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AIRPLANE PROPELLER

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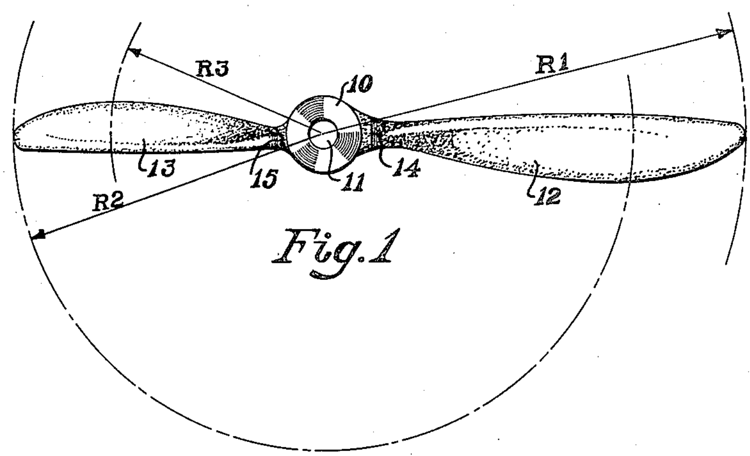

Fig.1

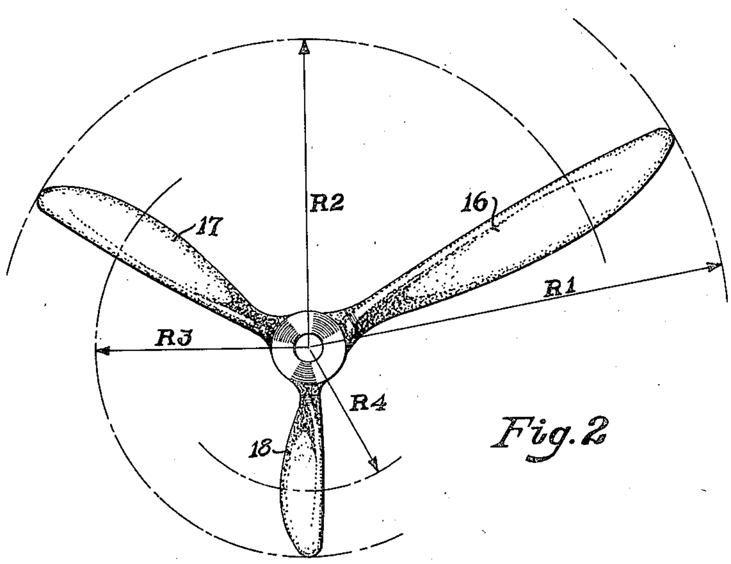

Fig. 2

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AIRPLANE PROPELLER

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1 Claim. (Cl. 170—166)

The present application is a refile of our previous application filed September 13, 1937, Serial No. 163,516 and comprises an improved airplane propeller having a plurality of blades of different length, the length of each successive blade being in a definite relation to the one preceding it.

It is a well known fact that airplane propellers having more than one blade of equal length are very inefficient. This is due to the fact that the high speed of one propeller blade will create an aerial void which will not have time to become equalized before the next propeller blade enters. The following propeller blade therefore has to operate in this void of wake from the preceding one and it thus works in a partial vacuum or a rarefied air which would be equivalent to operating at a very high altitude. It is well known that no propellers are very effective at extremely high altitudes and it is therefore readily seen that when the propeller speed exceeds a certain limit the effectiveness of a multiple blade propeller must necessarily be greatly diminished. For this reason it has been variously suggested to use and try a single blade and while this is possible and gives higher efficiency it has several serious disadvantages due to the dynamic unbalance created. It is furthermore well known that due to the higher peripheral speed the above condition is only prevalent at the outer ends of the propeller blades. The present invention proposes to eliminate all these difficulties by making the propeller blades of various lengths.

The object of our invention is therefore to provide an airplane propeller having a plurality of blades which are of different lengths and where the length of each shorter blade is a definite mathematical proportion to the length of the longer blade. A further object of our invention is to provide a propeller having a plurality of blades of unequal length where each blade is made of a different material and where the specific gravities of these materials are in a definite mathematical relation to the length of the blades. Still another object of this invention is to provide a multi-blade airplane propeller of higher efficiency and capable of giving increased power at lower speed thus being of smaller size for a given power. Other objects and advantages of the invention will be apparent from the following specification and claim.

In the accompanying drawing, forming a part of this specification, and in which like numerals are employed to designate like parts throughout the same:

Figure 1 is a front view of an airplane propeller having two blades of unequal length, and,

Figure 2 illustrates an airplane propeller having three blades of unequal length.

In the drawing, wherein for the purpose of illustration, is shown a preferred embodiment of our invention, the numeral 10 designates the hub of the propeller which has two blades 12 and 13. The blades 12 and 13 are fastened to the hub at 14 and 15. The radius to the tip of the longer blade is given the dimension R1 while the radius to the tip of the shorter is given the dimension R2. R3 is the radius to the effective part of the shorter blade.

Referring to Figure 2, the illustrated three blade propeller has a long blade 16 a shorter blade 17 and a still shorter blade 18 equally spaced around the hub 10. The radius to the tip of the longer blade is R1, the radius to the tip of the next shorter blade 17 is R2, the radius to the tip of the shortest blade is R3 and the radius to the effective part of the shortest blade 18 is R4. It will be noted that in each case the radius to the tip of a shorter blade is always equal to the radius of the effective part of the next longer one.

The relation between the various blades can be shown mathematically as follows:

For the purpose of the mathematical treatment the following denotations are used:

$R1$=length of the longest blade
$R2$=length of the next shorter blade
$R3$=length of the next shorter blade
I_1 =moment of inertia of longest blade
I_2 =moment of inertia of next shorter blade
M_1 =mass of the longest blade
M_2 =mass of the next shorter blade
W_1=weight of the longest blade
W_2=weight of the next shorter blade
Q_1 =cross section of the longest blade
Q_2 =cross section of the next shorter blade
w_1 =specific gravity of material used in the longest blade
w_2 =specific gravity of material used in the next shorter blade
g =acceleration of gravity.

So as not to unnecessarily complicate the calculations it shall be assumed that each blade has a constant cross section. The same calculations may, of course, be carried through for blades having variable cross sections. The result will be the same, but the mathematics are more complicated.

The moment of inertia may be expressed for each blade as follows:

$$I_1=\frac{M_1R_1^2}{3}$$

$$I_2=\frac{M_2R_2^2}{3}$$

The ratio of the moments of inertia is:

$$\frac{I_1}{I_2}=\frac{M_1R_1^2}{M_2R_2^2}\text{----------------}(1)$$

Now $M_1=W_1/g$ and $M_2=W_2/g$ and $W_1=wQ_1R_2$ and $W_2=w_2Q_2R_2$. If these values are substituted in (1) we have:

$$\frac{I_1}{I_2}=\frac{W_1R_1^2}{W_2.R_2^2}=\frac{w_1Q_1R_1^3}{w_2Q_2.R_2^3}\text{------------}(2)$$

Equation 2 may be further simplified by making $Q_1=Q_2$ and we have then:

$$I_1/I_2=w_1R_1^3/w_2R_2^3\text{------------}(3)$$

To be dynamically balanced the above ratio of the moments of inertia for a two-bladed propeller must be equal to one. The speed is the same for both blades, hence we may write:

$$w_1R_1^3=w_2R_2^3\text{--------------}(4)$$

From this equation it is possible to find the proper length of each blade for correct dynamic balance when the blades are made from materials of different specific gravity:

$$R_1=R_2\sqrt[3]{w_2/w_1}\text{--------------}(5)$$

If for example the two blades of a propeller are made from Dow metal of spec. gr. 1.7 and Dural of sp. g. 2.8 we have:

$$R_1=R_2\sqrt[3]{2.8/1.7}=1.18.R_2$$

In other words the longest blade must be 18% longer than the shorter one. By using wood or metallic alloys of the desired specific gravities dynamically balanced propellers may be produced which have the proper graduations in blade length to give better efficiency for each blade and less noise and vibration. Propellers with three or more blades may be calculated in the same way. In the latter case the components of the moments of inertia of the two or more shorter blades must be equal to the moment of inertia of the longest blade. This may be expressed as follows for a three-blade propeller: $I_1=I_2.\cos 60°+I_3.\cos 60°$. Now $\cos 60°=0.5$ and hence: $I_1=\frac{1}{2}(I_2+I_3)$.

The ratio for dynamic balance must be one:

$$\frac{I_1}{\frac{1}{2}(I_2+I_3)}=\frac{w_1R_1^3}{\frac{1}{2}(w_2.R_2^3+w_3R_2^3)}\text{-------}(6)$$

From Equation 6 the length of the blades of three blade propellers may be calculated. In a similar manner propellers with more than three blades may be calculated. It is obvious from Equation 2 above that propellers may also be built having blades of unequal length and each blade having a cross section differing from the cross sections of the other blades in such a manner as to dynamically balance the propeller.

The operation of our invention is obvious from the above. It consists in dimensioning the blades of the propeller in the relations shown thereby producing a dynamically balanced propeller of higher efficiency and of higher power at lower speeds thus permitting a smaller over-all size. The longer blade of the propeller will create a void in the space between R1 and R2, the next shorter blade will work inside of the radius R2 and will thus not be affected by the wake of the longer blade. The same thing happens with the third blade in a three-blade propeller.

It is to be understood that the form of our invention, herewith shown and described is to be taken as a preferred example of same, and that various changes in the shape, size and arrangement of parts may be resorted to without departing from the spirit of our invention, or the scope of the subjoined claim.

Having thus described our invention we claim:

A propeller of the character described having a plurality of blades of unequal length, each shorter blade having its length determined in relation to the length of the next longer blade, by

$$R_1=R_2\sqrt[3]{w_2/w_1}$$

and each blade being made of a different material in such a way that each shorter blade is made of a heavier material than the next longer one and that the specific gravities of these materials be related according to the following formula: $w_1=w_2R_2^3/R_1^3$.

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