(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 299 275 A1

# (12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
**28.03.2018 Bulletin 2018/13**

(51) Int Cl.:
***B63H 9/06*** *(2006.01)* ***B63H 9/10*** *(2006.01)*

(21) Application number: **17250010.0**

(22) Date of filing: **08.09.2017**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**
Designated Validation States:
**MA MD**

(30) Priority: **25.09.2016 GB 201616255**
**09.06.2017 GB 201709183**

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## (54) A WINGSAIL

(57) A wingsail comprising:
(a) a plurality of support members (2) which are slideable along a mast (3) and which are moveable between a first condition and a second condition;
(b) a sail covering (1) which is fastened to the support members (2) and which is formed by two continuous sheets of material, one on each side of the wingsail;
(c) fastener means (4, 5); and
(d) tension-providing means for hoisting and providing tension in the sail covering,
and the wingsail being such that:
(e) in the first condition the support members (2) each form a rigid aerofoil-shaped section in a plane perpendicular to the mast, which ensures that the sail covering (1), when the leading edges of the two sheets of material are connected together by the fastener means (5), forms a single double-surfaced covering with single curvature around the aerofoil sections formed by the support members (2), and the sheets of material are maintained in a taut condition between the support members by means of tension provided by the tension-providing means stretching the covering material over the support members (2);
(f) in the second condition, the support members (2) are such that the parts of the support members (2) to which each side of the sail covering (1) are fastened, each form a straight line in a direction transverse to the mast (3); and
(g) in going from the first condition to the second condition, the two sheets of material forming the sail covering (1) are separated from each other where they were connected together by the fastener means at the leading edge of the wing, the support members (2) vary their geometry so that the sail covering (1) changes from forming a single double-surfaced aerofoil shape in a plane perpendicular to the mast (3) in the first condition, to a pair of separate pieces of covering which are straight in a transverse direction to the mast (3) along a chord of the wingsail when the support members are in the second condition, thereby allowing the support members (2) to be lowered down the mast (3) when the tension in the tension-providing means is reduced, reducing the spacing between the support members (2) along the mast (3), while the sail covering (1) between the support members (2) is able to be flaked down while still attached to the support members (2), or detached from the support members (2) and rolled up, in either case without causing double curvature in the sail covering (1), with the exception of a transition zone between a first zone where the support members (2) are in the first condition thereby forming an aerofoil shape and a second zone where the ribs are in a second condition in which the covering is able to be flaked or rolled up, the transition zone being of a sufficient length to keep the degree of double curvature in the sail covering (1) within the limits that the sheets of material can accommodate without damage from creasing or crumpling.

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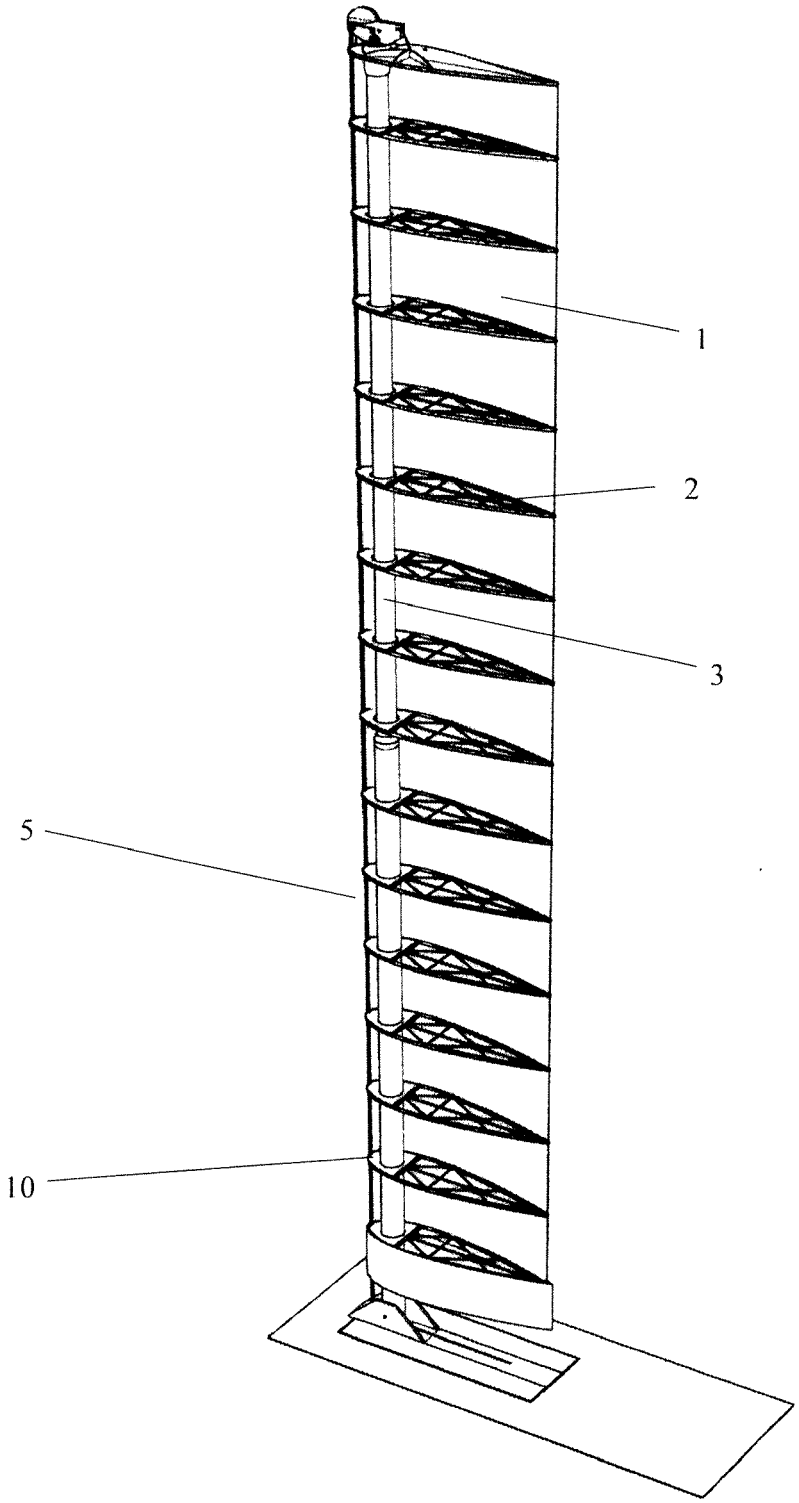


Figure 2

## Description

**[0001]** This invention relates to wingsails.

**[0002]** Modern sailcloth is increasingly being made of sheet materials, in some cases reinforced by fibres bonded on to them in areas where they are needed to cope with the tensile forces in the sail. This makes them much more efficient aerodynamically than traditional sails made from woven fabric. It also has a disadvantage in that they cannot be crumpled up or even folded with creases without suffering sufficient damage which would significantly reduce both the aerodynamic efficiency and longevity of the sails.

**[0003]** Rigid wing sails similar to the wings of an aircraft have been shown to offer considerable performance advantages over conventional soft sails made from a single layer of sailcloth.

**[0004]** Existing wingsail systems may be regarded as falling in the following categories:

(a) Permanently constructed units comprising both mast and sail together without any means of lowering or reducing the sail area apart from taking the whole wing sail including mast down and storing it in what is effectively an aircraft style hangar. These have been developed for racing boats usually with large budgets where practicality is not an issue and cost is a secondary concern, but have very limited use outside of this.

(b) Systems that can be lowered in a manner similar to a Chinese style collapsible paper lantern in which the lowered part of the sail is just simply crumpled up, a process which effectively prohibits the use of efficient modern sailcloth made from sheet materials such as Mylar® and even when woven fabrics commonly used for sailcloth, such as Dacron® are used, gradually degrades the quality and efficiency of the sails.

(c) Units having double sail surfaces that are effectively each a conventional soft sail and which rely on the stiffness of their battens unsupported by internal framework to maintain the shape of the sail. This has the drawback of resulting in a sail that tends to have greater curvature as it gets deformed by strong winds, whereas the opposite is required in order to reduce drive to maintain control of the boat in these conditions.

**[0005]** It is an aim of the present invention to provide an improved wingsail. More specifically, the present invention aims to provide a wingsail by which the problems described at (a) to (c) above may be avoided, while retaining the performance advantages of rigid aerofoil section sails using modern sheet film or similar materials by utilising a deployable wingsail with rigid sections.

**[0006]** Accordingly, in one non-limiting embodiment of the present invention there is provided a wingsail comprising:

(a) a plurality of support members which are slideable along a mast and which are moveable between a first condition and a second condition;

(b) a sail covering which is fastened to the support members and which is formed by two continuous sheets of material, one on each side of the wingsail;

(c) fastener means; and

(d) tension-providing means for hoisting and providing tension in the sail covering,

and the wingsail being such that:

(e) in the first condition the support members each form a rigid aerofoil-shaped section in a plane perpendicular to the mast, which ensures that the sail covering, when the leading edges of the two sheets of material are connected together by the fastener means, forms a single double-surfaced covering with single curvature around the aerofoil sections formed by the support members, and the sheets of material are maintained in a taut condition between the support members by means of tension provided by the tension-providing means stretching the covering material over the support members;

(f) in the second condition, the support members are such that the parts of the support members to which each side of the sail covering are fastened, each form a straight line in a direction transverse to the mast; and

(g) in going from the first condition to the second condition, the two sheets of material forming the sail covering are separated from each other where they were connected together by the fastener means at the leading edge of the wing, the support members vary their geometry so that the sail covering changes from forming a single double-surfaced aerofoil shape in a plane perpendicular to the mast in the first condition, to a pair of separate pieces of covering which are straight in a transverse direction to the mast along a chord of the wingsail when the support members are in the second condition, thereby allowing the support members to be lowered down the mast when the tension in the tension-providing means is reduced, reducing the spacing between the support members along the mast, while the sail covering between the support members is able to be flaked down while still attached to the support members, or detached from the support members and rolled up, in either case without causing double curvature in the sail covering, with the exception of a transition zone

between a first zone where the support members are in the first condition thereby forming an aerofoil shape and a second zone where the ribs are in a second condition in which the covering is able to be flaked or rolled up, the transition zone being of a sufficient length to keep the degree of double curvature in the sail covering within the limits that the sheets of material can accommodate without damage from creasing or crumpling.

**[0007]** The support members may be open lattice frames such for example as trusses. Other constructions for the support members such for example as solid continuous aerofoil sections may be employed.

**[0008]** The fastener means may be a zip fastener. Other types of fastener means may be employed. Thus, for example, the fastener means may be a strip with grooves on each side in to which bolt ropes attached to the leading edges of the sheets of covering material may be inserted. The strip may be segmented to facilitate adjustment of its position.

**[0009]** The support-providing means may be a halyard. The halyard may be used as a method of hoisting the sail. The support-providing means may alternatively be one which pushes the sail up the mast by hydraulics (for example similar to the extension of a boom of a mobile crane), and an arrangement such as this might be used in super yachts or ships.

**[0010]** The wingsail may be one in which some or all of the support members are each a rigid lamina forming the leading part of the aerofoil shape of the wing section from the leading edge of the wingsail to a point close to the thickest point of the aerofoil, and telescoping framing which causes the shape of the outer longitudinal frame members to which the covering is connected to change from a curve matching the aerofoil section of the wingsail in the first condition to straighten out when in the second condition.

**[0011]** Alternatively, the aerofoil may be one in which some or all of the support members each comprises a rigid lamina in the full aerofoil shape of the wing section, and longitudinal framing members which are wholly or partly detachable from the lamina as needed to facilitate the change of geometry of the support members from the first condition to the second condition. The longitudinal framing members may be, for example, channel sections fitting over the edges of the rigid lamina to which the covering is attached. Other types of longitudinal framing members may be employed.

**[0012]** The wingsail may be one in which the transition zone is covered by a separate removable sail cover which is able to act as a fairing to prevent the wind from adversely affecting the sail covering within the transition zone. The wingsail may be used without a separate removable sail cover if desired.

**[0013]** The wingsail may be one in which the sail covering is directly attached to the support members. Alternatively, the wingsail may be one in which the sail covering is indirectly attached by means of separate battens attached to the covering and fastened to the support members. This alternative construction may advantageously facilitate the complete removal of the wingsail covering from the mast while the mast remains in place on the vessel. It is still possible to reinforce this covering material to strengthen it and have holes for the fasteners through the reinforced covering, without separate battens, and detach the covering by undoing the fastenings.

**[0014]** The present invention extends to the wingsail when manufactured and sold with or without the mast. When the wingsail is sold with the mast, then the mast may be a solid or tubular mast.

**[0015]** The mast may be circular in cross section for facilitating rotation of the support members around the mast. Alternatively, the mast may be of another geometric cross-sectional shape which facilitates sliding of the support members longitudinally along the mast without the support members rotating transversely around the mast. In this case, the geometric shape will normally have straight sides, and so the mast may be square or rectangular in cross-sectional shapes. Other cross-sectional shapes may be employed.

**[0016]** The wingsail may be one in which the mast is a stayed mast formed by modifying the masthead to incorporate attachment points for stays which are offset outwards from the centreline of the mast sufficiently to allow for a limited degree of mast rotation. This arrangement may make the rig suitable for mounting on cross beams of open decked beach catamarans in place of the single surface sailed sloop rigs conventionally used. It may also make for the provision of a forestay that would facilitate the use of a foresail as is done with existing stayed rigid wingsail rigs.

**[0017]** Alternatively, The mast may be one in which the mast is a telescopic mast consisting of concentric tubes together with hoist means for hoisting the tubes utilising tensioning means for maintaining tension in the covering material of the wingsail while the inner section of the mast is being hoisted, as well as when sailing with a partially hoisted inner mast. Such a construction may advantageously enable the height of the mast to be reduced when not all of the full height of the wingsail is hoisted. The construction may allow for the reduction of the windage of the rig, which is particularly important for use in survival conditions with extremely high wind speeds. The construction may also allow for the reduction of air draft under bridges. The construction may also facilitate raising and lowing of the mast since a half-height mast is much simpler to keep under control during the operations than a fully extended mast would be.

**[0018]** During the use of the wingsail, in going from the first condition to the second condition, the sail covering may be detached from the support members in a region extending from the leading edge of the wingsail to a location near a thickest region of the aerofoil. The sail covering does not have to be detached from the support members and, in an alternative embodiment of the in-

vention, the sail covering can be left attached to the support members if the support members are flexible enough to go around the continuous lamina near the leading edge of the wing section and then straighten out.

**[0019]** The wingsail may include a plurality of multi-element wingsails that can be reduced in area to suit the wind and weather conditions, and that comprise individual aerofoil section wingsails of the present invention forming each element, and then articulating the elements so that the elements work together. This is as commonly done in the case of wingsails composed of fully rigid wing elements which cannot be adjusted in size when in use.

**[0020]** The most obvious use of this invention is in yacht, beach catamaran and other small craft sails enabling practically useable sailing boats to have much of the performance normally only associated with powerboats and this may encourage some powerboaters to make the switch to sailing craft, with consequent fuel savings.

**[0021]** The concept can also easily be scaled up to sizes suitable for use in superyachts and commercial shipping. In this area, there have been experiments involving the use of wing sails, but these wing sails are fixed in size and the size of the sails is thus limited by the ability of the ship to carry them in bad weather without risking being overturned by the force of the wind on the sails. They are mainly being considered as a means of reducing fuel consumption in a conventional motor vessel. A multiple element wing sail that can be reduced in area to suit the wind and weather conditions will allow a ship to carry a larger and more powerful rig in light winds and still have the aerodynamic performance advantages of a wing sail, increasing the potential fuel savings.

**[0022]** In the case of an auxiliary sailing rig on a conventional large motor vessel such as a bulk cargo carrier, the sails could be rolled up on either side of each mast and stored in boxes on or below deck when the ship is in port so as to leave a relatively unobstructed deck area during loading and unloading operations. The covering sheet material has been described as a film as is current practice for covering rigid wing sails in yachts, but particularly in the case of larger vessels such as commercial ships and superyachts, other laminar materials potentially including fibre reinforced plastic laminates or sheet metal could be used, possibly incorporating horizontal hinges as used in roller shutters to facilitate bending or rolling up in the vertical plane when not being used for sailing.

**[0023]** The use of a large wingsail rig which can be reduced in size when needed in conjunction with telescoping masts enables the height of the mast to be reduced when not all of the full height of the wing sail is hoisted. This allows for reduction of the windage of the rig which is particularly important in survival conditions with extremely high wind speeds and also reduces air draft under bridges and facilitates raising and lowering of the mast since a half height mast is much simpler to keep under control during these operations than the fully extended mast would be. This enables the development of sailing cruise ships, in which the sailing rig is the main power source, which can have a level of performance that matches or exceeds that of an equivalent fossil fuel powered cruise ship and can use harbours and waterways with bridges in a similar manner to motor ships. This can open up the market for sailing cruise ships from its current relatively small niche to a much more mainstream position. A market swing towards a significantly larger proportion of sailing cruise ships would result in significant reductions in fossil fuel use.

**[0024]** Embodiments of the invention will now be described solely by way of example and with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a double surfaced wingsail;

Figure 2 is a view like Figure 1 but shows internal parts of the wingsail;

Figure 3 is a view from the underneath and one side showing part of the construction of the wingsail shown in Figure 1;

Figure 4 is a view from above and one side showing part of the construction as shown in Figure 3;

Figure 5 illustrates the adjustment of the wingsail between the first condition and the second condition;

Figure 6 shows a frame part of the wingsail;

Figure 7 shows in enlarged form part of the frame shown in Figure 6;

Figure 8 shows an alternative form of construction of horizontal frames;

Figure 9 is a perspective view of part of a masthead with a wingsail;

Figure 10 is an underneath view of part of the masthead as shown in Figure 9;

Figure 11 shows a detail of part of the masthead and illustrates in particular a pulley system;

Figure 12 shows two views of a segment used in the wingsail of the present invention;

Figure 13 is a view of a wingsail with the lower part flaked on a mast;

Figure 14 is an end view of the flaked part of the wingsail shown in Figure 13;

Figure 15 shows an optional version of a wingsail;

and

Figure 16 is a close-up view of part of the wingsail as shown in Figure 15;

**[0025]** Referring to the drawings, Figure 1 shows a view of a double surfaced wing sail formed by stretching a sail covering in the form of layer of fabric or film 1 over a vertical series of parallel rigid aerofoil section frames 2.

**[0026]** Figure 2 shows a similar view to that shown in Figure 1, but with the sail covering 1 removed from one side of the aerofoil to reveal the internal structure of the aerofoil section frames 2 and the mast 3 that supports them.

**[0027]** Figure 3 shows a closer view of two of the frames 2 and one side of the covering film 1 with fastener means in the form of a trailing edge fastening 4 at each frame and a segmented leading edge fastening strip 5, both of which connect the two sides of the covering film 1 together.

**[0028]** Figure 4 shows a detailed view of a single frame 2 and the upper 3 and lower 21 sections of a telescoping mast which the frame 2 slides over, with a tapered joint bushing 42 which is likely to be advantageously made of a low friction material such as PTFE. This is to facilitate both the sliding of the frames 2 over it and the sliding of the inner mast tube 3 of a telescoping mast relative to the outer mast tube 21. It also shows details of fastenings 14 which connect removable battens 13, to which the covering film 1 is attached, to the longitudinal side members 8 of the frame 2.

**[0029]** Figure 5 shows detailed plan views of a single frame 2, which has been removed from the mast and covering film, in both a closed position in which it forms an aerofoil shape with the ends of the longitudinal side members 8 at the trailing edge of the aerofoil section joined together by a fastening 4 and in an open position with the longitudinal side members 8 parallel. This illustrates the frame's variable geometry which is achieved by allowing the outer telescopic tube 7 of the frame slide over the inner telescopic tube 18 to move the bracket 17 in Figure 6 into a position where the struts 15 are perpendicular to the centreline of the frame as the longitudinal side members 8 straighten out. When the frame 2, is in the closed position the struts 15 control the shape of longitudinal side members 8, ensuring that the correct aerofoil shape is maintained.

**[0030]** Figure 6 shows a perspective view of a frame 2 with the longitudinal side members 8 in Figure 5 removed for clarity.

**[0031]** Figure 7 shows a perspective view of the outer telescopic tube 7 of the frame together with bracket 17 and struts 15, shown separated from the rest of the frame.

**[0032]** Figure 8 shows an alternative form of constructing the horizontal frames in which longitudinal side members 12 are formed from initially straight channel sections fitted over a solid aerofoil shaped foam cored laminate 9 and bent around it. The webs of the channel sections are cut away with the exception of a few localised tabs 30 towards the leading edge of the frame to allow them to have sufficient flexibility to curve around it.

**[0033]** Figure 9 shows the masthead with details of pulleys (blocks) used for hoisting the wingsail up the mast and for adjusting the position of the bottom end of the segmented fastening strip and tensioning the segmented fastening strip 5 at the leading edge of the wingsail. This adjusting and tensioning may be necessary if the type of segmented fastening illustrated in Figure 15 is to be used. More specifically, this type of segment fastening strip is illustrated as it will work for all rigs regardless of size, power, but could be simplified by using a zip if the tension force generated can be accommodated by the teeth of the zip. In that case, the slider of the zip can easily be adjusted and does not need a special means of adjustment of the lower end of the zip, or greater tension vertically than the halyard can generate.

**[0034]** Figure 10 shows the masthead from below with details of a tapered collar 31 around the top of the mast to keep the top frame centred when hoisted up over it.

**[0035]** Figure 11 shows a close-up view of the masthead with the cover 24 in Figure 9 removed to illustrate the segmented leading edge fastening strip 5 of the wingsail going over a large diameter sheave 23 and down through the mast tube omitted to show the segmented strip inside it.

**[0036]** Figure 12 shows a close-up view of a single typical segment 20 at the leading edge of the wingsail showing grooves 22 on each side which are sized to accommodate bolt ropes attached to the leading edges, often referred to as luffs, of the covering film or fabric 1 in Figure 13 of the wingsail. A central hole 29 allows the segments 20 to be strung together over a rope made from low stretch fibres to form a continuous strip. It is shown superimposed over a view of the lowest segment 32 which is similar to the other segments apart from having flared out grooves 33 at the bottom of the segment in order to facilitate the entry of the boltrope of the covering film 1 in Figure 13 while avoiding contact with sharp edges of the segment 32. To further facilitate the entry of the boltrope of the covering film 1 in Figure 13 a sail feeder (not shown) such as is commonly used with conventional sails with bolt ropes could be attached to the bottom of each side of the bottom segment 32 to control the entry angle of each of the boltropes.

**[0037]** Figure 13 shows a view of the wingsail with the upper telescoping mast tube 3 in Figure 2 retracted into the lower mast tube 21 and the lower part of the covering film 1 loosely folded often referred to as "flaked".

**[0038]** Figure 14 shows a close-up view of the lower part of the wingsail with the lower part of the covering film 1 flaked while attached to the parallel longitudinal side members 8 of open frames and the upper portion is stretched over aerofoil shaped closed frames 2. In between these portions of the covering film 1 is a transition zone in which the bolt ropes in the leading edges of the covering film 1 on both sides of the wingsail exit from the

lowest segment 32 which is positioned just below the lowest closed aerofoil shaped frame 2 and the gap between them gradually widens out to allow them to become parallel to each other before being flaked down. The downhaul line 31 illustrated is attached to the lowest segment 32 and is a means of controlling the height of the lowest segment 32 when operated in conjunction with the tensioning line that runs through the centre holes in the segments 20 and runs over the masthead sheave 23 in Figure 11.

**[0039]** Figure 15 shows an optional version of the main wingsail 37 supported by a one-piece non-telescoping mast 35 with stays 34 to keep it upright. It also illustrates a double wing rig, which can also be used with an unstayed wingsail, with the main wing section 37 linked to a thinner trailing wing section 38 of similar construction supported by an upper boom 39 and a lower boom 40. If desired, the mast could be made from multiple pieces with ferrules like a fishing rod, but not able to slide "telescope" within one another except to be joined together rigidly.

**[0040]** Figure 16 is a close-up view of the masthead of the stayed rig showing the attachment of the stays 34 to a circular spreader fitting 36 at the masthead which keeps them clear of the wingsail while allowing it to have a limited degree of rotation around the mast during normal sailing, although it does not allow the 360 degree rotation possible with the unstayed version of the wingsail.

**[0041]** This invention relates to a wingsail in which the covering 1 in Figure 1 between the frames 2 in Figure 1 is held taut in the vertical direction by means of tension from halyard in the form of a line that hoists the sail. Unlike existing wings sails, the horizontal frames 2 in Figure 1 to which the sail fabric or film covering 1 in Figure 1 is attached straighten themselves out very quickly and easily when the sail is being hoisted or lowered, by unfastening a single fastener 4 in Figures 3 and 4 at the trailing edge of each frame and an easily releasable continuous fastening system 5 in Figure 3 that joins the two film surfaces covering each side of the wing section at or near the leading edge of the wing section.

**[0042]** As illustrated in Figures 2 to 5 the transverse frames may consist of a structural foam core with fibre reinforced plastic laminate or similar which is used to make a "D" section shape 10 in Figure 4 to form the profile of the leading edge of the sail together with variable geometry framing members between the "D" section and the trailing edge of the sail as illustrated in Figures 4 and 5. A circular cut-out 11 in Figure 5 is made in the laminate a short distance behind the leading edge of the frame to enable the frame to slide up and down over the mast 3 - upper mast tube and 21 - lower mast tube in Figure 4. The cut-out 11 is illustrated as circular to suite a circular mast but may be of other shapes.

**[0043]** As illustrated in Figures 3 to 5, the variable geometry framing 2 in Figure 3, can consist of longitudinal side members 8 in Figures 4 and 5 with variable cross sections resulting in stiffness in bending that is low enough to allow them to have sufficient flexibility to bend around the "D" section laminate 10 in Figure 4 at the leading edge of the sail and stiff enough between the "D" section 10 in Figure 4 and the trailing edge of the sail to enable the aerofoil section to maintain its shape in strong winds. These longitudinal side members 8 in Figures 4 and 5 may be formed from straight channel sections as illustrated in Figures 4 and 5 with variable reductions in horizontal stiffnesses produced by cutting away the flanges of the cross sections in particular. If needed the vertical web can be tapered in thickness to provide sufficient flexibility to curve around the "D" section 10 in Figure 4 at the leading edge of the wingsail. If desired, it is possible to bend the covering around the "D" section without the use of the part of the side members going around it. i.e. the leading (edge) part of the side members may help maintain a smooth transition at the junction between the "D" section and the rest of the frame/member, but it is not essential.

**[0044]** As has been illustrated in Figure 5, there is a telescoping longitudinal central member consisting of inner 18 in Figure 5 and outer 7 in Figure 5 concentric tubes. This has also been illustrated in Figure 6 with the longitudinal side members 8 in Figure 5 removed for clarity. The inner concentric tube 18 in Figure 5 is connected to the leading edge "D" section 10 in Figure 5 via a transverse channel section 19 in Figures 5 and 6 which fits over the trailing edge of the "D" section 10 in Figure 6. The outer concentric tube 7 in Figure 6 is connected to a bracket 17 in Figure 6 to which struts 15 in Figure 6 are connected with pinned joints 16 in Figure 6 allowing rotation of the strut relative to the bracket 17 in Figure 6 in the horizontal plane as illustrated in Figure 7, which shows the outer concentric tube 7 with its bracket 17 and connected struts 15 as a separate structure. The opposite end of each of the strut 15 in Figure 5 is connected to one of the longitudinal side members 8 in Figure 5 by a pinned joint 16 allowing rotation of the strut relative to the longitudinal side member 8 in Figure 5 in the horizontal plane. This connection restrains the longitudinal movement of the outer concentric tube 7 so that it cannot come off of the end of the inner concentric tube 18 in Figure 5, while being free to slide along it within the restricted range of available movement.

**[0045]** The geometric shape of the longitudinal side members 8 in Figure 5 between the "D" section 10 in Figure 5 near the mast 3 and 21 in Figure 4 and the trailing edge of the sail can be controlled by sliding the outer telescoping tube 7 together with its bracket 17 in Figure 6 which is attached to struts 15 in Figure 5 to produce the curvature required to give the desired aerofoil section when the frame is closed up in the sailing position.

**[0046]** As illustrated in the lower part of Figure 5, the geometry of the pin joints 16 in Figure 5 which connect the longitudinal side members 8 in Figure 5 to the rest of the framing including the struts 15 in Figure 5 which are in turn connected by the bracket 17 in Figure 6 to the

outer concentric tube 7 in Figure 5 has been designed to allow all the pin joints 16 in Figure 5 on the longitudinal side members 8 in Figure 5 to lie in a straight horizontal line parallel to the centreline of the frame 2 in Figure 5 when the outer concentric tube 7 in Figure 5 has been slid out to a position where the struts 15 in Figure 5 are perpendicular to the centreline of the frame 2 in Figure 5. For illustrative purposes the figures shown have all been based on the assumption of a NACA 0024 aerofoil section, though other sections may be used with minor variations in the geometry of the framing.

**[0047]** As illustrated in Figure 4, the covering film 1 in Figure 4 may be attached directly to the longitudinal side members 8 in Figure 4 or to battens 13 in Figure 4 which are connected to the longitudinal side members 8 in Figure 4 by means of fastenings 14 in Figure 4 which can be undone to enable the battens 13 in Figure 4 to be removed from the longitudinal side members 8 in Figure 4 when needed. This allows the covering film 1 in Figure 4 and the battens to which it is attached to be rolled up for storage when not hoisted up the mast. Fastenings 14 in Figure 4 connecting the battens 13 in Figure 4, to which the covering film 1 in Figure 4 is attached, to the longitudinal side members 8 in Figure 4 may consist of tumbuttons 14 in Figure 4, which are slotted through the battens 13 in Figure 4 as well as the covering film 1 in Figure 4.

**[0048]** Alternatively, as illustrated in Figure 8 which is shown with the mast removed for clarity, the frames may consist of aerofoil sections made from a rigid material such as a sandwich of a structural closed cell foam core faced with FRP laminates 9 in Figure 8, to which the film is attached by means of removable edge members such as channel sections 12 in Figure 8 which overlap the sandwich section and to which the film material covering the wing is attached.

**[0049]** These longitudinal side members 12 in Figure 8 have variable cross sections resulting in stiffness in bending that is low enough to allow them to have sufficient flexibility to bend around the highly curved part of the laminate 9 in Figure 8 near the leading edge of the sail and stiff enough between there and the trailing edge of the sail where there is much less curvature to enable them to stay fitted over the aerofoil section to maintain their shape in strong winds. The longitudinal side members 12 in Figure 8 are held in place by tension in the covering film 1 in in Figure 8 in the vicinity of the leading edge of the wingsail and by being joined to each other and/or to the trailing edge of the frame laminates 9 in Figure 8 by a similar trailing edge fastening 4 in Figure 4 to that described above for use with the variable geometry frame 2 in Figure 4.

**[0050]** The covering film 1 in Figure 8 may be attached to battens 13 in Figure 4 which are connected to the longitudinal side members 9 in Figure 8 by means of fastenings 14 in Figure 4 in a similar manner to the battens used with the variable geometry frames described above. Alternatively, the longitudinal side members 12 in Figure 8 may be connected to the edges of the laminate 9 in Figure 8 with similar fastenings 14 in Figure 4 with the covering film 1 in in Figure 8 attached e.g. by chemical bonding directly to the longitudinal side members 12 in Figure 8. Either of these alternatives allows the covering film 1 in Figure 8 and the battens 13 in Figure 4 or longitudinal side members 12 in Figure 8 to which it is attached to be rolled up for storage when detached from the frames.

**[0051]** The sandwich laminate framing 9 in Figure 8, is likely to be most suitable for smaller sails and for thinner aerofoil sections such as those used in the trailing edge flaps articulated from the main wing section in multi element wing sails. As illustrated in Figure 9 it is also suitable for the transverse frames at the top laminates 28 in Figure 9, and bottom of any wing sail as it is suitable for stiffening in order to distribute tension loading from the halyard and/or downhaul system without bending the frame vertically. A circular cut-out 11 in Figure 8 is made in the laminate a short distance behind the leading edge of the frame to enable the frame to slide up and down the circular section mast 3 and 21 in Figure 4. Other shaped cut-outs may be used to facilitate sliding over the mast if the mast has another section, e.g. square.

**[0052]** If as illustrated in Figure 4 the film on each side of the wing is attached e.g. by chemical bonding to detachable battens 13 in Figure 4 or channel sections 12 in Figure 8, the film panels forming each side of the wing can then be separated from the framing by undoing fastenings such as turnbuttons 14 in Figure 4 and fully or partially rolled up for storage either on the vessel or ashore if fully detached from the transverse framing.

**[0053]** The covering film 1 in Figure 14 can be straightened in the horizontal plane which allows it to be loosely folded with a sufficiently large bend radius to prevent creasing in a process commonly referred to as "flaking" in the vertical plane as illustrated in Figure 14 without introducing curvature in more than one direction once the fastenings at leading and trailing edges have been unfastened. This allows the wing sail to be fully or partially lowered as illustrated in Figures 13 and 14 without the covering film 1 in Figure 14 being crumpled, creased or otherwise damaged or degraded in functionality. There will be a transitional zone between the aerofoil sections above and the straightened sections where the sail covering film is flaked at the bottom of the wingsail where some degree of biaxial curvature is likely to occur. The effect of this can be limited by ensuring that the zone between the straightened and curved frames is sufficiently long vertically to ensure that the radii of curvature are large enough to prevent distress to the sail covering material 1 in Figure 14. The actual length needed for the transitional zone will therefore depend on the properties of the covering film 1 in Figure 14 or other material used in a particular wingsail. An external flexible fabric cover can be placed over the leading edge in particular of the transitional zone as well as the flaked part of the wingsail covering film 1 in Figure 14 to shelter it from strong winds.

**[0054]** This allows for a rapid reduction in sail area ex-

posed to the wind which may be necessary to prevent the vessel from being overpowered in a sudden gust of wind by flaking the sail material without detachment from the horizontal frames as well as the ability to roll up and remove the sail from the mast for storage in a suitable bag or other suitable container on or off the vessel when there is sufficient time for detaching the sail from the frames. This is more likely to happen when in port in the case of larger vessels or ashore in the case of smaller craft such as beach launched dinghies or catamarans.

**[0055]** As illustrated in Figures 5, 6 and 7, the frame trailing edge fastening system 4 in Figure 5 may consist of a vertical pin with a drop nose or alternatively a spring loaded horizontal catch or other means of securing it in place while being able to be quickly released. A spring loaded horizontal catch may consist of jaws mounted on the longitudinal side members 8 in Figure 5 which lock into the central frame telescopic tube 7 in Figure 5 and which can be released by pressing a spring loaded button 6 in Figure 6, similar in operation to the release button on an automotive mechanical handbrake and is mounted on the end of the outer part of a telescoping central tube 7 in Figure 5 of the frame 2 in Figure 5. In the case of frames consisting of aerofoil sections made from a rigid material 9 in Figure 8 this may run through a reinforced area of laminate.

**[0056]** The frame trailing edge fastening system 4 in Figure 5 may be supplemented by strips of a hook and loop fastener such as Velcro® bonded to the inner faces of the film on either side of the join at the trailing edge of the aerofoil 41 in Figures 3 and 4, to assist in keeping the trailing edges of the film covering panels in between the frame locations together.

**[0057]** As illustrated in Figure 12 the leading edge fastening system may consist of segments 20 in Figure 12 of sufficiently strong material that each contain a pair of luff grooves 22 in Figure 12 into which boltropes attached to the edges of the film panels 1 in Figure 10 are inserted as illustrated in Figures 9 and 10. The segments can be strung along a rope running through a central opening 29 in Figure 12 to form a segmented fastening strip 5 in Figure 9.

**[0058]** Figures 9, 10 and 11 also illustrate a means of maintaining tension in the luff grooves in the segmented fastening strip 5 in Figure 9 while the sail fabric or film panels are being hoisted as well as when sailing by running the segmented fastening strip 5 in Figure 11 containing the luff grooves over a large diameter sheave 23 in Figure 11 mounted on a swivelling masthead crane 27 in Figure 9 on the top of the mast 3 in Figure 9. A sheave cover 24 in Figure 9 ensures that the segmented fastening strip 5 in Figure 9 remains in place as it runs over the sheave.

**[0059]** The top of the segmented fastening strip 5 in Figure 11 is led down through the mast tube as illustrated in Figure 11 with the sheave cover 24 in Figure 9 and mast removed for clarity. The segmented fastening strip 5 in Figure 11 inside the mast tube is connected to a downhaul line which is led through a block pulley to a position where it can be tensioned from deck level.

**[0060]** This also allows the height of the bottom segment 32 in Figure 14 of the segmented fastening strip 5 in Figure 9 to allow the boltropes on the covering film to go from the segmented fastening strip 5 in Figure 9 where the frames form an aerofoil section to the transitional zone where the frames start opening out.

**[0061]** As illustrated in Figure 9 tension in the covering film material 1 in Figure 9 may be maintained by means of a halyard 25 in Figure 9 attached to the stiffened uppermost transverse frame 28 in Figure 9 and routed over a sheave 26 in Figure 9 mounted on the masthead crane 27 in Figure 9 and run down through the mast tube 3 in Figure 9. Downhaul lines attached to the bottom frame which is also stiffened resist the halyard tension, keeping the covering film 1 in Figure 9 in tension.

**[0062]** Alternatively and potentially more suited to smaller sails, the closure at the leading edge of the wing may be made using a zip fastener and/or a flap with a hook and loop fastener such as Velcro®, which may be used to form an aerodynamically smoother surface over the zip fastener. In the case of wing sails for very small inshore craft such as canoes or small dinghies that are only to be used in light winds, an overlap secured by a hook and loop fastener alone may suffice.

**[0063]** The invention may be used in yacht, beach catamaran and other small craft sails. The invention can easily be scaled up to sizes suitable for use in superyachts and commercial shipping. In this area, there have been experiments involving the use of wing sails, but these wing sails are fixed in size and the size of the sails is thus limited by the ability of the ship to carry them in bad weather without risking being overturned by the force of the wind on the sails. They are mainly being considered as a means of reducing fuel consumption in a conventional motor vessel. A multiple element wing sail that can be reduced in area to suit the wind and weather conditions will allow a ship to carry a larger and more powerful rig in light winds and still have the advantages of a wingsail.

**[0064]** In the case of an auxiliary sailing rig on a conventional large motor vessel such as a bulk cargo carrier, the sails could be rolled up on either side of each mast and stored in boxes 14 in Figure 13 on or below deck as illustrated in Figure 13 when the ship is in port so as to leave a relatively unobstructed deck area during loading and unloading operations. The covering sheet material 1 in Figure 13 has been described as a film as is current practice for covering rigid wing sails in yachts, but particularly in the case of larger vessels such as commercial ships and superyachts, other laminar materials potentially including fibre reinforced plastic laminates or sheet metal could be used, possibly incorporating horizontal hinges as used in roller shutters to facilitate bending or rolling up in the vertical plane when not being used for sailing.

**[0065]** Multiple element wing sails can be made using

the invention by using the method described above to make each element and then articulating them so that they work together, as illustrated in Figure 15, and as is normally done in the case of wingsails composed of fully rigid wing elements which cannot be adjusted in size when in use.

**[0066]** This invention can be used with a telescoping mast consisting of concentric inner and outer tubes as is illustrated in Figure 3 together with a means for hoisting the mast inner tube 3 in Figure 3 by means of a halyard attached to the lower part of the inner mast tube and running over a sheave mounted on the upper part of the mast outer tube 21 in Figure 3 and located between the two tubes. Figure 9 also illustrates a means of maintaining tension in the luff grooves while the inner section of the mast in 3 in Figure 3 is being hoisted as well as when sailing with a partially hoisted inner mast tube 3 in Figure 3.

**[0067]** This enables the height of the mast to be reduced when not all of the full height of the wing sail is hoisted. This allows for reduction of the windage of the rig which is particularly important in survival conditions with extremely high wind speeds and also reduces air draft under bridges and facilitates raising and lowering of the mast since a half height mast is much simpler to keep under control during these operations than the fully extended mast would be. In the case of an auxiliary sailing rig on a conventional large motor vessel such as a bulk cargo carrier, the mast itself could be lowered into a recess when not in use, leaving a deck completely unobstructed by the sailing rig.

**[0068]** The recess could be provided with a hatch cover over it in the deck to prevent water ingress and to enable the crew to walk over it safely.

**[0069]** This invention can be used with a stayed mast by modifying the masthead as is illustrated in Figures 15 and 16, making it suitable for mounting on the crossbeams of open decked beach catamarans in place of the single surface sailed sloop rigs conventionally used. The provision of a forestay would facilitate the use of a foresail as is done with many existing stayed rigid wingsail rigs.

**[0070]** Individual components shown in the drawings are not limited to use in their drawings and they may be used in other drawings and in all aspects of the invention. The invention also extends to the individual components mentioned and/or shown above, taken singly or in any combination.

## Claims

**1.** A wingsail comprising:

(a) a plurality of support members which are slideable along a mast and which are moveable between a first condition and a second condition;
(b) a sail covering which is fastened to the support members and which is formed by two continuous sheets of material, one on each side of the wingsail;
(c) fastener means; and
(d) tension-providing means for hoisting and providing tension in the sail covering,

and the wingsail being such that:

(e) in the first condition the support members each form a rigid aerofoil-shaped section in a plane perpendicular to the mast, which ensures that the sail covering, when the leading edges of the two sheets of material are connected together by the fastener means, forms a single double-surfaced covering with single curvature around the aerofoil sections formed by the support members, and the sheets of material are maintained in a taut condition between the support members by means of tension provided by the tension-providing means stretching the covering material over the support members;
(f) in the second condition, the support members are such that the parts of the support members to which each side of the sail covering are fastened, each form a straight line in a direction transverse to the mast; and
(g) in going from the first condition to the second condition, the two sheets of material forming the sail covering are separated from each other where they were connected together by the fastener means at the leading edge of the wing, the support members vary their geometry so that the sail covering changes from forming a single double-surfaced aerofoil shape in a plane perpendicular to the mast in the first condition, to a pair of separate pieces of covering which are straight in a transverse direction to the mast along a chord of the wingsail when the support members are in the second condition, thereby allowing the support members to be lowered down the mast when the tension in the tension-providing means is reduced, reducing the spacing between the support members along the mast, while the sail covering between the support members is able to be flaked down while still attached to the support members, or detached from the support members and rolled up, in either case without causing double curvature in the sail covering, with the exception of a transition zone between a first zone where the support members are in the first condition thereby forming an aerofoil shape and a second zone where the ribs are in a second condition in which the covering is able to be flaked or rolled up, the transition zone being of a sufficient length to keep the degree of double curvature in the sail covering within the limits that the sheets of material can accommodate without damage from

creasing or crumpling.

**2.** A wingsail according to claim 1 in which the support members are frames.

**3.** A wingsail according to claim 1 or claim 2 in which the fastener means is a zip fastener.

**4.** A wingsail according to any one of the preceding claims in which the tension-providing means is a halyard.

**5.** A wingsail according to any one of the preceding claims in which the support members are each a rigid lamina forming the leading part of the aerofoil shape of the wing section from the leading edge of the wingsail to a point close to a thickest point of the aerofoil, and telescoping framing which causes the shape of the outer longitudinal frame members to which the sail covering is connected to change from a curve matching the aerofoil section of the wingsail in the first condition to straighten out when in the second condition.

**6.** A wingsail according to any one of claims 1 - 4 in which the support members each comprises a rigid lamina in the full aerofoil shape of the wing section, and longitudinal framing members which are wholly or partially detachable from the laminae, as needed to facilitate the change of geometry of the support members from the first condition to the second condition.

**7.** A wingsail according to claim 6 in which the longitudinal framing members are channel sections fitting over the edges of the lamina, and to which the covering is attached.

**8.** A wingsail according to any one of the preceding claims in which the transition zone is covered by a separate removable sail cover which is able to act as a fairing to prevent the wind from adversely affecting the sail covering within the transition zone.

**9.** A wingsail according to any one of the preceding claims in which the sail covering is directly attached to the support members, or in which the sail covering is indirectly attached to the support members by means of separate battens attached to the covering and fastened to the support members.

**10.** A wingsail according to any one of the preceding claims and including the mast.

**11.** A wingsail according to claim 10 in which the mast is a solid or tubular mast.

**12.** A wingsail according to claim 10 or claim 11 in which the mast is circular in cross-section for facilitating the rotation of the support members around the mast, or in which the mast is of a geometric cross-sectional shape which facilitates sliding of the support members longitudinally along the mast without the support members rotating transversely around the mast.

**13.** A wingsail according to any claim 12 in which the geometric shape is a square or rectangular cross-sectional shape.

**14.** A wingsail according to claim 10 in which the mast is a stayed mast formed by modifying a masthead to incorporate attachment points for stays which are offset outwardly from the centre line of the mast sufficiently to allow for a limited degree of mast rotation, or in which the mast is a telescopic mast comprising concentric tubes, together with hoist means for hoisting the tubes utilising tension means for maintaining tension in the leading edge of the wingsail while the inner section of the mast is being hoisted, as well as when sailing with a partially hoisted inner mast.

**15.** A wingsail according to any one of the preceding claims and including a plurality of multi-element wingsails that can be reduced in area to suit the wind and weather conditions, and that comprise individual aerofoil section wingsails according to any one of the preceding claims making each element, and then articulating the elements so that the elements work together.

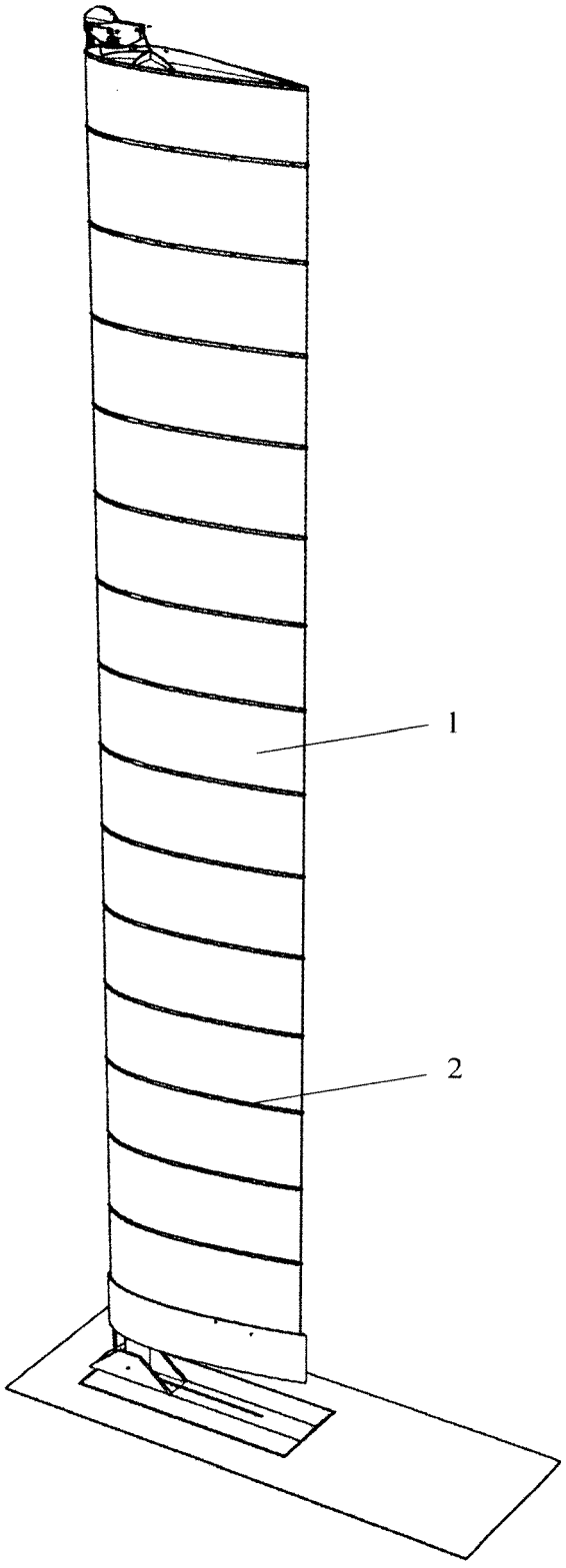


Figure 1

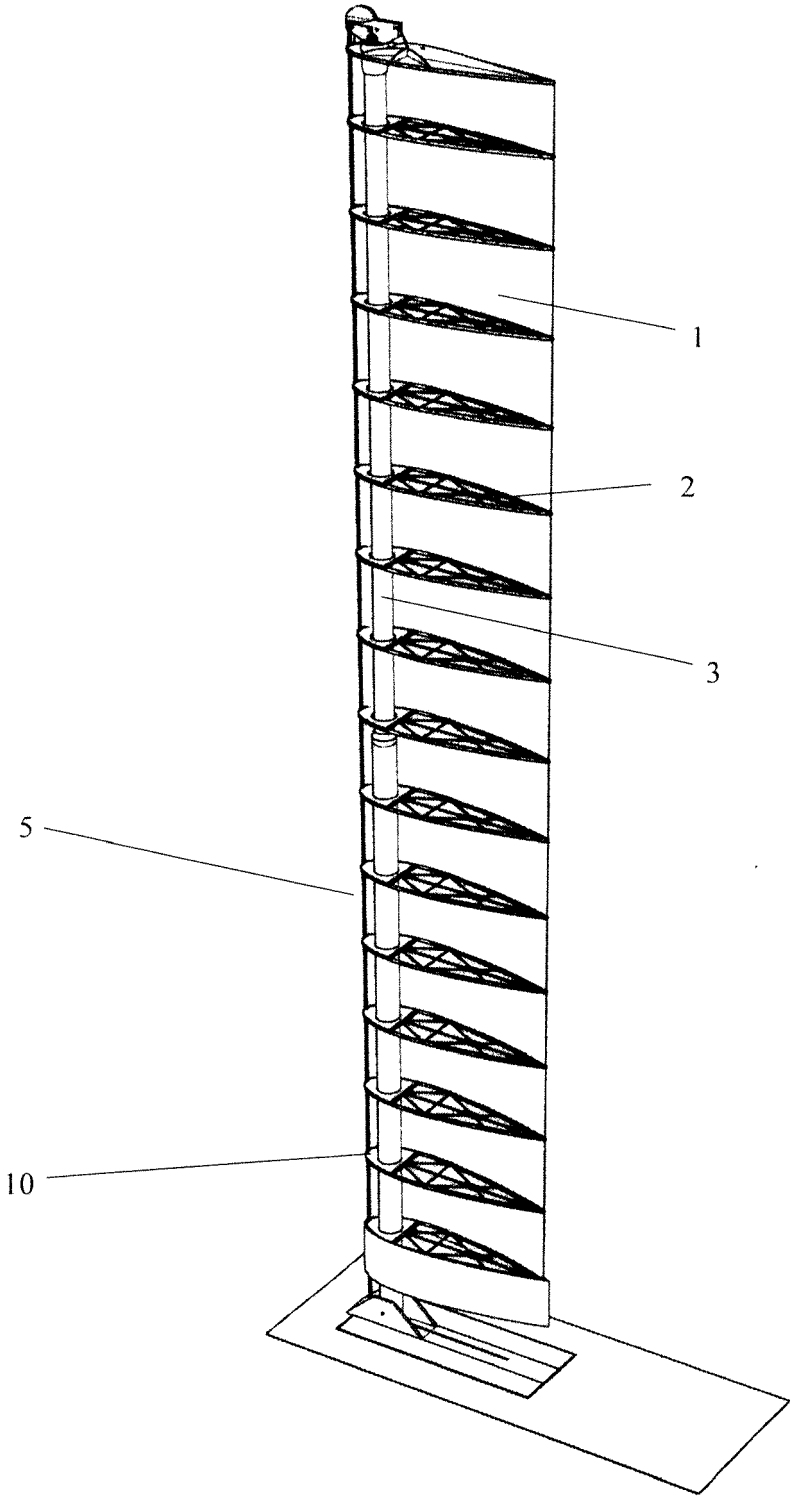


Figure 2

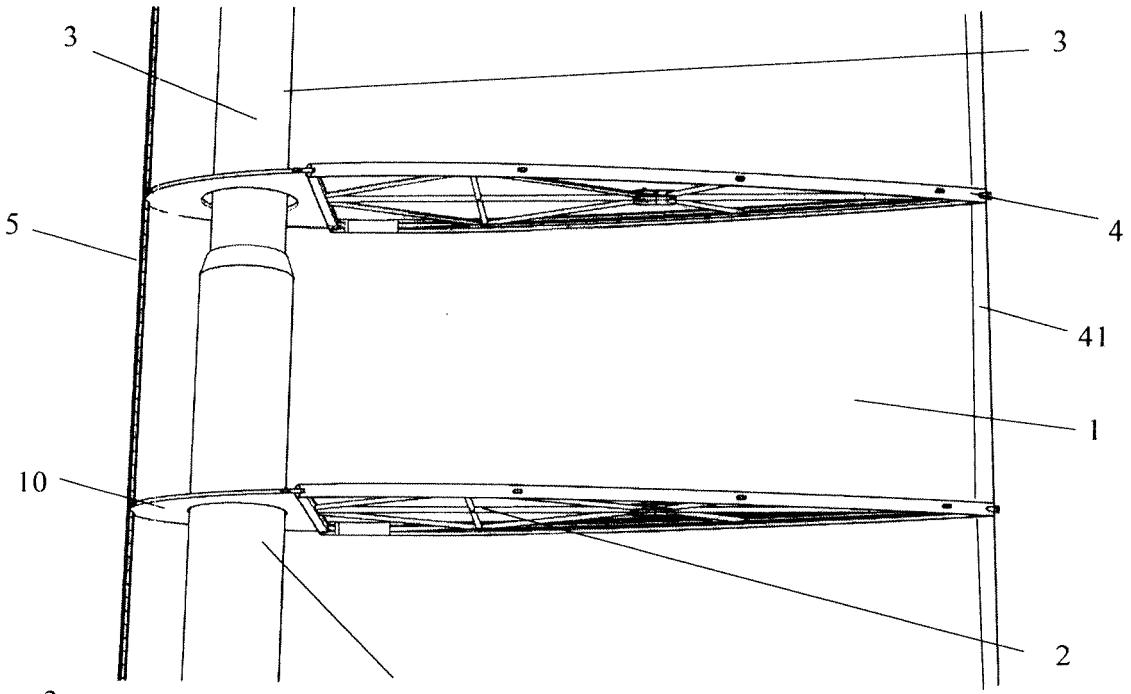


Figure 3

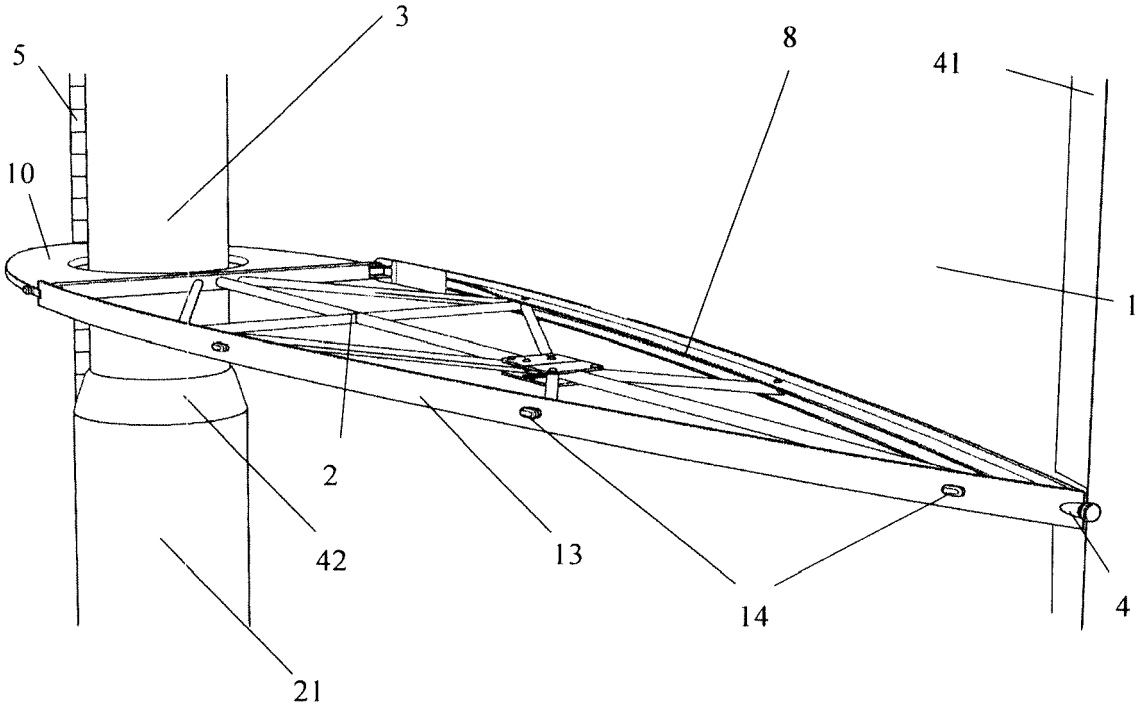


Figure 4

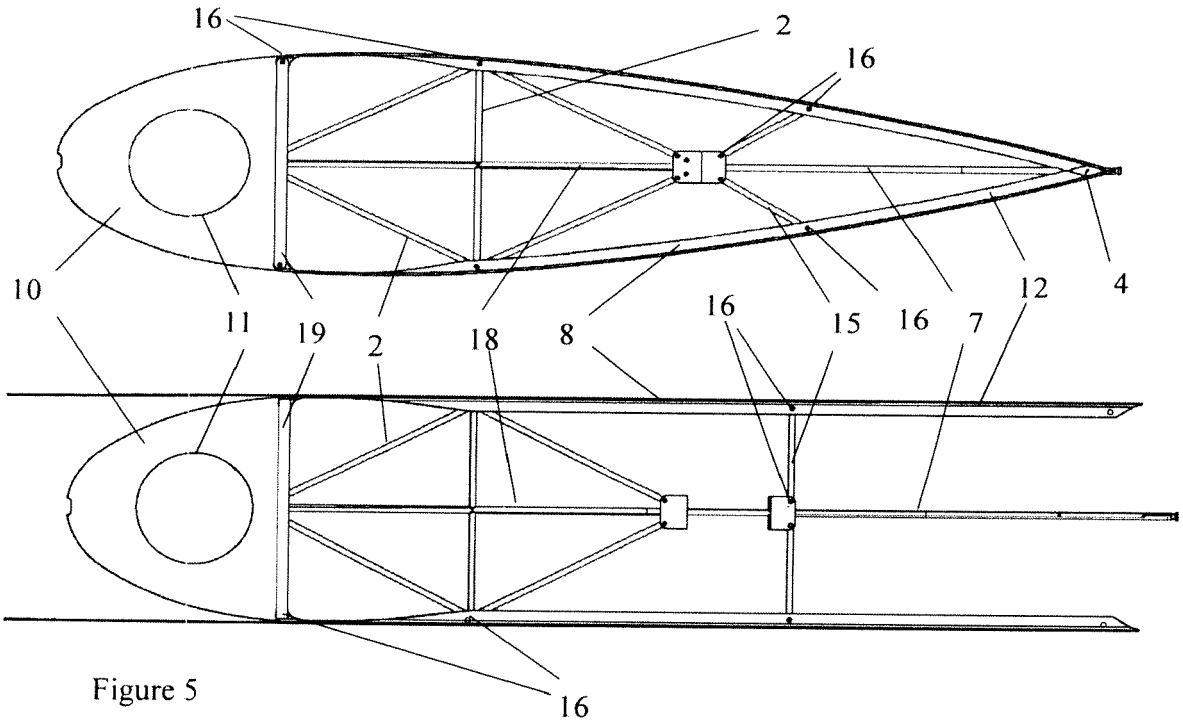


Figure 5

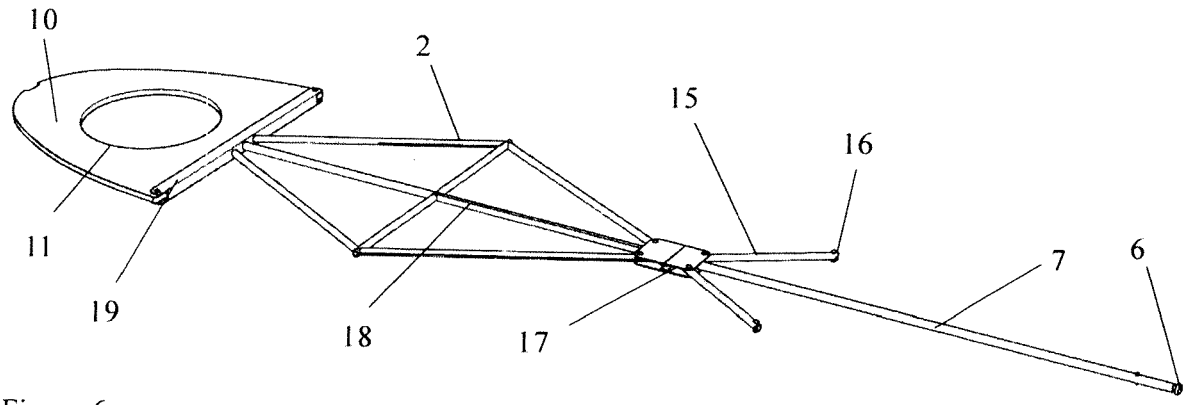


Figure 6

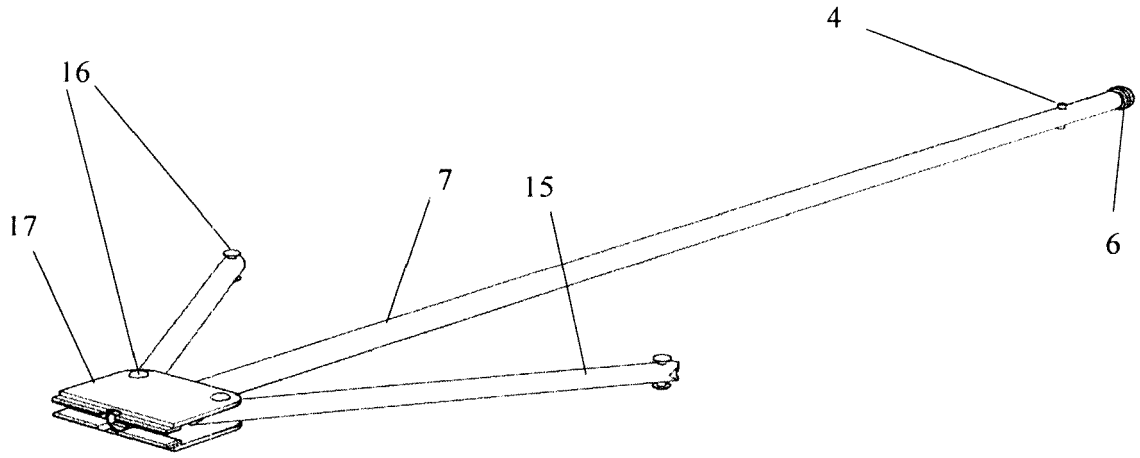


Figure 7

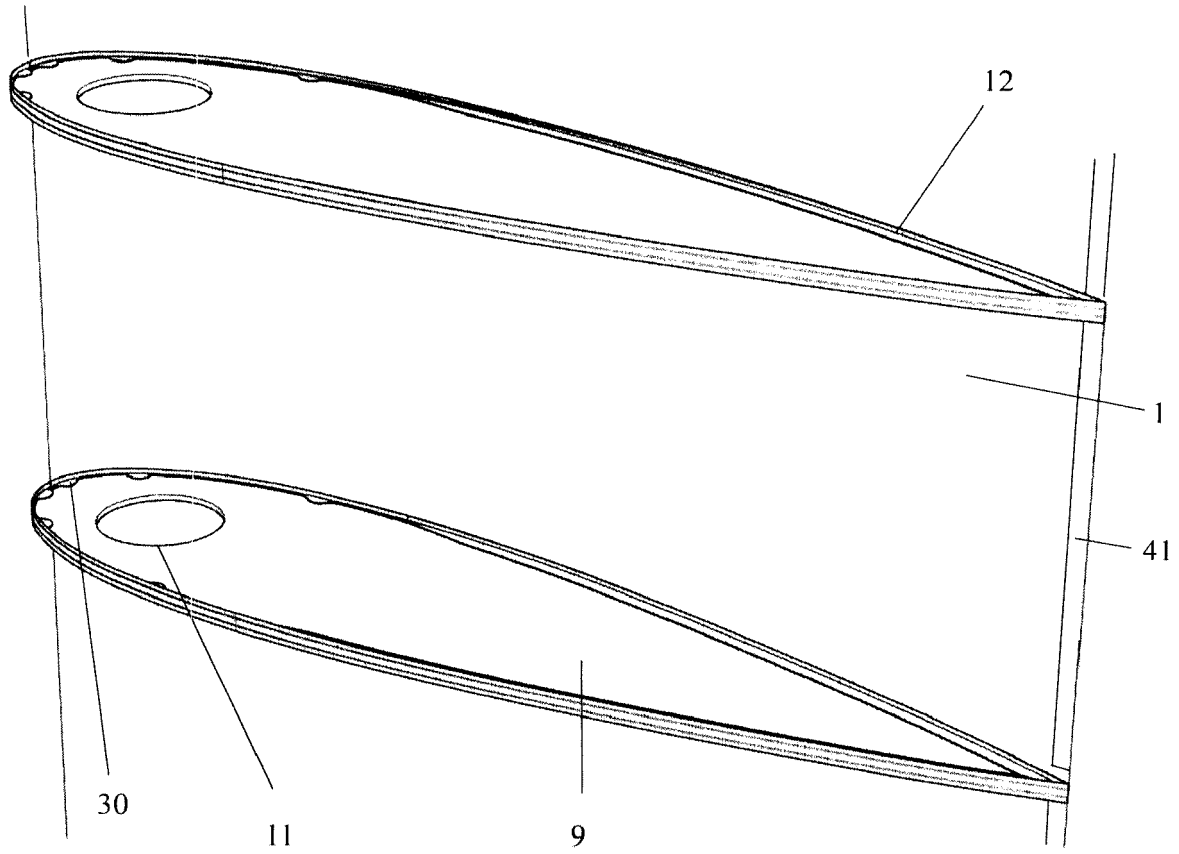


Figure 8

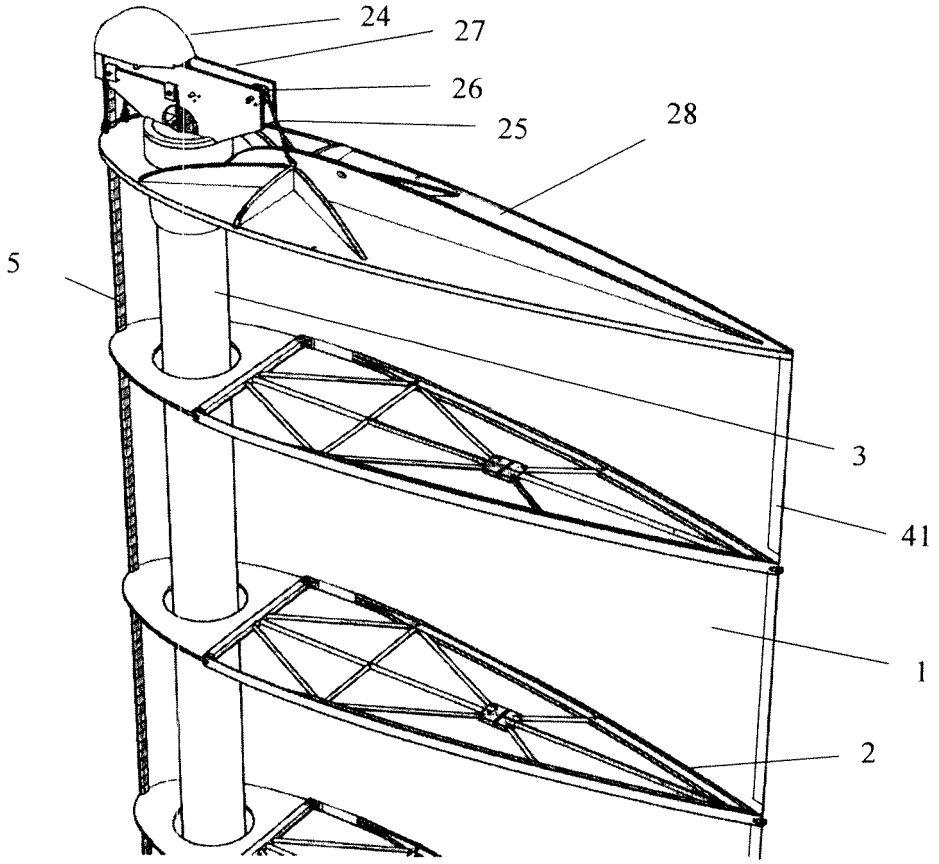


Figure 9

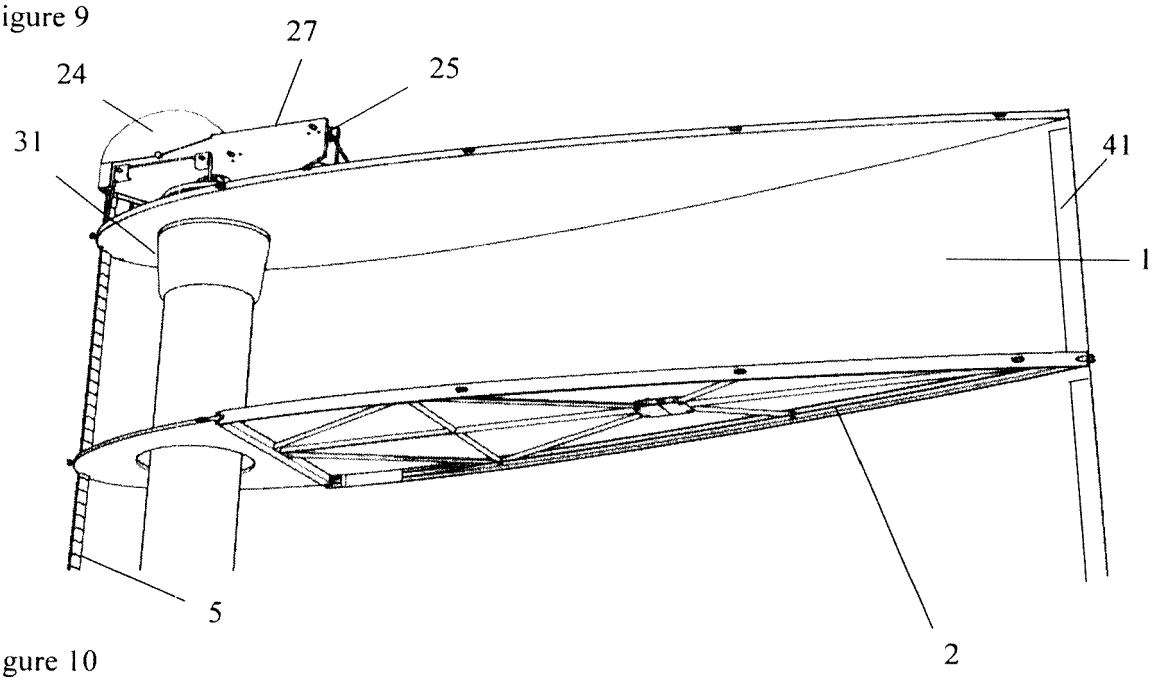


Figure 10

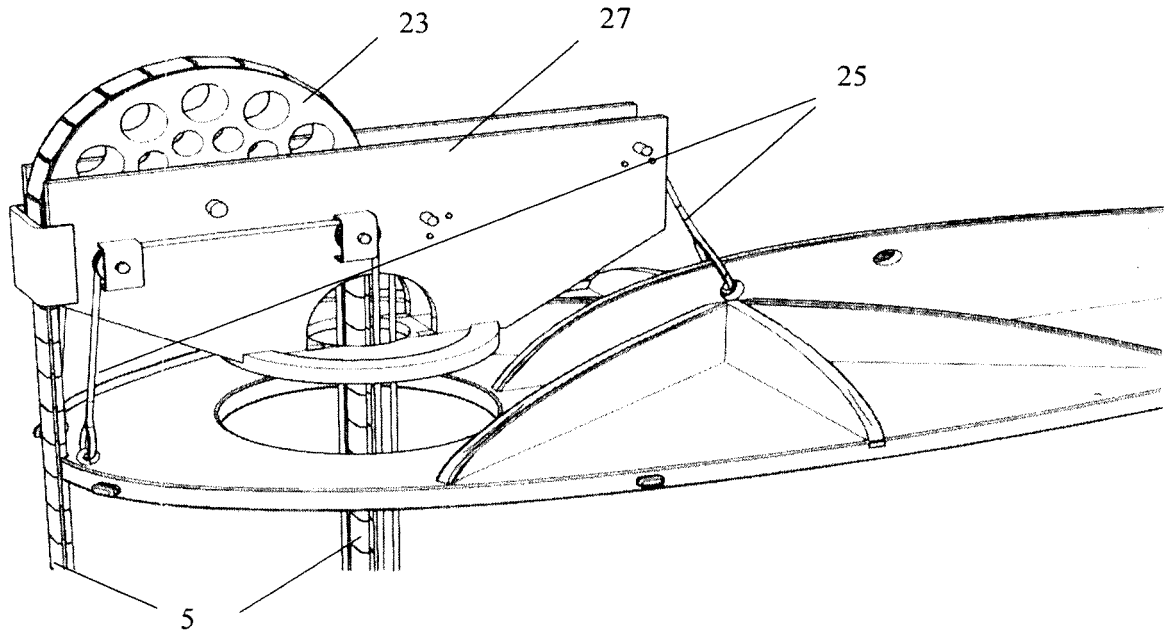


Figure 11

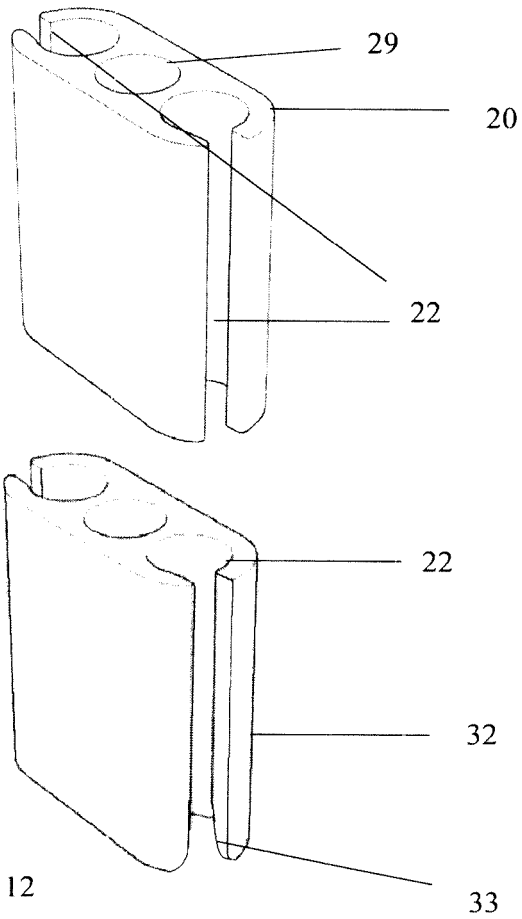


Figure 12

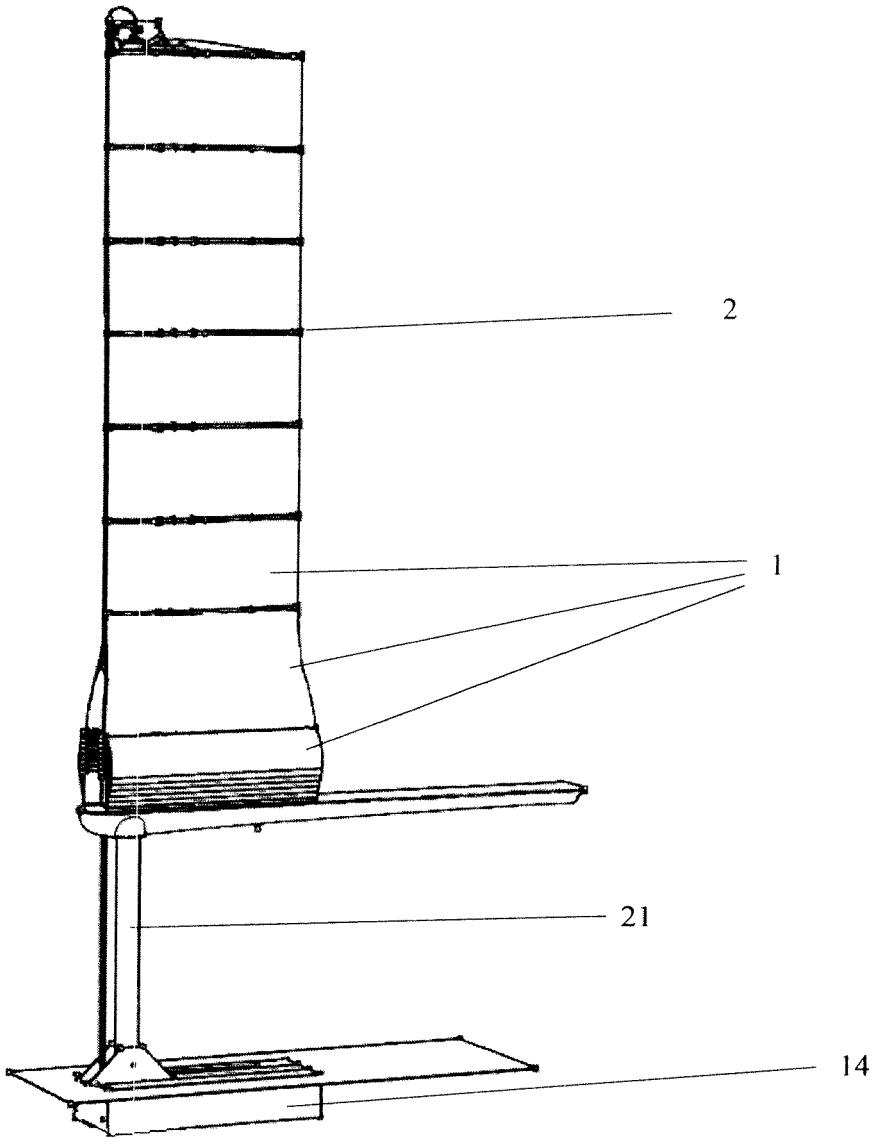


Figure 13

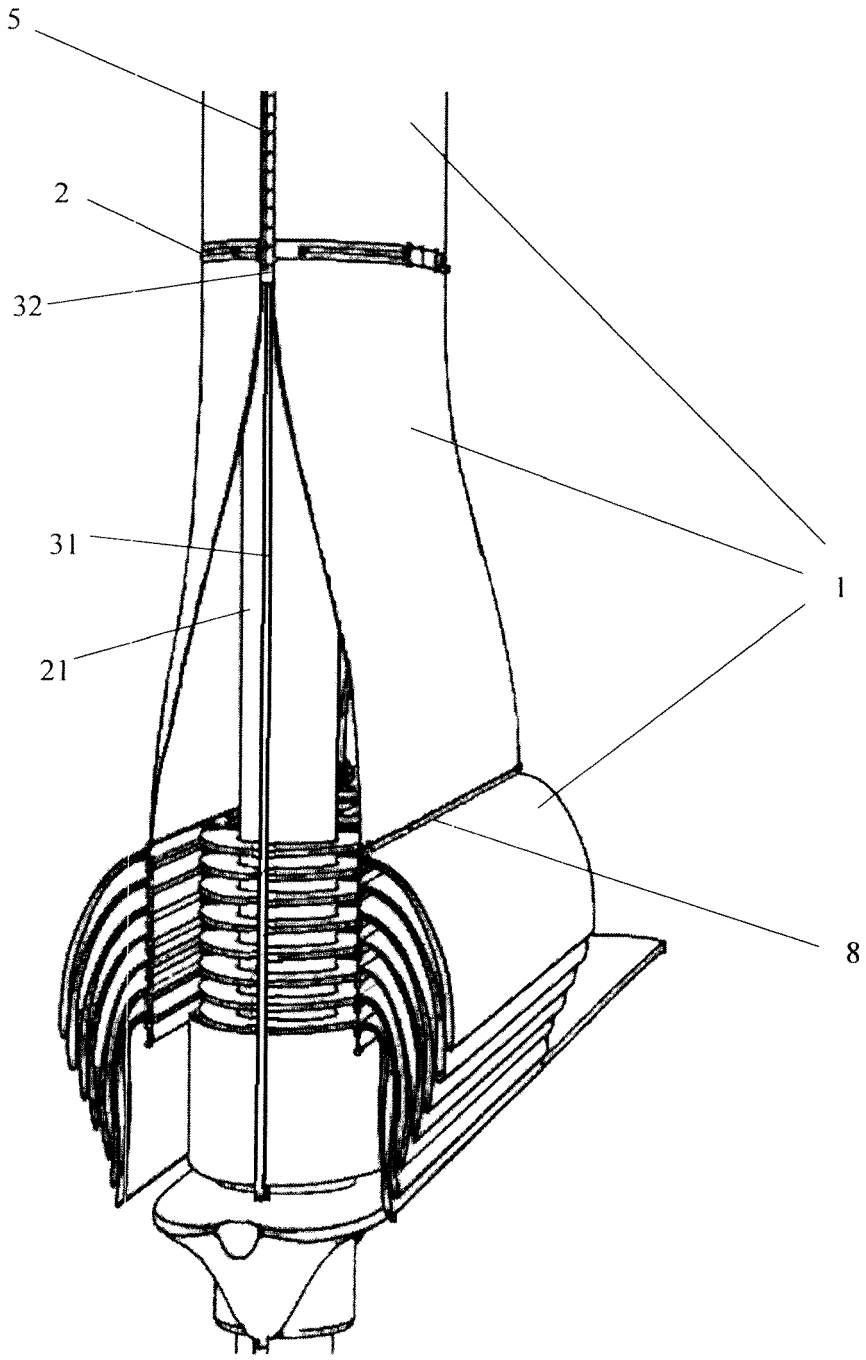


Figure 14

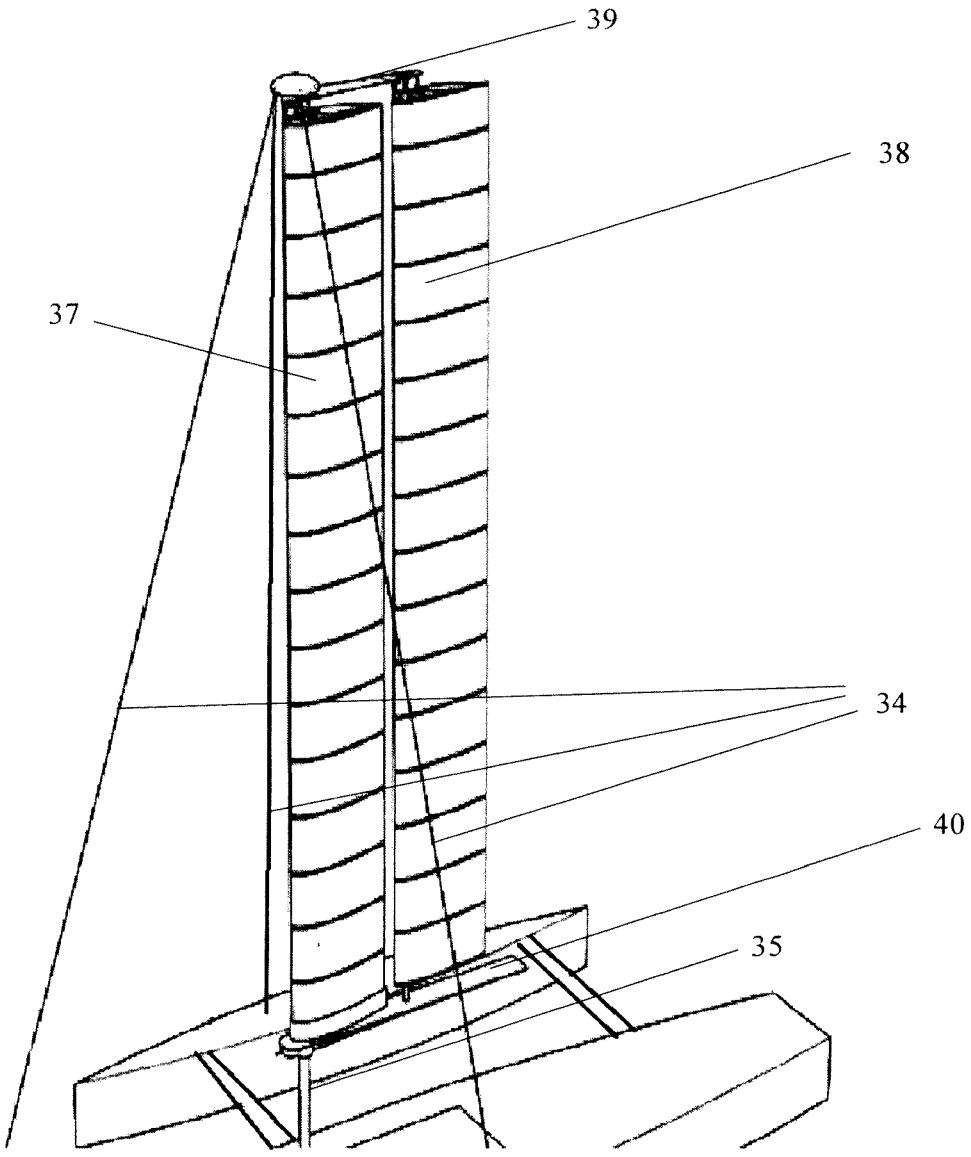


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Figure 15

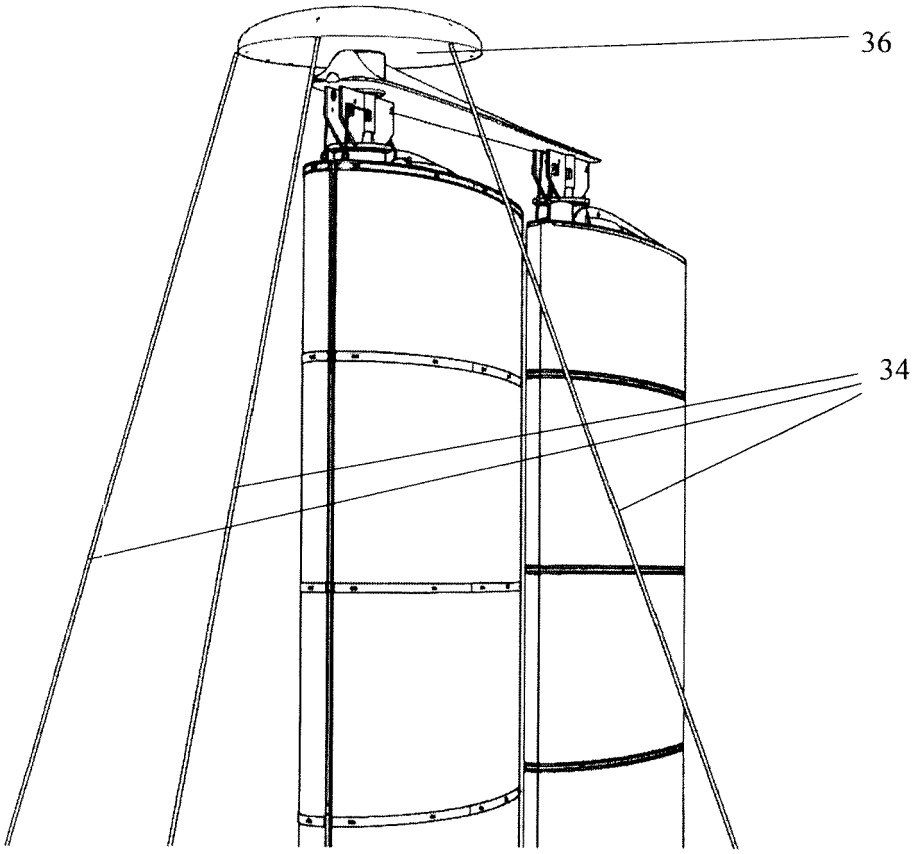


Figure 16

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# EUROPEAN SEARCH REPORT

Application Number
EP 17 25 0010

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| A | WO 03/039948 A1 (BELLINVIA PIETRO [IT]) 15 May 2003 (2003-05-15) * page 6, line 14 - page 7, line 5 * * figures 2, 7, 8 * | 1-15 | INV. B63H9/06 B63H9/10 |
| A | US 2009/165689 A1 (GONEN I; MAN G) 2 July 2009 (2009-07-02) * paragraph [0031] - paragraph [0034] * * figures 4, 5 * | 1-15 | |
| A | US 2001/047745 A1 (ABSHIER CHARLES ALLEN [US]) 6 December 2001 (2001-12-06) * paragraphs [0083] - [0088] * * figures 9 - 9C * | 1-15 | |

TECHNICAL FIELDS SEARCHED (IPC)

B63H
B63B

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 31 January 2018 | Lindemann, Ruben |

CATEGORY OF CITED DOCUMENTS

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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 25 0010

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31-01-2018

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