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(54) **METHOD OF STABILIZING A WALL WITH EXPOSED LAYERS OF CLAY**

(57) A clayward-facing side of a perforated support structure is placed against a wall with exposed clay. Perforations allow fluid transport through the perforated support structure from an opposing side of the perforated support structure to the clayward-facing side. After bringing the clayward-facing side in physical contact with the wall ,the opposing side is exposed to a water-containing fluid, whereby allowing the water containing fluid to contact the wall through the perforations. Water is absorbed in any clay that is exposed to the perforations, which causes local swelling of clay comprised in wall parts that are exposed to the perforations. The shear strength of the saturated clay prevents the clay from migrating though the perforations to the opposing side.

EP 3 702 581 A1

Description

Field of the Invention

[0001] In one aspect, the present invention relates to a method of stabilizing a wall comprising exposed layers of clay. The wall may be a wellbore wall in an open section of a wellbore in an earth formation.

Background of the Invention

[0002] A known problem encountered in coalbed methane gas wells, is swelling of formation clays in the interburden rock layers of coal seam gas wells. This may result in spalling of fine particles that may negatively impact gas production through damage to the well's pump and/or the permeability of the coal layers. Such phenomena may compromise the structural integrity of the wellbore and/or severely restrict production.

[0003] The conventional technology to mitigate the swelling of smectite clays in oil and gas reservoirs is to stabilize the clay using a brine such as 4 % KCl, and although this technology is relatively low cost and initially effective the mitigation of clay swelling is temporary presumably because K^+ ions are easily washed from the clay when the well is brought into production. An alternative approach recently reported is to use nanoparticles and nanofluids to control clay swelling.

[0004] There is a need for a low cost and more durable solution to the problem of clay swelling in wells.

Summary of the invention

[0005] The invention provides a method of stabilizing a wall comprising exposed layers of clay, comprising steps of:

- positioning a perforated support structure against the wall, said perforated support structure having a clayward-facing side and an opposing side which faces away from the clayward-facing side, and perforations which allow fluid transport through the perforated support structure from the opposing side to the clayward-facing side through the perforations;
- bringing the clayward-facing side in physical contact with the wall; and
- exposing the opposing side to a water-containing fluid, whereby allowing the water containing fluid to contact the wall through the perforations, thereby causing absorption of water in any clay that is exposed to the perforations and local swelling of said clay comprised in wall parts that are exposed to the perforations, whereby the clay is prevented from migrating though the perforations to the opposing side.

Brief description of the drawing

[0006] The appended drawing, which is non-limiting, comprises the following figures:

Fig. 1 schematically shows a test setup demonstrating the principle of the present invention;
Fig. 2 shows a first graph of clay pressure over time measured in the setup of Fig. 1;
Fig. 3 schematically shows an expandable slotted tubular in a formation invested with layers of clay;
Fig. 4 schematically illustrates expanding of the expandable slotted tubular of Fig. 1 against the layers of clay;
Fig. 5 schematically shows a string of expandable slotted tubulars having unexpandable connectors after running into a borehole;
Fig. 6 schematically shows the string of Fig. 1 after expanding; and
Fig. 7 shows a second graph of clay pressure over time measured in the setup of Fig. 1 using a different metal plate as in Fig. 2.

Detailed description of the invention

[0007] The invention will be further illustrated hereinafter by way of example only, and with reference to the non-limiting drawing. The person skilled in the art will readily understand that, while the invention is illustrated making reference to one or more specific combinations of features and measures, many of those features and measures are functionally independent from other features and measures such that they can be equally or similarly applied independently in other embodiments or combinations.

[0008] The presently proposed method involves allowing clay from a clay wall to absorb water through perforations of a perforated support structure that is positioned against the wall. As the clay swells, it can be kept in place by the perforated support structure. As a result, the pressure in the clay increases and eventually the clay becomes less permeable and it may even become fully impermeable to water. This stabilizes the wall against eroding.

[0009] The presently proposed method is based on a surprising finding that the clay is not (or practically not) squeezed through the perforations and is thus capable of building up pressure until a steady state is reached. Figure 1 schematically shows a setup in which the principle of the method is demonstrated. A cup 1 was partially filled with dry bentontite clay 2. A perforated support structure 3, embodied in the form of a slotted metal plate with a thickness of 8 mm, was positioned on top of the clay 2. The perforations 4 were rectangular in shape, 4x30 mm in size. A quantity of water 5 was provided on top of the metal plate. The clay 2 was in physical contact with a clayward-facing side 6 of the perforated support structure 3, while the water 5 was on an opposing side 7, which faces away from the clayward-facing side 6. The perforations 4 allowed fluid transport through the perforated support structure 3 from the opposing side 7 to the clayward-facing side 6 through the perforations 4. A load cell was arranged against the opposing side 7 to measure the load on the metal plate. None of the perforations was obstructed by the load cell.

[0010] Figure 2 shows the pressure measured by means of the load cell as a function of time over days. It can be seen that the pressure gradually increased and leveled off in a plateau which was reached after about 7 days. Even though the perforations remained open, during those 7 days and thereafter, the clay remained on the clayward-facing side and no clay had been pushed through the perforations. This was confirmed by visual inspection after 42 days. Although Applicant does not wish to be bound by this theory, the experiment supports Applicant's understanding that the shear strength of the saturated clay is larger than the swelling force exerted on the clay exposed by the perforations.

[0011] The swelling force reaches about 180 N once in equilibrium, which in the experimental setup as used corresponds to a pressure of less than 1 bar (100 kPa), which is much smaller than the collapse force of the supporting structure. In any case, the size of the perforations can be selected such that the perforations are large enough to shear the clay before the swelling pressure exceeds the collapse pressure.

[0012] One way of installing such a perforated support structure in an open section of a wellbore in an earth formation is by employing expandable slotted tubulars (EST) as the perforated support structure. The collapse pressure of typical EST is much higher than the swelling pressure that is expected from the clay. The basic principle is illustrated schematically in Figs. 3 and 4.

[0013] Fig. 3 specifically shows a length 12 of expandable slotted tubular which has been inserted into a borehole 8 in an earth formation. The borehole 8 is part of the wellbore. The earth formation in this case has producing zones 17 (which may be coal seams) separated from each other by layers of clay 3. The clay is exposed to the wellbore. The EST may be provided in the form of a metal (suitably carbon steel) pipe which has been provided with a pattern of slots 20. The slots may be oriented along the longitudinal axis and they may be provided in staggered rows which partly overlap. For reasons of clarity, not all slots are individually identified in the drawing.

[0014] As illustrated in Fig. 4, the clayward-facing side of the length 12 of EST is brought in physical contact with the wall by expanding the EST against the wall. This can be done by moving an expansion tool through the EST. This may for example be achieved by pulling an expansion cone 19 on a drill string 19'. The basic technology is described in for example now expired US patent 5,366,012. The slotted perforations 20 from Fig. 3 will dilate into deformed slots 20', which act as the perforations 4 of Fig. 1.

[0015] The method would then be completed by exposing the interior of the expanded slotted tubular to a water-containing fluid, whereby allowing the water containing fluid to contact the wall through the deformed slots 20'. Interestingly, only where the clay is located behind the deformed slots 20' will the slots eventually be blocked. The deformed slots 20' will remain open in the producing zones 17 where no or insufficient clay is present to fully block the deformed slots 20'.

[0016] The required dimensions for the slots will depend on various parameters including one or more of the clay type, the thickness of the EST wall, the amount of expansion or deformation of the slots, the shape of the slots, etc.. A main consideration for determining the slot dimensions would include that the exposure area (defined by an area of the wall that is exposed to the opposing side) though each of the deformed slots is sufficiently small that the force on the clay that is exposed (given in approximation by the swelling pressure of the clay after local swelling times the exposure area) is smaller than a shear strength of the clay after local swelling.

[0017] Figures 5 and 6 illustrate an embodiment, wherein a string of support structures is employed wherein each support structure is connected to its adjacent neighboring ones using a connector.

[0018] Fig. 5 schematically shows a string 10 of expandable slotted tubulars run in a borehole 8 in the earth. The string 10 comprises at least two tubular lengths 12 joined together. Each of the tubular lengths 12 comprise a first longitudinal end 14, a second longitudinal end, and an expandable middle section 18 which connects the first longitudinal end 14 and the second longitudinal end 16. The expandable middle section is provided with a pattern of slotted perforations 20 (for reasons of clarity, not all perforations are individually identified in the drawing). The first and second longitudinal ends (14,16) are respectively provided with first and second connectors which are not expandable. Such connectors may be standard treaded pipe or casing joints commonly used in the oil field industry. The first and second connectors (14,16) may be unslotted and/or unperforated, such as standard joints are. The first and second connectors (14,16) are preferably threaded connectors, but alternatively the first and second connectors may be welded connectors.

[0019] In an assembled configuration, the first connector 14 of one of the at least two tubular lengths is connected to the second connector 16 of an adjacent one of the at least two tubular lengths. Herewith, the string 10 of expandable slotted tubulars. In the assembled configuration, the expandable middle sections 18 of respective adjacent tubular lengths 12 are separated from each other by said connectors (14,16).

[0020] After providing the string 10 of expandable slotted tubulars as described thus far, the string 10 of slotted tubulars may be expanded. An expansion operation may include moving an expansion tool in a longitudinal direction though the string 10. In this case, the expansion tool is preferably a flexible expansion device which is capable of expanding the respective middle sections 18 while leaving the connectors (14,16) unexpanded. The end result is schematically illustrated in Fig. 6. The slotted perforations 20 from Fig. 5 have dilated into deformed slots 20'. (Again, for clarity reasons, not all deformed slots 20' have been marked in the figure).

[0021] The moving of the flexible expansion device through the string 10 of expandable slotted tubulars may be accomplished by exerting a translation force to the expansion device, which results in the expansion device applying a stress on the string of slotted tubulars in a contact area between the expansion device and the string of slotted tubulars. The flexible expansion device may be a force-limited collapsible cone. Such devices are known and available on the market.

[0022] Suitably, the stress is limited to a predetermined maximum stress, by (partly) collapsing of the flexible expansion device when the predetermined maximum stress is reached. Suitably, the predetermined maximum stress is higher than a first yield stress in the middle sections of the string of slotted tubulars and lower than a second yield stress in the connectors. The yield stress is a material property which defines the stress at which a material begins to deform plastically. Once the material is exposed to its yield stress, some fraction of deformation will be permanent and non-reversible.

[0023] The laboratory experiments described above with reference to Figs. 1 and 2 have been repeated with different metal plates. All had rectangular perforations having a length of 30 mm. The width of the perforations and the plate thickness were varied. Results of release of clay through the perforations are presented in the following Table.

Thickness (mm)	Width (mm)	Clay release	T/W ratio
8	4	No	2
8	8	Yes	1
16	8	No	2
2	4	Yes	0.5

[0024] The original test was demonstrated with 4-mm wide slots. Interestingly, 8-mm wide slots can work as well, provided that the support structure (in this case the thickness of the metal plate) is thick enough. This implies that the clay may slightly ingress into the perforations. It was found that the ratio of thickness (T) over width (W) should exceed 1, preferably should exceed 1.5. The test with 8-mm wide slots and plate thickness of 16 mm did not release any clay even after a period of two months.

[0025] Figure 7 shows the force measured by the load cell for the case of 2 mm thick metal plate and 4 mm width slots. Even though 4-mm wide slots worked well for the 8-mm thick plate (as illustrated by in Fig. 2), Fig. 7 shows force is released each time after it builds up. This suggests releases of clay take place when the force exceeds a certain limit. Visual inspection confirmed clay was accumulating on the water-facing side (i.e. the opposing side) of the slotted metal plate, whereas that was clearly not the case for the 4-mm slots in the 8-mm thick plate and for the 8-mm slots in the 16-mm thick plate.

[0026] In any of the embodiments described above, the slotted tubulars may be provided with expandable well screens, such as those disclosed in US patents 5,901,789 and 6,315,040 or similar. However, it is expected that such screens will not be required to stabilize the clay and therefore it is recommended to run a single layer of EST by itself.

[0027] Finally, it is recognized that various gravel packs, screens, and slotted tubulars are known in the art. However, to the inventor's best knowledge, these have merely been applied to control solid ingress and migration of particles (for example: sand) from the producing rock layers. In the present proposal, the perforated support structure acts to stabilize clay layers that are between the producing rock layers. There is no need to know the exact locations of the producing rock layers and non-producing clay layers, and the clay will become impermeable to water after swelling but not the producing rock layers. From this perspective, the method is self-organizing.

[0028] The person skilled in the art will understand that the present invention can be carried out in many various ways without departing from the scope of the appended claims.

Claims

1. A method of stabilizing a wall comprising exposed layers of clay, comprising steps of:

   - positioning a perforated support structure against the wall, said perforated support structure having a clayward-facing side and an opposing side which faces away from the clayward-facing side, and perforations which allow fluid transport through the perforated support structure from the opposing side to the clayward-facing side through the perforations;
   - bringing the clayward-facing side in physical contact with the wall; and
   - exposing the opposing side to a water-containing fluid, whereby allowing the water containing fluid to contact the wall through the perforations, thereby causing absorption of water in any clay that is exposed to the perforations and local swelling of said clay comprised in wall parts that are exposed to the perforations, whereby the clay is prevented from migrating though the perforations to the opposing side.

2. The method of claim 1, wherein the wall is a wellbore wall in an open section of a wellbore in an earth formation.

3. The method of claim 2, wherein said perforated support structure comprises an expandable slotted tubular and wherein bringing said clayward-facing side of the expandable slotted tubular in physical contact with the wall comprised expanding the expandable slotted tubular using an expansion tool on the inside of the expandable slotted tubular.

4. The method of claim 2, wherein said perforated support structure consists of an expandable slotted tubular and wherein bringing said clayward-facing side of the expandable slotted tubular in physical contact with the wall comprises expanding the expandable slotted tubular using an expansion tool on the inside of the expandable slotted tubular.

5. The method of any one of the preceding claims, wherein the perforations each have an exposure area defined by an area of the wall that is exposed to the opposing side, and wherein a swelling pressure of the clay after local swelling times the exposure area is smaller than a shear strength of the clay after local swelling.

6. The method of claim 5, wherein a collapse strength of the supporting structure exceeds a maximum force that is exerted by the swelling pressure.

7. The method of any one of the preceding claims, wherein said clay becomes impermeable to water upon local swelling and saturation with water.

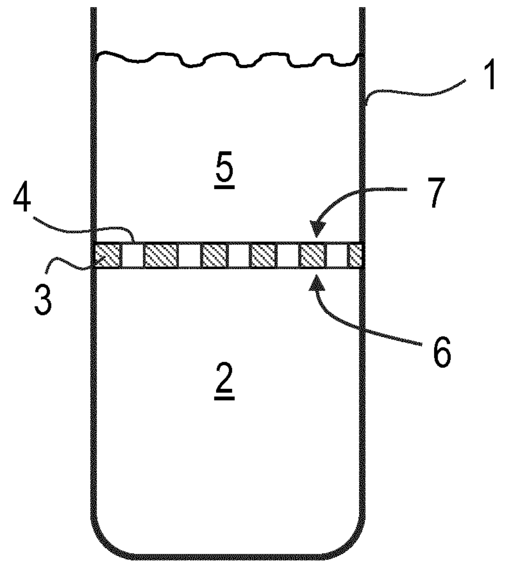
1
5
7
4
3
6
2

FIG. 1

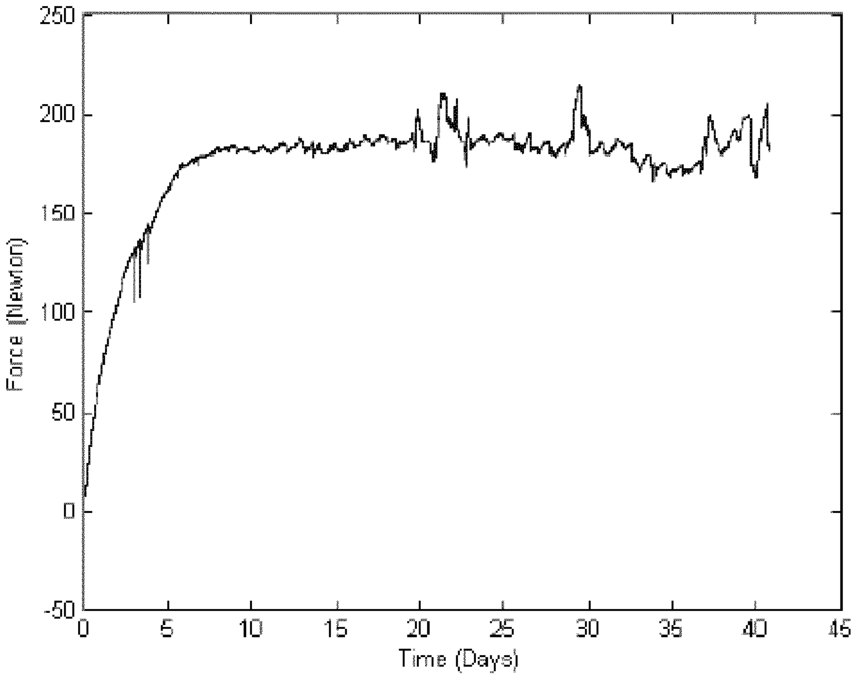
250
200
150
100
50
0
-50
Force (Newton)
0
5
10
15
20
25
30
35
40
45
Time (Days)

FIG. 2

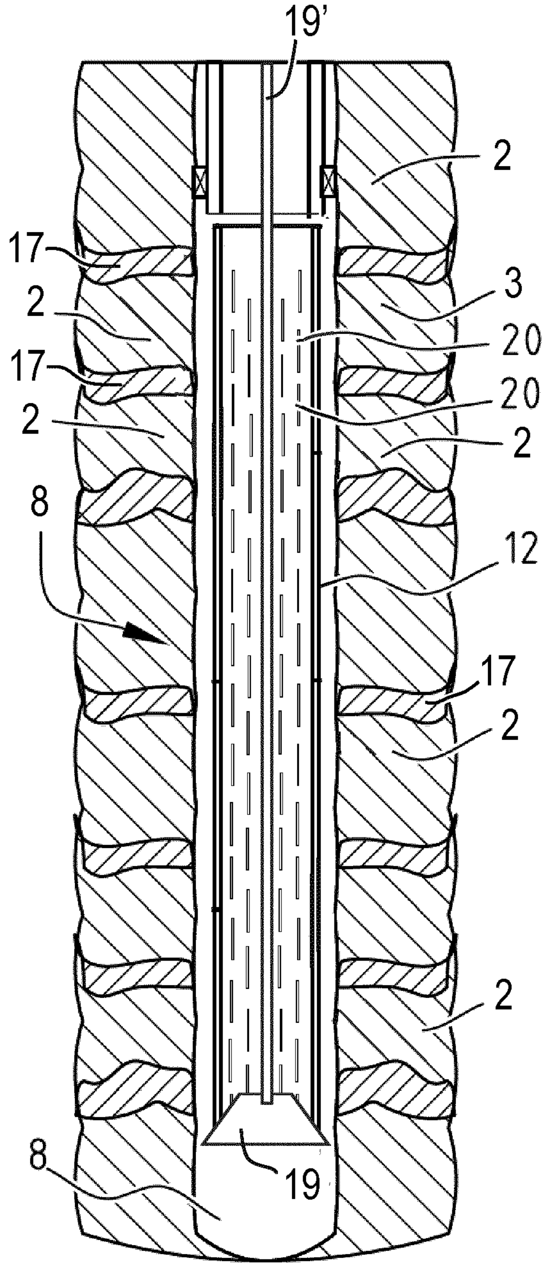

FIG. 3

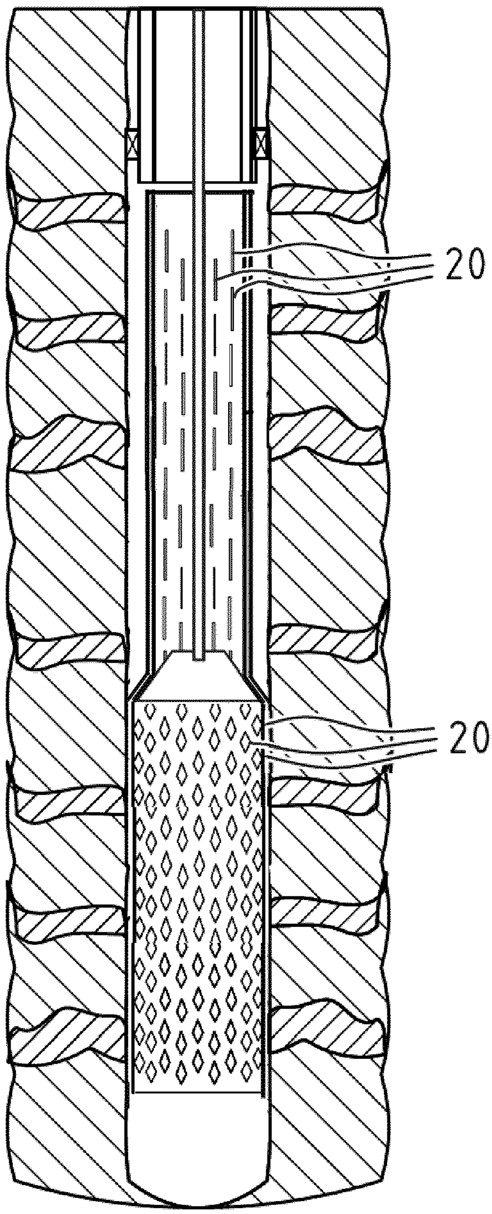

FIG. 4

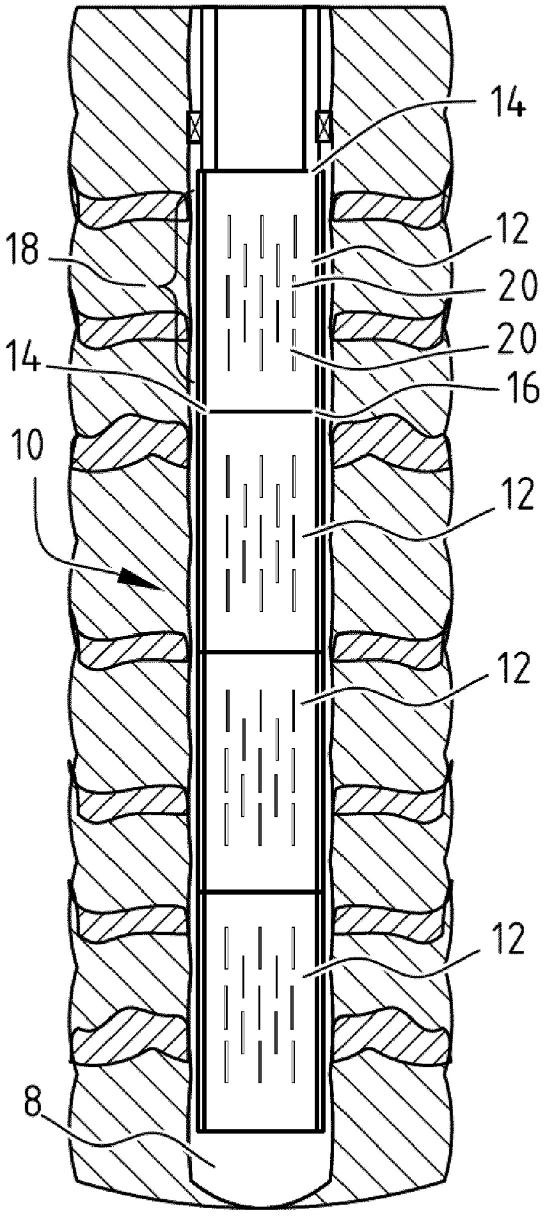

FIG. 5

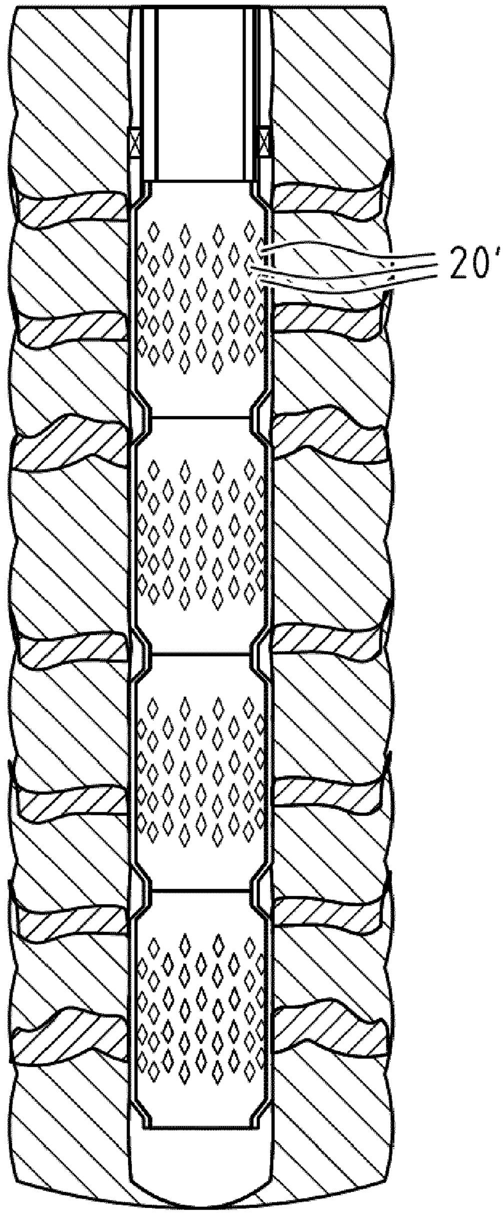

FIG. 6

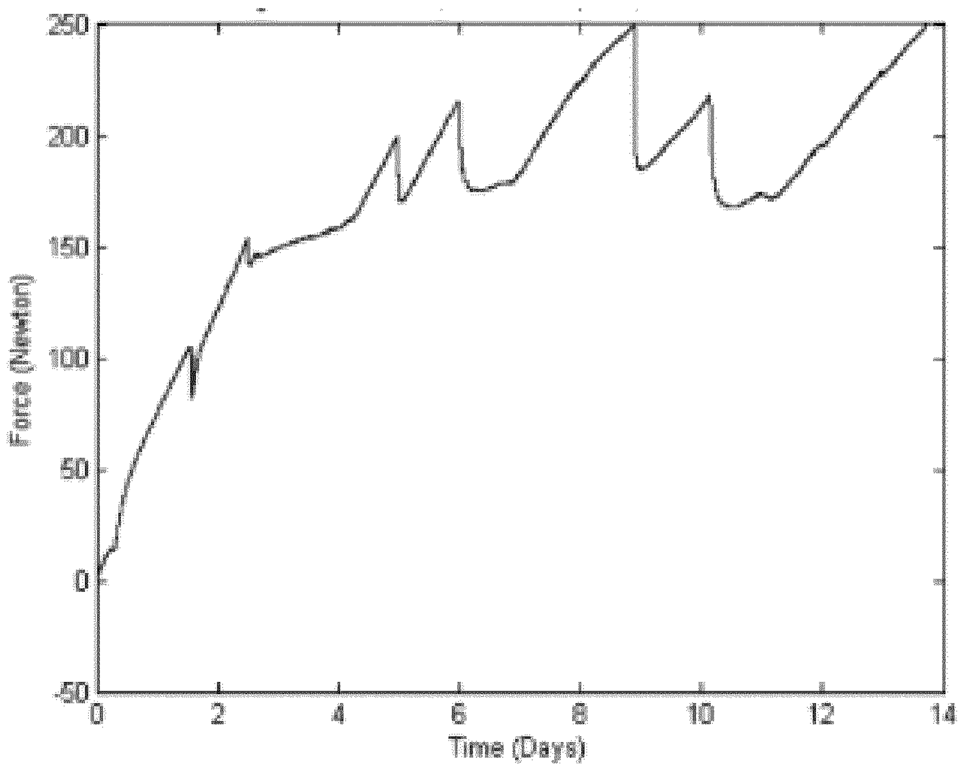

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 19 15 9329

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	GB 2 482 703 A (KRZYSIEK JAN [PL]; ELZBIETA NAPIERALSKA KRZYSIEK [PL]) 15 February 2012 (2012-02-15) * pages 6-8; figures 1,2 * * the whole document * -----	1	INV. E21B43/10 E21B43/08
A	US 2007/227733 A1 (VERCAEMER CLAUDE J [FR] ET AL) 4 October 2007 (2007-10-04) * figures 1,2 * -----	1	
A	WO 2018/191783 A1 (BERTANI ROMOLO LORENZO [AU]) 25 October 2018 (2018-10-25) * the whole document * -----	1	
A	US 2004/251033 A1 (CAMERON JOHN [US] ET AL) 16 December 2004 (2004-12-16) * figures 1-8 * * the whole document * -----	1	

TECHNICAL FIELDS SEARCHED (IPC)

E21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	10 July 2019	van Berlo, André

2

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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E : earlier patent document, but published on, or after the filing date
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L : document cited for other reasons
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 19 15 9329

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

10-07-2019

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
GB 2482703	A	15-02-2012	NONE	
US 2007227733	A1	04-10-2007	NONE	
WO 2018191783	A1	25-10-2018	NONE	
US 2004251033	A1	16-12-2004	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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- US 5901789 A **[0026]**
- US 6315040 B **[0026]**