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Amended claims in accordance with Rule 137(2) EPC.

(54) PROCESS OF ANCHORING A FLOATING PLATFORM ON A ROCKY SEABED

(57) A process of anchoring a floating platform (12) on a rocky seabed (14), comprising the following steps:
- providing at least one trench portion (20) in the seabed (14), the trench portion extending along a line (L),
- installing an anchor structure (22) in the trench portion, the anchor structure comprising a core (34) extending along the line, steel plates (36) welded to the core and extending from the core radially with respect to the line, and at least a first grout line (38),
- injecting grout (24) in said first grout line in order to fill the trench portion with grout, the plates being at least partly surrounded by the injected grout, and
- after curing of the injected grout, connecting a connecting point (28) of the core (to the platform using a mooring chain (26).

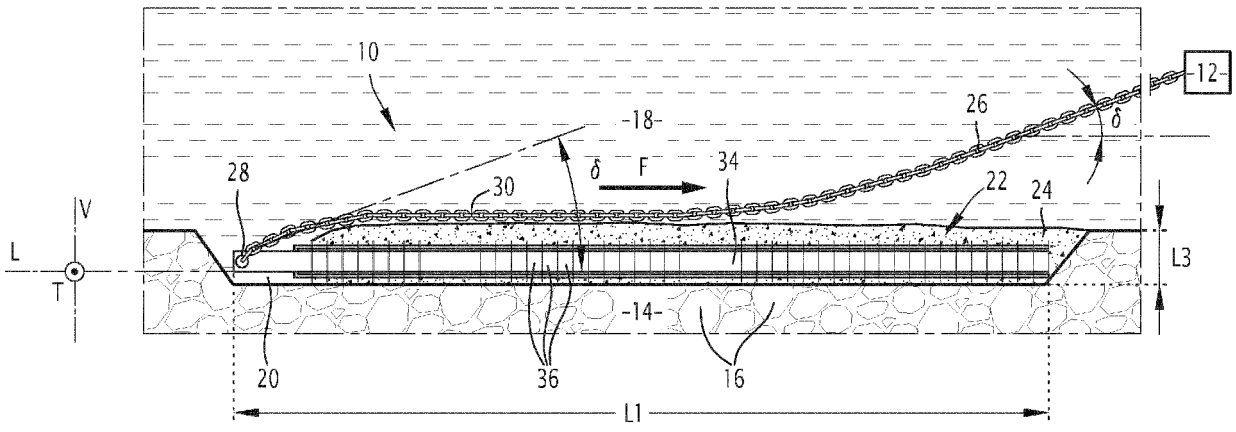

FIG.1

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Description

[0001] The present invention deals with a process of anchoring a floating platform on a rocky seabed, comprising connecting a mooring steel chain to a connecting point and to the platform.

[0002] It also deals with a corresponding anchoring system.

[0003] The growing industry of offshore wind and oil and gas projects pushes states or developers to consider more and more offshore areas. In some of them, soil conditions may represent a challenge to common industry practices for the installation of mooring points, such as drag anchors, driven piles or suction piles. Indeed, these technologies are not suited to a rocky seabed.

[0004] Drilled and grouted piles usually have a 3m diameter. Installing them requires digging a 20m deep hole, and filling the annulus between the pile and the rock with grout. They require investigating the seabed over a depth of more than 20m. The solution of drilled and grouted piles is in fact very challenging for water depths where jack-ups cannot be jacked, e.g. for water depths over 60m. There is also limited experience in drilling with a vessel using dynamic positioning and a heave compensated platform. Moreover, drilling is subject to risks, such as weather and ocean conditions, and technical problems such as hole collapse, very hard rock, management of cuttings.... The number of drilling contractors is quite limited in the world.

[0005] This explains why using piles for anchoring purposes is expensive.

[0006] Gravity based structures filled with sand and gravel represent an alternative. However, they lead to large structures occupying a surface of about 20m x 20m. They require thousands of tons of sand or gravel for ballasting. In the end, they are also quite expensive, and have a non-negligible environmental footprint because of their footprint and influence over the water column.

[0007] An aim of the invention is to provide an anchoring process adapted to a rocky seabed allowing reducing costs and environmental footprint.

[0008] To this end, the invention proposes a process of anchoring a floating platform on a rocky seabed, comprising the following steps:

- providing at least one trench portion in the seabed, the trench portion extending along a line,
- installing an anchor structure in the trench portion, the anchor structure comprising a core extending along the line, steel plates welded to the core and extending from the core (34) radially with respect to the line, and at least a first grout line extending along the line,
- injecting grout in said first grout line in order to fill the trench portion with grout, the plates being at least partly surrounded by the injected grout, and
- after curing of the injected grout, connecting a connecting point of the core (34) to the platform using a mooring chain.

[0009] In other embodiments, the process comprises one or several of the following features, taken in isolation or any technically feasible combination:

- providing the trench portion includes digging the seabed along the line using a subsea trencher;
- the line is straight;
- the plates are perpendicular to the core;
- the trench portion has a length along the line comprised between 5.0m and 40m;
- the trench portion has an average horizontal width perpendicularly to the line, said width being comprised between 0.3m and 2.5m;
- the trench portion has an average depth comprised between 1.0m and 5.0m;
- the trench portion has a U-shaped or V-shaped section perpendicularly to the line;
- the mooring chain has a portion lying on the seabed and exerting efforts on the anchor structure, said portion of the mooring chain and the line defining an angle at the connecting point, the angle being smaller than 30°;
- the core comprises a steel H-beam, a plurality of steel H-beams mechanically connected to each other along the line, or a grid of reinforcing steel bars at least partly surrounded by the injected grout;
- the core comprises a steel H-beam defining a first open housing and a second open housing transversely opposed to each other, a first group of said plates being received in the first open housing, and a second group of said plates being received in the second open housing;
- said first grout line extends along the first open housing and successively crosses holes respectively defined by the first group of plates, the anchor structure further comprising a second grout line extending along the second open housing and crossing holes respectively defined by the second group of plates;
- the process further comprises cleaning the trench portion before injecting grout, said cleaning using water jets directed at walls of the trench portion; and
- the process further comprises: providing a second trench portion in the seabed, the second trench portion extending along a second line, the second line and the line converging towards the connecting point; installing a second anchor structure in the second trench portion, the second anchor structure comprising a second core extending along the second line steel plates welded to the second core and extending from the second core radially with respect to the second line and at least a grout line extending along the second line the second core being mechanically connected to the connecting point; and injecting grout in said grout line in order to fill the second trench portion with grout, said plates being at least partly surrounded by the injected grout.

[0010] The invention also deals with an anchoring system adapted for anchoring a floating platform on a rocky seabed, the anchoring system comprising:

- at least one trench portion located in the seabed and extending along a line,
- an anchor structure at least partly located in the trench portion, the anchor structure comprising a core extending along the line, steel plates welded to the core and extending from the core radially with respect to the line, and at least a first grout line extending along the line,
- grout located in the trench portion, the plates being at least partly surrounded by the grout, and
- a mooring steel chain connected to a connecting point of the core, the mooring chain being intended to be connected to the platform.

[0011] The invention and its advantages will be better understood upon reading the following description, given solely by way of example and with reference to the appended drawings, in which:

- Figure 1 is a schematic side view of an anchoring system according to the invention,
- Figure 2 is a schematic upper view of the anchoring system shown in Figure 1,
- Figure 3 is a schematic perspective view of an anchor structure of the anchoring system shown in Figures 1 and 2,
- Figures 4 to 7 are schematic side views showing successive phases of the construction of the anchoring system shown in Figures 1 and 2, in order to illustrate a process according to the invention, and
- Figure 8 is a schematic upper view an anchoring system according to a variant of the system shown in Figures 1 and 2.

[0012] An anchoring system 10 according to the invention will now be described with reference to Figures 1 to 3 mainly.

[0013] The anchoring system 10 is adapted for anchoring a floating platform 12 (symbolized by a square in Figure 1) to a rocky seabed 14.

[0014] By "rocky", it is meant here that the seabed 14 comprises rocks 16, to which the anchoring system is fixed. The strength of the anchoring system depends on the strength of rock (from very weak to very strong) and the level of fracturation (from highly weathered/fractured (Rock Quality Designation: worse) to no weathered/fractured (Rock Quality Designation: excellent).

[0015] The platform 12 for example hosts a wind turbine (not shown). The platform 12 floats on a body of water 18 (see, ocean or lake) extending over the seabed 14.

[0016] The anchoring system 10 comprises a trench portion 20 located in the seabed 14 and extending along a line L, an anchor structure 22 located in the trench portion, grout 24 located in the trench portion, and a mooring steel chain 26 connected to the platform 12 and to a connecting point 28 of the anchor structure.

[0017] The anchoring system 10 is advantageously designed to resist efforts F applied by the mooring chain 26 on the anchor structure 22, for example up to 10000kN. The anchoring system 10 is advantageously designed to have a lifespan of at least 25 years.

[0018] In the example shown, said efforts F apply compression to the anchor structure 22 along the line L.

[0019] The line L is advantageously straight. The line L follows the seabed 14 and is for example horizontal in case of a flat seabed. A transverse direction T is also defined as perpendicular to the line L and horizontal.

[0020] As a variant (not shown), the line L may be inclined in order to follow a seabed with a gentle slope.

[0021] The efforts F are for example parallel to the seabed 14 (case of a catenary mooring system).

[0022] For example, a portion 30 of the mooring chain 26, extending from the connecting point 28, lies on the seabed 14 and/or on the grout 24. The portion 30 and the line L advantageously define an angle α smaller than 30°, and preferably smaller than 10°. This means that most of the efforts F are exerted on the anchor structure 22 along the line L.

[0023] As a variant (not shown), the mooring chain 26 does not have a portion 30 lying on the seabed 14 and/or on the grout 24, and defines an angle δ with a horizontal plan at the connecting point 28. This may happen when the efforts F are large.

[0024] Generally the angle δ remains smaller than 10°.

[0025] The trench portion 20 may be natural, from previous digging, or preferably from dedicated digging.

[0026] As symbolized in Figure 5, the trench portion 20 for example has a U-shaped or V-shaped section 32 perpendicularly to the line L.

[0027] The trench portion 20 for example has a length L1 along the line L comprised between 5.0m and 40m, advantageously between 10m and 30m.

[0028] The trench portion 20 for example has an average horizontal width L2 perpendicularly to the line L, said width being comprised between 0.3m and 2.5m, advantageously between 0.5m and 2.0m.

[0029] The trench portion 20 for example has an average depth L3 comprised between 1.0m and 5.0m, advantageously between 1.0m and 2.5m.

[0030] As shown in Figure 3, the anchor structure 22 comprises a core 34 extending along the line L, steel plates 36 welded to the core and extending from the core radially with respect to the line L, and two grout lines 38, 40 extending along the line L.

[0031] As variants (not shown), the anchor structure 22 only has one grout line, or includes more than two grout lines.

[0032] In the example, the anchor structure 22 is entirely located in the trench portion 20. In other words, the anchor structure 22 is below the seabed level. The anchor structure 22 advantageously extends over more than

90% of the trench portion 20 along the line L.

[0033] The anchor structure 22 is advantageously fully surrounded by the grout 24 around the line L. The grout aims at ensuring a sealing of the anchor structure 22 with the surrounding seabed 14.

[0034] In the example, the core 34 consists of a steel H-beam 42 extending along the line L. H-beams are usually standardized items, also known as "I-beams".

[0035] Advantageously, the core 34 defines or forms the connecting point 28, which is for example located at an extremity of the core along the line L.

[0036] As variants (not shown), the core 34 may include a plurality of steel H-beams mechanically connected to each other along the line L, or a grid of reinforcing steel bars at least partly surrounded by the grout 24.

[0037] The steel H-beam 42, and the above-mentioned variants, are adapted to withstand compression efforts, as well as traction efforts along the line L.

[0038] As another variant (not shown), the core 34 comprises or consists of a steel chain. In that case, the core 34 is adapted to withstand only traction efforts along the line L.

[0039] The H-beam 42 defines a first open housing 44 and a second open housing 46 transversely opposed to each other.

[0040] The plates 36 are preferably orthogonal to the line L.

[0041] For example, the plates 36 are rectangular. Advantageously, three edges 48, 50, 52 of each plate 36 are welded to the web and flanges of the H-beam 42.

[0042] In the example, a first group 36A of the plates 36 is received in the first housing 44, and a second group 36B of the plates is received in the second housing 46.

[0043] The grout lines 38, 40 are adapted to deliver grout within the trench portion 20 when grout is injected under pressure in them, for example at one of their extremities along the line L.

[0044] The grout line 38 extends in the first housing 44, for example through holes 54 cut in the first group 36A of plates.

[0045] Similarly, the grout line 40 extends in the second housing 46, for example through holes 56 cut in the second group 36B of plates.

[0046] The grout 24 for example could be a Portland grout and is adapted for curing underwater.

[0047] The grout 24 advantageously fills the trench portion 20 up to seabed level over at least 90% of the anchor structure 22 along the line L.

[0048] Advantageously, the grout 24 is adapted to develop a shear friction against the trench portion 20 rocky walls of as a minimum 100 kPa.

[0049] The mooring chain 26 is adapted to be tensioned by the floating platform 12 and to transmit/apply the efforts F to the anchor structure 22.

[0050] A process of anchoring the floating platform 12 on the seabed 14, using the anchoring system 10, will now be described with reference to Figures 4 to 7.

[0051] Optionally, as shown in Figure 4, the seabed 14 is first surveyed for example by a remotely operated vehicle 60. Goal is to detect possible obstacles which could cause issues with the installation. One may also rely on previous knowledge of the seabed 14 such as bathymetry and seabed imagery.

[0052] Then the trench portion 20 is provided in the seabed 14. For example, as shown in Figure 5, the trench portion is dug using a subsea trencher 65 commonly used for pipeline or cables burial.

[0053] The remotely operated vehicle 60 and the subsea trencher 65 are equipment known in themselves and available from the market.

[0054] As a variant, for example in case of a rough seabed with some benches, the trench portion 20 is an existing one, and does not have to be dug.

[0055] Optionally, the trench portion 20 is cleaned, advantageously using water jets 67 (Figure 6) directed at walls 69 of the trench portion. The jets 67 are for example produced by the remotely operated vehicle 60.

[0056] Then, the anchor structure 22 is installed, for example pre-assembled and lowered, in the trench portion 20, as shown in Figure 6.

[0057] Afterwards, grout is injected in the trench portion 20, in the example via the grout lines 38, 40 from a source 70, in order to obtain the grout 24.

[0058] Advantageously, grouting is stopped when the trench portion 20 is full of grout, or at least when the anchor structure 22 is surrounded by grout.

[0059] After curing of the grout 24, the mooring chain 26 is connected to the connecting point 28 and to the platform 12, and is tensioned. As a variant, the mooring chain 26 may have been connected to the connecting point 28 before grouting.

[0060] Then the mooring chain 26 exerts the efforts F on the anchor structure 22. Depending on the efforts F, the above mentioned portion 30 of the mooring chain 26 lies on the seabed 14 and/or the grout 24, or the mooring chain 26 defines the angle δ with a horizontal plan..

[0061] Thanks to the above features, the anchoring process is adapted to the rocky seabed 14 and preferably catenary mooring solutions and allows reducing costs and the environmental footprint. Design is fast. Limited soil investigation, for example over the top 3m of the seabed 14, is enough. All pieces of equipment are available in the market and easy to procure. The final assembly of the anchor structure 22 can be done locally. Installation is fast and requires only a dynamic positioning vessel. No pretension is needed.

[0062] As a variant of the above process of anchoring, shown in Figure 8, a second trench portion 120 is provided in the seabed 14.

[0063] The second trench portion 120 extends along a second line LL, preferably straight.

[0064] The second line LL and the line L converge towards the connecting point 28 and define an angle β together. The second line LL and the line L also define a median axis M.

[0065] The angle β is advantageously comprised be-

tween 20° and 90°.

[0066] A second anchor structure 122 is installed in the second trench portion 120

[0067] The second anchor structure 122 is analogous to the anchor structure 22. The second anchor structure 122 comprises a second core 134 extending along the second line LL, steel plates 136 welded to the core and extending from the second core radially with respect to the second line LL, and at least a grout line 138 extending along the second line LL.

[0068] The second core 134 is mechanically connected to the connecting point 28.

[0069] Then grout 124 is injected in the grout line 138 in order to fill the second trench portion 120. The plates 136 are at least partly surrounded by the injected grout 124.

[0070] Advantageously, the portion 30 of the mooring chain 26 and said median axis M define a third angle γ at the connecting point 28. The third angle γ is advantageously smaller than 30°, and preferably smaller than 10°. In other words, the efforts F are split between the two halves (defined by the median axis M) of the anchoring system shown in Figure 8.

[0071] Thanks to the features of the above described variant, anchoring is stronger.

Claims

1. A process of anchoring a floating platform (12) on a rocky seabed (14), comprising the following steps:

   - providing at least one trench portion (20) in the seabed (14), the trench portion (20) extending along a line (L),
   - installing an anchor structure (22) in the trench portion (20), the anchor structure (22) comprising a core (34) extending along the line (L), steel plates (36) welded to the core (34) and extending from the core (34) radially with respect to the line (L), and at least a first grout line (38) extending along the line (L),
   - injecting grout (24) in said first grout line (38) in order to fill the trench portion (20) with grout (24), the plates (36) being at least partly surrounded by the injected grout (24), and
   - after curing of the injected grout (24), connecting a connecting point (28) of the core (34) to the platform (12) using a mooring chain (26).

2. The process according to claim 1, wherein providing the trench portion (20) includes digging the seabed (14) along the line (L) using a subsea trencher (65).

3. The process according to claim 1 or 2, wherein the line (L) is straight.

4. The process according to any one of claims 1 to 3, wherein the plates (36) are perpendicular to the core (34).

5. The process according to any one of claims 1 to 4, wherein the trench portion (20) has a length (L1) along the line (L) comprised between 5.0m and 40m.

6. The process according to any one of claims 1 to 5, wherein the trench portion (20) has an average horizontal width (L2) perpendicularly to the line (L), said (L2) width being comprised between 0.3m and 2.5m.

7. The process according to any one of claims 1 to 6, wherein the trench portion (20) has an average depth (L3) comprised between 1.0m and 5.0m.

8. The process according to any one of claims 1 to 7, wherein the trench portion (20) has a U-shaped or V-shaped section (32) perpendicularly to the line (L).

9. The process according to any one of claims 1 to 8, wherein the mooring chain (26) has a portion (30) lying on the seabed (14) and exerting efforts (F) on the anchor structure (22), said portion (30) of the mooring chain (26) and the line (L) defining an angle (α) at the connecting point (28), the angle (α) being smaller than 30°.

10. The process according to any one of claims 1 to 9, wherein the core (34) comprises a steel (42) H-beam, a plurality of steel H-beams mechanically connected to each other along the line (L), or a grid of reinforcing steel bars at least partly surrounded by the injected grout (24).

11. The process according to any one of claims 1 to 8, wherein the core (34) comprises a steel (42) H-beam defining a first open housing (44) and a second open housing (46) transversely opposed to each other, a first group (36A) of said plates (36) being received in the first open housing (44), and a second group (36B) of said plates (36) being received in the second open housing (46).

12. The process according to claim 11, wherein said first grout line (38) extends along the first open housing (44) and successively crosses holes (54) respectively defined by the first group (36A) of plates (36), the anchor structure (22) further comprising a second grout line (40) extending along the second open housing (46) and crossing holes (56) respectively defined by the second group (36B) of plates (36).

13. The process according to any one of claims 1 to 12, further comprising a step of cleaning the trench portion (20) before injecting grout (24), said cleaning using water jets (67) directed at walls (69) of the trench portion (20).

14. The process according to any one of claims 1 to 13, further comprising:

- providing a second trench portion (120) in the seabed (14), the second trench portion (120) extending along a second line (L2), the second line (L2) and the line (L) converging towards the connecting point (28),
- installing a second anchor structure (122) in the second trench portion (120), the second anchor structure (122) comprising a second core (134) extending along the second line (L2), steel plates (136) welded to the second core (34) and extending from the second core (134) radially with respect to the second line (L2), and at least a grout line (138) extending along the second line (L2), the second core (134) being mechanically connected to the connecting point (28), and
- injecting grout (124) in said grout line (138) in order to fill the second trench portion (120) with grout, said plates (136) being at least partly surrounded by the injected grout (124).

15. An anchoring system (10) adapted for anchoring a floating platform (12) on a rocky seabed (14), the anchoring system (10) comprising:

- at least one trench portion (20) located in the seabed (14) and extending along a line (L),
- an anchor structure (22) at least partly located in the trench portion (20), the anchor structure (22) comprising a core (34) extending along the line (L), steel plates (36) welded to the core (34) and extending from the core (34) radially with respect to the line (L), and at least a first grout line (38) extending along the line (L),
- grout (24) located in the trench portion (20), the plates (36) being at least partly surrounded by the grout (24), and
- a mooring steel chain (26) connected to a connecting point (28) of the core (34), the mooring chain (26) being intended to be connected to the platform (12).

Amended claims in accordance with Rule 137(2) EPC.

1. A process of anchoring a floating platform (12) on a rocky seabed (14), **characterized in that** it comprises the following steps:

- providing at least one trench portion (20) in the seabed (14), the trench portion (20) extending along a line (L),
- installing an anchor structure (22) in the trench portion (20), the anchor structure (22) comprising a core (34) extending along the line (L), steel plates (36) welded to the core (34) and extending from the core (34) radially with respect to the line (L), and at least a first grout line (38) extending along the line (L),
- injecting grout (24) in said first grout line (38) in order to fill the trench portion (20) with grout (24), the plates (36) being at least partly surrounded by the injected grout (24), and
- after curing of the injected grout (24), connecting a connecting point (28) of the core (34) to the platform (12) using a mooring chain (26).

2. The process according to claim 1, wherein providing the trench portion (20) includes digging the seabed (14) along the line (L) using a subsea trencher (65).

3. The process according to claim 1 or 2, wherein the line (L) is straight.

4. The process according to any one of claims 1 to 3, wherein the plates (36) are perpendicular to the core (34).

5. The process according to any one of claims 1 to 4, wherein the trench portion (20) has a length (L1) along the line (L) comprised between 5.0m and 40m.

6. The process according to any one of claims 1 to 5, wherein the trench portion (20) has an average horizontal width (L2) perpendicularly to the line (L), said (L2) width being comprised between 0.3m and 2.5m.

7. The process according to any one of claims 1 to 6, wherein the trench portion (20) has an average depth (L3) comprised between 1.0m and 5.0m.

8. The process according to any one of claims 1 to 7, wherein the trench portion (20) has a U-shaped or V-shaped section (32) perpendicularly to the line (L).

9. The process according to any one of claims 1 to 8, wherein the mooring chain (26) has a portion (30) lying on the seabed (14) and exerting efforts (F) on the anchor structure (22), said portion (30) of the mooring chain (26) and the line (L) defining an angle (α) at the connecting point (28), the angle (α) being smaller than 30°.

10. The process according to any one of claims 1 to 9, wherein the core (34) comprises a steel (42) H-beam, a plurality of steel H-beams mechanically connected to each other along the line (L), or a grid of reinforcing steel bars at least partly surrounded by the injected grout (24).

11. The process according to any one of claims 1 to 8, wherein the core (34) comprises a steel (42) H-beam

defining a first open housing (44) and a second open housing (46) transversely opposed to each other, a first group (36A) of said plates (36) being received in the first open housing (44), and a second group (36B) of said plates (36) being received in the second open housing (46).

12. The process according to claim 11, wherein said first grout line (38) extends along the first open housing (44) and successively crosses holes (54) respectively defined by the first group (36A) of plates (36), the anchor structure (22) further comprising a second grout line (40) extending along the second open housing (46) and crossing holes (56) respectively defined by the second group (36B) of plates (36).

13. The process according to any one of claims 1 to 12, further comprising a step of cleaning the trench portion (20) before injecting grout (24), said cleaning using water jets (67) directed at walls (69) of the trench portion (20).

14. The process according to any one of claims 1 to 13, further comprising:

- providing a second trench portion (120) in the seabed (14), the second trench portion (120) extending along a second line (L2), the second line (L2) and the line (L) converging towards the connecting point (28),
- installing a second anchor structure (122) in the second trench portion (120), the second anchor structure (122) comprising a second core (134) extending along the second line (L2), steel plates (136) welded to the second core (34) and extending from the second core (134) radially with respect to the second line (L2), and at least a grout line (138) extending along the second line (L2), the second core (134) being mechanically connected to the connecting point (28), and
- injecting grout (124) in said grout line (138) in order to fill the second trench portion (120) with grout, said plates (136) being at least partly surrounded by the injected grout (124).

15. An anchoring system (10) adapted for anchoring a floating platform (12) on a rocky seabed (14), the anchoring system (10) comprising an anchor structure (22), the anchor structure (22) comprising a core (34) and steel plates (36) extending from the core (34), **characterized in that** the anchoring system (10) further comprises:

- at least one trench portion (20) located in the seabed (14) and extending along a line (L), the anchor structure (22) being at least partly located in the trench portion (20) and further comprising at least a first grout line (38) extending along the line (L), the core (34) extending along the line (L), and the plates (36) being welded to the core (34) and extending from the core (34) radially with respect to the line (L),
- grout (24) located in the trench portion (20), the plates (36) being at least partly surrounded by the grout (24), and
- a mooring steel chain (26) connected to a connecting point (28) of the core (34), the mooring chain (26) being intended to be connected to the platform (12).

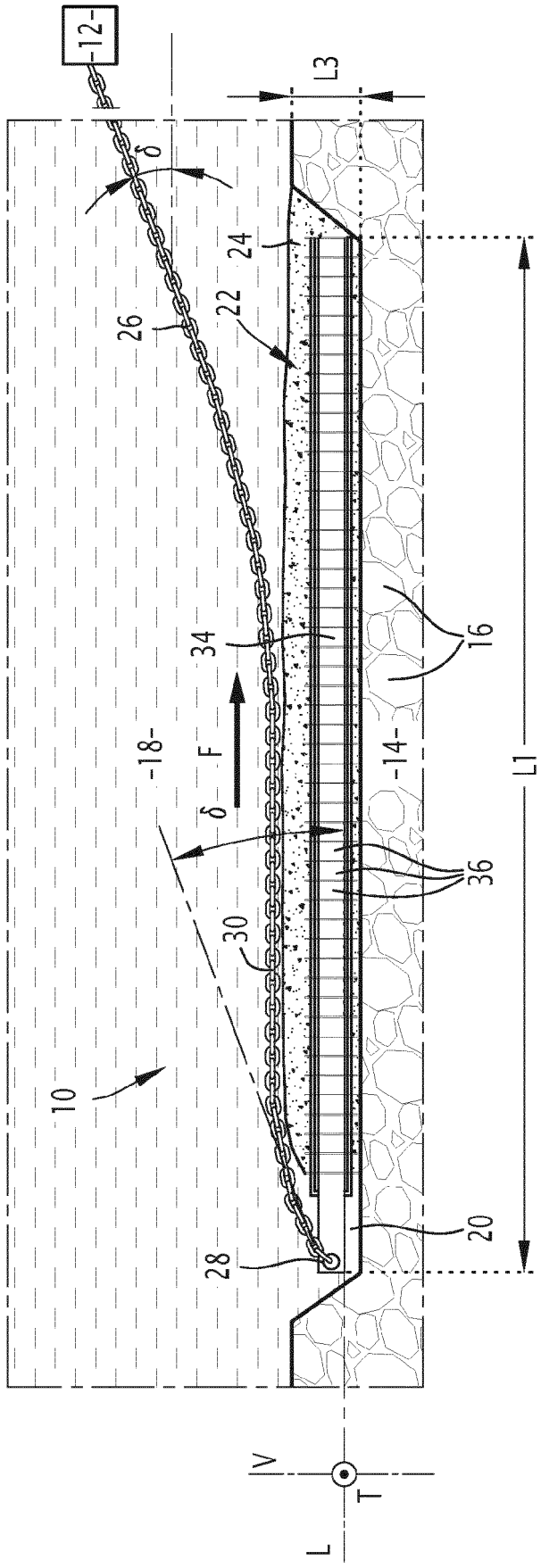

FIG.1

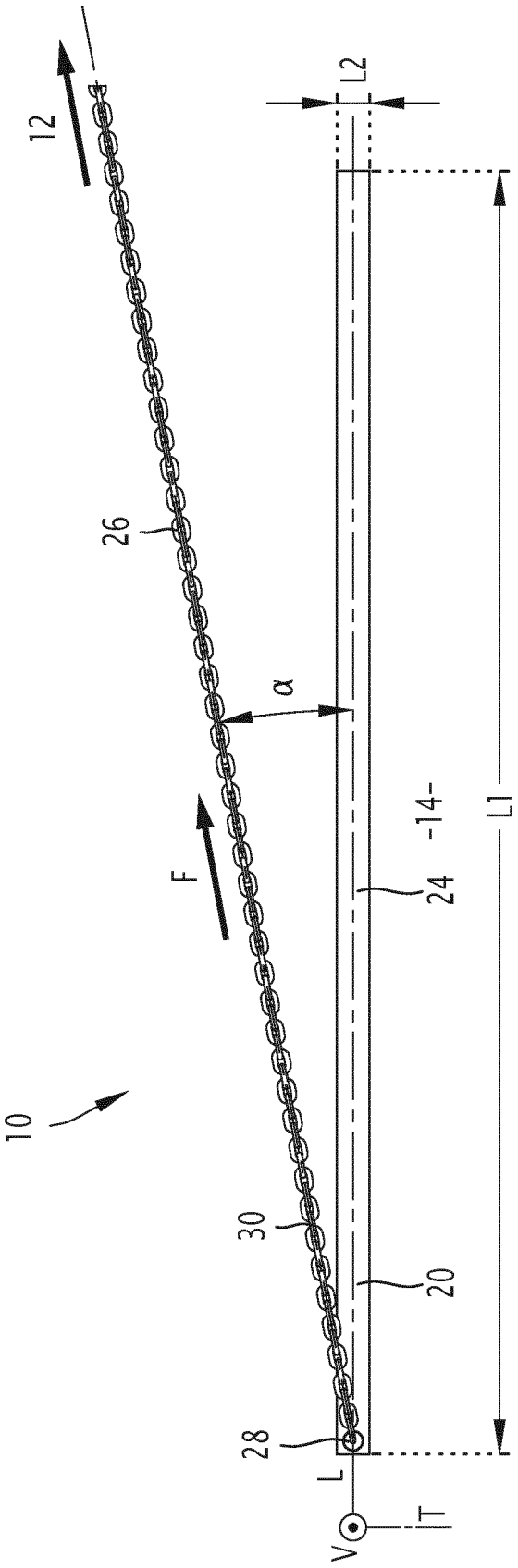

FIG.2

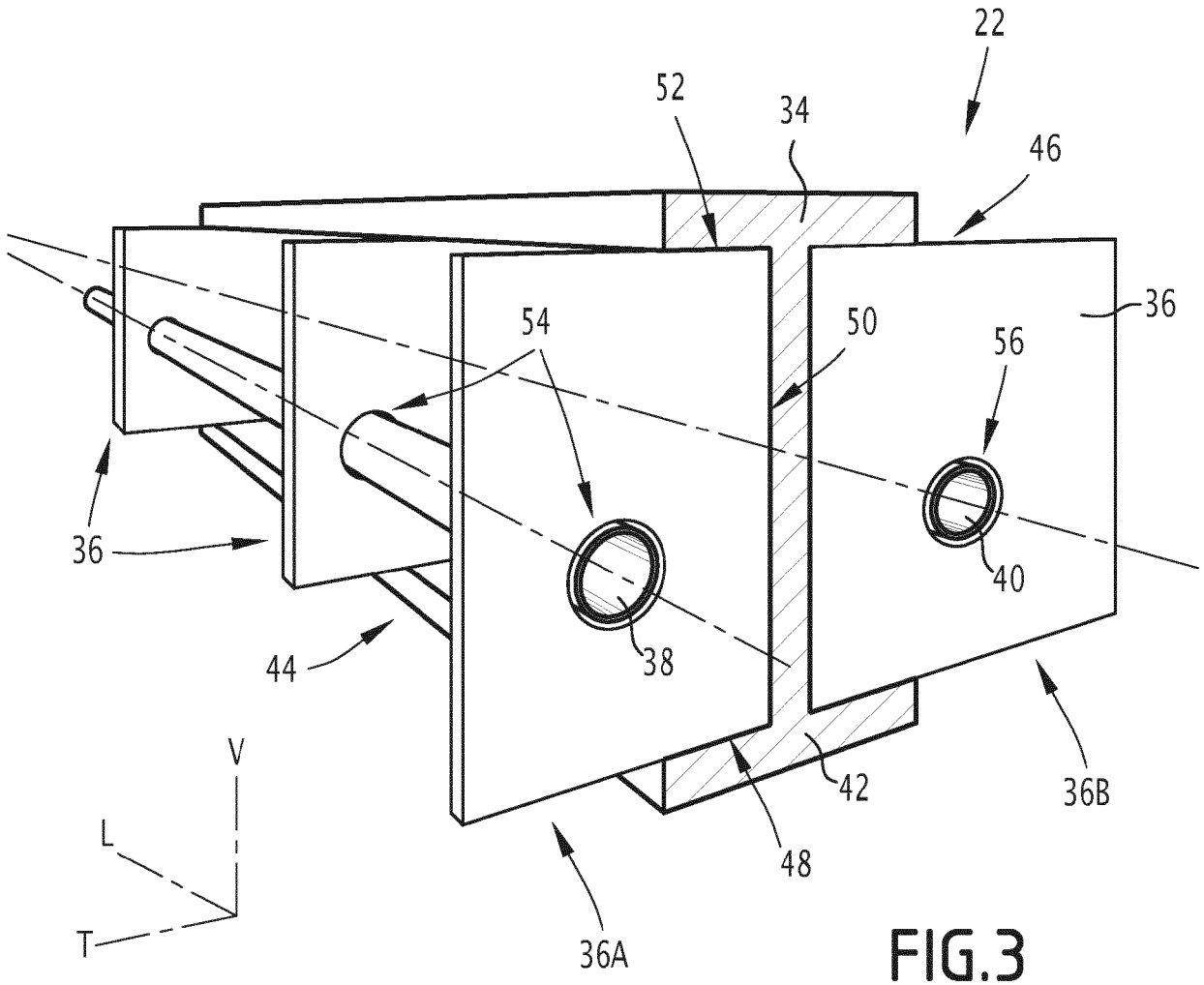

FIG.3

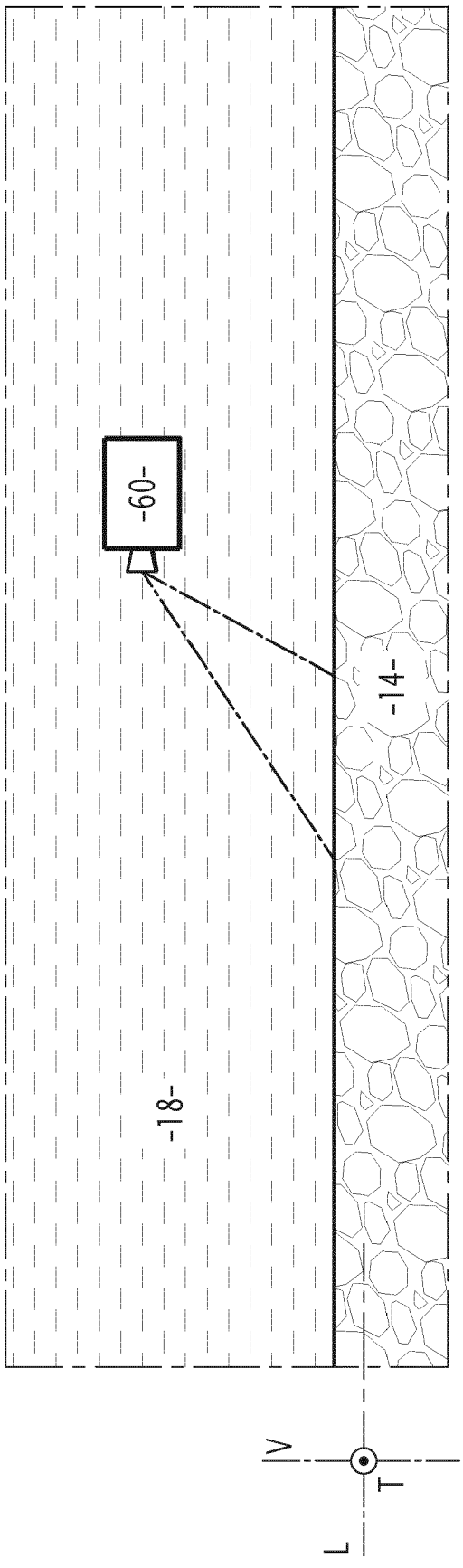

FIG.4

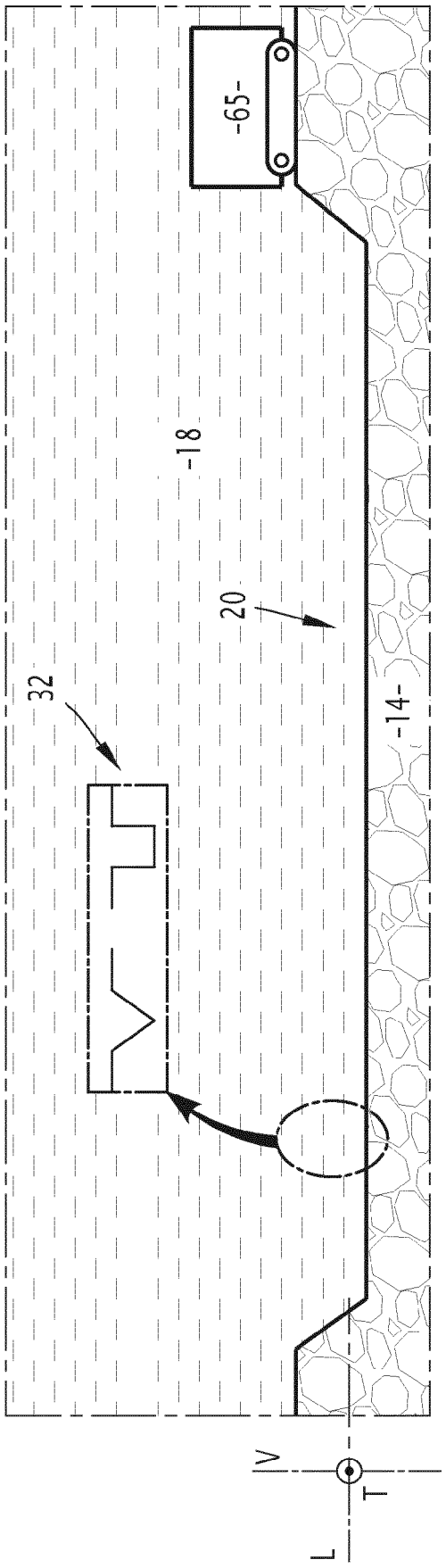

FIG.5

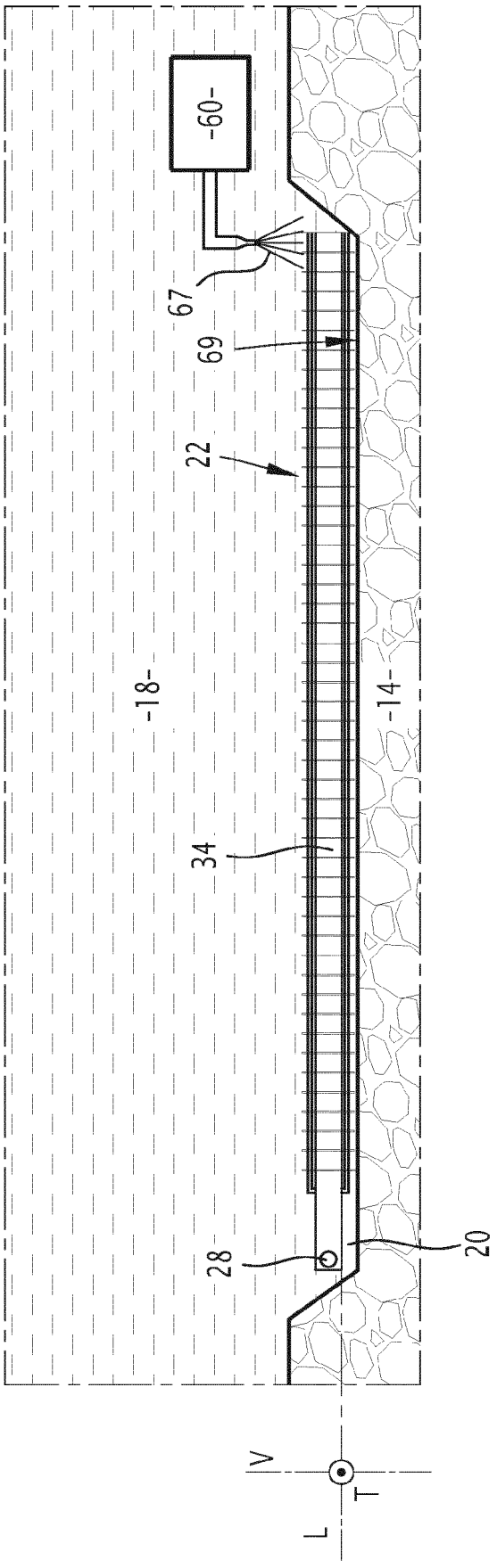

FIG.6

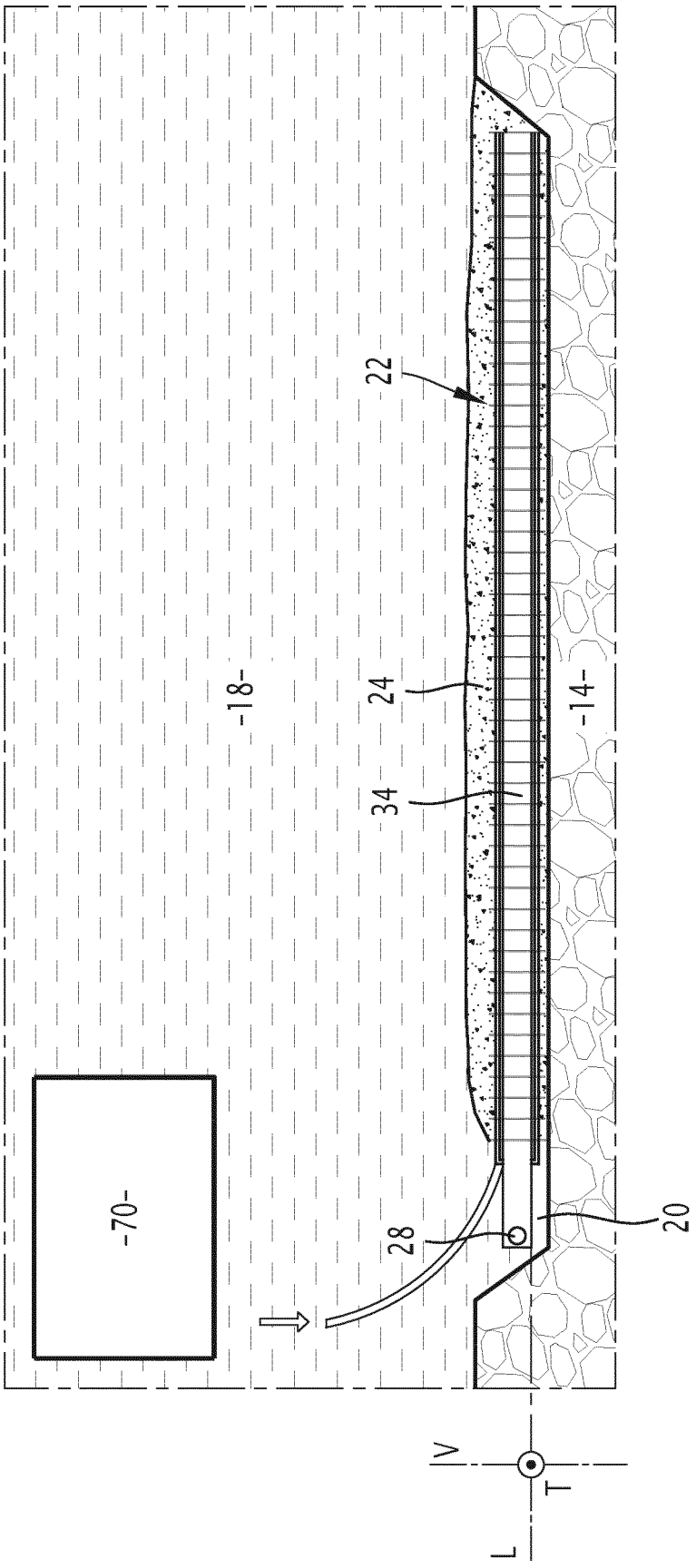

FIG.7

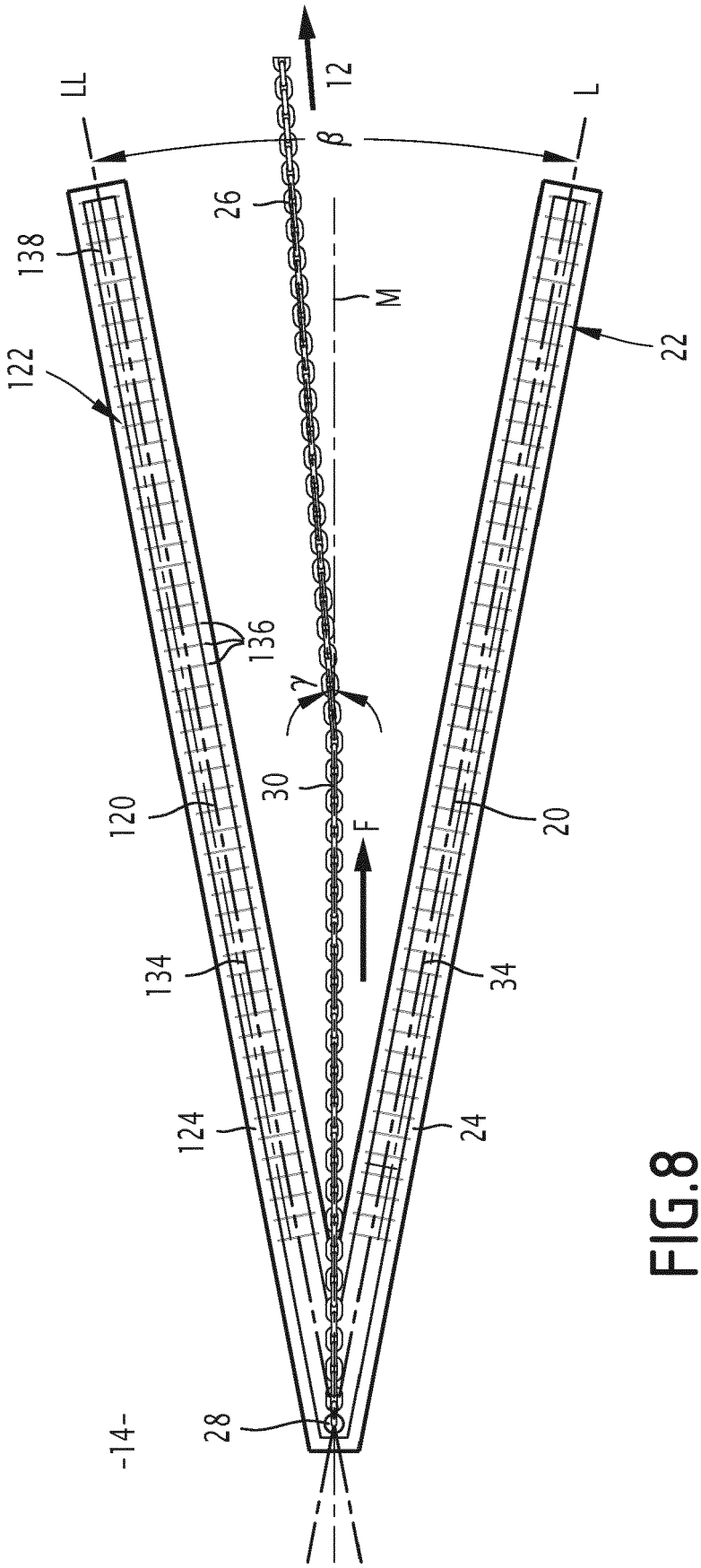

FIG.8

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EUROPEAN SEARCH REPORT

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B63B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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