The Holding Power of Anchors

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The essential principle in the action of all anchors is that a surface set at an acute angle to the ground will dig in if pulled horizontally. In order that an anchor may function properly it must satisfy two conditions. The first is that in whatever position it may fall as it strikes the sea floor, it must begin to dig in as soon as the pull comes on the chain. The second is that it shall remain in the ‘digging in’ position while it is dragged into the ground, or, in other words, it shall be stable in the ground. Up to the present only two essentially different designs have been used, or, if the grapnel is included, three.

In the traditional form, with two flukes and shank and a stock which is longer than the flukes, the stock serves a double purpose. It ensures that the anchor shall fall on the ground in such a position that one of the digging planes or palms will function as soon as the chain begins to drag along the ground; and it also serves, by lying flat on the ground, to keep the palm set at the correct angle as it buries itself.

In stockless anchors there are two digging blades set on opposite sides of the shank, and hinged to it by a horizontal hinge which allows them to set themselves at the correct digging angle which ever way up the anchor may fall on the ground. There is no difficulty in making them begin to bite as soon as the pull comes on the chain. Unfortunately, however, the simple design, consisting of two blades set on opposite sides of a shank, is essentially unstable in the ground. If one of the blades penetrates slightly more deeply than the other, the difference between the downward pressures on the two blades necessarily brings into play a couple which tends to rotate the anchor round its shank, burying the lower blade still more deeply and raising the upper blade out of the ground. After the upper blade has come out the lower blade continues to rotate round the shank till it also comes out of the ground on the opposite side to that on which it went in.

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In order to counteract this tendency to rotate round the shank, the upper parts of the blades of stockless anchors are usually made to flare out, so that only the lower part of the blade can bury itself. This method of stabilizing is often not completely successful. Experimenting with one of the best known makes, I found it nearly always dragged along with one blade lower than the other, but even when it is successful the weight of the part which must then remain above the ground causes the anchor to be very inefficient for its weight.

The efficiency of an anchor may be expressed as the ratio (holding force ÷ weight of anchor). In dry sand, recent experiments with models of varying linear dimensions but the same shape have proved that this ratio is constant for any particular design, though linear dimensions varied in the ratio 5: 1 and the weights in the ratio 125: 1. In different types of holding ground the relative efficiency of different designs varies, but this variation is never great enough to mask the very great superiority of the traditional pattern over all existing stockless varieties. The reason why stockless anchors are frequently preferred in large sizes appears to be entirely a question of ease in handling. The stock is, of course, a very awkward thing to deal with while bringing the anchor on board, and when the anchor is on board the stock makes stowage difficult unless it is unshipped. The manner in which a stockless anchor houses itself into a specially prepared hawse hole is its chief recommendation.

In considering how the efficiency of anchors might be improved so that lighter ones could be used than are needed at present, the designer naturally fixes his attention on the parts which are not essential for digging in. In the traditional pattern the stock is only needed for stability, and in action, only one fluke buries itself. One fluke and the shank seem to be essential, so that the problem which naturally suggests itself is to devise an anchor with a shank and one fluke which shall yet satisfy the requirements of taking hold of the ground as soon as the chain becomes taut and being stable when it has buried itself. The design which will now be described seems to be a solution of this problem.

The figures show the anchor in two positions: (1) The horizontal position which it assumes as it falls on the ground, and (2) the vertical position which it takes up when it is dragged through the ground. The fluke (marked A in *Figures* 1 and 2) resembles a double-bladed ploughshare, which is welded on to a steel arm (marked B) of triangular section. The end of this arm is bent so that it comes into line with the shank C. A steel pin D passes with a driving fit through the end of the fluke member. The end of the

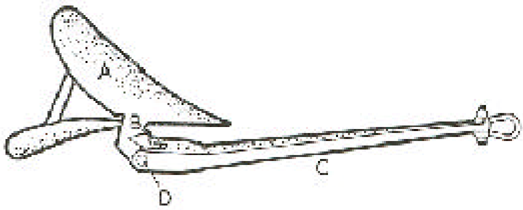

Figure 1. The 'C.Q.R.' anchor as it takes the ground.

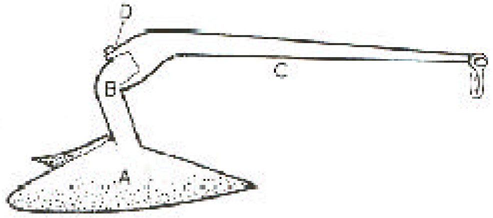

Figure 2. The 'C.Q.R.' anchor in the position it naturally takes up.

shank is expanded into the form of jaws, through which holes are bored to take the pin D, leaving considerable clearance. The opening of the jaws is considerably larger than would be necessary to take the end of the fluke member, so that the joint between the two members is very loose in every direction.

The pin lies in the plane of symmetry of the anchor so that it is horizontal in position 1 and nearly vertical in position 2.

When the anchor falls on the ground in position 1 it will be seen from the photograph that the point of the fluke is aiming obliquely into the ground. Thus it is originally in a position suitable for digging in. As the chain begins to pull the anchor along the ground the point begins to penetrate, and since the centre line of the pin lies a short distance behind the point of the fluke, the downward earth pressure on the point begins to turn the fluke still more down into the ground.

As the penetration proceeds the parts of the fluke behind the centre-line of the pin begin to receive a downward earth pressure. The fluke then ceases to turn down and begins to set itself in line with the shaft. Finally, when the fluke has penetrated so that the whole of the double blade is buried, the anchor has turned over in to the vertical position 2 (*Figure* 2), the shank lying along the surface of the ground. In this position the anchor is very stable, so that if during dragging it strikes a stone or other irregularity, which pushes it out of the vertical position, it very quickly recovers itself.

The stability in the ground was strikingly verified by an experiment which I made with a 1¼ lb. model about 1 ft. long. After dragging it into a sandy beach, I pulled it round in a circle. The anchor, while remaining under the sand, dragged round in a circle 5 ft. diameter. On digging round the anchor at one stage of the test, to see how it was lying, I found that it had banked itself in order to do the turn, just like an aeroplane.

The anchor which has just been described has been called the 'C.Q.R.' patent anchor (provisional application No. 8455/33). It was designed entirely by means of models weighing from 1 to 1½ lb. The correct angles and position of the hinge were found by trial and error and guessing. After completing the main elements of the design in this way, a large model, weight 42½ lb., was made and sent for test to the Seaplane Experimental Station at Felixstowe. We had concluded, as a result of our model tests that in good holding ground the holding power would be something like 1200 lb., and we designed the anchor to take that load. When the tests were carried out, however, the force on the cable rose steadily as the anchor dragged into the ground to the huge figure of 25 cwt., which was the maximum force measurable by the spring balance which was used. On raising the anchor the shank was found, to be bent. A heavier shank was then made, which raised the total weight to 52½ lb., and the tests repeated with a more powerful spring balance. It was then found that the holding power was 29 cwt., which is sixty-two times the weight of the anchor. This ratio 62 is about three times as great as that obtained in the same ground with the best anchor of the traditional type, and six or more times as great as the best result which would be obtained with any of the standard stockless anchors.

The results seemed so encouraging that we made some specimens weighing 23 lb. on the same lines as the first 42½ lb. anchor, in order that comparisons might be made with the best obtainable specimens of the same weight but of the traditional and stockless types.

Before starting our tests we made enquiries to find out whether any data was available showing how the traditional compares with the stockless anchor. We were unable to find any, except some recent work published by the Air Ministry on tests with some special seaplane anchors. Our results may therefore be of interest to yachtsmen independently of the data concerning our new anchor.

In comparing two anchors it is essential to make the comparison under identical conditions, and in as many different kinds of ground as possible. It is also useful to measure, if possible, the holding power with different lengths of cable, so that the pull on the anchor is at various angles to the horizontal.

Some of the tests were carried out by dragging the anchors horizontally along the foreshore just after the tide had left it, while others were made from a boat anchored by means of a very large anchor in the River Crouch. In the latter case the anchors to be tested were dropped from a dinghy at a distance of 35 fathoms from the moored boat, and pulled towards it by a winch. The cable was manila, ¾ in. diameter. The tension in the cable was measured by means of a spring balance operating at the end of a lever, which reduced the tension in the ratio 9½: 1.

Four anchors were treated:

(A) The new ‘C.Q.R.’ anchor, 231b.

(B) An anchor of the traditional pattern, with convex spear-shaped palms, 25 lb.

(C) An anchor of the traditional pattern with flat heart-shaped palms, 20 lbs.

(D) A 20 lb. stockless anchor.

Table 1. Average values of efficiency ratio, $\dfrac{\textit{holding power or drag}}{\textit{weight of anchor}}$.

	New Type	Traditional		Stockless
	Anchor *A*	Anchor *B*	Anchor *C*	Anchor *D*
Soft sand just covered with water	22.7	9.9	–	0*
Foreshore, consisting of mud and shingle	(25 fms.) 35.0	13.0	15.0	1.4
At anchor in 3½ fathoms, mud bottom	(25 fms.) 31.8 (20 fms.) 23.9 (15 fms.) 22.7	(20 fms.) 5.7 (15 fms.) 6.6	(20 fms.) 5.0 (10 fms.) 5.0	(25fms.) 2.3
At anchor in 2¼ fathoms, holding ground, consisting of a thin layer of soft mud over a bed of stiff clay	(15 fms.) 7.0 (8 fms.) 8.6 (5 fms.) 0	(20 fms.) 4.1 (15 fms.) 0	(26 fms.) 0	

The figures in brackets show the length of cable in fathoms.

* The figure 0 indicates that the anchor did not take hold. When the anchor *D* was pressed into the sand by hand it gave a drag equal to 5.5 times its weight.

As may be seen from the table of results the traditional type is always more efficient than the stockless, and it seems that the new type is, in all kinds of ground, more efficient than the traditional type. Indeed, the superiority of the new type is very marked, for it gives a rule about two-and-a-half times as big a drag as the best anchor of the same weight obtainable at the present time. The new anchor was designed primarily for possible use in seaplanes, where reduction in weight is so important that it overrides many other considerations which may affect the yachts-man. The cost of construction, for instance, is considerably greater than that of any other anchor of the same weight. It must be remembered however, that this anchor should be as good as one of the traditional type weighing twice as much. This saving of weight in short-handed yachts may be worth much. Whether the new type will prove easy to handle and stow is a question which I hope to be able to answer at the end of the coming season, for I propose to substitute a 60 lb. specimen for my present very excellent 120 lb. Nicholson in my 19 ton cutter Frolic. One thing is certain, however, the new anchor has no stock to foul the jib sheets when coming about, so that one continuously acting source of blasphemy will be removed.

For the benefit of people who like to try new things, it is proposed to put this anchor on the market at the beginning of the coming season in three sizes, namely 20, 35 and 60 lb. These are intended to replace ordinary anchors up to double their weight.

Phenomena Containing Taylor's name

Taylor – Couette instability
Taylor – Proudman theorem
Taylor column
Taylor dislocations
Taylor vorticity transfer theory
Taylor–Green problem
Taylor microscale
Taylor frozen-flow hypothesis
Rayleigh–Taylor instability
Taylor dispersion
Saffman–Taylor fingering

From: *The scientific legacy of G I Taylor*