C. M. OLMSTED.

AERIAL PROPELLER.

APPLICATION FILED OCT. 2, 1909.

1,019,078. Patented Mar. 5, 1912.

Fig. 1.

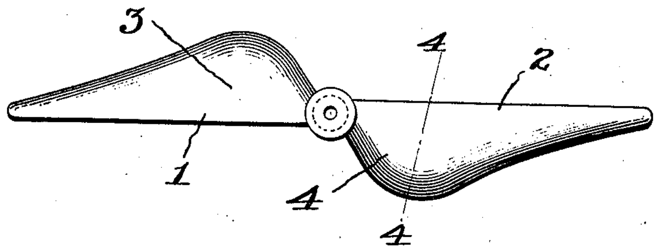


Fig. 2.

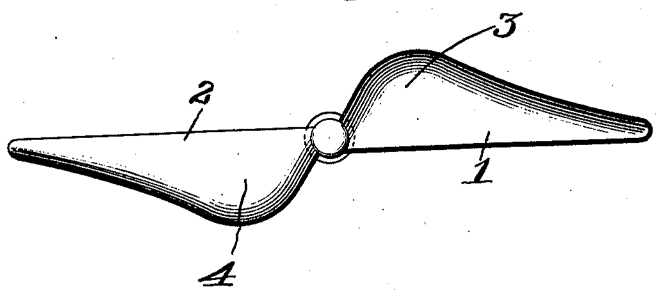


Fig. 3.

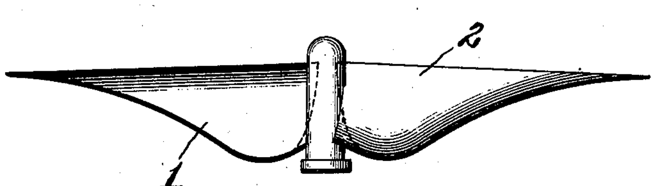


Fig. 6.

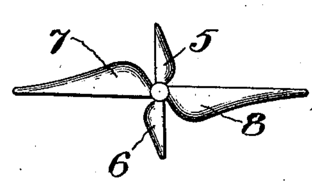


Fig. 4.

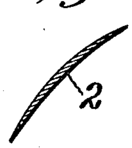
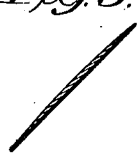


Fig. 5.



Witnesses

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AERIAL PROPELLER.

1,019,078. Specification of Letters Patent. **Patented Mar. 5, 1912.**

Application filed October 2, 1909. Serial No. 520,677.

To all whom it may concern:

Be it known that I, CHARLES M. OLMSTED, of Pasadena, in the county of Los Angeles and State of California, have invented certain new and useful Improvements in Aerial Propellers; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates more especially to propellers for the propulsion, support or control of aerial craft such as so called "flying machines" as well as helicoptic or other flying toys.

Heretofore it has generally been the custom of those employing helical propellers to propel aerial craft, to form these of two or more blades or vanes so proportioned that the posterior and anterior edges of these vanes shall be determined by the intersection of the surface of the helix with two parallel planes which are perpendicular to the axis of the helix; that is to say, the blades widen toward the periphery of the propeller. As is well known to those familiar with the art, the energy used in turning a propeller of this kind for a given time is more than the work represented by the pull of the propeller multiplied by the distance through which it moves its load in this time; the ratio of the work done to the energy used being known as the efficiency of the propeller. It is also known that various loads require various sized and pitched propellers to be moved with a maximum of efficiency. It is not generally known, however, that by departing from the described common form of helical propeller an efficiency greater than that obtainable with the aforesaid propeller may be secured.

The object of this invention is to secure such increased efficiency, and this I accomplish by so designing the propeller blades that every element of the blades will act upon the air in the most economical manner possible. I have discovered that this maximum efficiency may be attained by constructing a propeller which fulfils the following equation:

$$a=k\frac{(r^2 \tan.^2(\alpha-\varepsilon)-P^2)}{r(\cos.\ \alpha\ \sec.^2(\alpha-\varepsilon)}\quad(1)$$

where $\alpha=\tan.^{-1}\frac{C}{r}$.

In (1) "a" represents the total width of all of the blades at any distance "r" from the axis of the propeller; α the angle which the "surface" of the blade makes with the plane of the propeller (the "surface" being understood to mean not necessarily the physical surface of the blade at the point in question; but a plane to which the resultant force of the air pressure is perpendicular when the relative motion of air and blade is such that this resultant pressure is as near being perpendicular to the direction of related motion as it is possible, with the given blade, to make it); C, the constant which determines the pitch of the helix, obtained as hereinafter described; P, the distance which the propeller advances during a turn of one radian; and k and ε constants determined as hereinafter described. In such a propeller, the work of turning the propeller one radian is C times the pull, and the work done by the propeller is P times the pull. The efficiency of the propeller is therefore

$$\frac{P}{C}.$$

For any given valve of

$$\frac{P}{C},$$

the pull of a helical propeller is a maximum when Equation (1) describes the distribution and angle of blade surface, no matter how the diameter of the propeller may be restricted on account of mechanical reasons. In practice these propellers may be made with two or more blades symmetrically placed about the center. The plan of any particular blade makes little difference so long as the total width, at any distance from the center, of all the blades is of such an amount as to satisfy Equation (1).

The cross-section of the blades may be straight or curved as hereinafter described. I prefer the latter form, however, since it makes the constant k in Equation (1) smaller. By cross-section I mean the intersection of the blade with a cylindrical surface generated by revolving a line parallel to the axis of the propeller about said axis.

In order to construct a propeller according to my invention one may proceed as follows: If, as is generally the case, the resistance of the aerial craft which is to be moved is such a function of the velocity that it increases when the velocity increases, there will be a certain maximum speed with which a given amount of power can drive the craft. If the amount of power available is fixed, it is desired to obtain this maximum speed. Or, on the other hand, if a certain speed is desired, it is desirable to obtain it with a minimum of power. We shall consider the latter case.

As the speed of advance is fixed, ωP is fixed; ω being the angular velocity of rotation of the propeller expressed in radians per second. Now the total pull of the propeller is

$$\int \frac{\pi\rho}{g}\omega^2[r^2 \tan.^2(\alpha-\varepsilon)-\mathrm{P}^2]rdr \quad (2)$$

the integration being extended over all regions where $r^2 \tan.^2 (\alpha-\varepsilon)-\mathrm{P}^2$ is positive if there are no restrictions as to the maximum allowable diameter; or over all such positive regions within this limit when it exists. Here ρ is the weight of one cu. ft. of air, or about .08 lb.; and g, acceleration of gravity, taken as 32.

(2) shows that as ω is decreased and P increased, the value of the efficiency

$$\frac{\mathrm{P}}{\mathrm{C}}'$$

for a given pull increases. The necessary maximum radius to get a required pull, however, is constantly increasing. Two mechanical cases act to put a limit on the slowness of revolution: First, if the propeller is attached directly to the engine shaft, ω is at once fixed by the speed of the engine. Second, if the propeller is geared down, a maximum for ω is fixed by the available space for the propeller.

When ω has been decided upon P becomes fixed. P being known, the value of C necessary to get the desired pull may be deduced from (2), remembering that $\mathrm{C}=r \tan.\alpha$. It is preferred to do this by a series of trials resulting from the substitution of various values of C in (2). By interpolation the exact value of C necessary to produce a given pull can be found. C having been found, the value of a for various distances from the center may be computed from (1). In this computation the values of ε and k are determined experimentally.

Experiment (well known to those familiar with the art) shows that the direction of the reacting force of the air may be brought to within 2 to 5 degrees of perpendicularity in the case of planes or slightly concave surfaces. Call this angle ε. ε is then a small angle lying between 0° and say 5° in the case of planes or slightly concave surfaces, and is always no matter what the shape of the surface, the minimum to which the angle between the direction of the pressure on a surface and a plane perpendicular to its motion may be brought. k is equal to

$$\frac{\pi\rho}{gc}$$

where c is the pressure on a square foot of the employed surface when this is held at the most economical angle—that is to say when the resultant pressure on the surface makes an angle ε with the plane which is perpendicular to the line of relative motion of surface and air. The velocity of relative motion must be 1 ft. per sec.

As to the distribution of the total blade surface among the blades this may be done to suit the convenience of the designer. I prefer, however, to have as few blades as is consistent with mechanical strength and balance, two blades being sufficient, if these do not have to be excessively wide at any point to fulfil the conditions of Equation (1). If the imposed conditions are such that two blades would have to be excessively wide over part of their extent, these may be made narrower where necessary, with blades added to make up the required amount of blade surface.

A plurality of specific forms of propeller constructed in accordance with my invention are shown in the accompanying drawings, wherein,

Figure 1, represents in front elevation a two blade form of the propeller; Fig. 2, a rear elevation of said propeller; Fig. 3, a side elevation of said propeller, (here the dotted line indicates the theoretical boundary of blade where this does not coincide with practical boundary), and, Fig. 4, a cross-section on line 4—4 Fig. 1; Fig. 5, a cross-section of the propeller blade if made flat, and, Fig. 6, a front elevation of a form of my improved propeller where more than two blades are employed.

The propeller shown in Figs. 1 to 5, consists, as will be seen, of two blades 1 and 2, each of which increases in width from a point near the axis of the propeller, or base of the blade, until a maximum is reached at a distance from the axis where the pitch angle of the blades is greater than 45°, and then gradually decreasing from this point outward. In this propeller the blades are concavo-convex as at 3, 4, along any cross-section, but if desired, I may make the blades flat in cross-section as indicated in Fig. 5, this section being supposed to be taken at a point in the length of a flat propeller blade corresponding to the point where the section 4—4 is taken in a concavo-convex blade.

In Fig. 6, I have shown a form of my propeller to illustrate the case herein above mentioned where it becomes preferable on account of the total width of blade required to fulfil the requirements of Equation (1), in a given case, to add blades rather than make the blades of a two blade propeller excessively wide.

In the drawings blades 5, 6, represented those added to blades 7, 8, to get the proper amount of blade width. The two propellers which have been shown are only two of many specific shapes which may be included in the general scope of my invention.

As to application, these propellers are designed principally for the propulsion, support or control of aerial craft, including so called "flying machines" and helicoptic toys. The said propeller may, however, be used for any other desired purpose.

I claim as my invention:

1. An aerial screw-propeller comprising a hub and a plurality of rigid blades, the contours whereof substantially conform to a helicoidal surface throughout their entire extent, and the cross sections whereof are concavo-convex wherever taken between hub and tip, each blade having its widest portion adjacent to said hub, and more than twice as wide as the width of that blade at a distance from the axis equal to three-fourths of the extreme radius of the propeller.

2. An aerial screw-propeller comprising a hub and a plurality of rigid blades, the contours whereof substantially conform to a helicoidal surface throughout their entire extent, and the cross sections whereof are concavo-convex wherever taken between hub and tip, each blade having its widest portion adjacent to said hub, and more than twice as wide as the width of that blade, at a distance from the axis equal to three-fourths of the extreme radius of the propeller, and each blade directly connected to said hub over a width greater than twice the width of that blade taken at a distance from the axis equal to three-fourths of the extreme radius of the propeller.

3. An aerial screw-propeller having a plurality of rigid blades, every part of which conforms, as described, to a helicoidal surface, and each of which so varies in width that more than sixty per cent. of the total amount of blade surface is included within a cylinder described about the axis, with a radius equal to one half the radius of the propeller, the variation in width being such that the radial gradation in total width is gradual.

4. An aerial screw-propeller having a plurality of rigid blades, every part of which conforms, as described, to a helicoidal surface, and each of which so varies in width that more than sixty per cent. of the total amount of blade surface is included within a cylinder described about the axis, with a radius equal to one half of the radius of the propeller, and so that more than twenty-five per cent. of the total amount of blade surface is included within a cylinder described about the axis, with a radius equal to one fourth of the radius of the propeller, the variation in width being such that the radial gradation in total width is gradual.

5. An aerial screw-propeller with rigid helicoidal blades which are wider at a distance from the axis equal to one fourth the radius than they are at a distance equal to one half the radius, and which are more than twice as wide at a distance from the axis, equal to one half the radius as they are at a distance from the axis equal to three fourths of the radius.

6. An aerial screw-propeller having a plurality of rigid blades every part of which conforms as described to a helicoidal surface and each of which so varies in width that more than sixty per cent. of the total amount of blade surface is included within a cylinder described about the axis with a radius equal to one half the radius of the propeller, the variation in width being such that the total width of blade surface increases gradually to a maximum close to the hub, then decreases, at first slowly then rapidly, and finally again slowly as the tip is approached.

7. An aerial screw-propeller having a plurality of rigid blades every part of which conforms as described to a helicoidal surface and each of which so varies in width that more than sixty per cent. of the total amount of blade surface is included within a cylinder described about the axis with a radius equal to one half the radius of the propeller, the variation in width being such that the total width of blade surface which is greatest near the hub, decreases at first slowly, then rapidly, and then slowly again as the tip is approached.

8. A screw-propeller having rigid helicoidal blades, which are widest near the base, and which gradually decrease at first slowly, then rapidly, and then slowly toward the tip, the decrement in width growing at first gradually more and then gradually less, as the tip is approached.

9. A screw-propeller comprising a plurality of helicoidal blades, and in which the total width of blade gradually increases from the axis toward the periphery until a maximum is reached at a distance from the axis where the pitch angle is more than forty-five degrees, and then decreases from this point outward.

10. A screw-propeller comprising a plurality of helicoidal blades, and in which the total width of blade gradually increases from the axis toward the periphery until a maximum is reached at a distance from the axis where the pitch angle is more than forty-five degrees and then decreases from this point outward, the rate of increase growing gradually less as the maximum width is approached, and then the rate of

decrease growing at first gradually greater, and then gradually less, as the extreme radius, or tip, is approached.

11. A screw-propeller comprising a plurality of helicoidal blades, and in which the total width of blade gradually increases from the axis toward the periphery until a maximum is reached at a distance from the axis where the pitch angle is more than forty-five degrees, and then decreases from this point outward, and in which the wide bases of the blades, adjacent to the hub, are directly attached to the hub.

12. A screw-propeller comprising a plurality of helicoidal blades, and in which the total width of blade gradually increases from the axis toward the periphery, until a maximum is reached at a distance from the axis where the pitch angle is more than forty-five degrees, and then decreases from this point outward, the rate of increase growing gradually less as the maximum width is approached, and then the rate of decrease growing at first gradually greater and then gradually less, as the extreme radius or tip is approached, and in which the wide bases of the blades adjacent to the hub, are directly attached to the hub.

13. A screw-propeller comprising a plurality of helicodial blades, and in which the total width of blade gradually increases from the axis toward the periphery, until a maximum is reached at a distance from the axis where the pitch angle is more than forty-five degrees, and then decreases from this point outward, the rate of increase growing gradually less as the point of maximum width is approached, and then the rate of decrease, growing at first greater and then gradually less, as the extreme radius or tip is approached, and in which the wide bases of the blades, adjacent to the hub, are directly attached to the hub, and in which more than sixty per cent. of the total amount of blade surface is included within a cylinder described about the axle, with a radius equal to one half the radius of the propellers, and in which more than twenty-five per cent. of the total amount of the blade surface is included within a cylinder described about the axis with a radius equal to one-fourth of the radius of the propeller, and in which the total width of the blade, at a distance from the axis equal to one fourth of the radius of the propeller, is greater than the total width of blade, at a distance from the axis equal to one half the radius of the propeller, and in which the total width of blade at a distance from the axis equal to one half the radius of the propeller, is more than twice as great as is the total width of blade at a distance from the axis which is equal to three quarters of the radius of the propeller.

14. An aerial screw-propeller comprising a plurality of rigid blades which differ in shape one from another, and each of which is twisted longitudinally so that the resultant of all pressures, at any given distance from the axis, is substantially perpendicular to the helicoidal surface at such distance, and each of which is so graduated in width, that the total width of blade surface is greatest near to the axis, and decreases gradually toward the tip of the blade, the graduation in width being at such a rate that more than half of the blade surface is located within a cylindrical surface described about the axis, with a radius equal to half of the radius of the propeller.

15. An aerial screw-propeller comprising a plurality of rigid blades which differ in size one from another, and each of which is twisted longitudinally so that the resultant of all pressures, at any given distance from the axis, is substantially perpendicular to the helicoidal surface at such distance, and each of which is so graduated in width, that the total width of blade surface is greatest near the axle, and decreases gradually toward the tip of the blade, the graduation in width being at such a rate that more than half of the blade surface is located within a cylindrical surface described about the axis, with a radius equal to half the radius of the propeller.

16. An aerial screw-propeller comprising a plurality of rigid blades which differ in size and shape one from another, and each of which is twisted longitudinally so that the resultant of all pressures, at any given distance from the axis, is substantially perpendicular to the helicoidal surface at such distance, and each of which is so graduated in width that the total width of blade surface is greatest near the axle, and decreases gradually toward the tip of the blade, the graduation in width being at such a rate that more than half of the blade surface is located within a cylindrical surface described about the axle, with a radius equal to half of the radius of the propeller.

17. A screw-propeller comprising a plurality of helicoidal blades, and in which the total width of blade gradually increases from the axis toward the periphery until a maximum is reached at a distance from the axis where the pitch angle is more than forty-five degrees, and then decreases from this point outward, the distribution of the blade surface being determined by and substantially conformable, over the greater part of its extent, to the rule:

$$a=k\frac{r^2 \tan.^2(\alpha-\varepsilon)-P^2}{r \cos.\ \alpha \sec.^2(\alpha-\varepsilon)}$$

wherein "a" is the total width of blade surface at the distance "R" measured perpendicularly from the axis of the propeller; "k" and "P" are constants determined in the manner described; "ε" is the quantity determined in the manner described, and

$$\alpha = \tan.^{-1}\frac{C}{r}$$

where "C" is a constant determined in the manner described.

In testimony whereof, I have signed this specification in the presence of two subscribing witnesses.

CHARLES MORGAN OLMSTED.

Witnesses:

JUAN R. GOMEZ,

JAMES C. MORGAN.