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# Horizontal Folding Assembly for Multihull Boats

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**ABSTRACT:** Catamarans and trimarans may have problems in road transportation or marina berthing because of their large width. Therefore, several folding mechanisms have been designed to reduce their width. In this paper a new horizontal folding mechanisms is presented, which is much simpler and more stable than many existing. Furthermore, the length of the boat is not increased much when folded in. The mechanism may be used for catamarans and trimarans. The hulls of a catamaran or the outriggers of a trimaran are connected with beams that are separated in the center, where they overlap. Close to the center, the half beams are hinged to struts which connect both half beams and rotate during the folding process. The struts have a hole at their center that coincides with holes of the overlapping half beams when folded out. The whole structure may be stabilized by introducing one single bolt or screw at the position of these holes. Boats are normally equipped with two such mechanisms, one at the stern and the other close to the bow of the boat. These two mechanisms may be connected at their centers by a strut hinged to these centers. This strut may be replaced by the central main hull of a trimaran. This paper is based on a recent patent application, where further details can be found..
**KEYWORDS:** horizontal folding mechanism, catamaran, trimaran, multihull

## I. INTRODUCTION

Multihull boats have excellent sailing properties, because they have slim hulls and don't need ballast. They get their stability from their wide beam. They consist mainly of two-hulled catamarans and three-hulled trimarans. Trimarans have a central main hull, connected to two outriggers on the sides. However, these boats have a disadvantage in that they are often too wide for transportation by road and also for berthing in marinas. To overcome this disadvantage, many proposals have been devised to enable the hulls or outriggers to be moved to reduce the overall width of the boat, preferably on the water without need to dismantle the boat.

A horizontal folding mechanism, known as the swing-wing configuration, has been used extensively. Connecting beams are hinged pivotally at one end to the outrigger and at the other end to the central hull of a trimaran or a central support of a catamaran, e. g. described in [1]. This mechanism often increases the length of the boat when folded in, requiring a longer marina berth. Furthermore, all horizontal folding mechanisms have a common disadvantage in that due to the limited length of the hinges arises an unfavorable leverage, making a laborious construction necessary.

Another horizontal mechanism consists of telescoping tubes, e. g. described in [2]. As the inner tube, connected to the outrigger,, moves inside the outer tube at the main hull of a trimaran, the width reduction is limited and the movements of the crew may be hindered. Furthermore, slight damage of this assembly might cause a complete impasse.

Vertical folding mechanisms have the advantage, that the connecting beams may be screwed on top of the (main) hull, thus relieving the strain on the hinges and stabilizing the assembly. A mechanism has been described in [3] and an improved version in [4]. This extensively used design consists of 2 struts on each side of a trimaran, which are both pivotally hinged at their ends to a connecting beam and to the main hull, one strut forming the lower side of a four-sided vertical figure and the other strut is the upper side. When folded out, each connecting (half) beam on a side is screwed on top of the trimaran main hull with one screw, stabilizing the assembly, but leaving some load on the hinges.

ln a recent paper [8] and patent application [5] new vertical folding mechanisms are presented, that need many less hinges than those in [3] and [4] and may relieve the strain on the hinges of a trimaran completely, when folded out and screwed on top of the main hull. In one version the outriggers are fixed to the connecting beams of a trimaran and rotate during the folding process, in the other version the outriggers are hinged to the connecting beams and remain virtually upright. One variant has 2 hinges on top of a trimaran main hull, the other has only one hinge there. These hinges are located at the ends of two struts, whose other ends are pivotally connected to half beams, that themselves are hinged to each other at the center of the mechanism. This simple structure is stabilized during the folding process by ropes, making use of the elliptic course of points on the half beams during folding. Furthermore, a new vertical folding mechanism for catamarans is presented there, which can be used on the water. Such mechanisms have not been used extensively so far. The latter uses a composition of improved versions of assemblies, that reduce rotation of trimaran outriggers during folding and were presented in [6].

Although the different vertical folding mechanisms have the advantage of simple construction and stabilizing methods of the structure, a common disadvantage is the elevation of the structure when folded in, possibly making problems in road transport or passage under bridges on the water. Another problem with vertical folding mechanisms is the fact, that most of them cause an unfavorable rotation and up and down movements of trimaran outriggers during the folding process.

In a recent patent application [7] a new horizontal folding mechanism is described, where disadvantages of vertical and existing horizontal folding mechanisms are overcome. This simple and stable mechanism for catamarans and trimarans is the subject of the paper presented here.

## II. METHODS

Because of the simplicity of the structure the calculations needed to establish the drawings are straightforward.

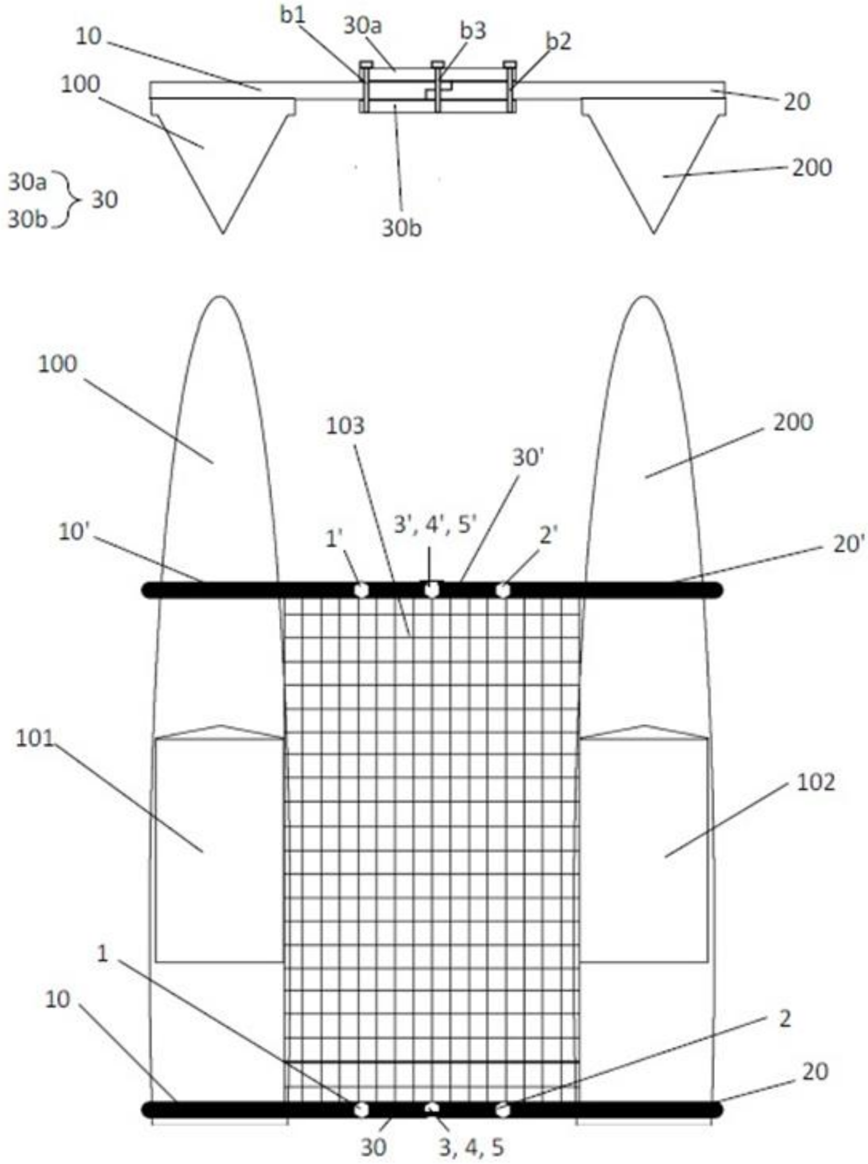


**Fig. 1.** Folding assemblies when folded out, top and side view (see text)

All figures consist of schematic drawings, showing the principles of the designs. The easiest way to understand these principles is looking at Fig. 1, showing a side view or section respectively at the upper part and a top view underneath in the folded out position. Characteristic points and structures are numbered in all drawings. The two mechanisms shown are the same, the upper part uses the same numbers as the mechanism at the stern of the two hulls 100 and 200, but additionally an apostrophe to differenciate. The description considers only the mechanism at the stern, but is valid for the bow mechanism as well. Half beams 10 and 20 are permanently fixed or screwed to the corresponding hulls and hinged to connecting struts 30a and 30b at pivot points 1 and 2, which can be seen in the side view, where bolts b1, b2 and b3 stabilize the structure. Both half beams overlap in the center, having recesses there, which can also be seen in the side view in Fig. 1. In all top views the struts 30a and 30b are collectively given the number 30. Folding can be achieved by removing bolt b3 and opening b1 and b2 half a turn, if they have a thread. The hulls carry cabins 101 and 102 and between them a trampoline 103. The position of the bolt b3 carries the numbers 3, 4 and 5, which will be explained later.

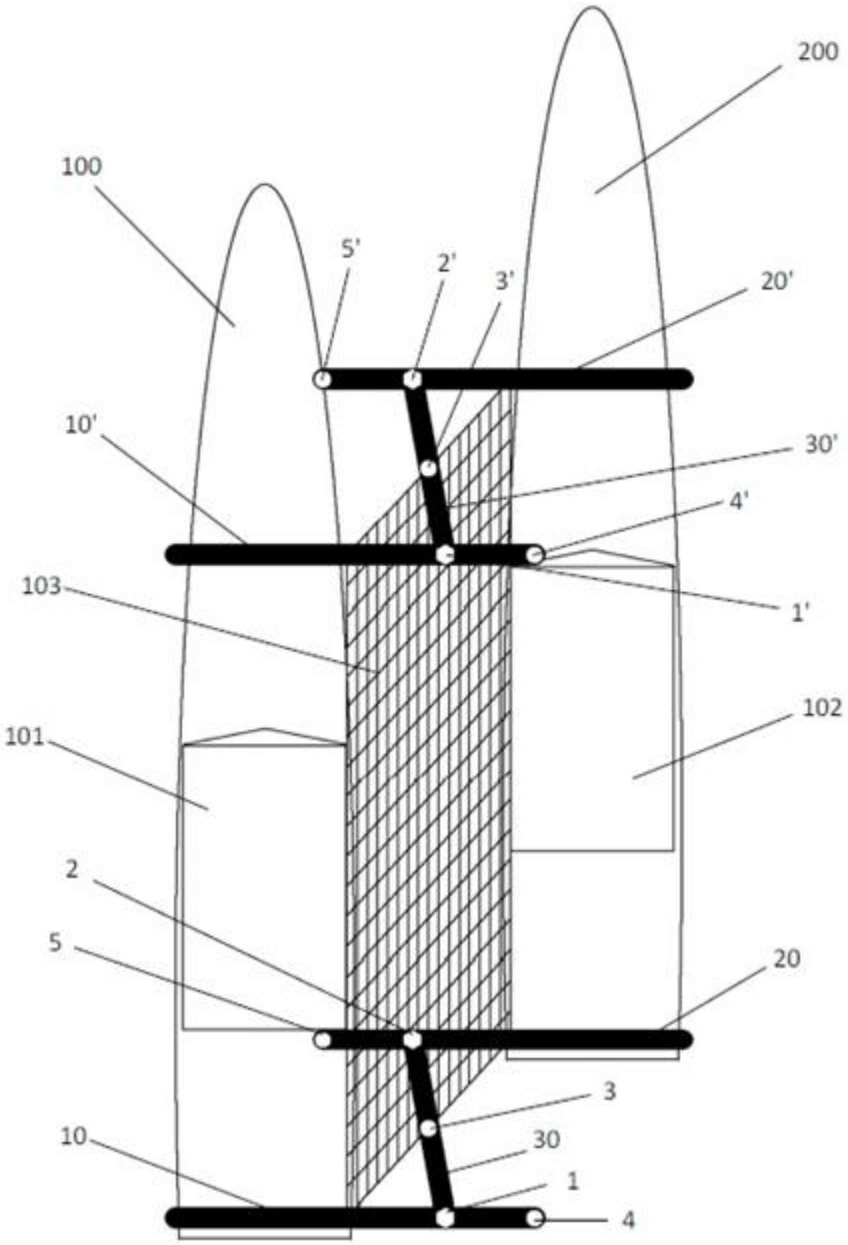


**Fig. 2.** Folding assemblies at an intermediate position (see text)

When the assembly is folded in, holes 4 and 5 appear at the ends of the half beams and hole 3 can be seen at the center of struts 30. All these holes coincide in the folded out position seen in Fig. 1, but appear in Fig. 2, showing an intermediate position.

Fig. 3. shows the assembly, when it is completely folded in. An additional strut 40 is shown here, which is hinged to points 3 and 3‘-

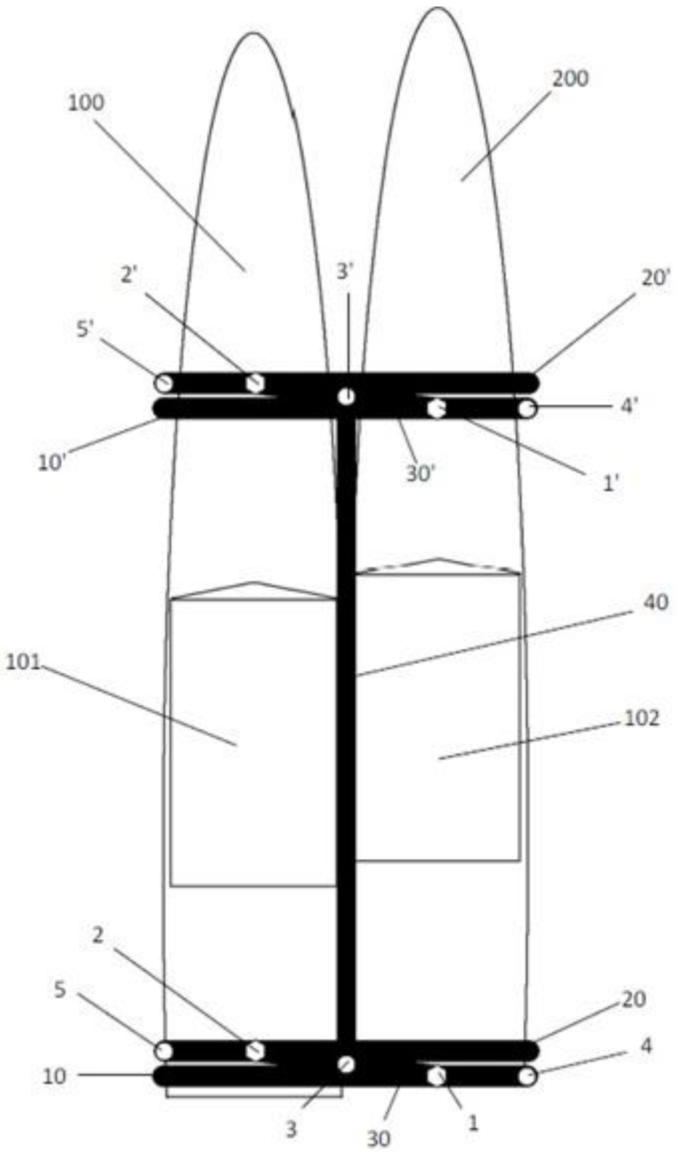


**Fig. 3.** Folding assemblies when folded in (see text)

For the calculation of the relevant positions during folding the left hull 100 is thought to be fixed. The distance between the pivot points 1 and 2 and their position on the half beams 10 and 20 is chosen in the example in order to achieve approximately a 50 % total boat width reduction during folding as can be seen from the drawings. If pivot point 1 is considered to be fixed, pivot point 2 rotates around it. From the rotation angle ß and the distance between both points d, the coordinates of point 2 relative to point 1 are d*cos ß and d*sin ß for the ordinate and abscissa, hole 3 having half this amount. The distances between points 2 and 5 as well as between points 1 and 4 must be d/2 in order to achieve superposition of points 3, 4 and 5 when folded out. If both hulls 100 and 200 are kept parallel during folding, positions of all points of hull 200 and its accessories show the same coordinate shift as that between points 1 and 2 mentioned above. The case when hulls are not kept parallel is left to the following discussion.

## III. DISCUSSION

The strut 40, mentioned in the previous chapter and shown in Fig. 3, is optional and can prevent a dislocation of the hulls from the parallel position during folding. Such a dislocation would otherwise be possible, but is not harmful, as a parallel position can always be adjusted. Furthermore, strut 40 can serve as support for the trampoline 103 between the hulls, which may consist of a net or water-proof material. Eventually this strut can be replaced by the central main hull of a trimaran. In the latter case the hulls 100 and 200, which are now trimaran outriggers, have to be slimmer than represented in the drawings in order to accommodate the bigger main hull in the center.

The pivot points 1 and 2 may be equipped with hinges or just consist of holes with bolts, e. g. b1 and b2 shown on top of Fig. 1. The best options are hollow hinges, allowing the insertion of bolts that have a thread at their ends. These bolts may then be screwed to the lower part of strut 30b, exerting pressure to the system for further stabilization. These bolts need not be removed for folding, they have just to be opened about half a turn. The central bolt b3, however, must be completely removed for folding. In the folded in position, shown in Fig. 3, other bolts could be used to stabilize the mechanism for road transport or during stay in a marina berth. If hull 100 is equipped with threads underneath holes 3 and 5, such bolts could pass through the holes and be screwed to this hull. For a small trimaran screwing the mechanism to the central main hull at position 3 in the folded out position might be sufficient, but bigger ships should additionally be screwed to the deck at positions 1 and 2 with longer screws passing through the corresponding hollow hinges and into threads on the deck.

The gap between the cabins on the hulls could be bridged by a hardtop in the folded out position in order to generate more space for the accommodation of the crew. Another option is the extension of the cabin 101 on hull 100 to the center of the boat in that position. If cabin 102 on hull 200 is open at the inner side, underneath and the back part, it may also be extended to the boat center when folded out and would glide over cabin 101 when folded in. The bottom of cabin 101 should then be slightly higher than the trampoline and the deck of hull 200. Both roofs of the cabins could have equal heights, if they are slightly sloping down to the front. Only at the boat center the heights should be different, if they overlap there. The extended cabin 101 may be completely closed, apart from an access, providing a safe accommodation for the crew. Cabin areas have to be avoided by the folding mechanisms if they are fixed to the decks, either permanently or using screws, and if cabins are higher that the deck level, which is normally the case. In the examples presented here, half beam 20 glides over the back part of the boat and half beam 20' glides over the front part during folding, thus avoiding cabin areas.

Masts for sails may be fixed to the front part on each hull or one single removable mast could be put at the boat center. Another option is an A-frame, whose name derives from its form. The feet of two slim masts are fixed to the ends of strut 30' and their top is joined together. Additionally they are joined together by a cross brace, thus looking like the letter A. A triangular sail may be hung between the cross brace and strut 30'. This sail is equipped with struts in the front and bottom leech for stabilization. If the struts are bent, the sail is also called crab claw sail. The A frame rotates during folding and because of its intrinsic stability the masts may be slim and stays on the side are not necessary. Stays are only necessary in order to prevent forward and backward movements of the structure under sail and may be fixed with snap hooks for easy removal when folding. If the A frame is too high and is therefore cut off at the cross brace level, some staying at the sides might be necessary as well.

If each hull of the catamaran is equipped with an engine, the folding process can be supported by the engines, provided the above mentioned bolts are loose or removed. When folded out, the engine of hull 100 pulls backwards and that of hull 200 pulls forward until a position shown in Fig. 2 is nearly reached. There is a "dead center", where pulling would not help, but the inertia of the moving masses may overcome this point, if the engines are stopped at the right moment. The position of the hulls should then approximately be that shown in Fig. 2. Now, the pulling direction of both engines is reversed and the folded in position shown in Fig. 3 may be obtained. An analogous procedure would achieve a folding out process. The process could be automatically controlled, especially if the engines are powered by electricity.

That these mechanisms not only work in theory has been shown in models, including the mentioned extended cabins and the frame for sail fixing.

## IV. CONCLUSIONS

The new horizontal folding mechanism for multihull boats presented here has a very simple yet stable structure. The fixing of this structure when folded out is simple and should withstand rough waters at high sea. Folding is quick and possible on the water, i. e. dismantling is not necessary. Just one screw per mechanism has to be removed for folding. It has been shown in models, that the mechanism including cabin space extension and sail fixing possibilities also work in practice. The assembly may be applied for catamarans and trimarans. The disadvantages of other horizontal and vertical folding systems are avoided. There is no obstructive elevation of the structure when folded in as in vertical folding systems and trimaran outriggers do not rotate or move up and down during folding. There is only a minimal boat length extension when folded in, unlike many horizontal folding systems. It is stable and would withstand minor damage without complete impasse, unlike for example telescoping horizontal systems. Last but not least the problem of unfavorable leverage of other horizontal mechanisms has been bypassed by taking the load off the hinges through struts screwed over them. This is one of the most important features of the new system, allowing simpler construction and also better stability.

## ACKNOWLEDGMENT

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