(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 January 2023 (26.01.2023)

WIPO | PCT

(10) International Publication Number
WO 2023/002448 A1

(51) International Patent Classification:
E02F 5/10 (2006.01) *E02F 5/12* (2006.01)
E02F 5/06 (2006.01)

(21) International Application Number:
PCT/IB2022/056794

(22) International Filing Date:
22 July 2022 (22.07.2022)

(25) Filing Language: Italian

(26) Publication Language: English

(30) Priority Data:
102021000019700 23 July 2021 (23.07.2021) IT

(71) Applicant: **SAIPEM S.P.A.** [IT/IT]; Via Luigi Russolo, 5, 20138 Milano (IT).

(72) Inventors: **SERENA, Alberto**; c/o SAIPEM S.P.A., Via Luigi Russolo, 5, 20138 Milano (IT). **LAZZARIN, Diego**; c/o SAIPEM S.P.A., Via Luigi Russolo, 5, 20138 Milano (IT).

(74) Agent: **LEIHKAUF, Steffen Falk** et al.; c/o Jacobacci & Partners S.p.A., Via Senato, 8, I-20121 Milano (IT).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH,

(54) Title: ASSEMBLY AND METHOD FOR TRENCHING UNDERWATER CABLES

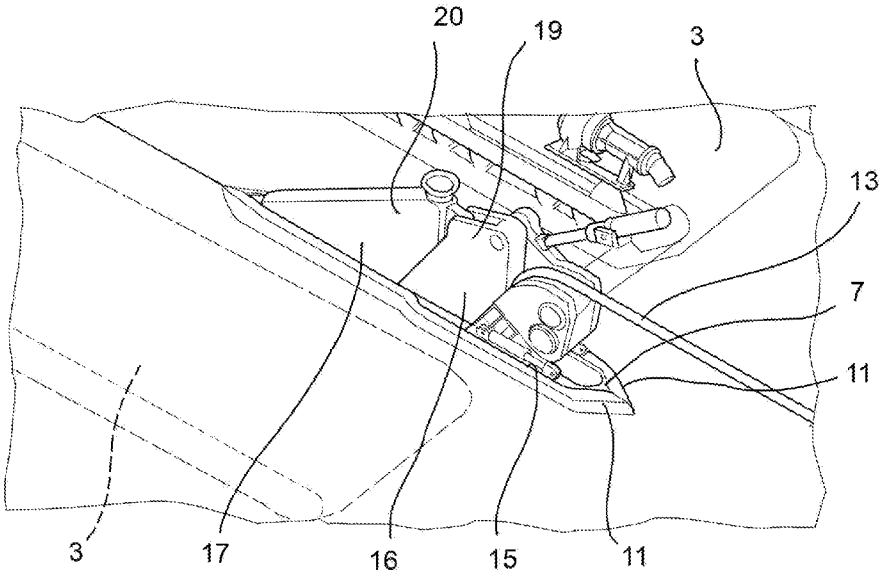

FIG. 5

(57) Abstract: An assembly (1) for trenching underwater cables, comprising a cutting and lifting device (7) for cutting and lifting at least one seabed clod (11) from the seabed (4) avoiding this seabed clod (11) from separating from the remaining part of the seabed (4) but freeing up an excavation path (P) adapted to create a trench (6); an excavation device (5) for excavating the seabed (4) where the at least one seabed clod (11) has been cut and lifted to form said trench (6) producing excavated material; a depression device (19), adapted to guide a cable (13) which is to be trenched in said trench (6) for laying it in said trench (4); a suction device (18) for sucking up said excavated material; a diffusion device (20) for distributing said excavated material and filling said trench (6) once said cable (13) has been laid on the bottom; a recirculation device (39) which collects the excavated material from said suction device (18) and sends it to said diffusion device (20) so as to isolate said excavated material inside said trench (6) forming a closed circuit for the excavated

WO 2023/002448 A1

[Continued on next page]

TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(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))*

material which, having been collected in the formation of the trench (6), returns to the trench (6); a device for restoring the at least one seabed clod (11) in the site thereof by closing said trench (6) at the top and preserving the area above said seabed clod (11) avoiding the dispersion of said excavated material outside said trench (6).

"Assembly and method for trenching underwater cables"

***

DESCRIPTION

[0001]. Field of the invention

[0002]. The present invention relates to an assembly for trenching underwater cables, and to a method for trenching underwater cables.

[0003]. In particular, the present invention relates to an assembly for trenching underwater cables with low environmental impact. Even more particularly, the invention relates to an assembly for excavating a trench preserving the soil surface, avoiding marine sedimentation, in particular, but not exclusively, for application on Posidonia-rich seabeds, but with further general applications in fields in which the environmental impact is to be reduced.

[0004]. Background art

[0005]. Posidonia, and generally aquatic plants to which Posidonia pertains, are autotrophic plants having a stem, roots, leaves, fruits, and flowers which synthesize the organic substances extracted from the soil by photosynthesis. For this reason, they proliferate on seabeds between 1 and 30 meters where light is still present.

[0006]. The ecosystem balance is important for other animal species and the action of humans, climate change, slow reproduction and slow growth have led such plants to a risk of uncontrolled reduction of their presence. For this and other reasons, in particular due to an

increased environmental awareness, there is now a specific protection even through national and international standards.

[0007]. In the specific case of Posidonia, the active part of the plant in the soil comes from horizontal and vertical rhizomes, which adapt the height of the plant to the gradual sedimentation process of the seabed, i.e., the bottom of the water body or bed of the water body. The result is a formation referred to as "matte" consisting of intertwined layers of rhizomes and roots of old plants.

[0008]. If a trench in a seabed needs to be created, one problem is linked to the uncertainty of the soil which, from its basic components, sand, silt and clay, forms several webs, which are more or less cohesive, dense, and hard structures.

[0009]. The knowledge of the soil and the reconnaissance data thereon are often limited. Furthermore, the mechanisms for balancing the soil of the seabed (and not only) are often explained by complex mechanical (sand), chemical (clay) and hydraulic models since the particles are also subjected to interstitial pressures by water particles, and therefore the soil subsidence is explained by "cut", "flow", "rip" and "shave" mechanisms adapted on a case-by-case basis to experimental tests, and therefore there are many types of work equipment, tools, and methods: rotary machines, plows, pressure water jets, explosives, etc.

[0010]. When excavating and trenching a cable, the trench section can be narrow. In the specific case of a low environmental impact excavation, the interactions of the excavation machine with the soil surface need to be reduced.

[0011]. In order to create a trench, for example, it is known to use of excavation tools such as plows with a vibrating vertical bulkhead, or chains or wheels having milling elements.

[0012]. Solutions of this type are known for example from US3857250A, EP0056778A1, FR2660494A1, EP0088190A1, US2014154014A1 and EP0117038A1.

[0013]. In the specific case of chain and wheel milling machines, the milling wheel or chain can have an upwards rotation (known as "up-milling") which tends to pull the chain under tension, pushing the cutting side of the chain into the soil. Since the chain is forced into the soil during the work, the excavation machine tends to rotate. Excavation machines with an upwards rotation thus have a configuration with excavation tools placed on the rear side. In this case, the support surface extends on the front part of the machine, and since the shear force tends to make the machine "strike", the shear force tends to make the excavation chain "collapse". The machine must provide an additional pull in order to overcome such a downwards force in addition to the action for moving the cutting front.

[0014]. On the contrary, when the rotation is applied downwards ("down-milling"), the force applied by the chain is directed downwards, therefore the reaction of the soil "lifts" the machine. From the static equilibrium it is apparent that the chain tends to push the machine forwards and out of the trench. Therefore, the machine must be heavy and balanced enough and requires a lower traction instead of the upwards one.

[0015]. In terms of excavation performance on hard soil, the most

convenient solution is the "up-milling" one. The "down-milling" solution can be applied in a new configuration with excavation equipment placed on the front side, a compromise between performance and respect for the environment on not particularly hard soils.

[0016]. Furthermore, the excavation is affected by the direction of the material removed which, in an upwards rotation, is pushed out of the trench, and vice versa in a downwards rotation is pushed into the trench.

[0017]. In particular, the down-milling excavation solution is almost never used because it implies a higher machine weight, weighing on the interface with the soil. Moreover, the material removal takes place more easily as it is brought to the surface by the chain itself, without needing to suck it up from the trench bottom (which happens in down-milling).

[0018]. Furthermore, there are substantial direction control problems (tracks or individual wheels) which, in order to avoid situations of wheels rubbing against the soil, require machine solutions with torque control traction, where tracks are not suitable.

[0019]. Therefore, a need is felt to suggest an assembly for trenching underwater cables having a limited environmental impact especially on soils where there are aquatic plants or algae.

[0020]. Solution

[0021]. It is an object of the present invention to overcome the drawbacks of the prior art and provide a solution to the need to provide a suitable assembly for laying underwater cables with low environmental impact.

[0022]. This and other objects are achieved by an assembly according to claim **1**, as well as a method for trenching underwater cables according to claim **9**.

[0023]. Some advantageous embodiments are the subject of the dependent claims.

[0024]. Drawings

[0025]. Further features and advantages of the device, assembly, and method will become apparent from the following description of preferred embodiments thereof, given by way of non-limiting examples, with reference to the accompanying drawings, in which:

[0026]. - figure 1 shows an axonometric view of an assembly for trenching underwater cables in order to excavate a trench in a seabed, in which a first layer has aquatic plants or algae to be preserved; in particular, part of the seabed is depicted in phantom in order to show the details of the components and devices present in the assembly;

[0027]. - figure 2 shows a side view of the assembly in figure 1, in particular it shows a view of the trench excavated by the assembly and how it is directly filled with the excavated material from the excavation by the diffusion device of the assembly;

[0028]. - figure 3 shows an axonometric view of the assembly in figure 1 in which the components of the assembly placed in the foreground are depicted in phantom to show the details in the background; furthermore, the seabed is also depicted in phantom;

[0029]. - figure 4 shows an axonometric view of a detail of the assembly in figure 1 and in particular of the rotary excavation device and the plow for lifting seabed clods;

[0030]. - figure 5 shows an axonometric view of the front or advancement part of the assembly in figure 1 in which the components of the assembly placed in the foreground are depicted in phantom to show the details placed in the background; in this case, it is highlighted how the plow lifts and guides two seabed clods, although cut vertically without separating them from the adjacent seabed clods and without overturning them and how they close up again upon the passage of the assembly;

[0031]. - figure 6 shows an axonometric view of the rear part of the assembly in figure 1 in which the components of the assembly placed in the foreground are depicted in phantom to show the details placed in the background; in this case, it is highlighted how the two seabed clods close up again upon the passage of the assembly;

[0032]. - figure 7 shows an axonometric view of the rear side of an assembly according to a further embodiment, similar to that in figure 1, in which in addition there is a restoration element comprising a seeding wheel and tanks for the seeding mixture;

[0033]. - figure 8 shows an axonometric view of an enlarged detail of the assembly in figure 7, highlighting the restoration element;

[0034]. - figure 9 shows an axonometric view from the rear side of an assembly according to yet another embodiment, similar to that in figure 1, in which in addition a restoration element is provided, comprising a carriage which supports a seed mat-holder drum of the geotube type;

[0035]. - figure 10 shows an axonometric view of an enlarged detail of the assembly in figure 9, highlighting the restoration element.

[0036]. Description of some preferred embodiments

[0037]. According to a general embodiment, an assembly 1 for trenching underwater cables comprises a cutting and lifting device 7 for cutting and lifting at least one seabed clod 11 from the seabed 4, avoiding this seabed clod 11 from separating from the remaining part of the seabed 4 but freeing up an excavation path P adapted to create a trench 6.

[0038]. Said assembly further comprises an excavation device 5 for excavating the seabed 4 where the at least one seabed clod 11 has been cut and lifted to form said trench 6 producing excavated material.

[0039]. Said assembly further comprises a depression device 19, adapted to guide a cable 13 which is to be trenched in said trench 6 for laying it in said trench 4.

[0040]. Said assembly further comprises a suction device 18 for sucking up said excavated material.

[0041]. Said assembly further comprises a diffusion device 20 for distributing said excavated material and filling said trench 6 once it has been laid on the bottom of said trench 13 so as to isolate said excavated material below the bed of the water body without contaminating the sea environment.

[0042]. Said assembly further comprises a recirculation device 39 which collects the excavated material from said suction device 18 and sends it to said diffusion device 20 so as to isolate said excavated material inside said trench 6 forming a path for the excavated material which, having been collected in the formation of the trench 6, returns

to the trench 6.

[0043]. According to an embodiment, said assembly further comprises a device for restoring the at least one seabed clod 11 in the site thereof by closing said trench 6 at the top and preserving the area above said seabed clod 11 avoiding the dispersion of said excavated material outside said trench 6.

[0044]. According to an embodiment, an assembly 1 for trenching underwater cables comprises a support structure 2.

[0045]. Said assembly 1 further comprises at least one rolling device 3 connected to the support structure 2 for the movement by motorized or idle rolling of the assembly 1 on a seabed 4 along an excavation path P locally having an advancement direction F, keeping said support structure 2 raised from said seabed 4.

[0046]. Said assembly 1 further comprises at least one rotary excavation device 5 adapted to mill said seabed 4 creating a trench 6, when said assembly 1 travels in an advancement direction F.

[0047]. Said at least one rotary excavation device 5 is supported at said support structure 2.

[0048]. Said assembly 1 further comprises at least one plow 7.

[0049]. Advantageously, said at least one plow 7 is arranged at the front, or at the front and contiguous, or at the front and operatively connected to, with respect to, i.e., it precedes in the advancement direction F, said at least one rotary excavation device 5.

[0050]. Said at least one plow 7 is shaped so as to cut and lift, at least on one side, at least one seabed clod 11 by a predefined

depth and width without separating it completely from the seabed 4, freeing up an underlying seabed layer which can be attacked and milled by said at least one rotary excavation device 5 for creating said trench 6 avoiding said at least one seabed clod 11 from being milled.

[0051]. According to an embodiment, said at least one plow 7 comprises at least one coulter 8, at least one plowshare 9, and at least one moldboard 10.

[0052]. Said coulter 8 is adapted to cut, in the vertical direction, said at least one seabed clod 11 from the seabed 4.

[0053]. Said at least one plowshare 9 is adapted to cut in the horizontal direction said at least one seabed clod 11 at a predefined depth from the seabed 4.

[0054]. Said at least one moldboard 10 is adapted to lift said at least one seabed clod 11 without separating it from the seabed 4.

[0055]. According to an embodiment, said at least one plow 7 comprises a coulter 8, two plowshares 9, and two moldboards 10. Said coulter 8 is adapted to cut, in the vertical direction, said at least one seabed clod 11 from the seabed 4.

[0056]. Said two plowshares 9 are adapted to cut in the horizontal direction two seabed clods 11 at a predefined depth from the seabed 4.

[0057]. Said two moldboards 10 are adapted to lift said at least two seabed clods 11 without separating them from the seabed 4 for sliding them in their entirety at the sides of said at least one rotary excavation device 5.

[0058]. According to an embodiment, said at least one plow 7 is shaped so as to cut the at least one seabed clod 11 avoiding it from being completely separated from the seabed 4 and avoiding it from being overturned.

[0059]. According to an embodiment, said at least one plow 7 is placed at least partially straddling said at least one rotary excavation device 5.

[0060]. According to an embodiment, said at least one plow 7 comprises a coulter 8, two plowshares 9, and two moldboards 10.

[0061]. Said two moldboards 10 extend as a continuation at the sides of said at least one rotary excavation device 5.

[0062]. According to an embodiment, said assembly 1 further comprises at least one suction device 18, adapted to suck up said excavated material milled by said at least one rotary excavation device 5.

[0063]. According to an embodiment, said assembly 1 comprises at least one depression device 19, adapted to guide a cable 13 which is to be trenched in said trench 6 on the bottom of said trench 6.

[0064]. According to an embodiment, said assembly 1 further comprises at least one diffusion device 20, operatively connected to said at least one suction device 18 and adapted to distribute said excavated material for filling said trench 6 once said cable 13 has been laid on the bottom, so as to isolate said excavated material below the bed of the water body without contaminating the sea environment.

[0065]. According to an embodiment, said assembly 1 further comprises at least one suction device 18 associated with said at least one rotary excavation device 5, at least one depression device 19 supported at said at least one rotary excavation device 5, at least one diffusion device 20 supported at said at least one depression device 19.

[0066]. Said at least one plow 7 is supported at said at least one rotary excavation device 5.

[0067]. According to an embodiment, said at least one rotary excavation device 5 is supported rotatably, from a raised position to a maximum excavation position, at said at least one support structure 2.

[0068]. At least one suction device 18 is associated with said at least one rotary excavation device 5.

[0069]. At least one depression device 19 is rotatably supported at said at least one rotary excavation device 5.

[0070]. At least one diffusion device 20 is supported rotatably at said at least one depression device 19.

[0071]. Said at least one plow 7 is supported rotatably from a raised position from said seabed 4 at a maximum depth, to said at least one rotary excavation device 5.

[0072]. According to an embodiment, said assembly 1 comprises at least one excavation actuator 21 interposed between said at least one support structure 2 and said at least one rotary excavation device 5.

[0073]. According to an embodiment, said at least one excavation

actuator 21 is commanded in a controlled manner to define the relative position between said at least one rotary excavation device 5 and said at least one support structure 2.

[0074]. According to an embodiment, said assembly 1 comprises at least one clod cutting actuator 22 interposed between said at least one plow 7 and said at least one rotary excavation device 5.

[0075]. According to an embodiment, at least one clod cutting actuator 22 is commanded in a controlled manner to define the relative position between said at least one plow 7 and said at least one rotary excavation device 5.

[0076]. According to an embodiment, said assembly 1 further comprises underwater ballast elements 24.

[0077]. According to an embodiment, said at least one moldboard 10 comprises at least one clod sliding surface 12 which continues along an entire flank of said assembly 1 for supporting and guiding said seabed clod 11 beyond said assembly 1 and allowing the seabed clod 11 to rest again in its place upon the passage of said assembly 1.

[0078]. According to an embodiment, said at least one moldboard 10 comprises at least one clod sliding surface 12 which continues along an entire flank of said assembly 1 for supporting and guiding said seabed clod 11 beyond said assembly 1 and allowing the seabed clod 11 to rest again in its place once a cable 13 has been laid in said trench 6 and said trench 6 has been filled again.

[0079]. According to an embodiment, said at least one moldboard 10 comprises at least one clod sliding surface 12 which continues along

an entire flank of said assembly 1 and comprises surfaces of the outer fairing(s) of said at least one rotary excavation device 5, said at least one depression device 19, and said at least one diffusion device 20.

[0080]. According to an embodiment, said at least one moldboard 10 comprises at least one clod sliding surface 12 inclined at least towards said at least one rotary excavation device 5 so as to avoid said seabed clod 11 from being completely separated from the seabed 4 and avoid it from being completely overturned.

[0081]. According to an embodiment, said at least one clod sliding surface 12 is a set of surfaces 12, 15, 16, 17 adjacent to one another which form one or more fairings 14 supported at said support structure 2 and extending along the entire extension of said assembly 1, passing by the side of said at least one rotary excavation device 5.

[0082]. According to an embodiment, said at least one clod sliding surface 12 is a set of surfaces 12, 15, 16, 17 adjacent to one another which form at least one fairing 14 supported at said support structure 2 and extending along the entire extension of said assembly 1, passing between said at least one rotary excavation device 5 and said at least one rolling device 3.

[0083]. According to an embodiment, said at least one clod sliding surface 12 is a set of surfaces 12, 15, 16, 17 adjacent to one another which form at least one fairing 14 supported at said support structure 2 and extending along the entire extension of said assembly 1, passing by the side of said at least one rotary excavation device 5, at least

one suction device 18, at least one depression device 19, at least one diffusion device 20.

[0084]. According to an embodiment, said set of surfaces 12, 15, 16, 17 creates a casing or fairing 14 in which the functions of material laying on the soil and backfilling are linked together and the unloading of excavation material outside the trench is avoided, avoiding contact between the excavation material and the external environment above the surface of the seabed 4, and the dispersion of said excavation material.

[0085]. According to an embodiment, said at least one support structure 2 is a structure placed straddling said at least one rotary excavation device 5 bringing said at least one rolling device 3 alongside said at least one rotary excavation device 5.

[0086]. According to an embodiment, said at least one rolling device 3 consists of at least two rolling devices 3 adjacent to each other.

[0087]. Said at least one support structure 2 is a structure placed straddling said at least one rotary excavation device 5 bringing said at least two rolling devices 3 on opposite sides of said at least one rotary excavation device 5.

[0088]. According to an embodiment, said at least one rolling device 3 is at least one track.

[0089]. According to an embodiment, said at least one rolling device 3 is at least one track comprising track shoes 23 of a suitable size for minimizing the impact on the seabed 4 with plants or algae.

[0090]. According to an embodiment, said at least one rolling device

3 is at least one wheel.

[0091]. According to an embodiment, said at least one rolling device 3 is at least one steering wheel.

[0092]. According to an embodiment, said at least one rolling device 3 is at least one wheel of a suitable size for minimizing the impact on the seabed 4 with plants or algae.

[0093]. According to an embodiment, said at least one rolling device 3 is at least one driving rolling device.

[0094]. According to an embodiment, said at least one rolling device 3 is at least one idle rolling device; and wherein said at least one support structure 2 is a structure adapted to be towed.

[0095]. According to an embodiment, said rotary excavation device 5 is a chain which supports milling elements.

[0096]. According to an embodiment, said rotary excavation device 5 is a disc mill or a wheel which supports milling elements.

[0097]. According to an embodiment, said rotary excavation device 5 rotates and creates a cutting movement directed downwards, i.e., towards the bottom of the trench 6.

[0098]. According to an embodiment, said rotary excavation device 5 is commanded in a controlled manner, controlling at least the cutting parameters such as, for example, the rotation speed.

[0099]. According to an embodiment, said assembly 1 is commanded in a controlled manner, controlling at least the excavation path P.

[00100]. According to an embodiment, said assembly 1 further comprises at least one restoration element 25 adapted for planting

the area of seabed 4 affected by the passage of the at least one plow 7 and the at least one rotary excavation device 5.

[00101]. According to an embodiment, said at least one restoration element 25 is a seeder 26.

[00102]. According to an embodiment, said at least one restoration element 25 is a mat planting device 27.

[00103]. According to an embodiment, said at least one restoration element 25 is supported at said support structure 2 and arranged downstream of the at least one rotary excavation device 5, on the opposite side to the at least one plow 7 as the last device of the assembly 1.

[00104]. According to an embodiment, said seeder 26 comprises a seeding wheel 28 adapted to rest on the seabed 4, in particular at least partially above said seabed clod 11 repositioned above said filled trench 11, and freely rotating when dragged by said assembly 1.

[00105]. According to an embodiment, said seeding wheel 28 supports injectors 29 arranged radially, adapted to be gradually inserted into the seabed 4 by an appropriate depth, for example 10 – 20 cm according to the rotation of the wheel.

[00106]. Said injectors 29 are connected to the delivery of a seeding pump 30 which sucks up a solution of seeds and water or other suitable liquid solution from a tank 31.

[00107]. The gradual injection takes place by rotation of the seeding wheel 29 which opens the delivery duct through a slot made

circumferentially or a control system through a slip ring; or an automatic distribution system is provided for managing the injection of the seeding mixture synchronously with the advancement speed of the assembly 1 along the excavation path P, or synchronously with the rotation speed of the seeding wheel 29.

[00108]. According to an embodiment, the mat planting device 27 comprises a seeding carriage 32 connected to the support structure 2 which rotatably supports a seed mat-holder drum 33 onto which a seed mat 37 is rolled.

[00109]. According to an embodiment, said seeding carriage 32 rotatably supports a rocker arm 34 which in turn supports a return roller 35, placed so as to remain raised from the seabed 4, and a laying roller 36 adapted to lay said seed mat 37.

[00110]. According to an embodiment, said rocker arm 34 supports a further soil preparation roller 37 arranged upstream of said laying roller 36.

[00111]. According to an embodiment, said assembly 1 further comprises a turbidity sampling and measurement device 38, adapted to collect samples of sea water close to the assembly and measure the turbidity.

[00112]. Said turbidity sampling and measurement device 38 comprises sensors for measuring the pollution produced in terms of water turbidity.

[00113]. According to an embodiment, said turbidity sampling and measurement device 38 is operatively connected to a control device

for controlling the excavation parameters.

[00114]. The present invention also relates to a method for trenching underwater cables, comprising the steps of

[00115]. cutting and lifting at least one seabed clod 11 from the seabed 4 avoiding it from separating from the remaining part of the seabed 4 but freeing up an excavation path P adapted to create a trench 6;

[00116]. excavating the seabed 4 where the at least one seabed clod 11 has been cut and lifted forming said trench 6 producing excavated material;

[00117]. sucking up said excavated material gradually as it is formed;

[00118]. guiding a cable 13 which is to be trenched in said trench 6 and laying it in said trench 4;

[00119]. collecting the excavated material from said suction device 18 and sending it to a diffusion device 20 forming a path for the excavated material which, having been collected in the formation of the trench 6, returns to the trench 6;

[00120]. distributing said excavated material and filling said trench 6 once said cable 13 has been laid on the bottom of the trench 6 so as to isolate said excavated material inside said trench 6, so as to isolate said excavated material below the bed of the water body without contaminating the sea environment.

[00121]. According to a variant for carrying out the method, there is provided the further step of restoring the at least one seabed clod

11 in the site thereof by closing said trench 6 at the top and preserving the area above said seabed clod 11 avoiding the dispersion of said excavated material outside said trench 6.

[00122]. The present invention also relates to a method for trenching underwater cables 13, comprising the steps of:

[00123]. - moving at least one support structure 2 by rolling on the seabed 4 at least one rolling device 3 which supports said at least one support structure 2 raised from the seabed 4;

[00124]. - providing at least one plow 7 arranged at the front, or at the front and contiguous, or at the front and operatively connected to, i.e., it precedes in the advancement direction F, said at least one rotary excavation device 5;

[00125]. - cutting and lifting on one side with at least one plow 7 at least one seabed clod 11, wherein said plow 7 cuts and lifts said seabed clod 11 by a predefined depth and width without separating it completely from the seabed 4, freeing up an underlying seabed layer which can be attacked and milled by said at least one rotary excavation device 5;

[00126]. - sliding said at least one seabed clod 11 on at least one clod sliding surface 12 which continues along said entire assembly 11;

[00127]. - milling the seabed 4 where said seabed clod 11 was cut and lifted, creating a trench 6;

[00128]. - laying a cable 13 in said trench 6;

[00129]. - filling said trench 6;

[00130]. – continuing to accompany said seabed clod 11, sliding it on said clod sliding surface 12, beyond said assembly 1;

[00131]. – allowing the seabed clod 11 to rest again in its place once said cable 13 has been laid in said trench 6 and said trench 6 has been filled again.

[00132]. According to a variant of the method for trenching a cable, there is provided the further step in which the milled excavated material obtained with said rotary excavation device 5 is sucked up and diffused into the trench, once the cable 13 has been laid, in order to fill the trench 6.

[00133]. According to a variant of the method for trenching a cable, there is provided the further step, before that of milling a trench, in which with said at least one plow 7 the seabed 4 is cut into two continuous seabed clods 11 and said seabed clods 11 are lifted without breaking them and without overturning them, uncovering an excavation path P free from these seabed clods 11 and ready to be milled in a trench 7.

[00134]. According to a variant of the method for trenching a cable, there is provided the further step in which a restoration element 25 is provided, placed downstream of said assembly 1 and the seabed 4 is seeded in the area affected by the plow 7 and the rotary excavation device 5.

[00135]. In order to meet specific, contingent needs, those skilled in the art can make several changes and adaptations to the above-described embodiments, and can replace elements with others which are

functionally equivalent, without however departing from the scope of the following claims.

[00136]. Some exemplary embodiments of the assembly according to the invention are provided below.

[00137]. According to an embodiment, the rolling device 3 can comprise a towed carriage or a tractor device or briefly a tractor.

[00138]. In case of the towed carriage, the assembly 1 is towed and the traction can be provided, for example, by a winch which pulls the assembly towards a distant stake. The origin of the force is on the winch and the reaction is far from the soil. Otherwise, the towing action can take place by a tugboat and then transferred to the desired point by ropes. In these cases, the reaction is not transmitted by the drive wheels or tracks, and the rotary excavation device 5 is thus housed on a towed carriage. In this case, the wheels or tracks are only used to better direct the trajectory of the vehicle. Thereby, the wheels/tracks only transmit the vertical force (i.e., the weight of the vehicle and any excavation forces) to the soil and not the horizontal component due to traction: the result is a less stressful action on the soil to be preserved.

[00139]. If the assembly is a tractor, the rotary excavation device 5 is pushed forward due to a reaction close to the device itself, e.g., by means of pulling belts or drive wheels.

[00140]. In the support structure 2, the force is the result of the vertical reaction (vertical weight force) and the pulling force (horizontal force). Therefore, with the same vehicle weight, the

impact on the soil also depends on the magnitude of the pulling force.

[00141]. In the tractor, the specific pressure of the assembly, determined by its weight divided by the support surface, and the pulling force (horizontal shear force that the wheels or tracks develop on the soil) determine possible damage to the soil, which can only be minimized by a large support surface of the tracks, and by a uniform distribution (balancing). Furthermore, the tractor requires steering control. In case of drive wheels, which must be distributed along the length, the weight of the machine which weighs on the rotary excavation device 5 but also on the wheels or tracks, requires a low specific weight, therefore a remarkable length.

[00142]. As for the depression device 19, it allows the cable 13 to be pressed on the bottom of the excavated trench 11. In an extended sense, the depression device is the shaped component that guides the cable 13 from the bottom surface of the trench 6 through the surface itself of the component and/or through rollers that maintain the desired curvilinear line thereof.

[00143]. As for the suction device 18, even if the excavated trench may be narrow and thus able to "close up again" upon the passage of the machine, and although the layback of the cable is very small (the depression device 19 accompanies the cable on the bottom of the trench 6, thus the walls of the trench itself remain easily stable upon the passage of the depression device), and even if the excavated material amount is relatively small, the material is sucked up avoiding the generation of turbidity in water and then sent directly to the

diffusion device to be put back in the trench 6 for filling it.

[00144]. In general, the working conditions of the assembly 1 are those of a not excessively hard soil, which lends itself to not particularly aggressive cutting actions.

[00145]. By virtue of the solutions suggested, it is possible to achieve the following advantages:

[00146]. - low environmental impact: water turbidity reduction, little abrasion of the soil surface, quicker recovery of damaged plants;

[00147]. - possibility to use a rotary excavation device 5, e.g., a mill, with a non-conventional chain rotation direction of "down-milling" rather than "up-milling"; thereby, the tension of the tools carried by the chain, the angle and tension of which varies during rotation, provides a less invasive action on the soil;

[00148]. - absence of excavated material brought to the soil level, but conveyed to the bottom of the trench 6, thus minimizing the dispersion of material of suitable size to cover the trench 6 again, and which could be dispersed in water in the form of turbidity;

[00149]. - lower vertical force (downwards) on wheels or tracks which thus "stress" the grassy layer (plants, algae) in a less extent;

[00150]. - balancing of the assembly (of the vehicle) which is heavier, moving the excavation tool into the front part of the vehicle itself, thus also improving the working conditions in terms of reducing the environmental impact because the excavation takes place at the front leaving space for the support elements which are placed

downstream;

[00151]. - new static balancing of the forces and thus a new position of the excavation tool which is placed in the front part while improving the support with a better distribution on the soil;

[00152]. - wide tracks or wide wheels which reduce the pressure exerted on the soil and thus optimize friction reducing the impact on the soil on this type of soils.

[00153]. Further variants of the invention are provided below.

[00154]. According to a further embodiment, in order to reduce the environmental impact, the assembly 1 for excavating trenches 6 while laying a cable 13 on the bottom of such a trench 6 comprises:

[00155]. - an excavation element 5, which comprises tools dragged by a chain or wheel and with upwards or downwards rotation,

[00156]. - a traction element 3, which comprises a traction member,

[00157]. - a carriage connected to the excavation element and which comprises a plow 7, a cable guiding depression element 19 and a diffusion element 20 of the system for recirculating the material removed by the excavation element 5 and underwater ballast elements 24.

[00158]. According to an embodiment, the plow 7 makes a temporary cut on the soil surface, or seabed 4, upstream of the cutting tools; such a plow collaborating with the cable guiding depression element 19 and the diffusion element 20 of the recirculation system, so that such a temporary cut remains open and the soil continuous, and facilitating the closure of such a cut downstream of the last element

which is the diffusion element 20 of the system for recirculating the material removed by the excavation tools 5.

[00159]. According to an embodiment, the traction element is included in the carriage, for example in the case of highly wide tracks for minimizing the vertical pressure on the soil and provided with plastic or rubbery shoes so as not to have a negative effect on the layer of plants or algae. The sliding blocks can be replaced by rubbery mats to further reduce the impact on the soil of the interaction forces between the machine and the soil itself.

[00160]. As an alternative to tracks, drive wheels, possibly steering wheels, or a front winch towing the carriage, or the support structure 2, e.g., by a cable connected to a fixed point, anchors or stakes placed in front along the excavation corridor at an appropriate distance, can be used to reduce the horizontal traction force of the assembly, or machine, which would otherwise be detached from the soil. Thereby, the contact of the machine with the soil only develops vertical forces (the horizontal pulling force acts on the winch through the anchor lines) significantly reducing the impact of the locomotion system on the soil.

[00161]. In further embodiments, the traction element is not included in the carriage, or support structure; for example, a tugboat connected to a pulling rope which tows the carriage or a winch placed outside the carriage itself or, alternatively, thereon.

[00162]. As for the filling of soil back in the trench, or backfilling, this takes place by a diffusion device 20 as wide as the

trench itself and applied directly inside the trench, connected to the depression device 19 and therefore to the plow 7; thereby, a casing is created in which the functions of material laying on the soil and backfilling are linked together and the unloading of excavation material outside the trench 6 is avoided, avoiding contact with the external environment at the surface (above seabed level) and related dispersions.

[00163]. The material is sucked up directly onto the bottom of the trench 6 straight downstream of the excavation chain 5, through a suction duct 18 incorporated into the depression device 19; the suction pump can be positioned on board the assembly, or vehicle (above the seabed) or, alternatively, integrated into the suction duct 18 inside the trench 6, depending on the size of the pump(s) and the section of the trench 6.

[00164]. Such a combination of elements (plow 7, excavation elements 5, depression device 19, diffusion device 20) immersed in the trench also operates in the case of an excavation chain 5 which works in the "up-milling" configuration, since only the suction of the pump is positioned at the upper part of the chain 5 with respect to the trench 6, at the level of seabed 4.

[00165]. The diffusion device 20 consists of an increasing passage section in order to reduce the speed of the fluid (milled excavated material) at the outlet and minimize the generation of turbidity and particles in suspension; the diffusion device 20 can further be provided with appropriate partitions which channel the flows therein

to reduce this polluting phenomenon.

[00166]. The disintegrating action of the excavation chain 5 on the excavation front itself is cancelled by the plow 7 placed immediately in front of the excavation chain 5 itself. The shape of the plow 7 is such as to cut the soil into two continuous clods 11 containing the roots of the plants/algae before they are cut and lifting and moving them without breaking them. The soil is cut by a vertical blade according to a longitudinal line and then cut horizontally at a desired depth depending on the type of algae, to detach it from the underlying soil; then, the clod 11 is lifted and slid resting on two inclined surfaces 12 of the plow 7, surfaces 16 of the depression device 19, and surfaces 17 of the diffusion device 20 which run along the entire length of the assembly 1.

[00167]. Once the assembly 1, the machine, has passed with all of the excavation tool thereof, the two clods 11 close again onto the seabed 4 cut by the excavation chain 5 directly above the backfilling material unloaded by the diffusion device 20.

[00168]. The plow 7 can have a single plowshare 9 and moldboard 10; in this case, a clod 11 is generated which slides on only one side of the assembly, or can be double (two plowshares 9 and two moldboards 10) and in this case two clods 11 are generated which slide on both sides of the assembly 1 without changing the meaning of the present invention.

[00169]. According to an embodiment, the rotary excavation device 5 is of the down-milling type, hence a device that excavates, for example

mills, the soil with a cutting movement towards the bottom of the trench 6. In this case, the suction device 18 will be arranged so as to suck up the excavated material at the base (bottom) or close to the base of the trench, isolating the excavated material below the bed of the water body by collecting the excavated material and recirculating it in the trench 6 downstream of the cable laying devices, i.e., the depression device 19, so as to isolate said excavated material below the bed of the water body without contaminating the sea environment. Alternatively, it is possible for the rotary excavation device 5 to be of the up-milling type, hence a device which excavates, for example mills, the soil with a cutting movement towards the exterior of the trench 6. In this case, the suction device 18 will be arranged so as to suck up the excavated material at the top or close to the top of the trench, but still isolating the excavated material by collecting the excavated material and recirculating it in the trench 6 downstream of the cable laying devices, i.e., the depression device 19, so as to isolate said excavated material below the bed of the water body without contaminating the sea environment.

[00170]. LIST OF REFERENCE SIGNS

1 assembly for trenching underwater cables
2 support structure
3 rolling device
4 seabed
5 rotary excavation device
6 trench
7 plow
8 coulter
9 plowshare
10 moldboard
11 seabed clod
12 clod sliding surface
13 cable
14 fairing
15 sliding surface of excavation and suction device
16 sliding surface of depression device
17 sliding surface of diffusion device
18 suction device
19 depression device
20 diffusion device
21 excavation actuator
22 clod cutting actuator
23 track shoes
24 underwater ballast elements
25 restoration element
26 seeder
27 mat planting device
28 seeding wheel
29 injectors
30 seeding pump
31 tank
32 geotube seeding carriage
33 seed mat-holder drum
34 rocker arm
35 return roller
36 laying roller
37 soil preparation roller
38 sampling and turbidity measurement device
39 excavated material recirculation device

P excavation path
F advancement direction

CLAIMS

1. An assembly (1) for trenching underwater cables, comprising

a cutting and lifting device (7) for cutting and lifting at least one seabed clod (11) from the seabed (4) avoiding this seabed clod (11) from separating from the remaining part of the seabed (4) but freeing up an excavation path (P) adapted to create a trench (6);

an excavation device (5) for excavating the seabed (4) where the at least one seabed clod (11) has been cut and lifted to form said trench (6) producing excavated material;

a depression device (19), adapted to guide a cable (13) which is to be trenched in said trench (6) for laying it in said trench (4);

a suction device (18) for sucking up said excavated material;

a diffusion device (20) for distributing said excavated material and filling said trench (6) once said cable (13) has been laid on the bottom;

a recirculation device (39) which collects the excavated material from said suction device (18) and sends it to said diffusion device (20) so as to isolate said excavated material inside said trench (6) forming a path for the excavated material which, having been collected in the formation of the trench (6), returns to the trench (6);

characterized in that

said cutting and lifting device comprises at least one plow (7);

and wherein said at least one plow (7) is arranged at the front, or at the front and contiguous, with respect to, and precedes in the advancement direction (F), said at least one rotary excavation device

(5); and wherein

said at least one plow (7) is shaped so as to cut and lift, at least on one side, at least one seabed clod (11) by a predefined depth and width without separating it completely from the seabed (4), freeing up an underlying seabed layer which can be attacked and milled by said at least one rotary excavation device (5) for creating said trench (6) avoiding said at least one seabed clod (11) from being milled.

2. An assembly (1) according to claim 1, wherein

said excavation device comprises at least one rotary excavation device (5) adapted to mill said seabed (4) creating a trench (6), when said assembly (1) travels along an advancement direction (F).

3. An assembly (1) according to claim 1, wherein

said at least one plow (7) comprises at least one coulter (8), at least one plowshare (9), and at least one moldboard (10); wherein

said coulter (8) is adapted to cut, in the vertical direction, said at least one seabed clod (11) from the seabed (4); and wherein

said at least one plowshare (9) is adapted to cut in the horizontal direction said at least one seabed clod (11) at a predefined depth from the seabed (4); and wherein

said at least one moldboard (10) is adapted to lift said at least one seabed clod (11) without separating it from the seabed (4);

and wherein

said at least one plow (7) is shaped so as to cut the at least one

seabed clod (11) avoiding it from being completely separated from the seabed (4) and avoiding it from being overturned,

and wherein

said at least one moldboard (10) extends as a continuation at the sides of said at least one rotary excavation device (5) for supporting said at least one seabed clod (11) in a raised manner.

4. An assembly (1) according to claim 1 or 2 or 3, wherein

said at least one moldboard (10) comprises at least one clod sliding surface (12) which continues along an entire flank of said assembly (1) for supporting and guiding said seabed clod (11) beyond said assembly (1) and allowing the seabed clod (11) to rest again in its place upon the passage of said assembly (1).

5. An assembly (1) according to claim 4, wherein

said at least one clod sliding surface (12) is a set of surfaces (12, 15, 16, 17) adjacent to one another which form one or more fairings (14) supported at a support structure (2) and extending along the entire extension of said assembly (1), passing by the side of said at least one rotary excavation device (5).

6. An assembly according to any one of claims 2 to 5 when dependent on claim 2, wherein

said rotary excavation device (5) is a chain which supports milling elements;

or wherein said rotary excavation device (5) is a disc mill or a wheel which supports milling elements;

and/or wherein

said rotary excavation device (5) rotates and creates a cutting movement directed downwards, i.e., towards the bottom of the trench (6).

7. An assembly according to any one of claims 1 to 6, wherein said assembly (1) further comprises a device for restoring the at least one seabed clod (11) in the site thereof by closing said trench (6) at the top and preserving the area above said seabed clod (11) avoiding the dispersion of said excavated material outside said trench (6);

or wherein

said assembly (1) further comprises at least one restoration element (25) adapted to plant the area of seabed (4) affected by the passage of the at least one plow (7) and the at least one rotary excavation device (5).

8. An assembly according to any one of claims 1 to 7, wherein said assembly (1) further comprises a turbidity sampling and measurement device (38), adapted to collect samples of sea water close to the assembly and measure the turbidity; and wherein

said turbidity sampling and measurement device (38) comprises sensors for measuring the pollution produced in terms of water turbidity;

and/or wherein

said turbidity sampling and measurement device (38) is operatively connected to a control device for controlling the excavation parameters.

9. A method for trenching underwater cables, comprising the steps of cutting and lifting at least one seabed clod (11) from the seabed (4) avoiding it from separating from the remaining part of the seabed (4) but freeing up an excavation path (P) adapted to create a trench (6);

excavating the seabed (4) where the at least one seabed clod (11) has been cut and lifted forming said trench (6) producing excavated material;

sucking up said excavated material gradually as it is formed;

guiding a cable (13) which is to be trenched in said trench (6) and laying it in said trench (4);

collecting the excavated material from said suction device (18) and sending it to a diffusion device (20) forming a path for the excavated material which, having been collected in the formation of the trench (6), returns to the trench (6);

distributing said excavated material and filling said trench (6) once said cable (13) has been laid on the bottom of the trench (6) so as to isolate said excavated material inside said trench (6), so as to isolate said excavated material below the bed of the water body without contaminating the sea environment.

10. A method for trenching underwater cables (13) according to claim 9, comprising the steps of:

- once said at least one seabed clod (11) has been cut and lifted, sliding said at least one seabed clod (11) on at least one clod sliding surface (12);

- continuing to accompany said seabed clod (11), sliding it on said clod sliding surface (12), beyond said excavation;

- allowing the seabed clod (11) to rest again in its place once said cable (13) has been laid in said trench (6) and said trench (6) has been filled again.

11. A method according to claim 9 or 10, wherein there are provided the further steps of

restoring the at least one seabed clod (11) in the site thereof by closing said trench (6) at the top and preserving the area above said seabed clod (11) avoiding the dispersion of said excavated material outside said trench (6);

or the step of

providing a restoration element (25) downstream of said assembly (1); seeding the seabed (4) in the area affected by the plow (7) and the rotary excavation device (5).

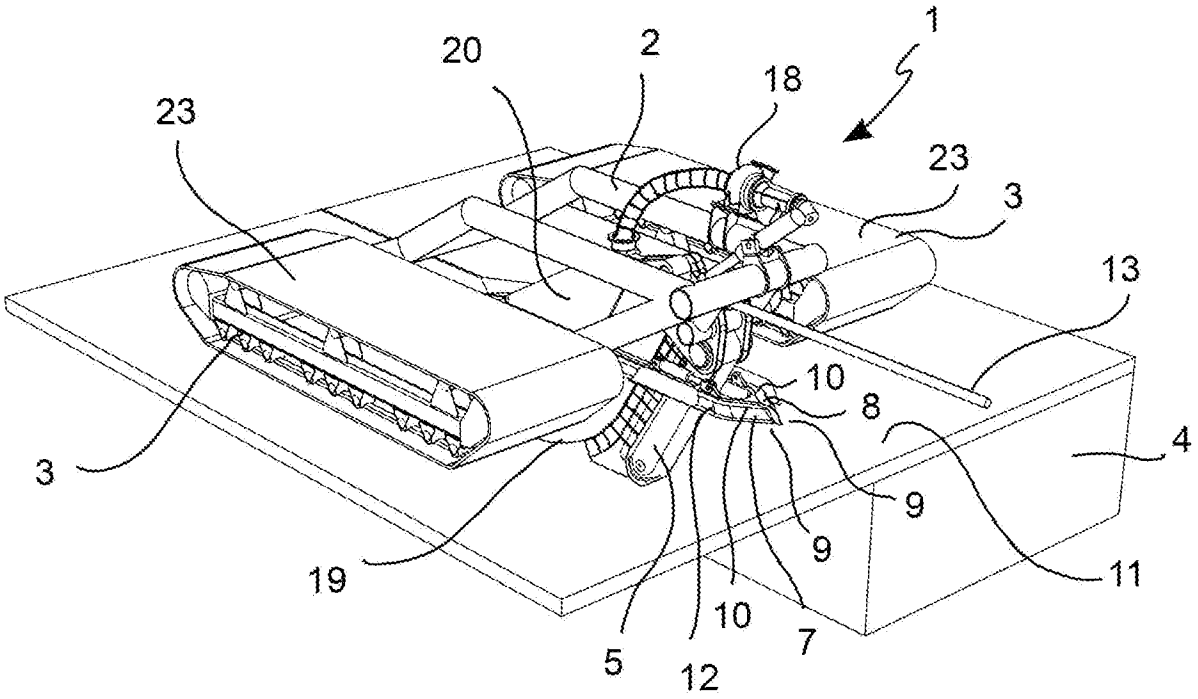
1
20
2
18
23
23
3
13
10
8
4
3
9
9
11
19
10
7
5
12

FIG. 1

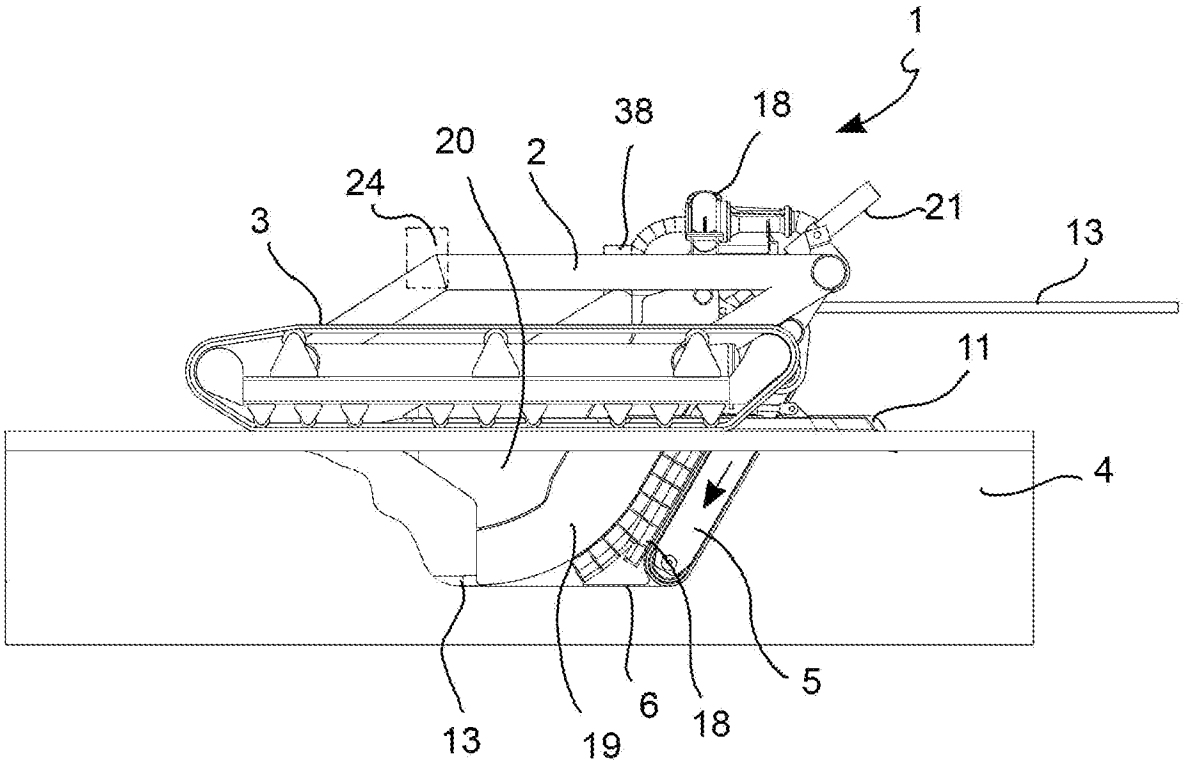
1
38
18
20
2
24
21
3
13
11
4
5
13
19
6
18

FIG. 2

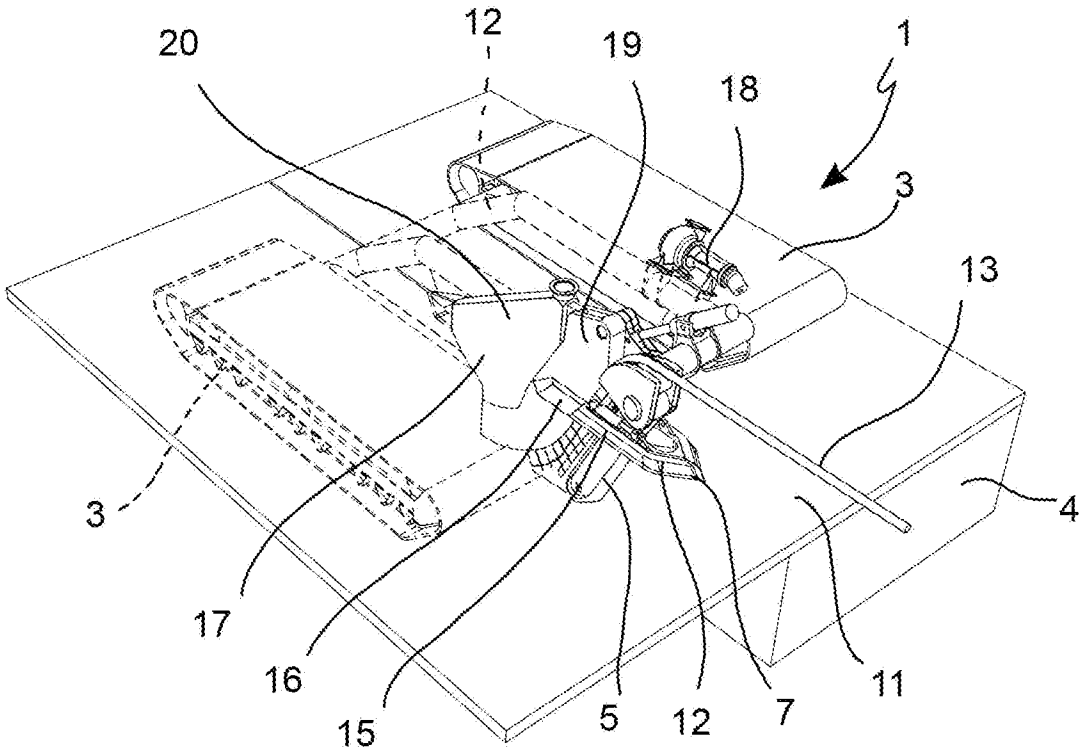

FIG. 3

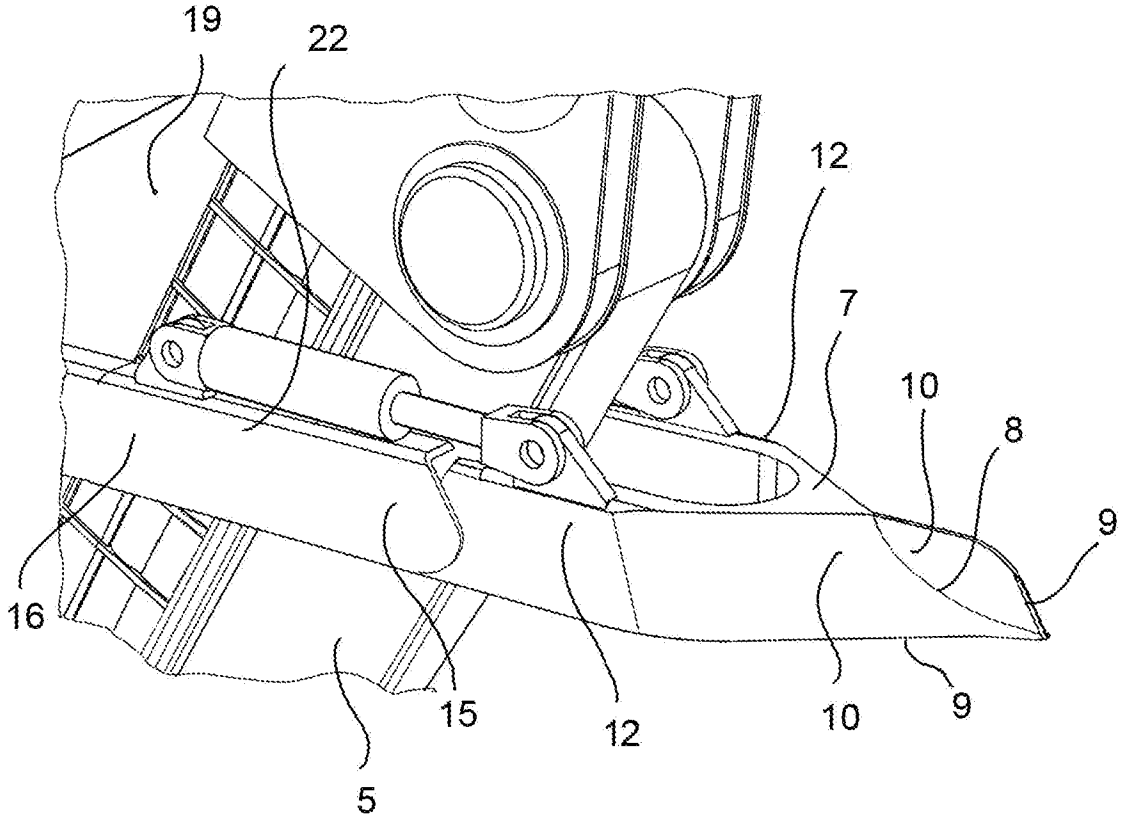

FIG. 4

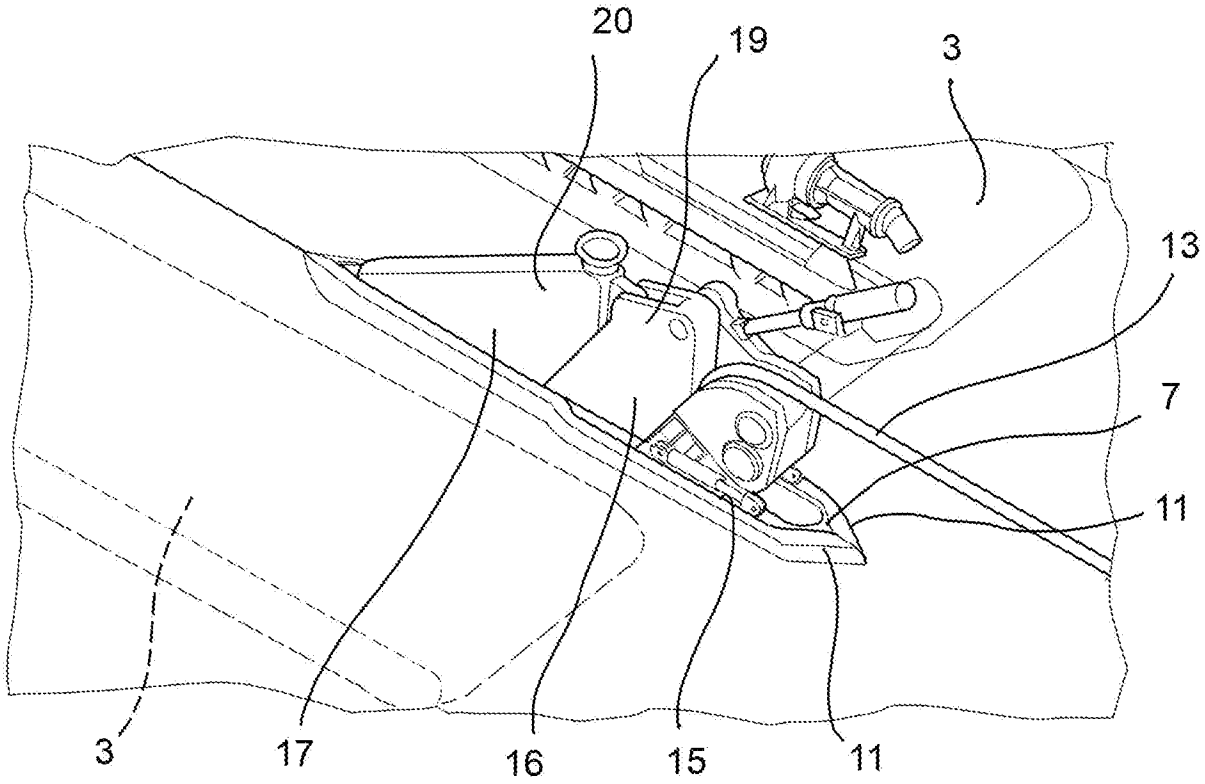

FIG. 5

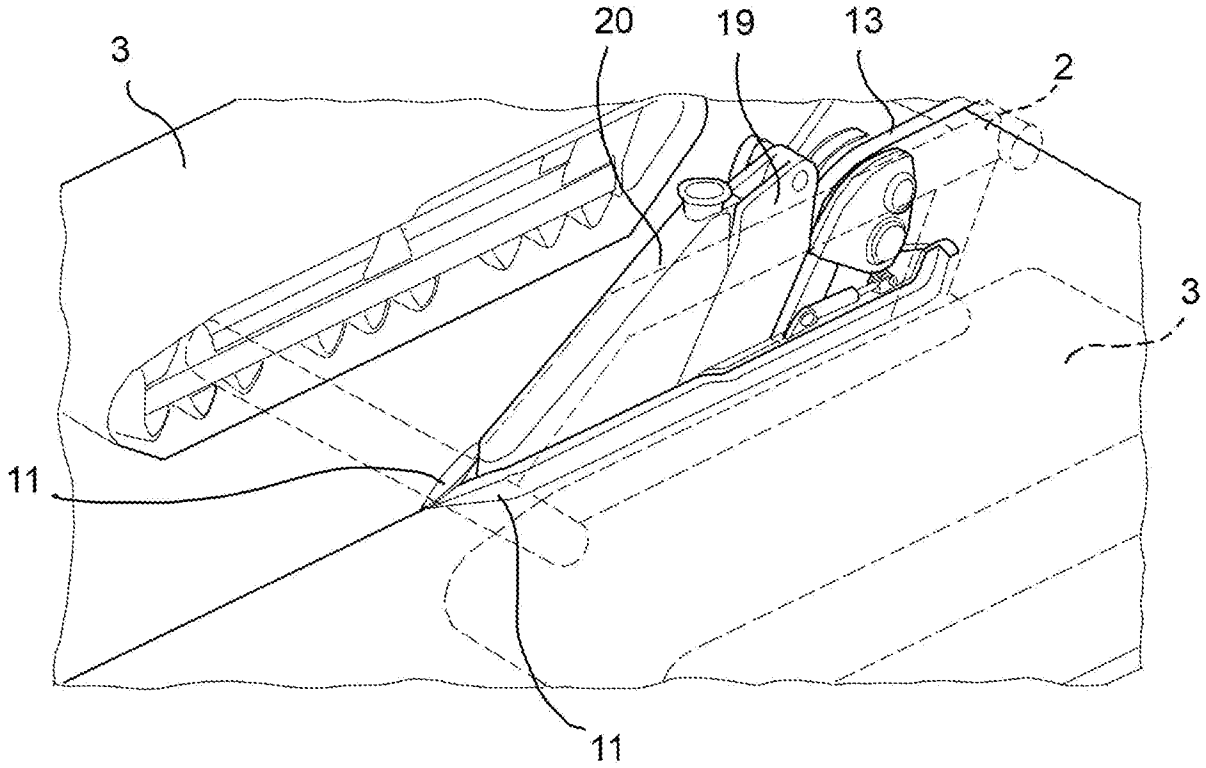

FIG. 6

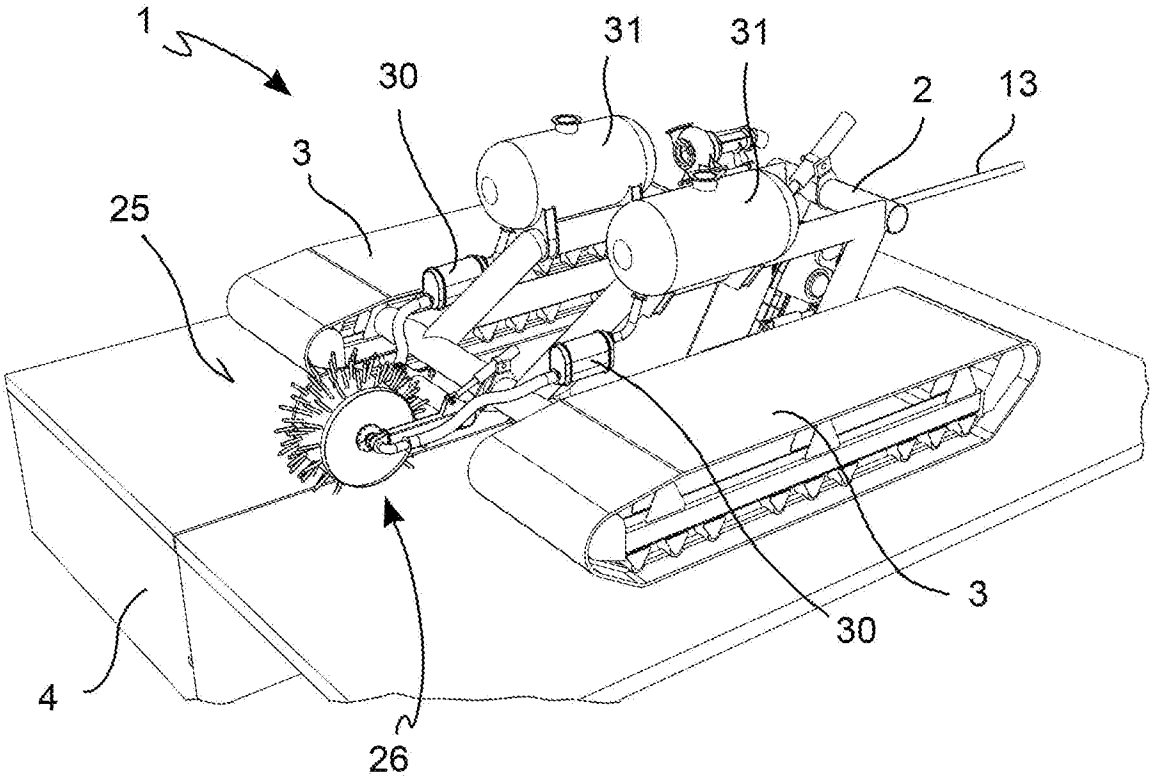

FIG. 7

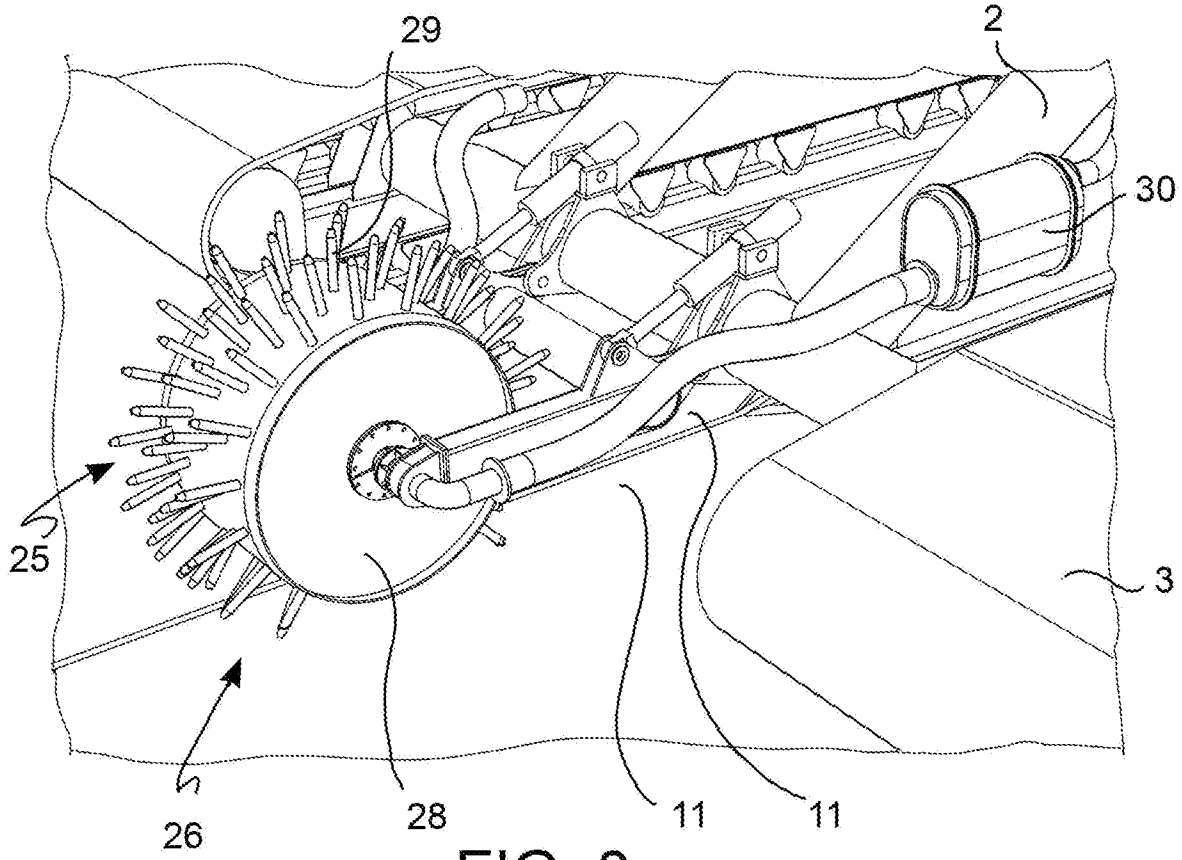

FIG. 8

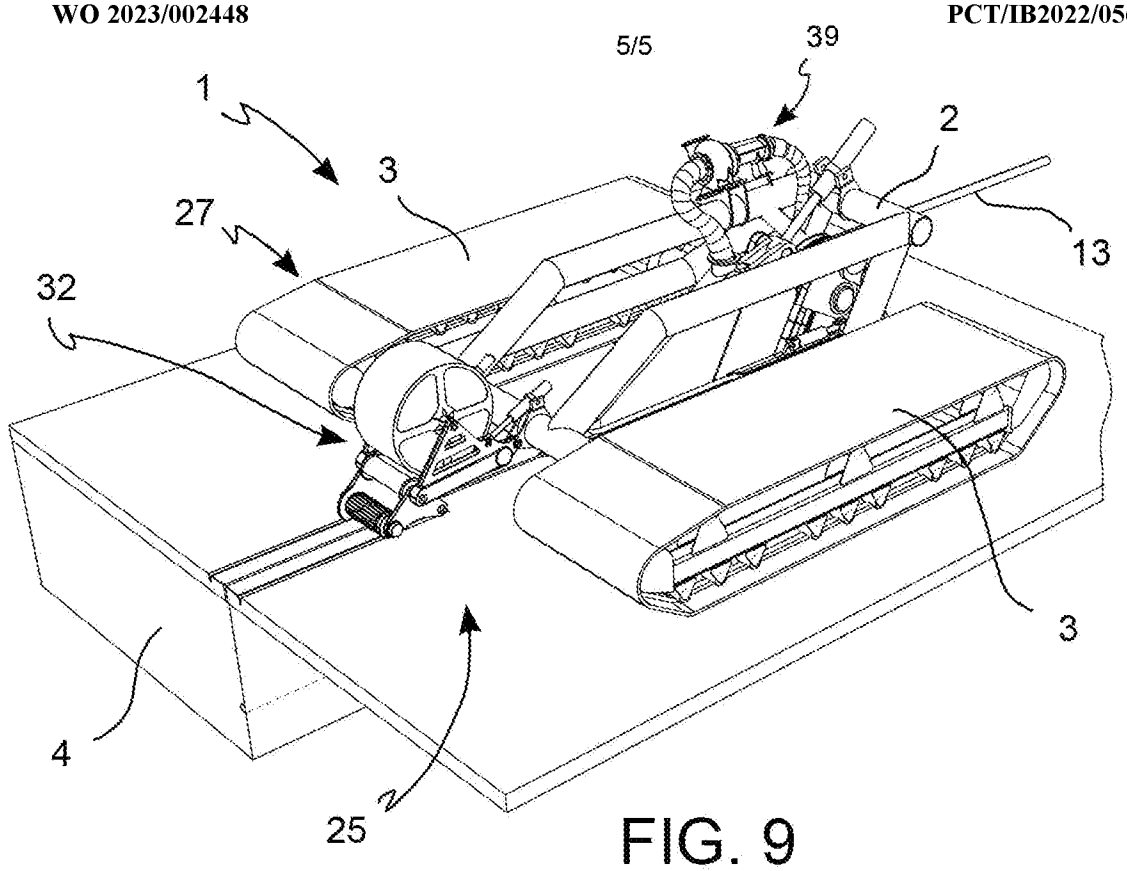

FIG. 9

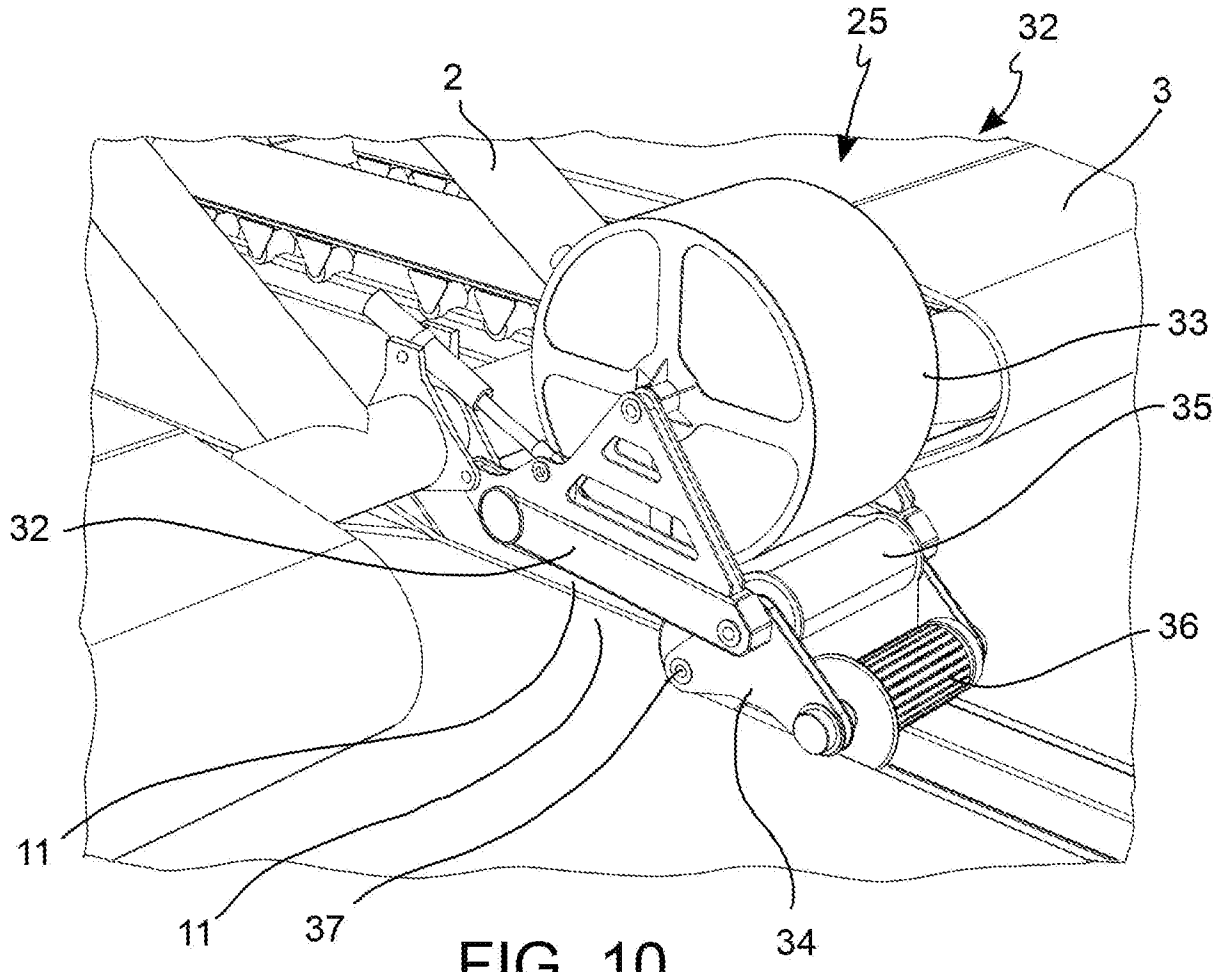

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2022/056794

A. CLASSIFICATION OF SUBJECT MATTER
INV. E02F5/10 E02F5/06 E02F5/12
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)
E02F

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP S58 113432 A (SUMITOMO ELECTRIC INDUSTRIES) 6 July 1983 (1983-07-06)	1,7-11
Y	figures 1-3	2,6
A		3-5

Y	EP 1 167 636 B1 (FOECKERSPERGER GEORG GMBH [DE]) 28 July 2004 (2004-07-28)	2,6
A	paragraph [0014]	1

X	JP H08 189058 A (KANSAI ELECTRIC POWER CO; ELECTRIC POWER DEV CO; KOMATSU MFG CO LTD) 23 July 1996 (1996-07-23)	1,9
Y	paragraph [0017] - paragraph [0027]; figure 2	2,6

☐ 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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 September 2022	07/10/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Rocabruna Vilardell

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2022/056794

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP S58113432 A	06-07-1983	NONE	
EP 1167636 B1	28-07-2004	NONE	
JP H08189058 A	23-07-1996	JP 3476034 B2	10-12-2003
		JP H08189058 A	23-07-1996