials which make the fibers adhere to each other in such a way that no or hardly no relative displacements are possible. Thus it can be ensured

10       that the filaments in an unimpregnated fiber may perform relative displacements with respect to each other so as to maintain a certain bending flexibility of the fibers. Additionally, preferably the fibers and the matrix are selected from materials which exclude or inhibit adhesion between said fibers and said matrix. The lack of a (strong) adhesion between the fibers and the surrounding matrix also promotes the bending

15       flexibility of the strips, making it further possible to wind the strips at a relatively small radius.

          Optionally, the fibers, before embedding thereof in the matrix, may be dipped in a mixture so as to cover said fibers with a rubber-like substance.

20       The invention will further be described with reference to the embodiments shown in the drawings.

          Figure 1 shows a view in perspective and in section of the high-pressure pipe.

          Figure 2 shows a view in perspective on a reinforcement strip for the pipe.

          The pipe as shown in figure 1 consists of an inner lining 1 around which first of all the reinforcement strip 2 is helically wound. Subsequently, onto said first

25       reinforcement strip 2, the second reinforcement strip 5 is helically wound, with an opposite winding angle. Next, an outer coating layer 6 is applied onto the second helically wound reinforcement strip 5.

          Each reinforcement strip 2, 5 consists of a body of matrix material 4 and the fibers 3 embedded in the body of matrix material 4. The fibers 3 each consist of carbon

30       filaments of which are twisted into each other. These filaments have been subjected to a sizing operation, and furthermore they are not impregnated with the matrix material 4. As a result, the fibers have a relatively high bending flexibility. Due to the

circumstance that the fibers 3 are not adhered to the surrounding body of matrix material 4, the reinforcement strip itself has a relatively high bending flexibility as well.

As a result, the reinforcement strips 2, 5 can be wound with a relatively small radius around the inner liner. This relatively small bending radius can even be obtained  
5 in case the fibers 3 have a relatively large thickness and thus a relatively large number of twisted carbon fibers. this means that a limited number, in particular only two, of reinforcement strips 2, 5 will be sufficient for manufacturing a pipe with a high resistance against internal pressures. Furthermore, the pipe itself will combine relatively high stiffness and strength against internal overpressures with a relatively low  
10 bending flexibility. Thus, such pipe is suitable for winding on a reel, which greatly simplifies the production and transport of the pipes.

List of reference numerals

1. Internal liner
2. First reinforcement strip
- 5 3. Fibers
4. Body of matrix material
5. Second reinforcement strip
6. Coating layer

10           While the invention has been described with reference to exemplary  
embodiments, it will be understood by those skilled in the art that various changes may  
be made and equivalents may be substituted for elements thereof without departing  
from the scope of the invention. In addition, many modifications may be made to adapt  
a particular situation or material to the teachings of the invention without departing  
15 from the essential scope thereof. Therefore, it is intended that the invention not be  
limited to the particular and/or preferred embodiments disclosed, but that the invention  
will include all embodiments falling within the scope of the appended claims

Claims

1. A high-pressure pipe, comprising an inner liner (1), an outer coating layer (6)  
5 and a reinforcement layer (2, 5) positioned between the inner liner and the outer coating  
layer, said reinforcement layer comprising helically wound strips (2, 5) which each  
comprise a matrix (4) and fibers (3) embedded in the matrix, said fibers comprising  
twisted high-strength filaments, wherein the filaments of a fiber are sized filaments  
obtained by subjecting the filaments to a sizing operation.
- 10 2. The high-pressure pipe according to claim 1, wherein the filaments are  
unimpregnated filaments.
3. The high-pressure pipe according to claim 1 or 2, wherein the filaments have a  
15 thickness of 4-100 $\mu$ m.
4. The high-pressure pipe according to any of the preceding claims, wherein the  
filaments are carbon filaments.
- 20 5. The high-pressure pipe according to any of the preceding claims, wherein  
filaments are coated with a flexible coating.
6. The high-pressure pipe according to claim 5, wherein the flexible coating  
comprises a rubber-like coating.
- 25 7. The high-pressure pipe according to any of the preceding claims, wherein the  
filaments have a length which is of the same order of magnitude as the length of the  
fiber containing said filaments.
- 30 8. The high-pressure pipe according to any of the preceding claims, wherein the  
reinforcement layer comprises only two oppositely wound helical strips (2, 5).

9. The high-pressure pipe according to any of the preceding claims, wherein a matrix material is lacking between the filaments of a fiber.

10. A method for producing a high-pressure pipe, comprising the steps of:

- 5       - providing high-strength filaments,
- sizing said high-strength filaments,
- twisting said sized high-strength filaments so as to form fibers (3),
- embedding the fibers in a matrix (4) so as to form a strip (2, 5),
- providing a tube-shaped inner lining (1),
- 10      - helically winding strips (2, 5) on top of each other and with opposite winding angle around the inner lining (1), and
- providing an outer coating (6) on top of the helically wound strips (2, 5).

11. The method according to claim 10, wherein the filaments are unimpregnated  
15   filaments.

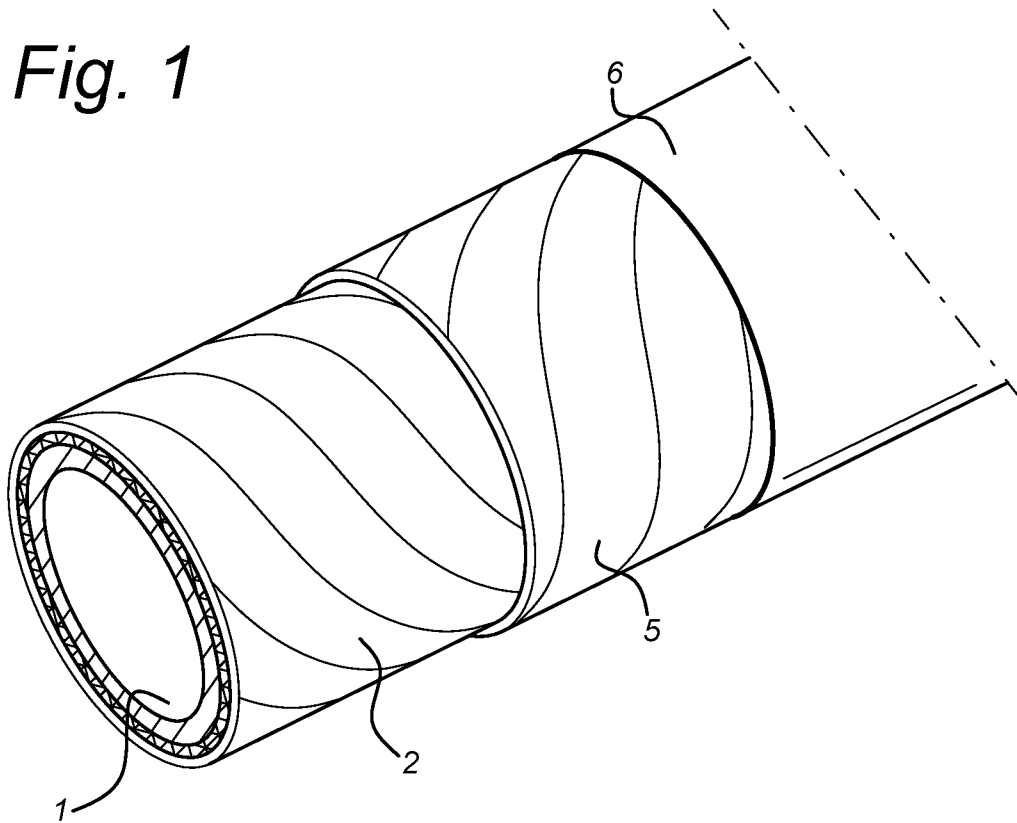
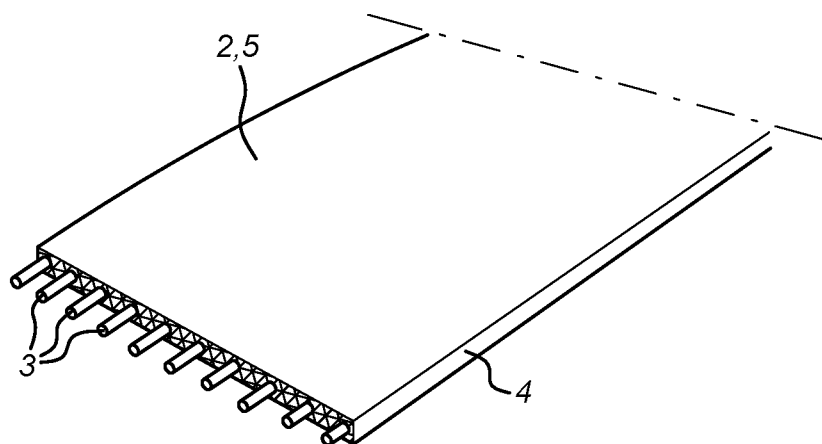
12. The method according to claim 11, wherein during the step of embedding the fibers (3) in the matrix (4) the unimpregnated state the filaments of the fibers is maintained.  
20

13. The method according to any of claims 10-12, wherein the fibers and the matrix (4) are selected from materials which exclude or inhibit adhesion between said fibers (3) and said matrix (4).

25       14. The method according to any of claims 10-13, wherein the fibers, before embedding thereof in the matrix, are dipped in a mixture so as to cover said fibers with a rubber-like substance.

15. Method according to any of claims 10-14, wherein the filaments of a fiber are  
30   arranged next to each other without interposition of a matrix material between said filaments.

16. A strip (2, 5) for use in the method according to any of claims 10-15, comprising a matrix (4) and fibers (3) embedded in the matrix, said fibers comprising twisted high-strength filaments, wherein the filaments of a fiber are sized filaments obtained by subjecting the unimpregnated filaments to a sizing operation.

*Fig. 1**Fig. 2*

## INTERNATIONAL SEARCH REPORT

International application No

PCT/NL2016/050604

## A. CLASSIFICATION OF SUBJECT MATTER

INV. F16L58/16 D01F9/16 D01F11/14 F16L11/08  
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16L D01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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|           | -/--                                                                                                                                           |                                |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&amp;" document member of the same patent family

Date of the actual completion of the international search

3 November 2016

Date of mailing of the international search report

18/11/2016

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International application No  
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| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                  |                       |
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