

June 22, 1926.

1,589,780

C. A. WRAGG

FLYING MACHINE

Filed Nov. 27, 1918

2 Sheets-Sheet 1

Fig. 1.

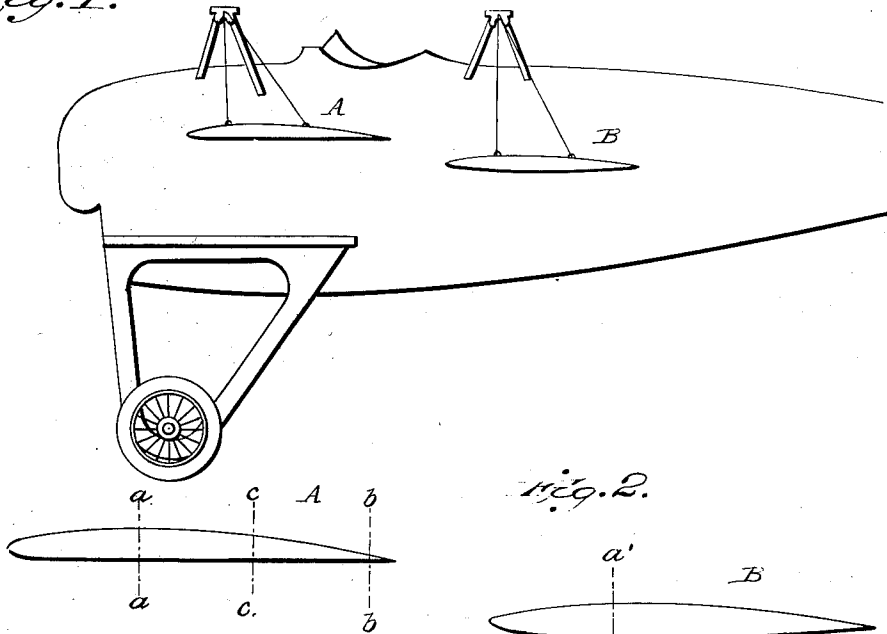


Fig. 2.

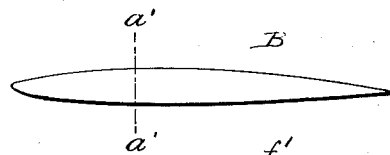


Fig. 3.

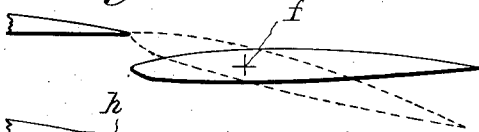


Fig. 4.

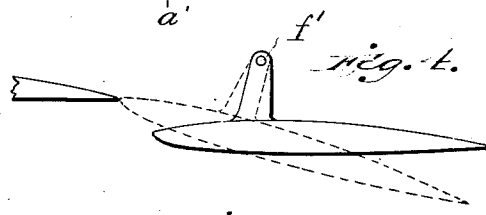


Fig. 5.

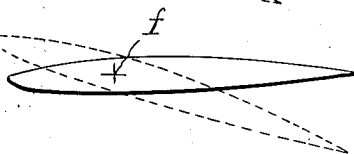


Fig. 6.

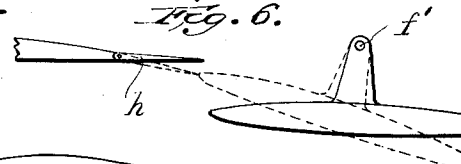
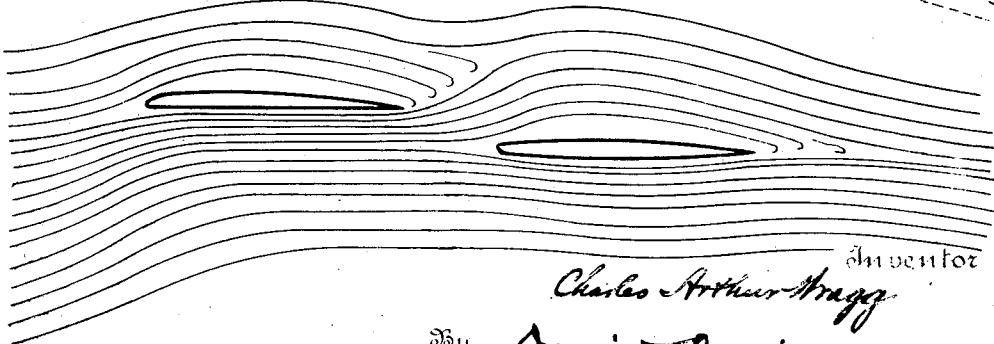


Fig. 7.



Inventor
Charles Arthur Wragg
By Davis & Davis
Attorneys

June 22, 1926.

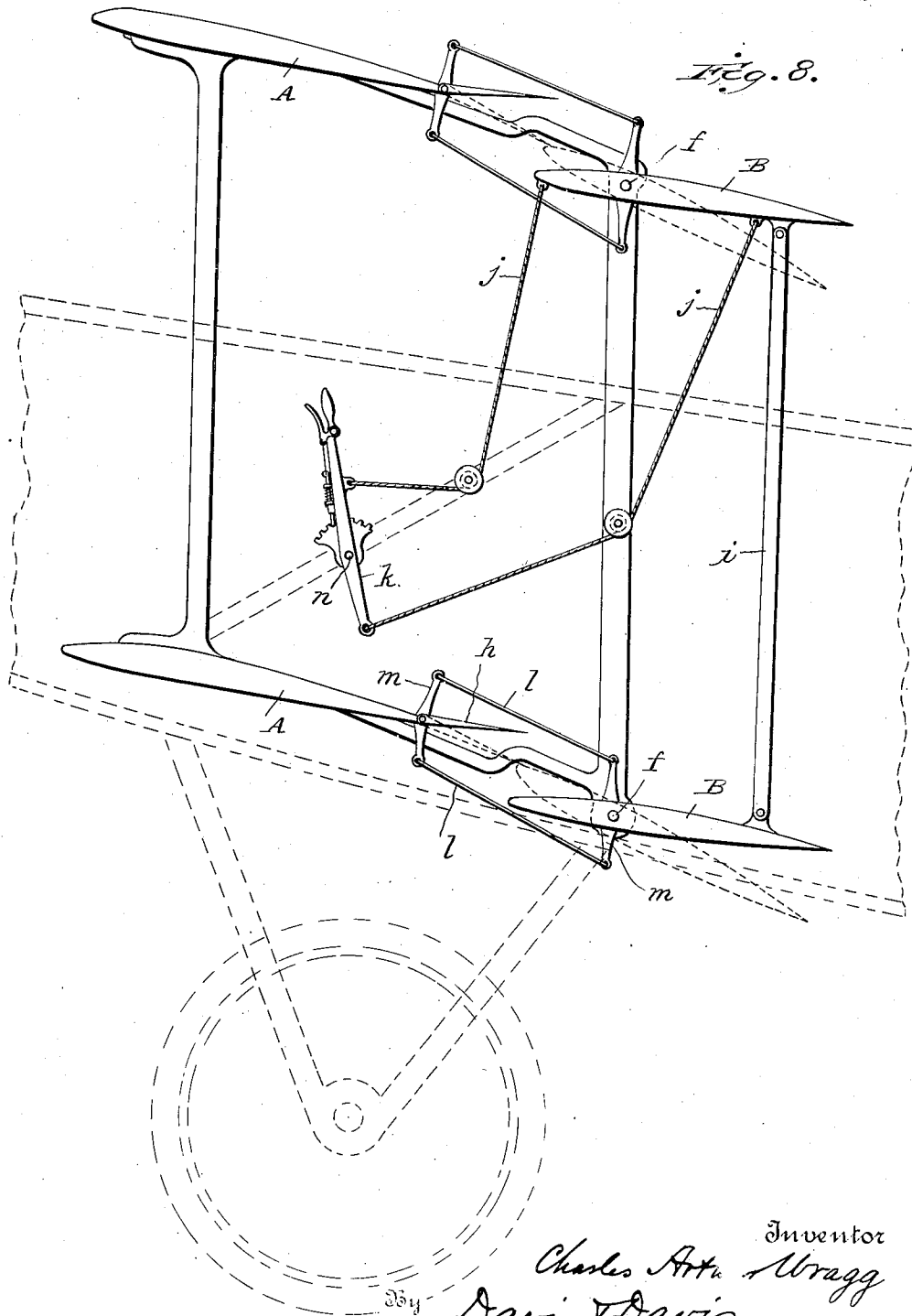
C. A. WRAGG

1,589,780

FLYING MACHINE

Filed Nov. 27, 1918

2 Sheets-Sheet 2



Inventor
Charles Arthur Wragg
Davis & Davis
Attorneys

UNITED STATES PATENT OFFICE.

CHARLES ARTHUR WRAGG, OF MELBOURNE, VICTORIA, AUSTRALIA.

FLYING MACHINE.

Application filed November 27, 1918. Serial No. 264,365.

This invention relates to certain improvements in flying machines and refers more especially to machines "heavier than air," tho it will be understood that the invention is equally applicable to "lighter than air" machines, such as dirigibles having projecting planes or vanes.

So far as the science of aviation has advanced at this time, the general principles involved in the construction of aerofoils are well understood, and thus we have biplanes and triplanes with wings whose chords, cambers, and ratio of chord to span follow well-known formulæ, whereby assured results are attained. Enlargement of these supporting surfaces, however, is impracticable beyond certain limits, the use of wings with very low drag values is difficult, and the general development of individual wings has about reached a limit.

In order further to improve the efficiency and lifting capacity of the supporting surface, my conclusion is that a compound aerofoil must be devised by the production of proper sections and by properly arranging them one behind another, not in true tandem but in a manner to be described, and accordingly, an object of this invention is to enable aerofoils to be efficiently set in their relation to each other in order to provide such a compound aerofoil for the purpose of enabling airplanes to be designed having a larger area than at present with improved speed and landing capacity.

In the drawing—

Fig. 1 is a diagram showing an end view of my compound aerofoil as applied to an airplane;

Fig. 2 is a detail diagram showing more in detail the relation of the two sections of the aerofoil;

Figs. 3, 4, 5 and 6 are diagrammatic views showing forms of my apparatus in which the rear sections are arranged to be tilted;

Fig. 7 is a diagram showing the manner in which the air currents are taken advantage of in my compound aerofoil; and

Fig. 8 is a diagrammatic view showing a mechanism for simultaneously shifting the movable parts of the aerofoils in a bi-plane.

It is well known that in combination of wings in which rear wings are set in a direct line longitudinally with the leading wings, the efficiency of the rear wings is much reduced. It is also known that in superposed wings, the general efficiency is

reduced. I have discovered that if wings are placed so that one wing is so far staggered in relation to another as not to constitute a substantial or true superposed arrangement and so far below the tandem position as not to constitute a true tandem arrangement (see sections A and B in Fig. 1 and Fig. 8,) and if the lifting value of the rear section is less than the lifting value of the forward section, (as also shown in said figures) and their curves faired for mutual action on the same airstream then an aerofoil is devised the rear section of which is in the most advantageous position for a compound or cooperative relation with the front section.

It is desirable in high-speed machines that the wings should have a cross-section or camber which gives a low lift-coefficient and a high efficiency at low angles; and as it is also advantageous to group the weights closely and to concentrate the surface area as much as possible, an object of this invention is to enable wings to be efficiently used in close proximity in order to increase the carrying surface for large airplanes. It will be observed from my drawings that this is done by choosing sections or camber for the compound which have a low lift-coefficient and a high efficiency at low angles. The term low lift-coefficient or low lift-value as distinct from a high lift-coefficient at given angles is taken to be, in this specification, inclusive of the lift-values which do not cause the efficiency of the compound to fall off so much as to make the compound non-useful.

The airflow immediately following a wing set at an angle of incidence has a general downward direction, but this is very slight at low angles, and at high speed with efficient high-speed sections, i. e., sections having a low lift coefficient, there is a reactionary upward tendency of the airflow due to the pressure on the lower surface being suddenly released and to the readjustment of the differences in the density of the air above the upper surface of the aerofoil and immediately under the lower surface of the aerofoil caused by the aerofoil's passage through the air. This adjustment of the two different atmospheric densities is completed at some distance to the rear of the aerofoil and causes a general disturbance of the air in a particular region. I have found by wind tunnel tests that a rear wing of less

lifting power having convex upper surface placed as described reduces the eddies, which represent dissipated energy, and improves the entire airflow over the whole of the front wing, showing a most extraordinary compounding effect. It necessarily follows from this that the efficiency can be improved by reduction of drag and increase of lift.

Moreover, if the lifting value of the rear section is less than the lift of the forward section, thus allowing the center of gravity to be situated further forward, an inherent stabilizing tendency is embodied in the aerofoil system, amounting in effect to a longitudinal dihedral angle or V between the angles of zero lift of the forward and rearward sections, respectively. Referring to Fig. 2, it will be seen that if the center of pressure on each section is at a and a' , respectively, and if the lifting value of each is equal, then the center of pressure of the compound would be midway between the two moments, as shown at b . But if the total lift on section B, due to difference in section or area or section and area, is less than the lift on section A, then the center of pressure of the compound (and of course the center of gravity) could be situated farther forward to some point as shown at c , because the product of each of the pressures and its distance from the center of gravity, or, in other words, the moment of each pressure in relation to the center of gravity, should be the same. Then if an air disturbance tilts the whole airplane about an axis passing through the center of gravity, the rear section B reaches its angle of zero lift quicker than section A and the balance is restored. Conversely, if the tilting causes the rear section B to move downwards, the magnitude of the moment at a' increases at a greater rate than that at a and a righting couple is again introduced restoring the equilibrium. The action of the lever-arm ($a'-c$) is a righting one in both cases.

The value of the lift on section B as compared with the lift of section A and their relation to the variations of the center of pressure on section A are some of the factors which determine the position of section B in relation to section A in the compound. A somewhat similar reasoning applies if the difference in lift on the sections is obtained by making them different in area instead of different in section.

The section and the area of wing B may be different from that of wing A for the purpose of securing the most efficient compounding to take advantage coincidentally of the airflow from the leading wing and of the stabilizing factor introduced by the compound.

The speed of airplanes is inter alia governed by the lift coefficient of the aerofoils,

and the lower the value of the lift, other factors remaining constant, the greater the speed. One of the limitations to greater speed is the difficulty of utilizing lower lift-value wings with safety and stability. The introduction of the stabilizing factor inherent in this compound aerofoil enables the use of sections having lower lift value at their angle of maximum efficiency and enables them to be set at lower angles of incidence than hitherto. Thus both sections could be set with their chords at zero angle of incidence in relation to the horizontal axis of the machine, each section having a different angle of zero lift and a maximum or high efficiency at the zero angle of incidence of chord.

If the stabilizing factor herein referred to is not desired in some machines of this type, the sections can be made similar without departure from this invention, providing each section is of the efficient high-speed type previously herein described. I have observed that when sections are successively modified in their cross-section curves so that the point of maximum efficiency occurs at lower angles and the lift coefficient made lower at given angles, the tendency is for the maximum point on the efficiency curve to be higher in some cases, and part of my invention is that if such sections are used an efficient closely-grouped arrangement is possible because the effect of each element of both wings when integrated into a faired or compound structure is to direct the airstream into a so-called streamline flow, i. e., one in which little or no energy is lost in eddies.

The increased area by reason of section B being added to section A enables greater weight to be carried at maximum speed.

In Figs. 3, 4, 5 and 6 I show in diagram different ways of obtaining an angular adjustment of the rear or trailing section. In each of these cases, the rear section is pivoted on a horizontal axis extending transversely of the line of flight and arranged in such relation to the forward section that when its forward edge is tilted upwardly, said forward edge will approach or meet the rear edge of the forward section, so that the upper surfaces of the two sections will be substantially continuous. The object of this is to increase the total lift for the purpose of landing slowly. It will be understood that when the rear section is swung to said position, I lose entirely the aerodynamic advantages of the compounding effect at high speed, but this effect would be in any case lost by the reduction in speed necessary for landing.

My compound aerofoil may be used in machines of a monoplane type, or it may be arranged in series, such as one or several superposed above another or in tandem or in

any of the formations in which single aerofoils are arranged.

In Figs. 3 and 5, it will be observed that the axis of oscillation is at f , a point within the body of the section, while in Figs. 4 and 6 the pivotal point is at f' , a point above the body of the section. In Figs. 5 and 6, the tapered trailing portion h of the forward section is hinged to adapt it to be adjusted downwardly to approach the front edge of the rear section. The tilting or oscillation of the rear section on the pivot f or f' may be manually brought about by any suitable devices.

In the drawing, the rear section is of less lift-value by reason of the fact that its under side is convexed while the under side of the forward section is horizontally flat, but it will be understood, as hereinbefore stated, that the lower lift-value of the rear section may be provided for in any other suitable manner.

It will be observed from the foregoing that one object of my compound aerofoil is to enable higher speed to be attained, and another is to enable greater weight to be carried. As with a given area and loading a high value of lift in the aerofoil is detrimental to high speed, and as with a given speed a low value of lift and low area are detrimental to large weight-carrying capacity, the exact character of the upper and lower cambers used in each section of my compound aerofoil and the exact position of each section in relation to the other are influenced by the particular objective in the mind of the designer. The sections and their relative position can be principally determined by the necessities of very high speed, or by large weight-carrying, or by a compromise for both, the sections being designed and compounded by fairing one with the other through the cooperative alinement of their surfaces as herein specified, to mutually affect each other most advantageously for the particular objective by reason of certain laws of physics and mechanics. These laws are of such a nature that if sections having a high lift coefficient were used in the compound the efficiency of the compound would fall off to such an extent as to make the device non-useful, but if the aerofoil is composed of sections having a sufficiently low value of lift and drag coefficient—that is, approaching the symmetrical in form—it then becomes useful; a reason being that the airflow from the trailing edge of a forward section suitable for use in the compound has a sufficiently upward trend, whereas the airflow from other sections previously suggested or tried for a similar grouping has a downward trend which rendered them non-useful. The airflow about the compound is diagrammatically illustrated in Fig. 7, in which the forward edge of the rear section is

indicated as being within the zone of reactionary upward airflow or plus density, that is, with its leading edge not farther back than a chord length from the trailing edge of the forward section, nor farther down in a vertical direction that half the chord length of the forward section. It will be seen also that this reactionary flow of the air at very high speed from the lower surface of the forward section assists in augmenting the evenness of flow and the rarefaction of the air above the upper surface of the rear section.

It will be understood that the foregoing desirable results may not be obtained in the most highly desirable degree at low speeds where the air currents may not be in the matter of direction exactly as shown in Fig. 7, as the nature of the airflow varies when there is any very great difference in speed, but there can be no question as to the correctness of the theory outlined where the higher speeds now demanded are attained.

In Figs. 5 and 6, the trailing portion h of the forward section is made angularly adjustable in combination with the angular adjustment of the rear section f for the purpose of increasing the space between when the sections are in position for high speed and for securing a deeper camber as a whole and a larger angle of incidence in the setting of the aerofoil for landing.

For simultaneously shifting the balanced rear sections B as well as the trailing portions h of the front sections of a bi-plane, I may use the mechanism shown in Fig. 8, in which the two rear sections are pivotally connected by an upright rod i and the upper section is connected at opposite sides of the pivotal point f by cables j to a lever k , while the pivots f of each of the sections B are connected by link-wires l and arms m to the pivots of the trailing members h , so that by oscillating the lever k on its pivot n all the pivotal members B and h may be simultaneously angularly adjusted either upwardly or downwardly to either entirely or only partly close the gap between the aerofoil sections. It will be seen that the adjustment of the rear wing to vary the size of space between the sections will vary the angle of incidence of the entire aerofoil and thus will allow the aeroplane to have a range of speed between that provided by the camber of the individual sections and the camber of the closed system or compound.

The usual individual aerofoil gives a high suction value on the upper surface near the leading edge over about one-third of the chord and dropping off very rapidly towards the trailing edge. The effect of the rear wing in my compound however, is to increase the suction over the remaining two thirds of the surface without causing the advantage gained to be lost again by the pas-

sage of the air over itself, making a more uniform distribution over the whole aerofoil as exemplified by stability while testing for lift and drag and also in pressure distribution tests. This uniform distribution of pressure is an assurance of stability.

It will be observed that a feature of importance in my airplane is that the forward wing shall have its maximum efficiency occur at low angles for best results, and in Fig. 2 I show a cross-section in which the underside is flat while the upper surface is faired to reduce vortices to a minimum, while producing lift; this type of wing produces results in compound not to be obtained by the deeply concaved wings used in disclosures of closely grouped systems which have equal chords. But it will be understood that other shapes of under surface may be used in my apparatus, provided all the elements of the surfaces of both wings are made integral and their chords proportioned to direct the airstream in the path of least dissipation of energy. Further, since this greater efficiency is obtained with the wings in close proximity, it will be seen that my compound wing is not only an aerodynamic improvement but has structural advantage in that the structure of my apparatus compares favorably with that of an ordinary wing.

The nature and scope of the invention having been thus indicated and its preferred embodiment having been specifically described, what is claimed as new is:

1. A compound wing composed of dissimilar wings comprising a main wing and an auxiliary wing set close one behind the other with a gap between, said wings acting on the same airstreams, said auxiliary wing having smaller chord and thinner cross-section than the main wing, the upper surface of said auxiliary wing being convexed and compounded with the curves of said main wing to reduce eddies in the airstream, said wings normally disposed in substantially parallel separate planes.

2. A compound wing composed of dissimilar wings set close one behind the other with a gap between, said wings acting on the same airstreams, the rear wing having less

than half the chord and thinner cross-section than the forward wing, said rear wing having its upper and lower surfaces convexed and compounded with the curves of said forward wing to reduce eddies in the said airstreams and embody inherent stability as described, said wings being normally in substantially parallel planes.

3. The structure according to claim 1, in which said main wing and said auxiliary wing have substantially equal span.

4. The structure according to claim 1, having means for closing the gap to the extent desired.

5. The structure according to claim 1, having the rear wing pivoted so that it may tilt to vary the angle of incidence.

6. The structure according to claim 2, having means to reduce said gap in accordance with changes in load and for landing.

7. The structure according to claim 2, having the leading edge of said rear wing in advance of the trailing edge of said forward wing.

8. In a compound aerofoil, a pair of wing sections set one behind and below the other with a gap between, the lower surface of the forward wing being non-concave at the trailing portion, said wing sections being set sufficiently close to mutually affect the airflow immediately above and below their surfaces, said forward wing being provided with a hinged trailing portion adapted to swing vertically so as to vary the extent of opening between the two wing sections.

9. A flying machine in which the wing is composed of two sections arranged one behind and below the other, characterized by the forward section being provided with a vertically-swinging trailing portion and the rear section being mounted pivotally on an axis extending transversely of the line of flight, and means for simultaneously shifting said rear section and said trailing portion to vary the extent of gap between the same.

In testimony whereof I hereunto affix my signature.

CHARLES ARTHUR WRAGG.