

IMPROVEMENTS IN MARINE ANCHORS

The present invention relates to marine anchors and particularly to drag embedment and direct embedment anchors and their embedment means.

A marine anchor for embedment in a mooring bed is attached generally to an anchor line for connection to an object to be restrained by mooring in a body of water over the mooring bed. The anchor includes a fluke member and a load application point to one side of the fluke member for the attachment of the anchor line thereto via anchor line attachment means (for example, a shackle) and includes a plane of symmetry containing a first direction in which the surface of the fluke member to one side of the fluke member when the anchor is in operation has a maximum projected area and a second (forward) direction (F) in which said surface has a minimum projected area. Correspondingly, in these directions maximum and substantially minimum resistance to movement of the anchor in a mooring bed soil occurs. The anchor fluke tends to advance in the soil along the forward direction (F) of minimum resistance.

A drag embedment anchor is a marine anchor as described above wherein the anchor line attachment means load application point is located on the anchor such that pulling horizontally on the line with the anchor lying on the surface of a mooring bed causes the anchor to tilt into penetrative engagement therewith and then moves into the mooring bed soil with a substantial component of displacement occurring in the forward direction of minimum projected area of the fluke member surface. This causes the anchor to follow a curved burial trajectory as it embeds into the mooring bed soil. The location of the load application point thus allows the anchor line attachment means to function as the embedment means of the anchor.

A direct embedment anchor is a marine anchor as described above which has an anchor line attachment means load application point located such that pulling on the attached anchor line causes the anchor to tend to move in the direction of maximum projected area of the fluke member when buried in the mooring bed soil. This causes the embedded anchor to follow a path that rises to and breaks out through the mooring bed surface and so prevents the anchor line and anchor line attachment means from functioning as the embedment means of the anchor. An alternative embedment means is therefore employed which comprises a pushing member, known as a follower, to engage with and push the anchor deep into the mooring bed soil substantially in the forward direction of minimum projected area of the fluke member.

US Patent No. 5474015 describes a marine anchor comprising a fluke and a shank attached to the fluke which is intended for drag embedment in a mooring bed by pulling the anchor substantially horizontally via the shank. Further, it is a particular feature of the anchor that two modes of operation are possible through the use of the line extending between the anchor cable attachment point on the shank and the fluke centroid being variable to provide a first line for drag embedment of the anchor, and a second line utilized when the anchor is embedded, wherein the pulling force on the anchor via the shank can now be at right angles to the fluke thereby providing an increased holding force due to the increased fluke area presented in the direction of the pulling force. The two modes enable the anchor to act first as a drag embedment anchor and subsequently as a direct embedment anchor.

Each anchor before-mentioned will hereinafter be referred to respectively as a marine anchor, a drag embedment anchor or a direct embedment anchor of the type described hereinbefore.

These anchors have disadvantages: the drag embedment anchor requires a sometimes unacceptable horizontal component of displacement to reach a desired embedment depth below the surface of a mooring bed and the direct embedment anchor suffers from a progressively reducing embedment depth when overloaded which ultimately results in catastrophic failure by breaking out of the mooring bed. Further, the direct embedment anchor requires to be pushed into the seabed by a long follower that is prone to being damaged and is difficult to handle when decking on an anchor-handling vessel.

The objectives of the present invention include inter alia mitigating these disadvantages. The present invention broadly provides anchoring apparatus comprising a marine anchor that follows a burial trajectory when dragged by an anchor line via an anchor line attachment means after being embedded to an

initial buried position below a seabed surface and embedment means for establishing the initial buried position.

According to the present invention, a marine anchor as hereinbefore described and in operational configuration for operation below the surface of a mooring bed, is a draganchor wherein a straight line containing the load application point and the centroid of the fluke member surface at the load application point side of the fluke member forms a forward-opening centroid angle β with the forward direction F, in which direction said fluke member surface has a minimum projected area, whereby a pulling force applied to the anchor by the anchor line at the anchor-line attachment-means load application point, when the fluke centroid C is buried below the mooring bed surface by at least twice the square root of the maximum projected area of said fluke member surface, causes the anchor to tend to move in the soil of the mooring bed with a substantial component of displacement in said forward direction F, and wherein said angle β is in the range 71° to 85° for operation of the anchor in soft cohesive soil and in the range 50° to 65° for operation of the anchor in non-cohesive soil.

"Preferably said centroid angle does not exceed 80° for operation in soft cohesive soil and does not exceed 60° for operation in non-cohesive soil.

Preferably said drag anchor is such that a plane orthogonal to the plane of symmetry of the anchor and containing a forward extremity of the fluke member and said load application point forms a forward-opening point angle α with said forward direction F, and said angle α is not less than 95° for operation in soft cohesive soil and not less than 85° for operation in non-cohesive soil.

Preferably said anchor comprises a fluke member with a plate-like shank member rigidly attached thereto and lying parallel to the plane of symmetry of the anchor.

Preferably said anchor is adapted for deeper burial by dragging and subsequent rearwards recovery in a direction substantially opposite to said forward direction F, and wherein said plate-like shank member includes an elongated slot for slidable movement therein of the anchor line attachment means with a forward end of said slot serving as a first anchor-line attachment-means load application point and with a rear end of said slot serving as a second anchor-line attachment-means load application point located towards a rear edge of said fluke member.

Preferably a slide stop means is provided just aft of the forward end of said slot to restrain said attachment means at said first load application point.

Preferably said slide stop means includes release means which cooperate with said anchor line attachment means whereby rotational displacement of said attachment means releases said slide stop means to permit said attachment means to slide in said slot towards a rear edge of said fluke member."

"Further preferably said anchor includes anchor line attachment means comprising an elongate member with an attachment point at one end for connection to an anchor line and with a clevis at the other end carrying a pin member engageable at said load application point in said shank member.

Preferably said anchor includes releasable rotation stop means which stops rotation of said elongate member at a predetermined position relative to said shank member when said pin member is at said load application point.

Preferably said anchor is such that a plane lying orthogonal to said plane of symmetry and containing a forward extremity of said fluke member and said attachment point for connection to an anchor line forms a forward-opening angle with said forward direction F when said elongate member is stopped by said stop means and is characterised in that said forward-opening angle is less than 95° and further preferably less than 75° ."

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings wherein:

- Fig. 1 shows a side elevation of a known drag embedment anchor;
- Fig. 2 shows a front elevation of the anchor of Fig. 1;
- Fig. 3 shows a plan view of the anchor of Fig. 1;
- Fig. 4 shows installation of the anchor of Fig. 1 in a mooring bed;
- Fig. 5 shows a side elevation of a known direct embedment anchor;
- Fig. 6 shows a front elevation of the anchor of Fig. 5;
- Fig. 7 shows a plan view of the anchor of Fig. 5;
- Fig. 8 shows installation of the anchor of Fig. 5 in a mooring bed;
- Fig. 9 shows a side elevation view of the drag embedment anchor of Fig. 1 and a follower member according to the present invention installed in a mooring bed;
- Fig. 10 shows an enlarged detail of the anchor and follower of Fig. 9;
- Fig. 11 shows a side elevation of a drag anchor according to the present invention;
- Fig. 12 shows a front elevation of the anchor of Fig. 11;
- Fig. 13 shows a plan view of the anchor of Fig. 11;
- Fig. 14 shows a shackle stop detail of Fig. 11 with the shackle stopped;
- Fig. 15 shows the detail of Fig. 14 with the shackle stop released;
- Fig. 16 shows the detail of Fig. 15 with the shackle in a position to move past the release stop;
- Fig. 17 shows a section A-A through the shackle stop in Fig. 15;
- Fig. 18 shows the anchor of Fig. 11 and a follower member according to the present invention traversing a stern roller of an anchor handling vessel;
- Fig. 19 shows the anchor of Fig. 11 and a follower member according to the present invention installed in a mooring bed;
- Fig. 20 shows rotation of the anchor of Fig. 11 by reacting against the follower member of Fig. 22;
- Fig. 21 shows anchor line tensioning of the rotated anchor and recovery of the follower member of Fig. 23;

Fig. 22 shows the anchor of Fig. 11 modified to act initially in the manner of the anchor of Fig. 1 and subsequently in the manner of the anchor of Fig. 11.

A known drag embedment anchor 1 (Figs. 1, 2, 3) for drag embedment in a mooring bed soil comprises a shank 2 connected at one end to a triangular plate-like or blade-like fluke 3 and at the other end to an anchor line 4 by means of a shackle 5 pivotably pinned in hole 6 in shank 2. Fluke 3 is of planar form and anchor 1 is symmetrical about a plane of symmetry X-X containing the centre of hole 6 in shank 2 and a centre-line 7 of fluke 3. Centre line 7 is parallel to a forward direction F of fluke 3 which points along fluke 3 away from the connection between shank 2 and fluke 3. A straight line in

plane of symmetry X-X containing the centre of shackle hole 6 and a foremost point of fluke 3 forms a forward-opening point angle α with forward direction F. A straight line in plane of symmetry X-X containing the centre of shackle hole 6 and the centroid C of the upper surface of fluke 3 forms a forward-opening centroid angle β with forward direction F of fluke 3.

Such a drag-embedment anchor is particularly disclosed in US Patent 2,674,969 to R.S. Danforth wherein the limits of α and β are given as 50° to 80° and 25° to 55° respectively. In UK Patent 553,235, Danforth discloses the importance of angles α and β and states that α values exceeding 75° give rise to lack of dependable engagement of an anchor with a mooring bed surface and that β values as high as 65° may be employed where an anchor is intended only for use on soft mud bottoms. These Danforth limits show that drag embedment anchor geometry hitherto has been constrained by the primary requirement to penetrate the surface of the seabed.

Drag embedment anchor 1 is laid out on a mooring bed surface 8 (Fig. 4) and pulled horizontally by anchor line 4. For a point angle α less than 75° , fluke 3 first penetrates the surface 8 and subsequently anchor fluke centroid C follows a curved trajectory 9 in the mooring bed soil 10 which eventually becomes horizontal at a limiting depth d below surface 8. The considerable horizontal displacement dd (drag distance) involved in achieving the desired penetration depth is often unacceptable when space available on the mooring bed is restricted.

A known direct embedment anchor 11 (Figs. 5, 6, 7) for direct embedment in a mooring bed comprises a triangular plate shank 2 connected at one end to a substantially rectangular plate fluke 3 and at the other end to an anchor line 4 by means of a shackle 5 pivotably pinned in a hole 6 in shank 2. Fluke 3 is of

planar form and anchor 11 is symmetrical about a plane of symmetry X-X containing shackle hole 6 in plate shank 2 and a centre line 7 of fluke 3. A forward direction F is parallel to centre-line 7 of fluke 3. A straight line in plane of symmetry X-X containing the centre of shackle hole 6 and the centroid C of the upper surface of fluke 3 forms an angle of 90° with centre-line 7.

Direct embedment anchor 11 is driven vertically (Fig. 8) into a mooring bed 10 by means of a rigid elongate follower member 13 detachably attached thereto. Follower member 13 comprises a pile 14 driven by a pile-driving hammer 15 attached thereto and suspended from a line 16. Driving is completed when centre of area C of fluke 3 is at a desired depth d below the mooring bed surface 8. The pile 14 is then disengaged from anchor 11 by pulling up on line 16 and an inclined pulling force applied via anchor line 4 causes anchor 11 to rotate and simultaneously displace upwards through distance k until the line of action of force in anchor line 4 passes through centroid C of fluke 3. The direct embedment anchor 11 is now orientated such as to provide maximum resistance to movement induced by tension in anchor line 4 at the d minus k burial depth actually achieved. However, if the anchor line 4 is loaded higher than this maximum resistance, the direct embedment anchor will fail catastrophically by moving in the direction of the anchor line 4 until it rises up to and breaks out of the sea-bed surface 8. For this reason, an installation factor of safety of 2 is generally required for such anchors.

In a first embodiment of the present invention, a drag embedment anchor 1 as hereinbefore described, with angle β (Fig. 1) at a preferred high value, is detachably and pivotably attached at pivot 17 (Fig. 9) on shank 2 to a cooperating clevis 18 in a lower extremity 19 of a heavy elongate follower 13 suspended by a lowering and retrieving line 16. Centre line 7 of fluke 3 is arranged initially parallel to a longitudinal axis 20 of follower 13 such that fluke

3 presents minimum projected area in the direction of axis 20 and the centre of area C1 (Fig. 2) of the sum of the minimum projected areas of anchor 1 and shackle 5 lies in line with axis 20. Pulling on anchor line 4 parallel to axis 20 rotates anchor 1 about pivot 17 until arrested by shank 2 contacting a stop 21 in clevis 18 whereupon a desired orientation of anchor 1 is established. A small shear pin 22 (Fig. 10) passing through clevis 18 and shank 2 serves to hold anchor 1 in clevis 18 with centre line 7 of fluke 3 parallel to axis 20 prior to said rotation.

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Embedment of anchor 1 (Fig. 9) is achieved simply by lowering anchor 1 attached to follower 13 onto the surface 8 of mooring bed 10 and continuing to pay out line 16 with anchor line 4 kept slack. Anchor 1 is forced into mooring bed 10 by the weight of heavy follower 13 until the centroid C of fluke 3 is at a desired depth d below mooring bed surface 8 that exceeds twice the square root of the maximum projected area of fluke 3. This is achieved by appropriately selecting the mass of follower 13. Line 16 is then left slack and anchor line 4 is heaved up. With follower 13 still in place to provide a reaction element, the heaving tension in line 4 causes shear pin 22 (Fig. 10) to part and anchor 1 to rotate in the mooring bed soil 10 about pivot 17 until shank 2 is arrested by stop 21 in clevis 18. The centroid C of fluke 3 thus moves slightly deeper than depth d below surface 8 and the disadvantageous loss of depth of burial k shown in Fig. 4 is eliminated. Follower 13 is then disengaged from anchor 1 by heaving up on line 16 and an inclined force is applied to anchor line 4 causing it to cut into soil to move anchor 1 substantially in forward direction F along a downwards inclined trajectory 9 wherein further embedment of anchor 1 allows progressively higher loads in anchor line 4 to be sustained. Although directly embedded without undesirable horizontal movement, anchor 1 does not fail catastrophically, when overloaded, by moving in the direction of anchor line 4 to pull out at surface 8 but instead moves horizontally at constant

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load or dives deeper with increasing load in a safe manner. Thus, an installation safety factor of 1.5 that is accepted for drag embedment anchors can be adopted instead of a safety factor of 2 that is usually mandatory for direct embedment anchors known to fail catastrophically. This allows smaller anchors to be utilised in a given mooring system at lower cost.

However, the drag embedment anchor 1 (Fig. 9) has values of angles α and β (Fig. 1) which are within the Danforth limits before-mentioned and so retains the capability of penetrating the sea-bed surface when dragged horizontally thereover. In consequence, the shank is longer than is necessary for progressive burying once the anchor is below the seabed surface. This excess length produces undesirably high penetration resistance when it is embedded vertically into the seabed and thus requires an unduly heavy follower 13 (Fig. 9).

A drag anchor according to the present invention, in contrast, has values of angles α and β which exceed the Danforth limits and so does not have the capability of penetrating the sea-bed surface when dragged horizontally thereover although it retains the capability of progressively burying when dragged horizontally from a position already below the sea-bed surface. The presently described drag anchor therefore requires only a short compact shank member and so provides minimal resistance to being pushed vertically into the seabed by a follower. Further, the high values of angles α and β allow the drag anchor advantageously to follow a trajectory 9 which is much steeper than is possible for the drag embedment anchor constrained by the Danforth limits.

Thus, both a drag embedment anchor and a drag anchor will bury when dragged in a mooring bed from a starting position at some depth below the surface of the mooring bed. The drag embedment anchor is constrained by

the inclusion of structural adaptation to enable self-penetration through the surface of a mooring bed. The drag anchor is not subject to such a constraint and, indeed, the drag anchor may be incapable of self-penetration through a mooring bed surface. A marine anchor comprising a drag anchor free of said constraint is disclosed in the present invention that permits hitherto unachievable capabilities to be realised.

According to a second embodiment of the present invention, a drag anchor 23 (Figs. 11, 12, 13) in a configuration permitting operation when installed below the surface 8 of a mooring bed 10 by a follower 13 (Fig. 22) comprises a quadrilateral steel plate shank 2 lying in a plane of symmetry X-X of anchor 23 and welded at right angles to an upper planar surface 24 of a square steel plate fluke 3 of length L. The average thickness of shank 2 and of fluke 3 does not exceed 0.04 times (and preferably does not exceed 0.03 times) the square root of the maximum projected area of fluke 3. Centre-line 7 of surface 24 lies in plane of symmetry X-X at right angles to an edge 25 of fluke 3 which is sharpened by bevelling to reduce soil penetration resistance.

A load application and attachment point 26 for a shackle 5 connecting an anchor line 4 to shank 2 is located at an extremity 27 of shank 2 remote from fluke 3. The direction from the centroid C of surface 24 along centre-line 7 to sharpened edge 25 defines a forward direction F. A plane containing shackle attachment point 26 and sharpened edge 25 forms a line intercept with plane of symmetry X-X that defines a forward-opening angle α in plane X-X with respect to forward direction F. A straight line containing the centroid C and shackle attachment point 26 forms a forward-opening angle β with respect to forward direction F. Angle α is not less than 95° for operation of anchor 23 in soft cohesive soil (clay) and not less than 85° for operation in non-cohesive soil (sand) with preference for α being not less than 100° and 90° for soft clay and

sand respectively. Angle β may be as close to 90° as possible without preventing anchor 23 from moving in the soil of mooring bed 10 with a substantial component 9B (Fig. 24) of displacement of centroid C occurring in direction F. Preferably, said substantial component may be regarded as being not less than 35 per cent of the displacement 9A in the actual direction of movement with 50 per cent further preferred. However, in practice, angle β (Fig. 11) does not exceed 85° for operation of anchor 23 in soft clay and does not exceed 70° for operation in sand. Further, angle β is in the range 71° to

85° for operation in soft clay and 50° to 65° for operation in sand. It is preferred that angle β does not exceed 80° for operation in soft clay and does not exceed 60° for operation in sand.

Shackle attachment point 26 (Fig. 11) is formed by a forward extremity 28 of an elongate straight slot 29 in shank 2. A rearward extremity 30 of slot 29 is located adjacent to a rear edge 31 of fluke 3 and slot 29 forms a forward-opening angle γ of up to 30° with centre-line 7, with 10° preferred. A forward edge 32 of shank 2 is sharpened by bevelling to reduce soil penetration resistance as for edge 25 of fluke 3. The separation of shackle attachment point 26 from centroid C is preferred to be in the range $0.15L$ to $0.6L$. A cylindrical steel pin 17 (Figs. 11-13) is mounted transversely through shank plate 2 to act as a pivot and bearing pin for mating with an installation follower 13 (Figs. 22, 23, 24). Axis 33 of pin 17 is spaced from surface 24 such that the line of axis 20 of follower 13 passes through the combined centre of area 34 (Fig. 12) of anchor 23 and shackle 5 (when anchor line 4 is pulled back to lie parallel to direction F) as viewed in opposition to direction F (Figs. 11, 12, 22). This ensures that the resultant soil penetration resistance force R (Fig. 22) on anchor 23 is co-linear with follower axis 20 during initial driven embedment of drag anchor 23. A releasable shackle stop 35 (Figs. 11, 14, 15, 16, 17) in shank 2 holds pin 36 of shackle 5 in extremity 28 of slot 29. Stop 35 includes

two rectangular plates 37 slidably located in undercut recesses 38 one at each side of shank 2 aft of extremity 28 of slot 29 and on a side of slot 29 remote from fluke 3. Plates 37 initially occupy a position partly in recesses 38 and partly in slot 29 whereby pin 36 of shackle 5 is prevented from sliding away from extremity 28 of slot 29. A drilled hole 39 (Fig. 17) in shank 2 between recesses 38 contains two steel balls 40 of a diameter slightly less than the diameter of hole 39. Steel balls 40 are held apart by a compression spring 41. Plate 37 has a central hole 42 and an offset hole 43 drilled therein which engages with a ball 40 to determine the slidable position of plate 37 in recess 38. Plate 37 also has an upstanding block 44 attached at an end remote from offset hole 43 that protrudes beyond side surface 45 of shank 2 (Fig. 17). A cam 46 (Fig. 14) protruding inside each eye 47 of shackle 5 is located such that sliding contact between cam 46 and block 44 occurs in the course of shackle 5 being rotated from parallel with to perpendicular to surface 24 of fluke 3. Cams 46 thereby push on blocks 44 to cause plates 37 to depress balls 40 out of engagement with holes 43 and then slide until balls 40 engage in holes 42 whereupon plates 37 are held wholly clear of slot 29 (Fig. 15). A shouldered non-rotatable sleeve 36A slidably in slot 29, may be fitted on pin 36 (Fig. 15) to prevent plates 37 being prematurely moved by friction between pin 36 and plates 37 as shackle 5 rotates to bring cams 46 into contact with blocks 44.

Subsequent pulling aft-wards of anchor line 4 rotates shackle 5 backwards until cams 46 clear blocks 44 thus allowing sleeve 36A and pin 36 to slide along slot 29 to relocate at extremity 30 (Fig. 11) whereby low load retrieval of anchor 23 by means of the anchor line 4 is possible. Resetting of stop 35 is achieved later simply by use of a hammer and drift on each of plates 37 in turn to re-engage balls 40 in offset holes 43 and so cause plates 37 to protrude once

again into slot 29 to stop shackle 5 from sliding away from extremity 28 of slot 29.

A follower member [Figs. 18-25] for directly embedding a marine anchor below the surface 8 of a mooring bed 10 comprises an elongate member 13 including a plurality of body segments 48.

The follower 13 functions substantially in the manner of the before mentioned rigid follower when suspended vertically by means of line 16 but permits recoverable bending without damage to occur while traversing stern roller 60.

Bottom terminal segment 51 of follower 13 is adapted for releasable connection to a drag anchor 23 as previously described and includes an elongated clevis 103 (Figs. 22-23) for straddling shank 2 of anchor 23 to enable a recessed socket 104 in each clevis leg to receive and mate with pivot pin 17 on shank 2. A lug 106 on each clevis leg 105 has a hole 107 drilled there through which registers with a hole 108 in shank 2 and receives a retaining shear pin 109 which holds anchor 23 temporarily in clevis 103 of bottom terminal segment 51 with forward direction F parallel to axis 20 and pin 17 mated in sockets 104. A stop 21 on a leg 105 of clevis 103 limits rotation of anchor 23 about pin 17 to a desired number of degrees by making contact with fluke 3. An anchor fore-runner line 4A, of length approximately five per cent longer than the length of pile 13, is attached at one end to shackle 5 of anchor 23 and at another end to a hinge link 110 for connection to anchor line 4. Hinge link 110 is fitted with a protruding hinge pin 110A. Two parallel hooks 111 are spaced apart and mounted on face 74 of control segment 66 remote from yoke 87. Each hook 111 serves as a support for engaging a protruding end of hinge pin 110A whereby hinge link 110 may be detachably attached to control segment 66 such that pulling upwards on anchor line 4 at an angle less than 60° off vertical disengages hinge link 110 from hooks 111. This detachable connection permits the azimuthal heading of anchor 23 to be controlled during

installation by anchor line 4 pulling on hooks 111 without prematurely releasing shackle stop 35 and so preserving the facility of disengaging link 110 from hooks 111 subsequently by heaving up on anchor line 4.

At sea, anchor handling vessel 62 and the anchor line-carrying vessel proceed to the installation site. One end of anchor line 4 is passed over to vessel 62 for connection to hinge link 110 which is engaged on hooks 111 of control segment 66 of pile 13. Anchor line 4 is then allowed to hang slack in a bight between the vessels to provide directional control of pile 13 and anchor 23. On vessel 66, tugger winch lines are attached to control segment 66 via pulley blocks fixed adjacent stern roller 60 and operated to pull control segment 66 aft on deck 61 and so push drag anchor 23 and follower 13 overboard via stern roller 60. The weight of drag anchor 23 together with bottom terminal segment 51 projecting overboard causes follower 13 to bend through 90° over roller 60.

When a sufficient weight of segments 48 are overboard, follower 13 becomes self-launching with braking restraint provided by winch 102 as it pays out line 16 ultimately to lower follower 13 and drag anchor 23 to the surface 8 of the mooring-bed 10 below. The anchor line-carrying vessel pays out anchor line 4 in step with line 16 being paid out by anchor handling vessel 62 and keeps sufficient tension in line 4 to control the azimuthal direction of follower 13 and anchor 23 until anchor 23 is buried in sea bed soil 10.

Drag anchor 23 is forced through mooring-bed surface 8 into soil 10 (Fig. 27) by the combined buoyant weight of anchor 23 and follower 13 as lines 16 and 4 are paid out. Line 16 may conveniently include a heave compensator comprising, for example, an elastic nylon portion to act as a stretchable absorber of heave motion of vessel 62 to facilitate smooth penetration of surface 8 by drag anchor 23.

Completion of penetration of anchor 23 is signalled by a load cell on winch 102 on anchor handling vessel 62 and indicated by the tension in line 16 reducing to the submerged weight of line 16 when anchor 23 and follower 13 are completely supported by the sea bed soil. Line 16 is then paid out slack to allow vessel 62 to move clear of the position of follower 13. The anchor line-carrying vessel now moves to a position directly over follower 13 and heaves up on anchor line 4 so that hinge link 110 is disengaged from hooks 111 on follower 13 and line 4 becomes taut. A mark is made on taut line 4 which is then heaved in again until the mark has moved through a distance approximately equal to the length of two segments 48 of follower 13. This raises anchor 23 and follower 13 together in the sea bed soil 10 and simultaneously pivots anchor 23 about pin 17 in socket 104 (Figs. 22-23) to cause shear pin 109 to part and force fluke 3 to tilt away from vertical. Anchor line 4 is next paid out to allow the submerged weight of follower 13 to drive anchor 23 downwards in the now tilted direction F of fluke 3 (Fig. 23). As line 4

is heaved upwards, a powerful couple is formed between the submerged weight of follower 13 and the tension in anchor line 4. As line 4 is subsequently paid out, a powerful couple is formed between the submerged weight of follower 13 and the now offset soil resistance force R acting on anchor 23. Both couples act to augment the desired rotation of anchor 23. This sequence is repeated several times. Each repetition rotates fluke 3 of anchor 23 further away from vertical until stop 21 makes contact with fluke 3 (Fig. 23). This rotation process, also known as keying, occurs without causing centroid C of fluke 3 to decrease in depth of penetration below sea bed surface 8 through a distance k as previously described for a direct embedment anchor 11 (Fig. 8) loaded after removal of the installing follower 13.

Anchor line 4 is now paid out slack to allow the anchor line-carrying vessel to move away to permit anchor-handling vessel 62 to reposition directly over follower 13 so that winch 102 can heave in line 16 to haul follower 13 off anchor 23, out of mooring bed 10, and up to stern roller 60.

Hauling by winch 102 is stopped when all of follower 13 is on deck 61.

Vessel 62 then steams ahead to pull the anchor line 4 into soil 10 (Fig. 24) at an appropriate angle to horizontal for the mooring of an object to be restrained on the sea surface. The resulting movement of shackle 5 causes peg 46 (Figs. 14-16) on shackle eye 47 to push plates 37 of stop 35 into the released position on shank 2 of anchor 23 ready for easy later retrieval of anchor 23. Pulling anchor line 4 away from the direction of the restrained object then

causes shackle 5 to slide in slot 29 to extremity 30 (Fig. 11) whereby low resistance to recovery of anchor 23 may be realised during retrieval.

As for the directly embedded drag embedment anchor 1 previously described, directly embedded drag anchor 23 will follow a downwardly inclined curved trajectory 9 if loaded beyond the capacity it can provide at the target embedment depth. Anchor 23 will thus increase capacity to match the overload. Ultimately, as for traditional drag embedment anchors, drag anchor 23 will reach a limiting depth below surface 8 of mooring bed 10 at which maximum capacity will be reached but catastrophic failure will not occur since anchor movement is now horizontal and, in consequence, a normal safety factor of 1.5 for drag embedment anchors may be utilised.

Anchor 23, further, may be adapted to have an elongate plate member 138 (Fig. 34), instead of a shackle attached to shank 2, with an anchor line attachment hole 139 at an end 140 and a clevis 141 at another end 142 that straddles shank 2 and carries pin 36 for slidable and rotatable engagement in straight slot 29. Shank 2 has an arcuate surface 143 centred on attachment point 26 at a forward extremity 28 of slot 29. A stop 144 inside clevis 141 makes sliding contact with surface 143 whereby pin 36 is held at point 26 until rotation of member 138 about point 26 brings the direction of movement of stop 144 parallel to slot 29 whereupon pin 36 is free to slide in slot 29. A rotation-stopping shear pin 145 is mounted in holes 146 in clevis 141 and in registering hole 147 in shank 2 and serves to hold elongate plate member 138 at a

desired position where angle α' is less than 95° and preferably less than 75° . Shear pin 145 is of a size such as to part when a particular value of loading at hole 139 from anchor line 4 is exceeded. This allows anchor 23 to act initially as a drag embedment anchor prior to parting of shear pin 145, and then to act as a drag anchor of greatly increased holding capacity when dragged further.

A drag anchor 23 (Figs. 22-24), weighing 9 kg., and a follower 13, weighing 126 kg., were subjected to tests in a slightly over-consolidated soft clay sea bed 10. All mechanisms and procedures previously described functioned as planned. With centroid C (Fig. 24) of anchor 23 installed by follower 13 to a depth below sea bed surface 8 of three times the square root of the area of fluke 3, anchor 23 provided a holding capacity of 53 times anchor weight (immediately after recovery of follower 13 from sea bed 10) when anchor line 4 was pulled at an inclination of 18° to horizontal at sea bed surface 8. Further pulling caused anchor 23 to drag whilst burying deeper to give a progressively increasing holding capacity that ultimately became constant at 189 times anchor weight with centroid C moving horizontally and with anchor line 4 inclined at 23° to horizontal.

In a test where centroid C on fluke 3 of anchor 23 was installed by follower 13 to a depth below sea bed surface 8 of 1.1 times the square root of the area of fluke 3, anchor 23 gave a progressively decreasing holding capacity and rose back up to sea bed surface 8 on being dragged from its installed position. This test proved the effectiveness of installation by follower of drag anchor 23 and of eschewing the before-mentioned Danforth limits for angles α and β (Fig. 11) of anchor 23.

The disclosures herein provide particular embodiments of the present invention and the tests outlined above show that the objectives of the invention have been met. It will be apparent that variations in these embodiments are within the scope of the invention.

CLAIMS

1. Anchoring apparatus in the form of a marine anchor (23), including a fluke member (3) and a load application point (26) on the marine anchor to one side of the fluke member for attaching an anchor-line attachment-means (5), said marine anchor in operational configuration being an anchor for operation below the surface of a mooring bed (10), wherein a straight line containing said load application point (26) and the centroid (C) of the fluke member surface at said one side of the fluke member forms a forward-opening centroid angle β with a forward direction F, in which direction said fluke member surface has a minimum projected area, whereby a pulling force applied to the anchor by the anchor line at the anchor-line attachment-means load application point (26), when the fluke centroid (C) is buried below the mooring bed surface by at least twice the square root of the maximum projected area of the fluke member surface at said one side of the fluke member, causes the anchor (23) to tend to move in the soil of the mooring bed (10) with a substantial component (9B) of displacement in said forward direction F, characterised in that said angle β is in the range 71° to 85° for operation of the anchor in soft cohesive soil and in the range 50° to 65° for operation of the anchor in non-cohesive soil.

2. Anchoring apparatus as claimed in claim 1, characterised in that said centroid angle β does not exceed 80° for operation in soft cohesive soil and does not exceed 60° for operation in non-cohesive soil.

3. Anchoring apparatus as claimed in claim 1 or claim 2, wherein a plane orthogonal to a plane of symmetry (X-X) of the anchor (23) and containing a forward extremity of the fluke member (3) and said load application point (26) forms a forward-opening point angle α with said forward direction F, characterised in that said angle α is not less than 95° for operation in soft cohesive soil and not less than 85° for operation in non-cohesive soil.

4. Anchoring apparatus as claimed in claim 1 or claim 3, characterised in that said anchor (23) comprises a fluke member (3) with a plate-like shank member (2) rigidly attached thereto and lying parallel to the plane of symmetry (X-X) of the anchor.

5. Anchoring apparatus as claimed in claim 4, wherein said anchor (23) is adapted for deeper burial by dragging and subsequent rearwards recovery in a direction substantially opposite to said forward direction F, characterised in that said plate-like shank member (2) includes an elongated slot (29) for slidable movement therein of the anchor line attachment means (5) with a forward end (28) of said slot (29) serving as a first anchor-line attachment-means load application point and with a rear end (30) of said slot serving as a second anchor-line attachment-means load application point located towards a rear edge of said fluke member (3).

6. Anchoring apparatus as claimed in claim 5, characterised in that a slide stop means (35) is provided just aft of the forward end (28) of said slot (29) to restrain said attachment means (5) at said first load application point (26).

7. Anchoring apparatus as claimed in claim 6, characterised in that said slide stop means (35) includes release means (44, 46) which cooperate with said anchor line attachment means (5) whereby rotational displacement of said attachment means (5) releases said slide stop means (35) to permit said attachment means (5) to slide in said slot towards a rear edge (31) of said fluke member (3).

8. Anchoring apparatus as claimed in any of the preceding claims, characterised in that said anchor (23) includes anchor line attachment means comprising an elongate member (138) with an attachment point (139) at one end (140) for connection to an anchor line (4) and with a clevis

(141) at the other end carrying a pin member (36) engageable at said load application point (26) in said shank member (2).

9. Anchoring apparatus as claimed in claim 8, characterised in that said anchor (23) includes releasable rotation stop means (145) for stopping rotation of said elongate member (138) at a predetermined position relative to said shank member (2) when said pin member (36) is at said first load application point.

10. Anchoring apparatus as claimed in claim 8 or 9, wherein a plane lying orthogonal to said plane of symmetry (X-X) and containing a forward extremity of said fluke member (3) and said attachment point (139) for connection to an anchor line forms a forward-opening angle α^1 with said forward direction F when said elongate member is stopped by said stop-means, characterised in that said angle α^1 is less than 95° .

11. Anchoring apparatus as claimed in claim 10, characterised in that said angle α^1 is less than 75° .