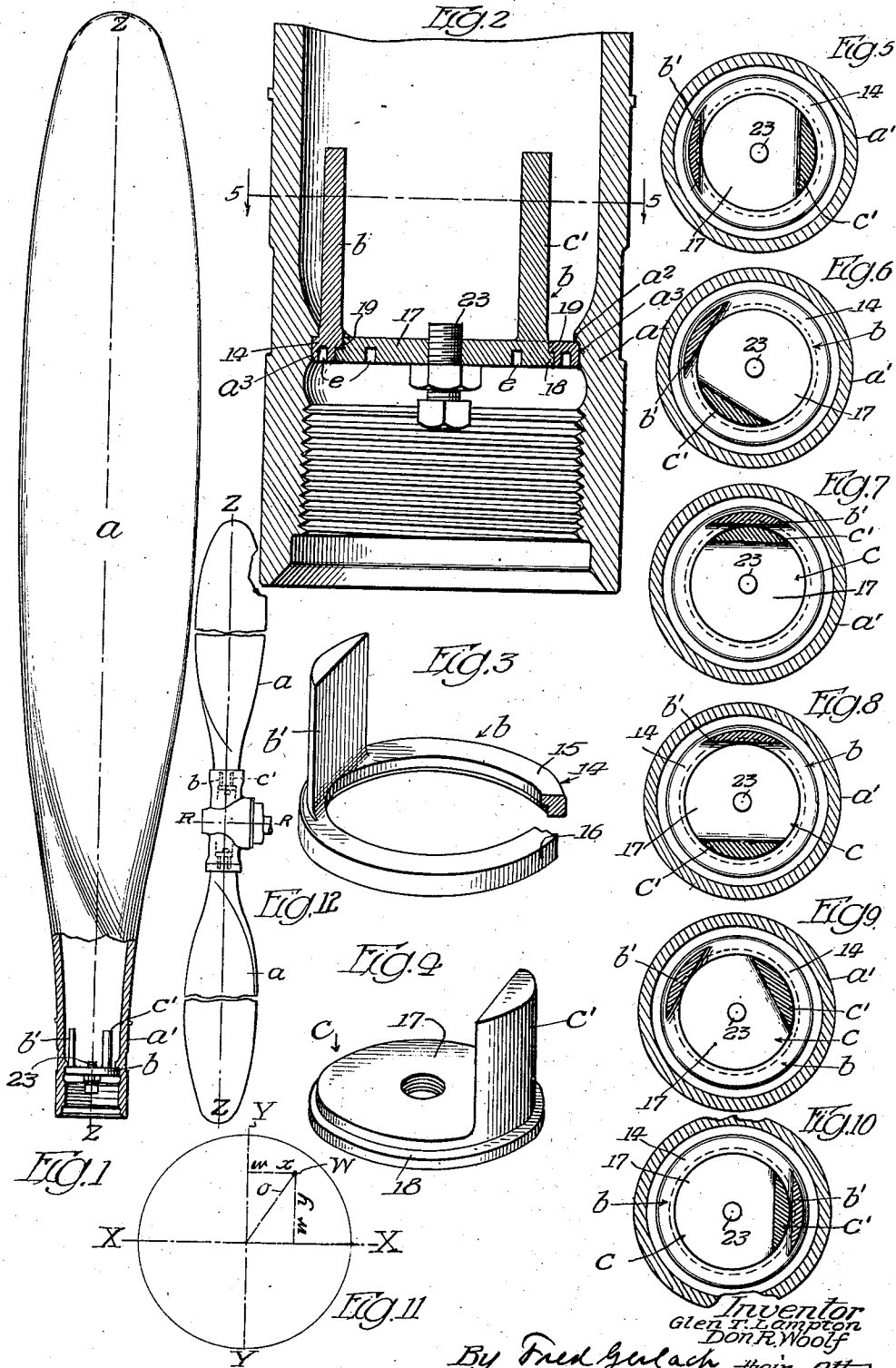


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BALANCING PROPELLER BLADES

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BALANCING PROPELLER BLADES

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The invention relates generally to propellers for aircraft, and more particularly to a method of, and devices for, statically balancing the blades about their longitudinal axes.

In practice the moments of the weights of the blades of a propeller about its axis of rotation should be equal in order to minimize unbalance and prevent vibration stresses which may exceed the designated limits and cause failure in affected parts of the engine-propeller-airplane combination. It is likewise necessary that each propeller blade be balanced around its longitudinal axis for the same reasons. It is possible to balance a propeller blade about its axis of rotation and at the same time have the propeller blade unbalanced about its longitudinal axis. In the manufacture of propeller blades it has been found relatively easy to correct one or the other of these unbalances individually, but difficult to correct or maintain both balances. It is now common procedure in correcting unbalance to add an amount of metal or mass, usually solder, lead or type metal, in the cavity of the shank of the propeller blade proportional to the unbalance of the propeller blade. If the blades of a propeller are balanced about its axis of rotation and any blade is unbalanced about its longitudinal axis, metal added to correct the unbalance about its longitudinal axis may destroy the balance moment about the axis of rotation of the propeller. The present invention contemplates the fabrication of blades by the addition of the same or a predetermined weight of metal to all blades and variation of its radial position around its longitudinal axis for balance moment around the longitudinal axis at a uniform distance from the axis of rotation of the propeller so as to maintain the balance between the blades of a propeller. The effect of the weight is varied by a change of its position around the longitudinal axis of the blade without increase or decrease of the weight, for correction of any unbalance about the longitudinal axis. The addition of weight of an equal amount to each blade for said purpose will not change the balance of the blade around the axis of rotation of the propeller so that relatively the balance remains unchanged.

One object of the invention is to provide a method of correcting an unbalance condition in a propeller blade about its longitudinal axis without affecting the balance of the blades about the axis of rotation of the propeller.

Another object of the invention is to provide a method of statically balancing propeller blades about their longitudinal axes by adding mass in

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correct positions to rectify the unbalance according to the magnitude and radial direction of the unbalance caused by variation in the physical dimensions of the blades so that the blades after being balanced around their longitudinal axes are of uniform balance and will be statically balanced relative to each other.

Another object of the invention is to provide a mass of predetermined weight with component parts which are adapted respectively to be fixedly placed in any radial direction in the shank of a propeller blade so that the resultant moment of the mass will be equal in magnitude and in opposite direction to the unbalance moment of the blade.

Another object of the invention is to provide eccentric weights of equal balancing moment which by positioning relatively to each other can be made to correct any unbalance from an unbalance equal to the sum of the balancing moments of the eccentric weights to no unbalance inclusive.

Another object of the invention is to provide a mass for adding weights for balance around the longitudinal axis of the blade, which is composed of eccentric weights of different radii and equal balancing moments which can be rotatively positioned to all radial positions before being permanently fixed in the blade.

Another object of the invention is to provide a standard set of weights for compensating for the unbalance about the longitudinal axis of the blade produced by loads of different magnitudes and located in any radial direction.

Other objects of the invention will appear from the detailed description.

The invention consists in the several novel features which are hereinafter set forth and are more particularly defined by claims at the conclusion hereof.

In the drawings:

Fig. 1 is an elevation, partially in section, of a propeller blade embodying the invention.

Fig. 2 is a longitudinal section of the shank-portion of the blade and the balancing weights on an enlarged scale.

Fig. 3 is a perspective of one of the balancing sections which comprises a ring and a weight.

Fig. 4 is a perspective of the other balancing section with the weight thereon.

Fig. 5 is a section taken on line 5—5 of Fig. 2.

Figs. 6, 7, 8, 9 and 10 are similar sections, respectively, showing the balancing weights in different positions in the blade.

Fig. 11 is a diagram of the parallelogram of

forces through the use of which the effective magnitude and position of the load which causes the unbalance may be determined.

Fig. 12 is a diagrammatic view illustrating a propeller indicating the location of the balancing weights relatively to its axis of rotation and the longitudinal axis of the blade.

The invention is exemplified in connection with a steel propeller blade *a* having a hollow shank *a*¹. The shank of the blade may be secured in a propeller hub in any well known manner. The blade is completely fabricated before the mass for statically balancing it about its longitudinal axis is added. The shank *a*¹ is counter-bored as at *a*³ to an annular shoulder *a*² to receive the balancing mass. The longitudinal axis of the blade is indicated by the line Z—Z in Fig. 1. A plurality of blades are usually secured in a hub and are rotatable together on the axis indicated at R—R in Fig. 12. In practice the blades are usually finished to a predetermined balance moment about the axis of rotation R—R before they are statically balanced about their longitudinal axes Z—Z.

The invention provides for the addition of a standard mass for all production blades of a similar character and which mass is composed of sections for statically balancing the blade about its longitudinal axis to compensate for any unbalance. Due to production methods the unbalance in different blades will probably be of differing magnitudes and require different positioning of the standard mass. Generally the unbalance is produced by inaccuracies in physical dimensions and may be located in any radial direction from the axis. These sections comprise two eccentric weights of equal balancing moment about the axis Z—Z and which can be separately positioned in any radial direction relatively to the axis Z—Z of each blade. By adding to each blade, the standard mass or eccentric weights at an equal distance from the axis R—R, for static balance about axis Z—Z, the moment of all blades about the axis R—R will be the same. If there is no unbalance about the longitudinal axis Z—Z, the weights are located in mutually balancing radial positions in the blade but the blade will have the same moment about the axis R—R as the blades wherein it was necessary to balance about the axis Z—Z. The sections of the mass hereinafter described are adapted to add to each blade, mass of uniform weight.

For brevity, the balance about the longitudinal axis Z—Z of the blade is hereinafter referred to as the vertical balance and the balance of the blades about the axis of rotation R—R is referred to as the horizontal balance.

The mass for vertical balance of the blade comprises a pair of separate sections *c* and *b*, each of which has an integral weight. The weights are on the sections, respectively, and adapted to be circumferentially positioned in the counterbore *a*³ of the shank in any radial direction through 360°. Section *b* comprises a ring 14 of metal which has an end-face 15 which is adapted to abut against the annular shoulder *a*² in the shank *a* to position it longitudinally in the shank and a cylindrical periphery 16 which is adapted to fit into the bore *a*³ so that the ring will fit and is rotatable concentrically to any position in the shank. Section *b* has an eccentrically located weight *b*¹ which is integral with ring 14 and adapted to be rotatively positioned at a uniform distance around the axis Z—Z, projects longitudinally inward from the ring 14, and has an outer arcuate face concentric with the longitudinal axis

of the blade and a chordal inner face. The section *c* comprises a wall 17 which has a circular periphery concentric with axis Z—Z and fitting in ring 14. Section *c* is formed with an annular flange 18 which fits in a counterbore 19 in the outer face of ring 14, and with an integral weight *c*¹. Said weight *c*¹ is eccentrically located, is rotatable around axis Z—Z to any radial direction with section *c*, projects longitudinally inward from ring 17, and has an arcuate outer face concentric with the said axis, and has a chordal inner face. These weights are located on different radii so they are rotatable past each other and so that each can be set into any radial direction around the axis of the blade, before being fixed therein, and are preferably of the same length. The balancing effect of each weight about the longitudinal axis of the blade is a product of its mass, times the distance of the center of mass from the longitudinal axis of the blade. The mass of the inner weight *c*¹, on the shorter radius is greater than the mass of outer weight *b*¹ on the greater radius, and they are proportioned to produce equal balancing moment about the longitudinal axis of the blade. Ring 14 and cross-wall 17 are each provided with sockets *e* for receiving a turning tool or wrench for rotating them in the shank into the radial directions desired. This construction adapts the sections for rotative positioning of the weights in the shank and relatively to each other into any radial direction to effect static balance of the blade around its longitudinal axis and for permanent attachment to the blade thereafter.

In carrying out the invention, the magnitude of unbalance and the location of the load which produces it, for calculation of the radial directions in which the eccentric weights must be placed to compensate for the unbalance, are first determined. For this purpose, the blade is successively supported for movement across radial planes perpendicular to each other and the unbalance in each plane is measured. Any suitable testing apparatus may be used for this purpose. The unbalance is usually measured in units of an ounce inch which is the unbalance due to a weight of one ounce located a radial distance of one inch from the axis of the blade. The two rectangular components of the force which produces the unbalance by the tests in axial planes which are perpendicular to each other, are measured. The location of the force and its magnitude which produce the unbalance are determined by laying out vectors from these components. For example, in Fig. 11, assuming the load which causes the unbalance to be located at W the load across the plane X—X is *w**x* and the load which causes the unbalance across the plane Y—Y to be *w**y*, then the unbalance of the load would be equivalent to a weight W in the angular direction *o* and at a distance *r* from the axis Z—Z. The angular direction *o* and the magnitude of the load W can then be calculated from the parallelogram. From these resultants the radial directions in which the eccentric weights of predetermined moment must be placed oppositely to said load in order to add mass to accurately compensate for the unbalance produced by said load, are calculated. The blade is indexed or marked for the planes in which the measurements are taken. The compensating angles or radial directions for the weights are indexed on the ring *b* and section *c*. The ring *b* and section *c* are then placed in the bore *a*³ with the ring seated on the shoulder *a*² and the section *c* seated on the ring *b*

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so that the centers of mass of the weights b^1c^1 will be positioned in the indexed radial directions in which they will compensate for the measured unbalance caused by the load W according to its position in the blade and its magnitude.

The construction of the ring b and section c adapts each of the eccentric weights to be positioned in any radial direction from the axis $Z-Z$ of each blade so that measured loads of differing magnitude and in any portion of the blade may be accurately compensated for. The blade with the weights set in compensating radial directions may then be again tested in perpendicular planes to determine whether the weights have been set for accurate static balance around the longitudinal axis of the blade. If the unbalance is accurately compensated for, the sections b and c are permanently secured in the shank a^1 by brazing or soldering. Figs. 6, 7, 8, 9 and 10 illustrate some of the different radial positions in which the weights are adapted to be fixed for compensation for the unbalance of different magnitudes caused by loads in different portions of the blade. If the weights as shown by the second test indicate any slight error in calculation, they can be rotated until they are radially directed for accurate balance before they are fixed in the blade. If the initial tests in planes perpendicular to each other indicate no unbalance, the weights are located in diametrically opposite positions, as illustrated in Fig. 5 or 8, where they will add mass to correspond to that added to other blades for balance around axis $R-R$. In thus statically balancing the blades, a plurality of sections of masses of uniform weight are added to each blade and the weights are rotated into positions to compensate for the unbalance. Each pair of sections provides a standardized weight-construction for all blades.

In carrying out the foregoing method the total weight added to each of the blades for vertical balance and the distance each weight is located from the axis of rotation $R-R$ is identical in all blades. The change of the longitudinal center of gravity caused by the addition of the weights for vertical balance is the same in all blades so that they will have the same moment of force to avoid disturbance of the static balance of the blades in the propeller. As a result, the vertical balancing of the blade is attained without disturbing the horizontal balance.

A screw-stud 23 is threaded through the cross-wall 17 of section c for longitudinally balancing the blade within precision limits to compensate for production limits or tolerances of the sections b and c . The sections b and c with the stud 23 therein, when secured in the shank of the blade, form a closure or plug for sealing the chamber in the working portion of the blade which prevents the admission of oil to said chamber from the hub in which the blade is mounted, and also excludes moisture and prevents resultant corrosion.

The invention exemplifies a method for producing vertical balance of a propeller blade which comprises adding to and fixing in the shank of all blades of one type a uniform mass composed of a plurality of sections provided with eccentric weights and positioning the weights in different radial directions to compensate for the unbalance of the particular blade in which the weights are positioned and maintaining the horizontal balance of all of the blades substantially the

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same. The same total weight is added to all blades and at the same distance from $R-R$.

The invention also exemplifies simple and efficient construction of balancing means which comprises a plurality of eccentric weights which are adapted to be placed and fixed in the blade in any radial direction to compensate for unbalance in any portion of the blade. The invention also provides a pair of sections with eccentric weights of standard construction for statically balancing blades about their longitudinal axes for quantity production. The invention also provides a pair of weight-carrying sections which function as a closure or seal which excludes oil and moisture in the chamber in the working portions of the blade.

The invention is not to be understood as restricted to the details set forth, since these may be modified within the scope of the appended claims without departing from the spirit and scope of the invention.

Having thus described the invention, what we claim as new and desire to secure by Letters Patent, is:

1. A propeller blade, provided in its shank with a cylindrical bore which is concentric with the axis of the shank, comprising a plurality of elements, each provided with a mass of fixed weight having its center of gravity radially displaced from the elements having means for confining them for rotative positioning around the axis in the bore and relatively to each other, with the radii and the weight of the masses remaining constant and whereby such positioning will compensate for unbalancing loads of different magnitudes located in different portions of the blade, the elements being adapted to be fixedly secured in the bore of the blade, for balancing the blade about its longitudinal axis, each mass extending and projecting at a different radius from the other and from the confining means and into the bore of the blade.

2. A propeller blade, provided in its shank with a cylindrical bore which is concentric with the axis of the shank, comprising: an element provided with an annulus rotatively fitting in and adapted to be permanently secured in the bore and with a mass of fixed weight having its center of gravity on a fixed radius from the axis; and a second element rotatably fitting and adapted to be permanently secured in said ring and provided with a mass of fixed weight having its center of gravity on a fixed radius from the axis said elements being adapted to be rotatively positioned in the bore, for compensating for unbalanced loads of different magnitudes located in different positions of the blade to balance the blade around its longitudinal axis and, when secured in the bore, to balance the blade around its longitudinal axis.

3. A propeller blade, provided in its shank with a cylindrical bore which is concentric with the axis of the shank, comprising: an element provided with an annulus rotatively fitting in and adapted to be permanently secured in the bore and with a mass of fixed weight having its center of gravity on a fixed radius from said axis; and a second element rotatably fitting and adapted to be permanently secured in said ring and provided with a mass of fixed weight having its center of gravity on a fixed radius from said axis, said elements being adapted to be rotatively positioned in the bore, for compensating for unbalanced loads of different magnitudes located in substantially all portions of the blade to bal-

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ance the blade around its longitudinal axis and, when secured in the bore, to balance the blade around its longitudinal axis.

4. A propeller blade, provided in its shank with a cylindrical bore which is concentric with the axis of the shank, comprising: an element provided with a ring confined in the bore and provided with a fixed weight extending longitudinally from the ring and having its center of mass on a fixed radius from the axis; a second element having a part rotatively fitted in the ring and provided with a fixed weight extending longitudinally from said part with its center of mass on a fixed radius; said elements being adapted by rotative positioning in the bore to compensate for unbalancing loads of different magnitude located in different positions of the blade and to be permanently secured in the blade to balance it around its longitudinal axis.

5. A propeller blade, provided in its shank with a cylindrical bore which is concentric with the axis of the shank, comprising: an element provided with a ring confined in the bore and provided with a fixed weight extending longitudinally from the ring and having its center of mass on a fixed radius from the axis, a second element having a part rotatively fitted in the ring and provided with a fixed weight extending longitudinally from said part with its center of mass on a fixed radius, said elements being adapted by rotative positioning to compensate for unbalancing loads of different magnitude located in substantially all portions of the blade and to be permanently secured in the blade to balance it around its longitudinal axis.

6. A propeller blade, provided in its shank with a cylindrical bore which is concentric with the axis of the shank, comprising: an element provided with a ring confined in the bore and provided with a fixed weight extending longitudinally from the ring and having its center of mass on a fixed radius from the axis, a second element having a part rotatively fitted in the ring and provided with a fixed weight extending longitudinally from said part with its center of mass on a fixed radius shorter than the radius of the weight on the ring, said elements being adapted by rotative positioning to compensate for unbalancing loads of different magnitude located in different positions of the blade and adapted to be permanently secured in the blade to balance it around its longitudinal axis.

7. A propeller blade, provided in its shank with a cylindrical bore which is concentric with the axis of the shank, comprising: an element provided with a ring having its periphery fixedly secured in the bore and a fixed weight extending longitudinally outwardly from the ring with its center of mass on a radius from the axis; and a second element having a part fixedly secured in the ring and provided with a fixed weight extending longitudinally outward from said part, with its center of mass on a radius from the axis, the said elements being adapted to be rotatively positioned around the axis to points where

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the weights will compensate for unbalancing loads of different magnitude located in different portions of the blade, before the elements are secured in the blade to balance it around its longitudinal axis.

8. A propeller blade, provided in its shank with a cylindrical bore which is concentric with the axis of the shank, comprising: an element provided with a ring having its periphery fixedly secured in the bore and a fixed weight extending longitudinally outwardly from the ring with its center of mass on a radius from the axis; and a second element having a part fixedly secured in the ring and provided with a fixed weight extending longitudinally outward from said part, with its center of mass on a radius from the axis, the said elements being adapted to be rotatively positioned around the axis to points where the weights will compensate for unbalancing loads of different magnitude located in substantially all portions of the blade, before the elements are secured in the blade to balance it around its longitudinal axis.

9. A propeller blade, provided in its shank with a cylindrical bore which is concentric with the axis of the shank, comprising: an element provided with a ring having its periphery fixedly secured in the bore and a fixed weight extending longitudinally outwardly from the ring with its center of mass on a radius from the axis; and a second element having a part fixedly secured in the ring and provided with a fixed weight extending longitudinally outward from said part, with its center of mass on a shorter radius from the axis, the said elements being adapted to be rotatively positioned around the axis to points where the weights will compensate for unbalancing loads of different magnitude located in different portions of the blade, before the elements are secured in the blade to balance it around its longitudinal axis.

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