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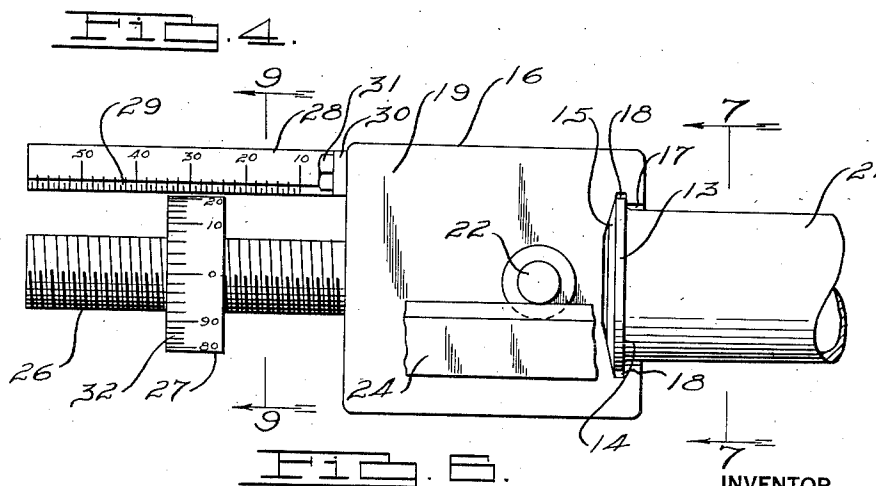
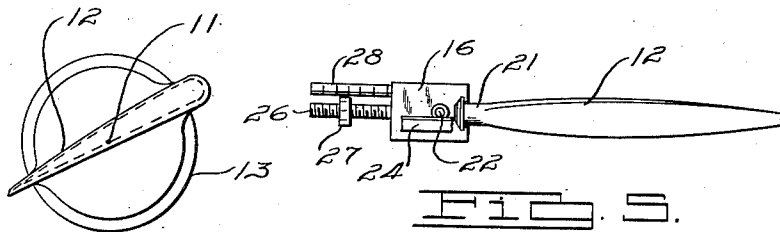
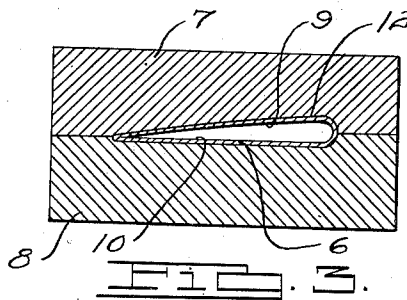
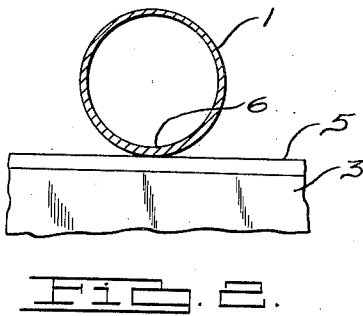
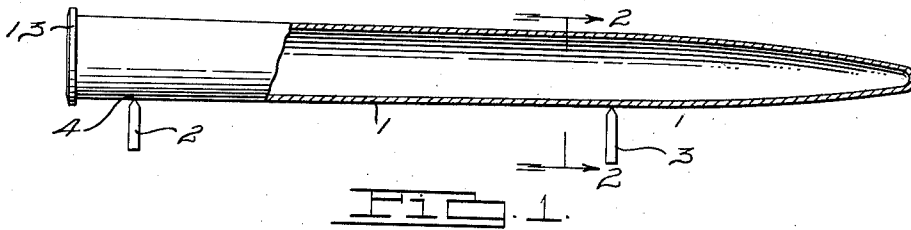
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METHOD OF BALANCING PROPELLER BLADES

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METHOD OF BALANCING PROPELLER
BLADES

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8 Claims. (Cl. 29—156.8)

This invention relates to an improved method and apparatus for balancing propeller blades.

The main objects of the invention are to obviate both statically and dynamically unbalanced conditions in propellers of the type used on airplanes; to provide an improved balancing method for this purpose by which corrections are individually made in each blade of the propeller; and to provide a method of this kind for rendering identical the moment characteristics of propeller blades with respect to a corresponding reference plane of each so that one or both blades of a propeller may be removed and replaced without requiring the assembled propeller to be rebalanced or even necessitating an investigation of its balance.

Further objects of the invention are to provide an improved balance-testing apparatus for propeller blades; to provide apparatus of this character which is adapted to definitely indicate, in selected units, the degree that a propeller blade is unbalanced with respect to a predetermined standard; to provide means in apparatus of this kind for accurately measuring the out-of-balance of a propeller blade in units which can be conveniently converted to linear units that designate the change in the position of the center of mass of the blade required to bring the latter into perfect balance with the standard; and to provide a blade-holding member in balance-testing apparatus of this kind for supporting a propeller in a manner similar to that in which it is normally held by the hub of a propeller.

An illustrative embodiment of the invention is shown in the accompanying drawings, in which:

Fig. 1 is a side elevation of a propeller blade blank, partly in section, illustrating the initial balancing operation thereof.

Fig. 2 is a vertical section taken on line 2—2 of Fig. 1.

Fig. 3 is a transverse section of a propeller blade and forming die showing the relation in which the heaviest side of the stock, as determined by the initial balancing operation, is arranged with respect to the die parts.

Fig. 4 is an outer end elevation of a propeller blade.

Fig. 5 is a reduced side elevation of a propeller blade balancing device illustrating the balancing operation to which the blade is subjected after it is formed in its final shape.

Fig. 6 is a side elevation showing the propeller blade balancing device in detail.

Fig. 7 is a vertical section taken on the line 7—7

of Fig. 6 showing the balancing device in end elevation.

Fig. 8 is a plan view of the balancing apparatus illustrated in Figs. 5 and 6.

Fig. 9 is a vertical section taken on line 9—9 of Fig. 6.

Fig. 10 is a fragmentary sectional view of the inner end portion of a propeller blade illustrating one location on the blade at which corrections for over-balance may be made.

Fig. 11 is a fragmentary sectional view of the inner end portion of a propeller blade illustrating another location on blade at which corrections for over-balance may be made.

Fig. 12 is a fragmentary section similar to Figs. 10 and 11, illustrating the usual locations at which corrections for over-balance are required.

The high speeds at which propellers of the type used on aeroplanes are rotated demand that the blades of the propeller be balanced within close limits. Thus the moments created by the mass of each blade with respect to the axis of rotation of the propeller must be substantially equal, and the mass of each blade must be distributed evenly on the respectively opposite sides of the longitudinal axes of the blades in order to eliminate, as far as possible, an unbalanced condition within each blade itself which, under the centrifugal force to which it is subjected, would otherwise set up undesirable stresses in it.

The latter requirement of propeller blade construction is conveniently complied with in the manner illustrated in Figs. 1 to 4, inclusive, of the drawings in which is illustrated an expedient way of determining the location of an unbalanced mass in a propeller blade blank and positioning it at a location in the blade, during formation thereof, where it is substantially evenly distributed with respect to the longitudinal axis of the blade and ineffective as a factor in the inherent balance of the blade itself.

After the tubular blank 1, shown in Fig. 1, from which a propeller blade is formed, is machined to true outer dimensions, there may still be an uneven distribution of the mass of the material of which the blank consists due to non-uniform thickness of the material at certain locations in the blank. In order to locate the position of the unbalanced mass of the blank 1, it may be placed upon spaced supports 2 and 3 which have knife edges 4 and 5 extending normal to the longitudinal central axis of the blank, and the blank is allowed to roll with unobstructed freedom until it comes to rest. When the blank ceases to roll upon the knife edges 4 and 5 the thickened portion 6 of its material which

assumes the lowest elevation is marked in any suitable manner.

The intermediate and outer end portions of the blank are then flattened by compression between a pair of complementary die parts 7 and 8 having opposed faces 9 and 10. The blank 1 is placed between the die parts 7 and 8 with the marked portion which reclines upon the knife edge after the blank ceases to roll located at the mid-portion of the face 10 of the die part 8. The die part 8 urges this thickened portion of the blank substantially into alignment with the central longitudinal axis 11 of the propeller blade 12 which results from flattening of the blank. The side of the blank 6 is thus located where its non-uniform thickness is ineffective as an inherent unbalancing factor in the blade itself, and this weight is somewhat evenly distributed on the respectively opposite sides of the longitudinal axis 11 of the blade.

Formed on the hub end of the blank 1 is a peripheral flange 13 which is shown in detail in Fig. 6. This flange has a radial inner side 14 and an inclined outer side 15, and provides a means of securing the blade to a hub member, not shown.

In order to maintain a propeller which is made up of interchangeable blades in dynamic balance, it is essential that the moment which the mass of each blade creates with respect to the axis of rotation of the propeller be equal. The moment created by a blade is a function of its mass and the distance of its center of mass from the axis of rotation of the propeller and therefore changes in the moment of a blade may be produced by shifting it outwardly with respect to the axis of rotation of the propeller. In the present instance the moment arm, or distance between the axis of rotation of the propeller and the center of mass of the blade is increased by trimming off the outer face 14 of the flange 13 which is received in a groove of a propeller hub an amount necessary to bring it to accordance with a fixed standard.

The grooves of the propeller hub in which the flanges 13 of the blades are received, are accurately machined and they are accurately located at equal distances from the axis of rotation of the propeller hub. Only the side faces 14 and 15 of the flanges of the blades are engaged by the walls of the groove and thus either the outer or inner side faces of the flanges may be relied upon to determine the locations of the centers of mass of the blades from the axis of location of the propellers. In practice, the flanges 13 are intentionally made thicker than the grooves of the hub so as to permit corrections to be made in the locations of the centers of mass of the blades, and the outer side faces of the flanges 13 initially occur in too close proximity to the centers of mass to allow the blades, as originally formed, to balance the standard moment differential of the testing apparatus. As the blanks from which the blades are formed are machined accurately both internally and externally the distribution of weight in all blades is substantially alike and therefore only slight corrections in the locations of their centers of mass are required.

In Figs. 5 to 12, inclusive, is illustrated a method and apparatus for equalizing the moments of the blades of a propeller with respect to the axis of rotation thereof. This apparatus includes a block 16 of substantial weight having a tapering dovetailed groove 17 at one end which extends between and is open at the respectively opposite sides 19 and 20 of the block 16 for receiving the flange 13 of the propeller blade 12. The groove 17 is under-

cut in parallelism with the side edges thereof, as best shown at 18 in Fig. 6, the undercut portion being shaped in section complementary to the section of the flange 13 so as to removably receive the flange therein and thereby enable the blade to be secured relative to the block without contact of the block with the shank of the blade.

Formed on the respectively opposite sides 19 and 20 of the block 16 are trunnions 22 and 23 which rest upon the knife edge supports 24 and 25 respectively and pivotally support the block. The trunnions 22 and 23 are in alignment with each other but they are in misalignment with the center of mass of the block 16. They are located in closer proximity to the end of the block in which the flange receiving groove 17 is formed than to the opposite end of the block. This arrangement sets up a moment differential between the portions of the block on respectively opposite sides of the trunnions 22 and 23 which is of a predetermined amplitude.

A threaded stem 26 is provided on the left end of the block 16, as viewed in Fig. 6. Threaded on the stem 26 is a variable weight 27 of cylindrical shape which, when in its extreme left hand position in Fig. 6, augments the moment differential of the block 16, producing a standard moment differential equal to the moment desired to be created by the blade 12 with respect to the axis of the block 16. The weight 27 may be placed closer to the block so as to balance a propeller blade. A scale 28 having linear graduations 29 is provided with flanges 30 by which it is clamped by bolts 31 to the left end of the block 16. This scale is parallel to the axis of and lies in close relation to the periphery of the weight 27 which is provided with cooperating micrometer graduations 32.

One revolution of the weight 27 corresponds to one unit of the linear scale 28. Thus the number of whole units is indicated on the scale 28 at the left edge of the weight 30 and the micrometer scale indicates in hundredths of a unit, the position of the weight between successive whole units of the linear scale.

These scales may be calibrated in units of moment if desired and in this case a graph, (not shown) is used in connection with the apparatus to convert the units of moment to linear units indicating the amount of metal to be removed from one of the side faces of the flange 13 to bring the center of mass of the blade at a predetermined distance therefrom. Such a graph may include a curve which shows the reduction in the thickness of the flange 13 required to shift the center of mass of the blade outwardly so as to compensate for each unit the propeller blade is out of balance with respect to the standard moment differential.

The linear and micrometer scales 28 and 32 respectively may, however, be calibrated so as to read directly in terms of the amount of metal required to be removed from a face of the flange 13 to overcome the deficiency in the moment of the propeller blade. This calibration of the scales may be conveniently accomplished by attaching a blade to the apparatus which has a substantial deficiency in moment and then trimming down the thickness of the flange a known amount in successive steps so as to move the center of mass of the blade outwardly and noting the position of the weight 27 which balances the propeller blade after each reduction in thickness of the flange.

By testing each blade in the above described

apparatus the distance which it is necessary to trim back the outer side face of the end flange 13 is accurately determined either directly in linear units or in units which can be conveniently converted to linear units with the aid of a suitable graph. If the blade upon testing exactly balances the standard moment differential of the apparatus then the inner side face of the flange 13 and the inner extremity of the blade is trimmed, as illustrated in Fig. 10, so as to produce a flange of predetermined thickness shown at 33 without changing the location of the outer side 14 of the flange. If the cut required at the outer side face 14 of the flange is sufficient to reduce the thickness thereof to its predetermined thickness then the inner side face 15 of the flange is left unaltered. These two cases are not usual ones. Generally the outer side face 14 is trimmed off sufficiently to bring the blade into exact balance with the moment differential of the apparatus and then the inner side face 15 and inner extremity of the blade is machined slightly, as indicated in Fig. 12, to produce a flange of predetermined thickness.

In some cases the inner side face 15 of the flange is used as the reference plane for determining the location of the center of mass of a blade from the axis of rotation of a propeller hub during the mounting of a blade upon a hub. Under these circumstances the inner side face 15 is machined first during modification of the flange to bring the blade into balanced relationship with a standard moment differential and then sufficient metal is removed from the outer side face 14 to bring the flange to a predetermined thickness.

It will be apparent from the above that by the method disclosed herein it is possible to form any number of propeller blades so that their center of mass will be located at a fixed distance from the center of rotation of the propeller of which they are to form a part. It is to be particularly noted that this feature is, as far as I am aware, entirely new in the art. Furthermore, in view of the fact that, at least in its more specific forms, the propeller employed is of a thin walled hollow construction, formed of steel or other ferrous alloy wherein the density of the metal is substantially uniform throughout, the center of mass of the blade will always be exceedingly close to a predetermined distance from the axial line of the blade in a direction normal thereto, and will always lie in the same direction therefrom relative to the face of the blade.

Heretofore in order to obtain a propeller which is dynamically in balance, it has been the practice to either mount blades in a hub member, or the equivalent, when the blades are of the removable type, and then spin the propeller, or when the blades are not of the removable type, to spin the propeller as is, in suitable apparatus designed to indicate the location and amount of the unbalanced force therein, and which apparatus is well known in the art, and then by either removing metal from a thus located position, or adding weight to the propeller in a thus located position, as for instance, by drilling a hole therein and plugging it with a heavier metal, to so vary the original characteristics of the propeller as to place it in dynamic balance. It will be readily understood that in following such conventional methods the distance of the center of mass of one blade of the propeller may be substantially different than the distance of the center of mass of the other blade or propeller from the center of

rotation, and although the ultimate results obtained, that is a propeller in substantially perfect dynamic balance, may be the same as that obtained in the method covering the present application, the method of obtaining it involves a more lengthy and costly process than by the process disclosed herein. Furthermore it is relatively unimportant in employing such conventional methods of balancing that the distance of center of mass of each and every blade from the center of rotation of the propeller of which it forms a part accurately conforms with a predetermined standard distance. Consequently, it will be apparent that in providing a propeller blade having its center of mass at a predetermined distance from its center of rotation, or as it is herein apparent, from its point of attachment with a hub member, that a new article is accordingly provided herein. The result is that propeller blades of the same size manufactured in accordance with the present invention may be assembled to a suitable hub structure with the assurance that the resulting propeller assembly will be in substantially perfect static and dynamic balance.

Although but one specific embodiment of this invention has been herein shown and described, it will be understood that numerous details of the construction shown may be altered or omitted without departing from the spirit of this invention as defined by the following claims.

I claim:

1. In manufacturing a propeller having a hub and having blades provided at their inner ends with attaching members for securement thereto, the method of bringing the moment of each blade to a predetermined value which consists in determining the correction in the distance between an attaching member of each blade and the center of mass thereof required to secure said predetermined moment, and altering the attaching member so as to change the distance between the same and the center of mass of the blade the determined required amount.

2. In manufacturing a propeller having a hub and having blades provided at their inner ends with attaching members for securement to said hub, the method of bringing the moment of each blade to a predetermined value which consists in determining the correction in the distance between the center of mass of each blade and the axis of rotation of the propeller required to secure said predetermined moment, and altering the distance between said attaching members and the center of mass of each blade by a machining operation on said members so as to effect the required change in the distance between said center of mass and said axis of rotation.

3. In manufacturing a propeller having a hub and having blades each provided at its inner end with a radial flange for securement to said hub, the method of bringing the moment of each blade to a predetermined value which consists in determining the correction in the distance between the center of mass of each blade and the axis of rotation of the propeller required to secure said predetermined moment, and reducing the thickness of the flange of each blade so as to effect said correction.

4. In manufacturing a propeller including a hub and having propeller blades each having an element securable to said hub and provided with a reference face for predetermining the location of the center of mass of each blade with respect to the axis of rotation of said pro-

45 peller, the method of bringing the moment of each blade with respect to said axis to a predetermined value which consists in determining the correction in the distance between the reference faces and the center of mass of each blade required to secure said predetermined moment, and machining back the reference faces of said blades to effect the determined correction.

50 5. In manufacturing a propeller including a hub and including detachable blades each provided with a flange securable to said hub and having a reference face adapted to predetermine the location of the center of mass of the blade with respect to the axis of rotation of said propeller, the method of bringing the moment of each blade to a predetermined value which consists in individually supporting each blade from the flange thereof, determining the correction in the distance between the flange and center of mass of each blade required to secure said predetermined moment by balancing each blade individually while supported in such manner against a standard moment of said predetermined value, and altering the position of the reference face of each flange during modification of the latter to a predetermined thickness so as to effect the determined correction required in the distance between the reference face and the center of mass of each blade.

55 6. In manufacturing a propeller having a hub and interchangeable blades, the method of bringing the moment of each blade with respect to the axis of rotation of said propeller to a predetermined value which consists in initially providing each blade with an excessively thick flange for securement to said hub, determining the correction in the distance between the outer side face of the flange and center of mass of each blade respectively required to bring the moment of each blade to a predetermined value, machining off the outer side face of the flange of each blade a layer of material equal in thickness to the correction determined for each blade respectively, and trimming the flanges to a predetermined

mined thickness by machining their inner side faces.

80 7. In manufacturing a propeller including a hub and including propeller blades each provided with a flange for securement to said hub having a reference face on one side for predetermining the location of the center of mass of each blade with respect to the axis of rotation of said propeller, the method of bringing the moment of said blade with respect to said axis to a predetermined value which consists in initially providing the flange of each blade with an excessive thickness, determining the correction in the distance between the center of mass of each blade and the reference face of the flange thereof required to secure said predetermined moment, and altering the position of the reference face of each flange during modification of the latter to a predetermined thickness so as to effect the determined correction required in the distance between the reference face and the center of mass of each blade.

85 8. In manufacturing a propeller having a hub and having blades formed from tubular blanks provided at their inner ends with flanges for attachment to said hub, the method of bringing the moment of each blade to a predetermined value whereby to render such blades interchangeable with respect to each other and to diverse propellers which consists in locating the heaviest side of each tubular blank, compressing each blank to blade shape between complementary dies with the heaviest side of the blank located substantially at the mid-point of the die parts which form that plane of each blade which is closest to its central longitudinal axis, determining the correction in the distance between the flange of each blade and the center of mass thereof required to secure said predetermined moment, and altering the flange of each blade so as to change the distance between such flange and the center of mass of the blade the determined required amount.

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