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(54) **COMPACT SELF-TRIMMING WINGSAIL.**

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Description

This invention relates to wingsails and especially to self-trimming wingsails.

A wingsail is an assembly including one or more aerofoil sections, usually rigid, that is mounted span upright to propel a vessel. European patent specifications 61291, 96554 and 328254 and GB-A-198649 describe various aspects of wingsails, including self-trimming wingsails, of a general type to which the present invention has particular relevance. In such a self-trimming wingsail the angle of attack of a main thrust wing or wings about an upright axis is controlled by an auxiliary control aerofoil or vane, called a tail vane, mounted on a boom extending downwind from the thrust wing. Success with designs incorporating upwind auxiliary control aerofoils has not so far been achieved.

With the prior art self-trimming arrangements incorporating a tail vane, the wingsail assembly has a substantial overall trimming circle which is acceptable on craft with a wide beam, such as multihull sailing vessels or on ships where wingsails are used as auxiliary power, when the trimming circle will remain within the plan area of the craft, but on narrower single hulled craft the trimming circle might overhang the gunwales, which is not very practical. One aspect of the present invention is therefore directed towards providing a self-trimming rig with a more compact trimming circle.

Another problem that can arise with self-trimming wingsails is that the movement of the centre of pressure of the main thrust wing as the angle of attack changes, or as the relative deflection of the wing elements are changed, changes the effective turning moment about the main axis of the thrust wing. If the centre of pressure of the main thrust wing is too far from the main axis the compensatory trimming moment required from the auxiliary vane is greater, which in turn leads to a requirement for a larger auxiliary vane and more powerful associated deflection control mechanisms, or to a longer boom and therefore a larger trimming circle. Other aspects of the invention are directed towards controlling the position of the centre of pressure with respect to the main thrust wing axis, and to techniques for minimising the power requirements for auxiliary vane movement.

Accordingly the invention provides a wingsail assembly comprising a wingsail assembly comprising at least one thrust wing mounted about an upright axis and trimmed by an auxiliary vane mounted upwind of the thrust wing characterised by the thrust wing being freely rotatable about the upright axis, by means for moving the thrust wing to provide a predetermined distance between the instantaneous centre of pressure of the thrust wing and its upright axis of rotation and by the auxiliary vane itself being trimmed by a secondary control vane mounted downwind of the auxiliary vane within a turning circle defined by the thrust wing and auxiliary vane.

The invention preferably also comprises an auxiliary vane upwind of the thrust wing and arranged to trim the thrust wing about the axis, in which the auxiliary vane is freely pivoted upwind of its centre of pressure and the angle of attack of the auxiliary vane is controlled by the position of a secondary control vane positioned downwind from the auxiliary vane.

A further aspect of the invention provides a wingsail assembly comprising a thrust wing freely rotatable about an upright axis and an auxiliary vane upward of the thrust wing and arranged to trim the thrust wing about the axis, in which the auxiliary vane is freely pivoted upwind of its centre of pressure and the angle of attack of the auxiliary vane is controlled by the position of a secondary control aerofoil positioned downwind from the auxiliary vane.

The invention is now described by way of example with reference to the accompanying drawings in which:

Figure 1 schematically illustrates a vessel carrying a wingsail with a tail vane;

Figure 2 schematically illustrates a wingsail thrust wing having a tilting mechanism and with an upwind control vane and secondary control vane;

Figure 3 schematically illustrates a plan view of the wingsail of Figure 2;

Figure 4 schematically illustrates the wingsail of Figure 2 tilted;

Figure 5 illustrates in plan view the wingsail of Figure 4 with aerofoils deflected for thrusting; and

Figure 6 schematically illustrates an alternative secondary control vane mounting.

Referring firstly to Figure 1, a self-trimming wingsail is shown on a vessel. The wingsail comprises a thrust wing 1, which may be a single-plane or multi-plane, and each plane may be simple or may comprise a leading element and trailing element that can be pivoted to deflected positions as described for example in European Patent Specifications 61291, 96554 and 328254. A tail vane 2 is mounted on a boom 3 extending from the thrust wing. The complete wingsail assembly is freely rotatable about a main bearing axis 4. A countermass 5 is provided to mass balance the wingsail about the main axis. In operation, deflection of the tail vane to a particular angle with respect to the wind provides a turning force, acting over the length of the boom 3, to rotate the wingsail about the main axis 4 to a trimmed angle of attack. The arrangement shown has a trimming circle of radius indicated by line 6. A trimmed angle of attack configuration may be defined as one in which the moment of the main thrust wing about the axis 4 is balanced by an equal and opposite moment provided by the auxiliary vane, in this case a tail vane.

It is preferable in all wingsails to provide for a requirement for zero crosswind force. Also, position of the centre of pressure of the thrust wing is not constant, for example when a leading and trailing element thrust wing is aligned with the elements coplanar the centre of pressure may be in the region of approximately 25% to 26% along the chord, but moves to a location about 34% to 35% along the chord when one element is deflected with respect to the other. With a tail vane it is usually possible to locate the main pivot axis in a position that is sufficiently close to both the centre of pressure with one element deflected with respect to the other and the centre of pressure when the elements are coplanar. It is however preferable to provide some means of compensating for the shift in the thrust wing centre of pressure, and the present invention provides this.

It is therefore proposed in one aspect of the present invention to enable movement of the thrust wing relative to the main axis. In this way a relatively constant location of the centre of pressure with respect to the main axis can be achieved, thereby minimising changes in moment and reducing the auxiliary vane moment required to trim.

Figure 2 illustrates a preferred embodiment of the invention in which a compound thrust wing 1 is provided with an upstream auxiliary vane 7. It will be seen from the plan illustration in Figure 3 that the trimming circle 6 is now reduced to a radius substantially equal to the length of the thrust wing downwind of the main axis: of course it is not necessary for the upwind and downwind projections of the assembly from the main bearing to be equal, but this is a convenient practical arrangement.

As shown in Figure 2 the thrust wing 1 includes a substantially horizontal pivot at the base, this pivot enabling the thrust wing to be pivoted in the upwind and downwind sense, thereby moving the centre of pressure of the thrust wing with respect to the bearing axis. Upwind is in an anticlockwise direction as viewed in the drawing. The pivoting movement may be controlled by a linear actuator such as a hydraulic cylinder and piston 11 mounted between the thrust wing and main bearing. In the location shown in Figure 2, contraction of the actuator produces upstream tilting: clearly it would be possible to provide an actuator downstream of the main axis operating in the opposite sense. Other means such as an electric actuator may replace the hydraulic cylinder.

Figure 4 illustrates the configuration adopted when the wingsail is in a thrusting mode. In this thrusting position, especially when the wing has a trailing element, the centre of pressure moves downstream to a location 13 on the thrust wing. Actuator 11 is contracted and the thrust wing is tilted upstream as illustrated, so that the span of the thrust wing is inclined with respect to the main axis 8, bringing the centre of pressure to close proximity with the main axis.

In a possible modification the tilting process can be continued further in order to reduce the elevation of the wingsail for example for passing under bridges or to ease assembly or dismantling.

Instead of pivoting movement, the upstream/downstream movement of the thrust wing may be provided or augmented by translation, for example by using sliding ways.

The facility to bring the centre of pressure of the thrust wing into close proximity with the main axis at all thrusting configurations means that the size of the trimming auxiliary vane and/or length of boom can be reduced compared with the requirements in the absence of the facility where the maximum values of the thrust wing moment could be excessive. This is of significance both for power requirements for rotating the auxiliary vane and also for compactness of wingsail design, particularly for reduction of trimming circle, in both tail vane and upwind vane designs.

It will be realised that the moment arm in an upwind control vane configuration is generally less than the moment arm of a tail vane. In order to compensate for the reduced moment arm length the size of the auxiliary vane may be increased, although this results in an increased power requirement to rotate the vane.

The power requirements are minimized in the invention by providing the pivoting or sliding arrangement so that the thrust wing centre of pressure can be maintained close to the main axis.

A secondary control aerofoil 15, shown in Figures 3 and 4, which trims the auxiliary vane, is used to enable the main control vane to be freely pivoted ahead of its centre of pressure. The secondary control aerofoil is mounted as a tail vane to the auxiliary vane 7.

In the preferred arrangement the auxiliary vane 7 has a symmetrical aerofoil section and is freely pivoted on a spanwise axis 19 between booms 14. One boom also preferably supports a balance mass 16. The secondary control aerofoil 15 is also of symmetrical aerofoil section and is mounted downstream of the auxiliary vane 7 for example by means of its own secondary booms 18 as shown in Figures 2 and 4 or by mounting at the trailing edge of the vane 7 as shown in Figure 6. A control linkage (not shown) enables the helmsman or an automatic control system to deflect the secondary aerofoil 15 to left or right of wind. When it is desired to permit the wingsail to weathercock, the secondary aerofoil 15 is set coplanar with the auxiliary vane 7, which then weathercocks freely, pivoting at zero crosswind force about its spanwise axis 19, which is positioned upstream of any possible centre of pressure of the combined auxiliary vane and secondary control aerofoil. The actuator 11 is adjusted so that the main axis passes upstream of the centre of pressure of the thrust wing and therefore the thrust wing weathercocks about the main bearing.

Figures 4 and 5 show the aerofoil configurations required to thrust right of wind. The secondary control aerofoil 15 is deflected right of wind and holds the auxiliary vane 7 at an angle of attack to the airflow so that its thrust, indicated by arrow 22, is sufficient to balance the moment of the thrust wing force 20 about the main axis 8. In order to keep the centre of pressure of the thrust wing close to the axis 8, the actuator 11 has been retracted to tilt the thrust wing upstream as previously described. In the event that the thrust wing has a flap or flaps 21 (which is not necessarily the case) these will be deflected left of wind for thrust right of wind. The control force required is only that needed to adjust the secondary aerofoil 15, and the required auxiliary vane moment is minimised by the tilting (or translation) of the thrust wing.

If it is required to return to zero crosswind force without centralising the flaps 21, this may be achieved by returning the secondary aerofoil vane 15 to be coplanar with the auxiliary vane 7. The thrust force 20 will tend to rotate the wingsail towards an angle of zero crosswind force. To minimise downwind drag, the actuator 11 should be extended to return the thrust wing to the upright position and any flaps 21 should be realigned with respect to the leading element of the thrust wing.

For thrust left of wind, the process is repeated in mirror image with the thrust wing again being tilted upstream but this time the secondary control aerofoil 15 being deflected left of wind and the flaps right of wind. In both thrusting configurations the wingsail remains freely rotatable about its main axis.

When the wing is tilted, the mass balancing conditions will change. To compensate for this the balance mass 16 is mounted so that it can move downwind as the thrust wing moves upwind, and vice versa, the movement of the mass being controlled proportionately to the movement of the thrust wing. A schematic arrangement permitting this movement is shown in Figure 4, in which the balance mass 16 is connected to the main trunnion frame of the bearing. More specifically, the mass 16 slides in a track 30 and is biased to the upwind end of the boom 14 by a spring 31 and is connected to the base of the thrust wing by a line 32 passing over a sheave 33 within the thrust wing and then fixed via a second sheave on an arm 34 projecting downwind from the main trunnion frame. The upstream tilting of the thrust wing results in the mass being pulled downwind against the bias of spring 31 by the inextensible line 32, the geometrical arrangement providing that, on rotation, the moment change of the mass 16 about the free upright axis 8 is equal and opposite, or broadly equal and opposite, to the moment change of the complete wingsail, apart from mass 16, about the axis 8. Other means may be used, provided that they satisfy this requirement.

Various modifications are envisaged, for example in which the thrust wing comprises a plurality of planes or in which a plurality of auxiliary vanes and/or secondary control aerofoils may be used. Also, instead of coplanar auxiliary and control aerofoil arrangements the aerofoils may be offset so that the aerofoils have parallel, but not coplanar, axes of symmetry, for example the pivot axis of the secondary aerofoil 15 need not be in the plane of symmetry of the auxiliary vane.

Claims

1. A wingsail assembly comprising at least one thrust wing (1) mounted about an upright axis (4) and trimmed by an auxiliary vane (7) mounted upwind of the thrust wing characterised by the thrust wing being freely rotatable about the upright axis, by means for moving (11) the thrust wing to provide a predetermined distance between the instantaneous centre of pressure of the thrust wing and its upright axis of rotation and by the auxiliary vane itself being trimmed by a secondary control vane (15) mounted downwind of the auxiliary vane within a turning circle defined by the thrust wing and auxiliary vane.

2. A wingsail assembly according to claim 1 in which the thrust wing is pivoted at its base about a substantially horizontal axis (10) to enable the leading edge of the thrust wing to be pivoted forwardly.

3. A wingsail assembly according to any preceding claim in which the thrust wing is forwardly pivotable to a recumbent position.

4. A wingsail assembly according to any preceding claim further comprising a balance mass provided with means for moving the mass downstream as the thrust wing is moved upstream.

5. A wingsail assembly according to claim 1 or claim 4 in which the secondary vane is mounted on a boom extending downwind from the auxiliary vane.

6. A wingsail assembly according to claim 1 or claim 4 in which the secondary vane is mounted at the trailing edge of the auxiliary vane.

7. A wingsail assembly according to claim 1 or claim 6 in which the secondary vane is mounted on a boom extending downwind from the auxiliary vane.

8. A wingsail assembly according to claim 1 or claim 6 in which the secondary vane is mounted at the trailing edge of the auxiliary vane.

9. A marine craft including a wingsail assembly according to any preceding claim.

Patentansprüche

1. Flügelsegelanordnung mit mindestens einem Vortriebsflügel (1), der um eine aufrechte Achse (4) drehbar gelagert ist und durch einen luvseitig des Vortriebsflügels angelagerten Hilfsflügel (7) getrimmt wird, dadurch **gekennzeichnet,** daß der Vortriebsflügel um die aufrechte Achse frei drehbar ist, daß Mittel (11) zum Bewegen des Vortriebsflügels vorgesehen sind, um einen vorgegebenen Abstand zwischen dem momentanen Druckzentrum des Vortriebsflügels und seiner aufrechten Drehachse zu bewirken, und daß der Hilfsflügel seinerseits durch einen sekundären Steuerflügel (15) getrimmt wird, der leeseitig von dem Hilfsflügel innerhalb eines von dem Vortriebsflügel und dem Hilfsflügel definierten Drehkreis gelagert ist.

2. Flügelsegelanordnung nach Anspruch 1, bei der der Vortriebsflügel an seiner Basis um eine im wesentlichen horizontale Achse (10) schwenkbar ist, um eine Vorwärtsschwenkung der Anströmkante des Vortriebsflügels zu ermöglichen.

3. Flügelsegelanordnung nach einem vorhergehenden Anspruch, bei dem der Vortriebsflügel nach vorne bis in eine liegende Stellung schwenkbar ist.

4. Flügelsegelanordnung nach einem vorangehenden Anspruch, die ferner eine Ausgleichsmasse aufweist mit Mitteln zum Bewegen der Masse zur Leeseite, wenn der Vortriebsflügel zur Luvseite bewegt wird.

5. Flügelsegelanordnung nach Anspruch 1 oder 4, bei dem der sekundäre Steuerflügel an einem Ausleger gelagert ist, der sich von dem Hilfsflügel zur Leeseite erstreckt.

6. Flügelsegelanordnung nach Anspruch 1 oder 4, bei der der sekundäre Steuerflügel an der Abströmkante des Hilfsflügels gelagert ist.

7. Flügelsegelanordnung nach Anspruch 1 oder 6, bei dem der sekundäre Steuerflügel an einem Ausleger gelagert ist, der sich von dem Hilfsflügel zur Leeseite erstreckt.

8. Flügelsegelanordnung nach Anspruch 1 oder 6, bei der der sekundäre Steuerflügel an der Anströmkante der Hilfsflügels gelagert ist.

9. Wasserfahrzeug mit einer Flügelsegelanordnung nach einem vorangehenden Anspruch.

Revendications

1. Dispositif de voilure comprenant au moins une aile de poussée (1) montée sur un axe vertical (4) et réglée par un volet auxiliaire (7) monté en amont de l'aile de poussée, caractérisé en ce que l'aile de poussée peut tourner librement autour de l'axe vertical, en ce que le dispositif comprend des moyens (11) servant à déplacer l'aile de poussée pour établir une distance prédéterminée entre le centre de pression instantané de l'aile de poussée et son axe de rotation vertical et en ce que le volet auxiliaire est réglé à son tour par un volet de commande secondaire (15) monté en aval du volet auxiliaire dans les limites d'un cercle de rotation défini par l'aile de poussée et par le volet auxiliaire.

2. Dispositif de voilure selon la revendication 1, dans lequel, au niveau de sa base, l'aile de poussée est articulée pour pivoter autour d'un axe (10) à peu près horizontal pour permettre de faire pivoter le bord d'attaque de l'aile de poussée vers l'avant.

3. Dispositif de voilure selon une quelconque des revendications précédentes, dans lequel l'aile de poussée peut pivoter vers l'avant jusqu'à une position couchée.

4. Dispositif de voilure selon une quelconque des revendications précédentes, comprenant en outre une masse d'équilibrage équipée de moyens pour la repousser vers l'aval lorsque l'aile de poussée est déplacée vers l'amont.

5. Dispositif de voilure selon la revendication 1 ou la revendication 4, dans lequel le volet secondaire est monté sur une poutre s'étendant en aval du volet auxiliaire.

6. Dispositif de voilure selon la revendication 1 ou la revendication 4, dans lequel le volet secondaire est monté au bord de fuite du volet auxiliaire.

7. Dispositif de voilure selon la revendication 1 ou la revendication 6, dans lequel le volet secondaire est monté sur une poutre qui s'étend en aval du volet auxiliaire.

8. Dispositif de voilure selon la revendication 1 ou la revendication 6, dans lequel le volet secondaire est monté au bord de fuite du volet auxiliaire.

9. Engin marin comprenant un dispositif de voilure selon une quelconque des revendications précédentes.

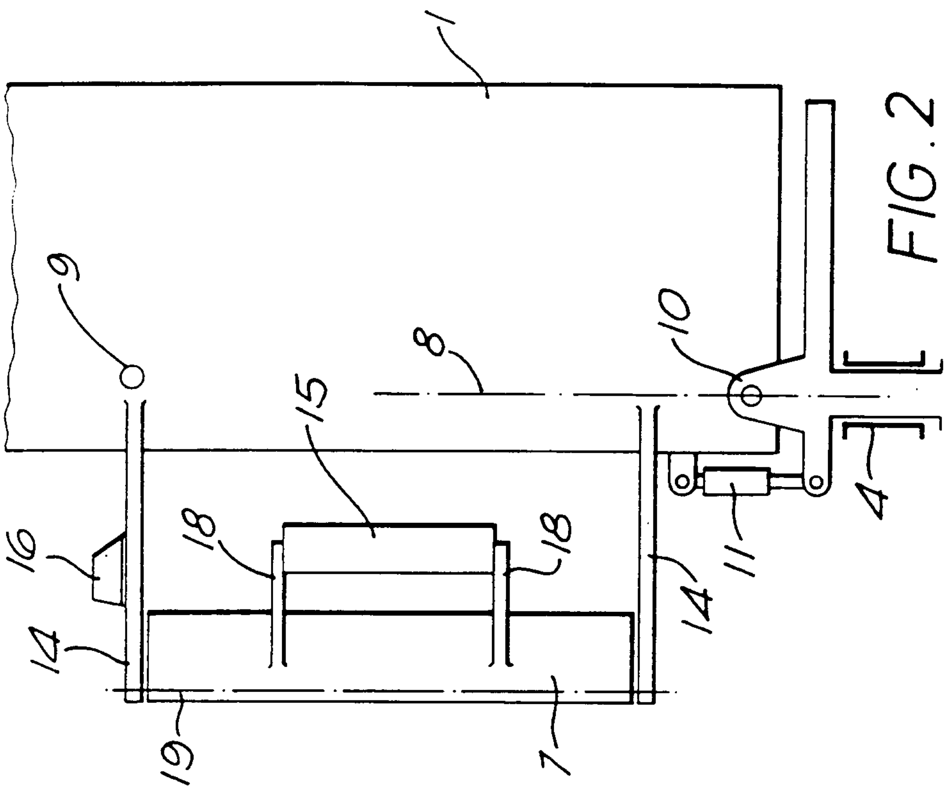

FIG. 2

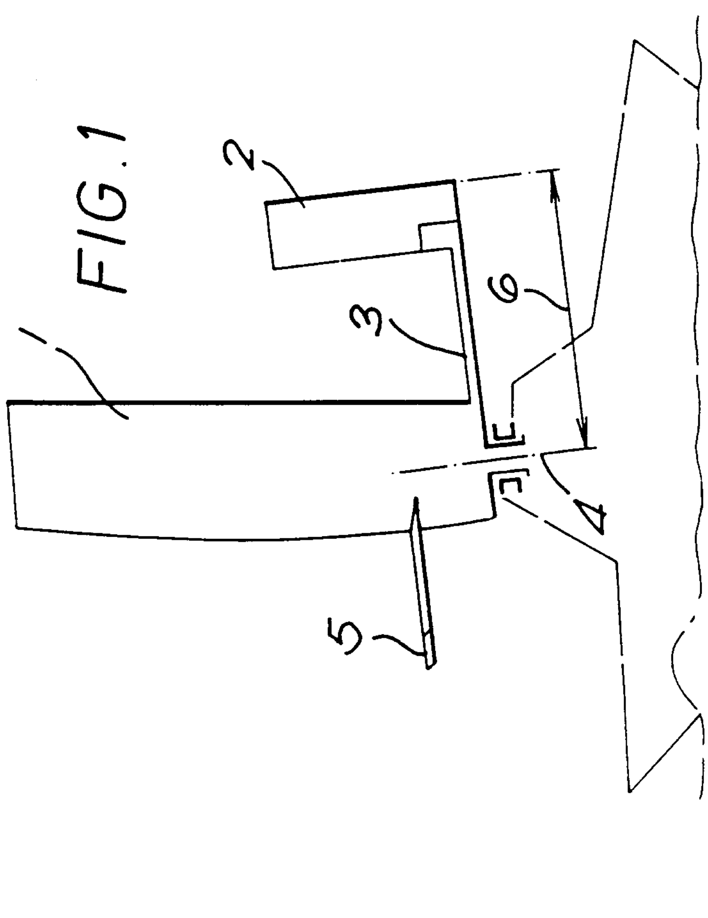

FIG. 1

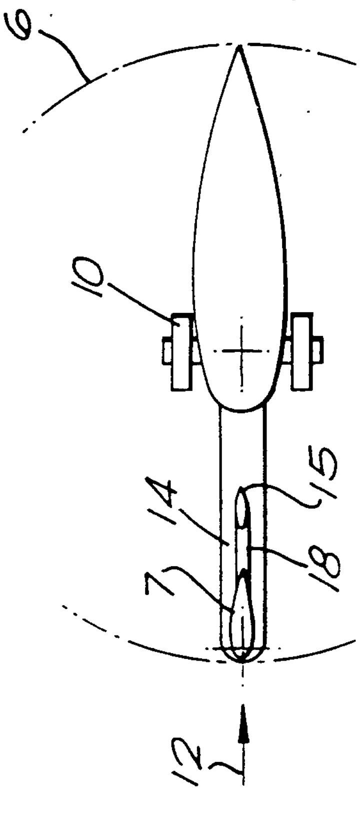

FIG. 3

FIG. 5

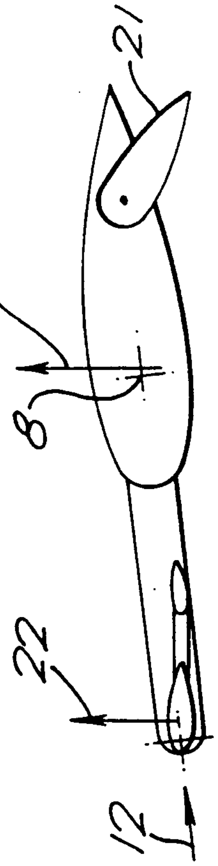

FIG. 6

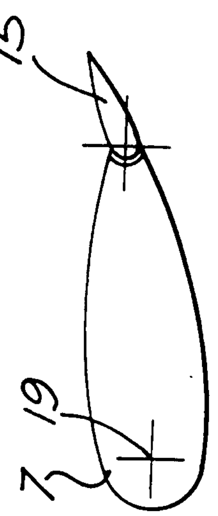

FIG. 4