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(54) **Wingsail stalling.**

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Description

This invention relates to wingsail aerofoils for land or marine vehicles and to arrangements for stalling wingsail aerofoils.

A wingsail aerofoil is mounted and operated somewhat differently to the more familiar aeroplane wing; it is mounted with the span upright (i.e. vertically or near vertically extending) and the aerofoil section plane substantially horizontal, and since the vehicle to which the wingsail is attached is supported by land or water the aerofoil is used to supply or augment propulsive power which for practical purposes needs to be capable of being applied in all potential directions or travel. The type of wingsail assembly with which the present invention is principally concerned is a self-setting or self-trimming wingsail assembly. Such a wingsail assembly comprises a set of aerofoils, termed hereinafter a sailset, having at least one thrust wingsail that reacts the propulsive force and is freely rotatable about an upright axis so that it can be trimmed to different angles in accordance with the wind and desired direction of travel, and at least one auxiliary aerofoil (usually a tail aerofoil) mounted on a boom or booms rigidly connected to the thrust wingsail and which is used to trim the thrust wingsail as explained hereinafter.

The thrust wingsail is of multi-element structure comprising a leading aerofoil element and a trailing aerofoil element positioned closely behind the leading element, the trailing element being laterally pivotable with respect to the leading element so that a wingsail adopts an asymmetrical configuration for thrust right or left of the wind. The trailing element can be locked in the thrusting position and released for returning to the aligned position or to a mirror image cambered position. Generally the axis of rotation of the sailset passes through the leading element or, in the instance of a sailset having a multi-plane structure of a plurality of side by side thrust wingsails, through the central plane of symmetry of the leading elements, and the trailing element pivots independently of the main pivot axis. When the aerofoils are all coplanar the sailset will be rotated like a weathercock to the position of minimum resistance. If the thrust wing is then set to the thrusting configuration by rotating and locking the trailing element the wind creates a turning moment about the main axis. However the auxiliary aerofoil can also be independently rotated and although much smaller it is, by virtue of its distance from the main axis, capable of exerting a comparable moment. Thus by selection of the angular deflection of the auxiliary aerofoil (that is selection of its moment compared with the thrust wing moment about the main axis for a given angular deflection of the thrust wing) the trim of the thrust wing to the wind can be selected, and upon a change of wind direction the resulting change in the moments of the thrust wing and auxiliary aerofoil about the main axis will cause a natural rotation of the sailset until the moments again balance when the trim angle to the wind is restored to its original value.

The direction of travel of the vehicle with respect to prevailing wind direction may be considered to fall into three general categories: towards the wind, broadly across the wind, and away from or downwind, and for each of these categories different settings with respect to the wind are preferable. In between the general categories the best settings will be intermediate those exemplified below with respect to the general categories.

If the vehicle is being propelled towards the wind the trim is usually adjusted to provide the maximum possible aerodynamic efficiency, commonly termed the lift/drag ratio; which is the ratio of the output force resolved into components at right angles to the wind and in the direction of the wind. If the direction is across the wind the trim is adjusted to provide the maximum force available without stalling, and if the travel is downward then the downwind component of force is maximised, with stalling deliberately enabled if found more effective.

The present invention is particularly concerned with multiplane sailsets and with configurations that enable maintenance of full stall for maximum speed in running downwind. During stalling the airflow over the aerofoils is eddying and turbulent such that an auxiliary tail aerofil may become blanketed and to rendered less effective in controlling the trimming of the thrust wings in stalling conditions. There may also be an additional moment resisting achievement of full stall created by the shifting of the create of pressure of the thrust wing downwardly away from the main rotation axis. We have already proposed in WO 86/06342 a system in which non-central trailing aerofoils are arranged to have an initial angular disparity with their trailing edges inclined inwardly towards the central plane of symmetry. This initial angular disparity is maintained as the trailing section is deflected so that the thrust wing on the inside curve of the camber (the windward side) is less deeply stalled than the leeward thrust wing, with the result that the deeper stalling of the leeward wing tends to hold the sailset in stall. However it is not always desirable to have an angular disparity in the symmetrical position, or it may be preferred to vary the degree of disparity as the trailing section deflection varies.

Accordingly the invention provides a wingsail arrangement comprising a plurality of thrust wings each of which comprises an upright leading aerofoil having a leading edge and a trailing edge and an upright trailing aerofoil having a leading edge and a trailing edge the leading edge of the trailing aerofoil being positioned closely behind the trailing edge of the leading aerofoil and means for mounting the trailing aerofoil for pivoting movement about an upright axis relative to the leading aerofoil from an aligned position in which the trailing aerofoil is aligned coplanar with the leading aerofoil to positions to each side of and angularly displaced from the aligned position, and in which the simultaneous respective angular displacements of at least two trailing aerofoils from their coplanar position are different, characterised in that the arrangement includes means for controlling at least two of the trailing aerofoils for respectively greater and lesser rotation as they are angularly displaced from the aligned position.

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

Figure 1 illustrates for the purpose of explanation a plan view of a single plane wingsail sailset;

Figure 2 illustrates for the purpose of explanation a schematic perspective view of part of a thrust wing assembly;

Figure 3 is a schematic plan of twin plane thrust wings;

Figure 4 illustrates an embodiment of the invention on twin plane thrust wings shown in the symmetrical position;

Figure 5 illustrates the thrust wings of Figure 4 in an angularly deflected configuration set to thrust right of the wind.

Referring to Figure 1, the main parts of a wingsail sailset are shown schematically in plan view. For simplicity a single plane thrust wing is illustrated, however the present invention concerns thrust wings that are multiplane as shown in Figures 3 to 5. A main thrust wing is composed of a leading element 1 and a trailing element (termed a flap) 2. The flap 2 is pivotable from side to side about a pivot axis 3 located within the leading section 1, the flap being connected to the pivot axis 3 by a series of hinge arms 4 illustrated more clearly in Figure 2. The pivot axis 3 may not be continuous axis, it may comprise a series of aligned axes associated with respective hinge arms 4. A small slat (not shown) that forms an extension to the trailing edge of the leading element 1 when the trailing section 2 is pivoted out of alignment with the leading element 1 is preferably provided. Such a slat is the subject of my U.S. patents 4,467,741 and 4,563,970.

A tail aerofoil 11 is pivotally mounted about axis 5 on booms 6, usually provided towards or at the top and bottom of the thrust wings, the booms being rigidly connected to the leading element 1. Hydraulic or pneumatic cylinders 7, 8 or other movement mechanisms are provided for respectively rotating the flap 2 and tail about their pivot axes 3 and 5, these fluid cylinder or other mechanisms may conveniently be mounted on the booms 6 which also form an end plate assembly. A counterbalance 9 for the tail is also provided so that the sailset is mass balanced about an axis 10, about which the sailset is freely rotatable. In order to dynamically balance the sailset the counterbalance is located at approximately half height on the leading element although some inertial response advantage can be gained by locating the counterbalance a little below the half height.

A multiplane sailset comprises the same elements as shown and described with reference to Figure 1 but, as shown in Figures 3 to 5 has a plurality of sets of thrust wings, each having a leading element 1 and flap 2 of the structure shown in Figure 2. A single auxiliary tail aerofoil (not shown in Figures 3 to 5) is still usually employed although multiple auxiliary aerofoils may be used. If the multi-plane sailset has an odd number of thrust wings the central structure is similar to that shown in Figure 1 with the main axis 10 aligned with the central leading section. For an even number of thrust wings the main axis 10 will lie midway between the innermost leading sections. The thrust wings of a multiplane sailset may be linked so that one flap (usually the flap on a central wing of an odd numbered multiplane) is controlled as a master with the rest driven as slaves, or alternatively each flap may be separately driven with the drives controlled so that whether by virtue of physical interconnection or by a control mechanism the flaps are moved in unison.

Figure 3 illustrates a twin plane set of thrust wings, each thrust wings comprising a leading element 1 and a trailing flap element 2. The flaps 2 are each pivotable about an axis 3 located on the centre chord of the respective leading elements, so that each flap is capable of being angularly deflected laterally to each side of its respective leading element. The spacing of the leading element is preferably fixed and maintained by members interconnecting the two leading elements at intervals in the upright direction, so that the leading elements are maintained parallel to one another.

The known arrangements are for the flaps to be maintained parallel to one another, so that the angular deflection of each flap relative to its leading element is the same, or for an initial flap trailing edge inward angular disparity that is maintained during deflection so that the leeward wing (outside of the camber) is more deeply stalled by the extent of the initial angular disparity.

In an embodiment of the invention shown in Figures 4 and 5 the flaps are linked so that they are parallel in the central non-deflected position but exhibit differing degrees of angular deflection when deflected so that the leeward flap is at a greater angle. Figure 4 shows the in line configuration, the leading aerofoils being rigidly connected parallel to each other and the spacing of the flaps 2 being maintained parallel and coplanar with the leading aerofoils by a link 14 that is pivotally connected at 15 to respective arms 16 attached to the trailing edges of the flaps. The arms 16 are inwardly directed towards the plane of symmetry of the sailset so that the length of the link 14 is less than the distance between the respective chord planes of the wings.

Considering now Figure 5 which shows the flaps angularly deflected towards the wind (shown by the arrow) the leeward flap 2a is deflected through an angle α, but the windward flap 2b is deflected through an smaller angle β due to the non-parallelogram linkage formed between the hinge axes 3 of the flaps and the pivotal connections 15 on the arms. The precise angular difference between α and β depends upon the geometry of the quadrilateral joining the hinge axes 3 and pivotal connections 15, and the length of the arms 16 and linkage 14 are selected according to the desired angular disparity at full flap deflection. It will be realised that at less than full flap deflection the angular disparity will be intermediate that at zero deflection, i.e. in the symmetrical position (which is zero angular disparity in Figure 5) and that at full flap deflection (usually of the order of 2° per wing in about 40° of deflection).

The non parallel linkage principle described with reference to the embodiments of Figures 4 and 5 may be utilised in combination with a non-deflected flap setting in which there is an initial angular disparity, in which case this initial angular disparity plus the linkage geometry will determine the final angular disparity in the fully deflected position of the flap. An initial angular disparity in combination with non-parallel linkage need not only have the flap trailing edges convergent, settings may be chosen in which the zero deflection (symmetrical position) has the trailing edges of the flaps divergent.

In a similar embodiment for a three wing system, the linkages are arranged so that at full deflection the angles of deflection are +38°, +40° and +42° or on the opposite tack angles of -38°, -40° and -42°. For configurations with four or more wings, pairs of wings may have linkages with differing non-parallel linkages to maintain a leeward progression to deeper stalling.

The leading aerofoils have been described as spaced with their chord lines parallel, but it should be realised that it is possible for departures from parallel to be made so that the chordal planes of the leading aerofoils are divergent or convergent as compared with the parallel arrangement. The deflection control arrangements may also be utilized on thrust wings that are not rotated by an auxiliary or tail aerofoil.

Claims

1. A wingsail arrangement comprising a plurality of thrust wings each of which comprises an upright leading aerofoil (1) and an upright trailing aerofoil (2), the leading edge of the trailing aerofoil being positioned closely behind the trailing edge of the leading aerofoil, means for mounting the trailing aerofoil for pivoting movement about an upright axis (3) relative to the leading aerofoil from an aligned position in which the trailing aerofoil is aligned coplanar with the leading aerofoil to positions to each side of and angularly displaced from the aligned position, and in which the simultaneous respective angular displacements of at least two trailing aerofoils from their coplanar position are different, characterised in that the arrangement includes means for controlling at least two of the trailing aerofoils for respectively greater and lesser rotation as they are angularly displaced from the aligned position

2. A wingsail arrangement according to claim 1 in which said means for controlling comprises a non-parallelogram mechanical linkage (14,15,16).

3. A wingsail arrangement according to claim 1 or claim 2 in which the mechanical linkage comprises a respective member (16) rigidly attached to each of the trailing aerofoils of said pair and extending towards the other of said pair and a rigid link (14) pivotally connected to each member.

4. A wingsail arrangement according to any preceding claim comprising two thrust wings.

5. A wingsail arrangement according to any of claims 1 to 3 comprising at least three thrust wings.

6. A wingsail arrangement according to any preceding claim in which said means for controlling provides a progressive angular disparity in the trailing aerofoils of said plurality when they are angularly displaced from the aligned position with that trailing aerofoil that is on the windward side being least angularly displaced.

Patentansprüche

1. Flügelsegelanordnung mit einer Anzahl von Vortriebsflügeln, mit jeweils einer aufrecht stehenden vorderen Tragfläche (1) und einer aufrecht stehenden hinteren Tragfläche (2), wobei die Vorderkante der hinteren Tragfläche dicht hinter der Hinterkante der vorderen Tragfläche angeordnet ist, und mit Mitteln zur Lagerung der hinteren Tragfläche für eine Schwenkbewegung um eine aufrechte Achse (3), relativ zur vorderen Tragfläche aus einer fluchtenden Position, in welcher die hintere Tragfläche koplanar mit der vorderen Tragfläche ausgerichtet ist, in von der fluchtenden Positionauf nach jeder Seite abgewinkelte Stellungen, wobei die gleichzeitigen Abwinkelungen von wenigstens zwei hinteren Tragflächen aus der koplanaren Position unterschiedlich groß sind,
dadurch **gekennzeichnet,** daß
die Anordnung Mittel zum Steuern von wenigstens zwei der hinteren Tragflächen aufweist, derart, daß sie eine größere bzw. kleinere Drehbewegung bei ihrer Winkelversetzung aus der fluchtenden Position heraus durchführen.

2. Flügelsegelanordnung nach Anspruch 1,
in welchem die Mittel zum Steuern eine nichtparallelogrammförmiges mechanische Lenkeranordnung (14, 15, 16) umfassen.

3. Flügelsegelanordnung nach Anspruch 1 oder 2,
in welchem die mechanische Lenkeranordnung je ein mit jeder der hinteren Tragflächen des Paares fest verbundenes Element (16), das sich zur anderen Tragfläche des Paares erstreckt, und ein starres Kopplungsglied (14), das mit jedem der Elemente schwenkbar verbunden ist, auweist.

4. Flügelsegelanordnung nach einem der vorhergehenden Ansprüche mit zwei Vortriebsflügeln.

5. Flügelsegelanordnung nach einem der Ansprüche 1 bis 3 mit wenigstens drei Vortriebsflügeln.

6. Flügelsegelanordnung nach einem der vorangehenden Ansprüche,
in welchem die Mittel zur Steuerung einen progressiven Winkelunterschied der hinteren Tragflächen bewirken, wenn diese aus der fluchtenden Position winkelversetzt werden, wobei diejenige hintere Tragfläche, die auf der Luvseite liegt, am wenigsten winkelversetzt wird.

Revendications

1. Dispositif de voilure comprenant une pluralité d'ailes de poussée, comprenant chacune une aile avant verticale (1) et une aile arrière verticale (2), le bord d'attaque de l'aile arrière étant situé très près de l'arrière du bord de fuite de l'aile avant, des moyens pour monter l'aile arrière pivotante autour d'un axe vertical (3) par rapport à l'aile avant à partir d'une position alignée dans laquelle l'aile arrière est dans le même plan que l'aile avant jusqu'à des positions situées de chaque côté et inclinées sous un certain angle par rapport à la position alignée, les déplacements angulaires respectifs simultanés d'au moins deux ailes arrière à partir de leur position dans un même plan étant différents, caractérisé en ce qu'il comprend des moyens pour commander au moins deux ailes arrière pour leur faire subir une rotation respectivement plus grande et plus petite que leur déplacement angulaire depuis la position alignée.

2. Dispositif de voilure selon la revendication 1, caractérisé en ce que lesdits moyens de commande comprennent une articulation mécanique qui est différente d'un parallèlogramme (14,15,16).

3. Dispositif de voilure selon l'une quelconque des revendications 1 ou 2, caractérisé en ce que l'articulation mécanique comprend un élément (16) respectivement attaché de façon rigide à chacune des deux ailes arrière et orienté vers l'autre aile arrière et une bielle rigide (14) reliée de façon pivotante à chaque élément.

4. Dispositif de voilure selon l'une quelconque des revendications précédentes, caractérisé en ce qu'il comprend deux ailes de poussée.

5. Dispositif de voilure selon l'une quelconque des revendications 1 à 3, caractérisé en ce qu'il comprend au moins trois ailes de poussée.

6. Dispositif de voilure selon l'une quelconque des revendications précédentes, caractérisé en ce que lesdits moyens de commande engendrent une disparité angulaire progressive des ailes arrière de ladite pluralité quand elles sont déplacées angulairement depuis la position alignée, l'aile arrière qui est au vent étant moins déplacée angulairement.

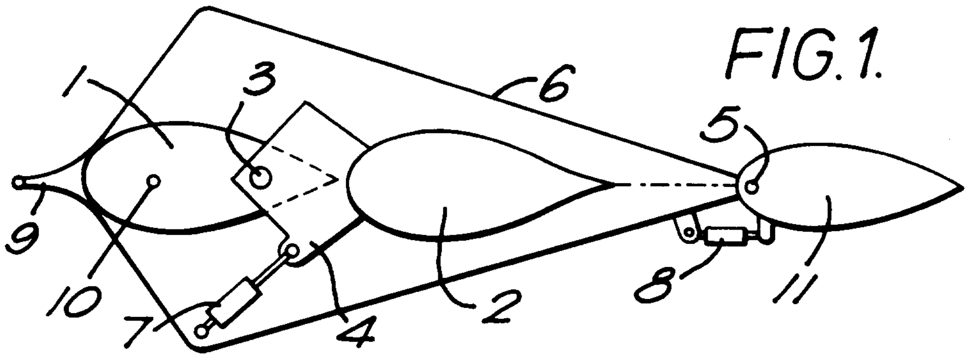

FIG.1.

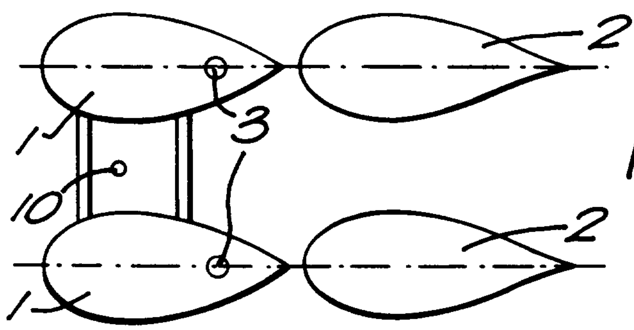

FIG.3.

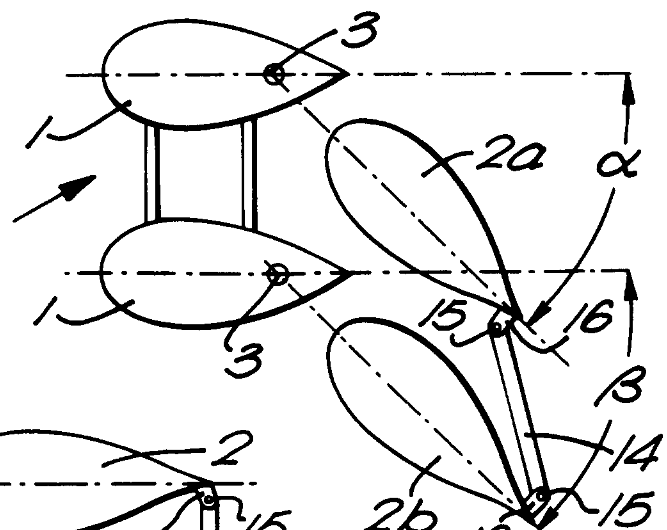

FIG.5.

FIG.4.

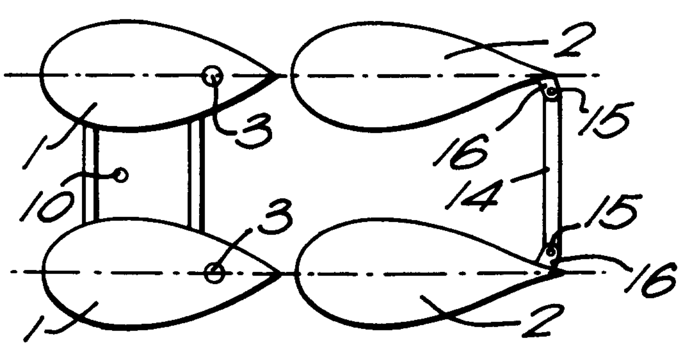

FIG.2.