May 26, 1936. E. G. McCAULEY 2,041,849

PROPELLER

Filed July 1, 1932

FIG. 2.

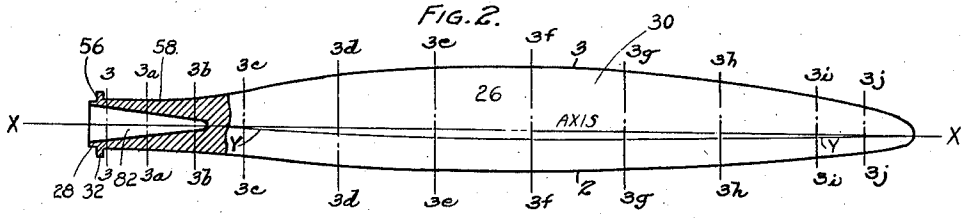


FIG. 3.

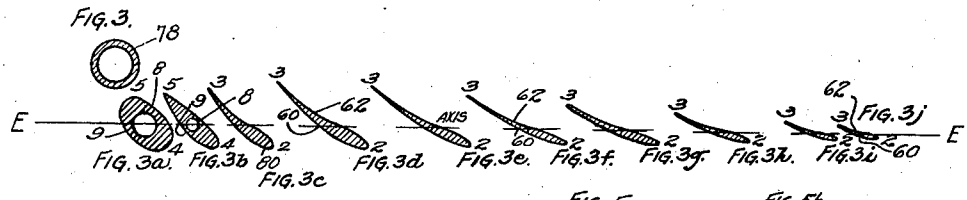


FIG. 3a. FIG. 3b FIG. 3c FIG. 3d FIG. 3e. FIG. 3f. FIG. 3g. FIG. 3h. FIG. 3i. FIG. 3j

FIG. 5. FIG. 5a FIG. 5b. FIG. 5c.

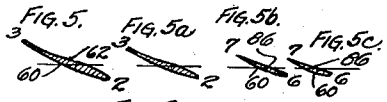


FIG. 6.

FIG. 6a. FIG. 6b. FIG. 6c. AXIS

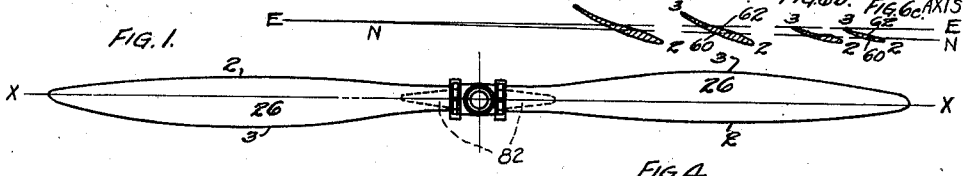


FIG. 1.

FIG. 4

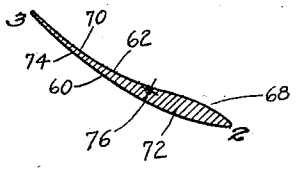


FIG. 9.

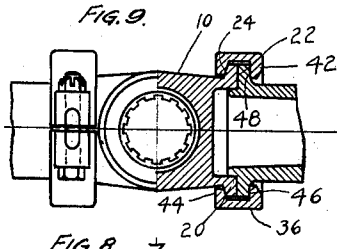


FIG. 8.

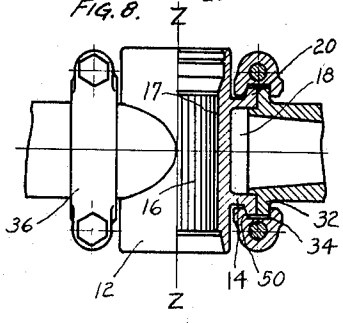


FIG. 10.

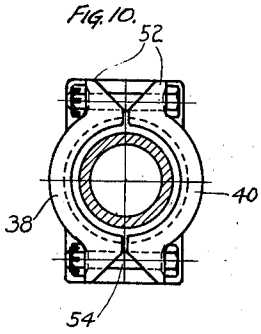
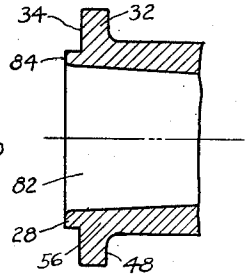


FIG. 7.



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PROPELLER

Ernest G. McCauley, Dayton, Ohio

Application July 1, 1932, Serial No. 620,462

48 Claims. (Cl. 170—159)

This invention relates to propellers, and more particularly to aeronautical propellers of the type in which a plurality of blades are connected to a hub portion.

It is well known that propellers have been previously constructed of conventional airfoil sections and of solid metal construction; likewise attempts have been made to build propellers of stampings of thin sheet metal.

Heretofore in the construction of propellers of this character the blade sections were of such thickness that they did not have a very high efficiency above a tip velocity of approximately 950 feet per second and at speeds beyond this range their efficiency fell off considerably due to the lack of sufficient rigidity in the cross-sectional area of the blade sections, which permitted the outer end or tip portion of the blade to violently flutter and eventually crystallize and break off, due to fatigue of the thin material.

Furthermore, previous attempts to provide a metal propeller with substantially solid blades have in general resulted in merely decreasing the cross-sectional area of the blade section a small proportion below those used on the conventional wood propellers, and propellers constructed thusly, while they have shown advantages of from two to five percent in efficiency over the wood propellers, have nevertheless had their limitations in that they were not highly efficient at the prevailing aeronautical tip speeds and were extremely inefficient in the ranges of tip velocities, at and beyond the speed of sound which is approximately 1186 feet per second.

Further disadvantages have been the limitations on the engine speeds, the increasing of the engine speeds would cause the tip velocities of the propellers to be increased beyond their best efficient operating range, and flutter violently, thereby producing objectionable noises.

It is therefore a primary object of this invention to provide a propeller of such construction that will permit an increase in the present engine speeds with a consequent increase in the efficiency and horsepower of the engines, and that will operate efficiently at speeds in the range at and beyond the speed of sound. Accordingly, I provide a propeller of metal so constructed and arranged as to afford very thin aerodynamically efficient blade sections of relatively small cross-sectional area in similar proportion to the width and thickness thereof, which sections vary in width and thickness thruout the length of the blade and are so designed as to prevent a fluttering of the blade, and especially at the outer end or tip portion thereof when the same is rotating at high velocity and to possess an extremely high rigidity to withstand torsional and thrust stresses that are applied to said sections.

Furthermore, I provide a propeller of this character with an airfoil of such shape or contour that will improve the aerodynamic properties of the propeller by diminishing the prejudicial deformation due to thrust and torque at high tip velocities that will approach or exceed 950 feet per second, which would be substantially equivalent in a small propeller, to approximately 5 feet diameter running at 3600 R. P. M., and in a large propeller approximately 15 feet diameter running at 1250 R. P. M., and that will resist during such velocities bending or flexion sufficiently to prevent failure of the section against the ensuing thrust and torque loadings and avoid excessive noises.

A still further object of this invention is to provide in a blade of this character a distribution of the material in such manner as to provide a propeller of utmost strength and rigidity to withstand the high loadings due to centrifugal force, and the combined bending stresses of thrust and torque.

Another object of my invention is the provision of a propeller of this character having a hub portion in abutting engagement with the blades to provide a solid base on the hub for clamping the blades, and means detachably connected to said blades and hub for retaining the blades against the entire action of the centrifugal force and a major portion of the rotational torque loads, said means permitting of an angular setting of the blades.

A still further object of my invention is to provide a very accurate and simple means of balancing the blades.

Various other objects and advantages will appear from an inspection of the following specification in connection with the drawing which is hereto annexed and forms a part thereof and in which

Fig. 1 is a plan view of a propeller constructed in accordance with my invention;

Fig. 2 is a view similar to Fig. 1 showing an enlarged view of the propeller blade;

Fig. 3, Fig. 3*a*, Fig. 3*b*, Fig. 3*c*, Fig. 3*d*, Fig. 3*e*, Fig. 3*f*, Fig. 3*g*, Fig. 3*h*, Fig. 3*i*, Fig. 3*j*, are transverse cross sections of views taken on the corresponding lines 3—3, 3*a*—3*a*, 3*b*—3*b*, 3*c*—3*c*, 3*d*—3*d*, 3*e*—3*e*, 3*f*—3*f*, 3*g*—3*g*, 3*h*—3*h*, 3*i*—3*i*, to 3*j*—3*j* on Fig. 2.

Fig. 4 is an enlarged view of a cross section of

the blade showing the general contour or profile of the blade airfoil sections;

Fig. 5, Fig. 5*a*, Fig. 5*b*, and Fig. 5*c*, are a fractional outline of a blade tip portion together with corresponding various cross section showing a variation having the various cross sections with the median line located on line N—N;

Fig. 6, Fig. 6*a*, Fig. 6*b*, and Fig. 6*c* are a view similar to Fig. 5, Fig. 5*a*, Fig. 5*b*, and Fig. 5*c* showing a further variation;

Fig. 7 is an enlarged fractional view in longitudinal cross-section of the blade showing the root end and a portion of the shank;

Fig. 8 is a front elevational view showing the hub in quarter section and fragmentary portions of the blades;

Fig. 9 is a plan view corresponding to Fig. 5 in the 90° position, and

Fig. 10 is an enlarged view of the right of Fig. 8.

Referring to the drawing and with particular reference to Figs. 8 and 9 the hub portion **10** of the propeller comprises the axle portion **12** and the integral radially extending socket portions **14** which extend a relatively short distance laterally away from the axle portion.

The hub portion is preferably in the form of a steel drop-forging, the axle portion having an internal cylindrical spline bore **16** provided with splines **17** by means of which the hub is securely mounted on a propeller shaft (not shown). The socket portions **14** are preferably formed with shallow cylindrical bores **18** that extend inwardly to a surface corresponding to the outer wall surface of the axle portion. The ends of the socket portions **14** are each formed with outwardly turned flange **20**, the outwardly presenting faces **22** of which are disposed in planes at right angles to the longitudinal axis *x—x* of the hub or propeller and the inwardly presenting faces **24** of which are made frustro-conical for a purpose hereinafter described.

As herein disclosed a novel propeller blade **26** preferably made of metal in the form of a steel forging and in a manner hereinafter described is attached to each of the hub socket portions by providing the root of the blade with a projection **28** that is received within the bore **18** of the socket portion and with an outwardly turned annular flange **32** positioned at a relatively short distance from the outer end of the projection **28** so as to be capable of having its face **34** about the face **22** of flange **20** of the hub, this projection serving, when the blade is connected to the hub, for a purpose hereinafter described.

Each blade is attached as shown in Figs. 8 and 9, to the hub and held against centrifugal forces by means of a split clamp **36** having split-clamp parts **38** and **40**, each of which is of substantially semi-cylindrical construction having inturned flanges **42** and **44**, the former flange being formed with a straight inner face **46** contacting with the face **48** on the propeller blade and the latter flange having a frustro-conical face **50** contacting with the face **24** on the hub flange.

The clamp parts **38** and **40** of each pair of clamps **36**, that are disposed on opposite sides of the axle portion of the hub are provided with lugs **52** so that the clamp parts may be secured together by means of bolts **54** which, when tightened, cause the clamp parts to move closer together in the direction of the longitudinal axis of the propeller and due to the tapered faces or surfaces **24** and **50** the blades are caused to move slightly inwardly towards the propeller axis of rotation *z—z* with the flanges of the blade held in tight abutting engagement with the flanges of the hub so that the blades are held rigidly against a solid base on the hub. The clamp parts **38** and **40** of each clamp form practically the sole restraining means for holding the blades against centrifugal force and serve to take substantially the entire load in the transmission of rotational torque force to the blades.

Each of the blades, as shown consists of a cylindrical root portion **56**, as shown in Fig. 2 and Fig. 3, a shank portion **58**, comprising Fig. 3*a* and Fig. 3*b* having the leading and trailing edges **4** and **5** respectively, and an upper surface **9** and a lower surface **8** as illustrated, and an airfoil portion **30**, with cross sections as shown in Fig. 3*c*, Fig. 3*d*, Fig. 3*e*, Fig. 3*f*, Fig. 3*g*, Fig. 3*h*, Fig. 3*i*, Fig. 3*j*, having the leading and trailing edges **2** and **3** respectively, and upper surface **60** and lower surface **62**, as also shown in Fig. 4, which planform profile in Fig. 2 between the sections of Fig. 3*c* to Fig. 3*j* provide a contour of the leading and trailing edges of opposite convex curved profiles, that has the maximum width at a point substantially midway of the blade length, from the axis of rotation, and is preferably in the form of a steel forging which may be heat-treated to a high tensile strength, and is formed with relatively thin sections in which the material is so distributed as to present the utmost strength and rigidity to the forces of centrifugal, thrust and torque. With the use of special alloy steel, such as nickel-chrome molybdenum or its equivalent, heat treated to a tensile strength of approximately from 150,000 to 175,000 lbs. per square inch, it will be apparent that thinner blade sections may be employed than is possible to obtain with other materials of less tensile strength provided, however, a proper distribution of the material is made without sacrifice in the efficiency of the blade section ranging substantially in diameters from 5 feet to 15 feet or greater.

In accordance with my invention, therefore, in order to provide an airfoil section of such contour and thinness that greater efficiency may be obtained without substantially increasing the weight of the blade, as a whole, when compared with other blades of the same diameter now generally in use and made in the form of solid aluminum alloy or steel forgings, I have designed an airfoil section, as shown in Fig. 4, having a profile such that the upper surface **60** thereof is convexly arcuate and the lower surface **62** is in the form of an ogee or reverse curve, both surfaces merging into somewhat sharply rounded edges **2** and **3** and so arranged that the swelling or thicker portion is disposed adjacent the leading edge **2** and the arched or thin portion adjacent the trailing edge **3**. There is thus provided a blade in which the leading edge portion is formed with a double-convex surface and the trailing edge portion with a concavo-convex surface, the point of tangency or merging of the convex and concave portions **68** and **70** of the lower surface **62** occurring approximately one third the chord length of the airfoil section from its leading edge **2** as represented by the line Y—Y on Fig. 2.

The double convex or leading edge portion **72** has each cross section relatively gradually increasing in thickness from the tip end of the blade to the inner end of the shank portion to virtually provide a tapering beam of such strength as to sustain a major portion of the stress in service operations of the blade.

The concavo-convex or trailing edge portion 74 of the blade likewise has each cross section relatively gradually increasing in thickness throughout the length of the airfoil portion 30 of the blade, and in a corresponding manner, so that the trailing edge portion because of its peculiar arched construction which may be formed by forging in suitable dies, that will not only have a high strength weight ratio but will also possess sufficient rigidity and stiffness to withstand bending and deflection from the thrust loadings and will furthermore supplement the leading edge portion 72 to provide sufficient strength to withstand the forces of torque loadings.

According to these improvements the greater mass of the material will be located near the leading edge and the center of gravities 76 both in plan and elevation of the blade sections from tip to root are disposed in a straight line that is coincident with the longitudinal axes X—X and E—E respectively, of the blade or propeller. This may be changed so that the median line of gravity will follow closely along the path of the line Y—Y on the leading edge portion 72, and may even cross over the axis X—X near the outer extremity of the blade to the trailing edge portion 74. The centrifugal force will thus assist in keeping the blade as a whole from deflecting rearward in the path of rotation and add further strength to the blade in this direction.

The shank portion 58 of the blade has its cross sections gradually varying from a circular section 78 at its inner end to an airfoil section 80 at its inner end that consists of Fig. 3, Fig. 3*a*, and Fig. 3*b*, which planform in Fig. 2 provides a contour of the leading edge 4 and trailing edge 5 of opposite concave curved profiles that merge into the cylindrical section 78 at the root end portion of the blade, and is formed with a longitudinally disposed conical bore 82, the base of which is disposed at the root end of the blade. The dimensions of this cone are such that the walls of the shank portion are of sufficient thickness as to provide the required strength to sustain the operative stresses of the propeller and each cross section thereof has its material increasing in area in continuation of the gradual increase in the cross sections of the airfoil portion 30 to provide a blade whose cross-sectional areas gradually increase from tip to root. With this gradual increase of areas, the character of the blade cross-section, or section profile has similar proportions, and the relative thickness thereof i. e. the ratio of maximum thickness to the chord of the cross-section, which is selected for each section to give the highest possible aerodynamic efficiency there is afforded a blade of maximum strength weight ratio, which will withstand deformations, due to torsion, and distorsion due to flexion or bending with the result that a highly rigid and efficient blade is obtained.

The cylindrical projection or extention 84 of the blade root is made to have a close turning fit with its complementary socket or bore 18 so as to center the blade and readily permit an adjustment thereof to vary the pitch angle and, also, provides a bearing area which together with the bearing area afforded by the abutting faces 22 and 34 of the flanges 20 and 32 respectively resists deflection in any direction of the blade at the point of engagement with the hub.

By reason of its construction my propeller is capable of being horizontally balanced without adding weight as has been the practice heretofore. It is, of course, well known that after assembling the blades complete with the hub a balance must be obtained and in accordance with my invention this may be obtained by facing off the necessary amount of material of the abutting face 34 of the flange 32 of that blade which is heavy in balance thus allowing the weight of the entire blade to be moved inwardly towards the axis Z—Z of rotation of the hub when assembly is again made to thereby obtain the proper balance.

In Fig. 5, Fig. 5*a*, Fig. 5*b*, and Fig. 5*c*, I have shown a propeller blade constructed in a manner as hereinabove described except that the tip end portion is provided with a substantially flat bottom face or under surface 86 which gradually merges longitudinally into the ogee or reverse curve of the lower surface 62 of the adjoining airfoil portion, and having the leading and trailing edges 6 and 7 respectively, merging with 2 and 3 at a point substantially as shown in Fig. 5*a* the equivalent to Fig. 3*h*.

A further variation of propeller construction embraced in my invention is shown in Fig. 6, Fig. 6*a*, Fig. 6*b*, and Fig. 6*c*. The propeller blade of this propeller is similar to that described in connection with Fig. 3 to Fig. 3*j*, except that the center of gravities of the blade sections which lie on the neutral line N—N, are inclined downwardly and outwardly with respect to the longitudinal axis E—E as viewed in Fig. 6 or in the direction of thrust or forward movement of the propeller, starting from a point about one fourth the length of the blade measured from the root end and terminating at the tip end thereof.

It will thus be seen that with this construction the centrifugal force will provide a restoring force tending to position the center of gravity line N—N in coincidence with the longitudinal axis E—E of the propeller and will thereby prevent the bending of the blade, especially at the tip end, by the thrust loads exerted thereon.

While the foregoing description defines a blade made of solid steel construction, it is intended that the scope of this invention pertaining to the characteristics of the airfoil section may be applied to blades of other suitable materials, and other variations from the airfoil described and the method to provide rigidity in a thin section may be made by those skilled in the art, without departing from the spirit of the invention. Reference will therefore be had to the appended claims for a definition of the limits of the invention.

What I claim and desire to secure by Letters Patent is:

1. A propeller blade having an outer portion of airfoil cross-section of the character described, said outer portion gradually increasing in cross-sectional area from the tip inward, a cylindrical root portion adapted for anchorage to a propeller hub and a shank portion exterior of said hub connection of cross-section gradually varying from a cylindrical to the outer portion airfoil section, said blade having a longitudinally disposed conical bore extending thruout the length of the root portion and into the shank portion, said conical bore being of such diameter and depth as to provide a gradually increasing cross-sectional area of the blade from the tip towards the root and substantially thruout the entire length of the blade.

2. A propeller blade having an outer portion of airfoil cross-section of the character described, a cylindrical root portion adapted for anchorage to a propeller hub and a shank portion exterior of said hub connection of cross-section gradually varying from a cylindrical to the outer portion airfoil section, said blade having a longitudinally disposed conical bore extending thruout the length of the root portion and into the shank portion, said conical bore being of such diameter and depth as to provide a gradually increasing cross-sectional area thruout substantially the entire length of the root and shank portions.

3. A propeller blade having an outer portion of solid airfoil cross-section of the character described, said outer portion gradually increasing in cross-sectional area from the tip inward, a cylindrical root portion adapted for anchorage to a propeller hub and a shank portion exterior of said hub connection of cross-section gradually varying from a cylindrical to the outer portion airfoil section, said blade having a central longitudinal tapering bore of circular cross-section formed within the root and shank portions, said bore tapering inwardly from the root of the blade and in such manner as to provide a gradually increasing cross-sectional area from the tip towards the root and substantially thruout the entire length of the blade.

4. A propeller blade having an outer portion of airfoil cross-section of the character described, said outer portion gradually varying in cross-sectional area, a cylindrical root portion adapted for anchorage to a propeller hub and a shank portion exterior of said hub connection of cross-section gradually varying from a cylindrical to said airfoil section and said blade having the leading edge portion that extends forward approximately from the longitudinal axis of the blade of such varying cross-sectional area throughout the length as to provide a tapering beam portion along the leading edge of sufficient strength to sustain a major portion of the torque stress in service operation of the blade.

5. A propeller blade in which the airfoil cross-sections are formed with concavo-convex lower surfaces and convex upper surfaces having similar proportions in width and thickness and in which the material is so distributed as to locate the median line of gravity in substantial coincidence with the blade axes in both longitudinal planes thereof.

6. A propeller blade in which the airfoil cross-sections are formed with concavo-convex trailing edge portions disposed rearward of the longitudinal axis of the blade and reduced in mass sufficiently to locate the median line of gravity in substantial coincidence with the blade axes in both longitudinal planes thereof, so that the trailing edge portion of arched construction forms a high strength weight ratio to provide sufficient strength to withstand deflection from thrust loadings.

7. A propeller blade in which the airfoil cross-sections are formed with concavo-convex trailing edge portions disposed rearward of the longitudinal axis of the blade and reduced in mass sufficiently to locate the median line of gravity in substantial coincidence with the blade axis in the planform plane, and forward with respect to the thrust side of the blade, in the plane of rotation, said trailing edge portion of arched construction in connection with the restoring action of centrifugal force will provide utmost rigidity to withstand deflection from thrust loadings.

8. A propeller blade having its median line of gravity for substantially the blade length disposed at substantially one-third the length of the blade sections measured from the leading edge and having that portion between the median line and leading edge confined within convexly curved upper and lower surfaces and constituting a tapering beam, extending along the leading edge throughout the length of the blade from root to tip, to sustain a major portion of the torque stress in the blade.

9. A propeller blade having the median line of gravity for substantially the blade length disposed at substantially one-third the length of the blade sections measured from the leading edge and having that portion between the median line and leading edge confined within convexly curved upper and lower surfaces throughout the length of the blade, and constituting a virtual tapering beam, the relative thickness of the cross-sections of said beam increasing gradually from the tip to the root end of the blade.

10. A propeller blade having a hollow shank inner portion and an outer portion having the leading edge portion confined within converging convexly curved upper and lower surfaces and the trailing portion confined within upper convex and lower concave surfaces, said upper and lower surfaces of the leading edge portion merging respectively with the surfaces of said trailing edge portion.

11. A propeller blade having a cylindrical root portion, a shank portion, and an outer portion of aerofoil cross section having the forward portion of said section extending from the leading edge for approximately one-third the chord length formed with oppositely curved convexed upper and lower surfaces and the trailing portion formed with concavo convex surfaces that merge respectively with said upper and lower leading edge surfaces, the sections of said blade diminishing in area from the root to the tip at a progressively decreasing rate, whereby the ratio of thickness to the chord of the cross-sections will provide utmost rigidity and strength to the blade.

12. A propeller comprising a hub having blade mounting members, blades having their inner ends mounted against and within said members and means for clamping the inner ends of said blades to the members of said hub in such a manner that the driving force of said hub is transmitted thru said means to said blades.

13. A propeller comprising a hub having blade mounting members, blades having their inner ends mounted against and within said members and means for clamping the inner ends of said blades to the members of said hub in such a manner that the driving force of said hub is transmitted thru said means to said blades, said blades and members having telescoping parts for locating said blades within said hub, said means for clamping the ends of said blades with the hub members for attaching the blades to the hubs in such manner that the driving force of said hub is transmitted thru said means to said blades.

14. A propeller comprising a hub having sockets provided with flanges, blades having their inner ends formed with flanges and projections for abutting with the flanges of said hub and said projections are received within said sockets for centralizing said blades, and means for attaching the blades to the hub in such manner that substantially all the driving stresses of hub operation

are transmitted thru said flanges to the blades.

15. A propeller comprising a hub having a plurality of flanges and sockets to abut against similar flanges on the root end of the blades provided with projections to be mounted in said sockets, said sockets to provide a driving means from said hub to said blades and means for retaining said blades with said hub.

16. An airplane propeller comprising a plurality of blades having cylindrical flanges and projections at their inner ends, a hub having sockets and cylindrical base flanges interfitting and in abutting engagement with said projections and flanges of said blades, and means for attaching said blades to said hub for rigidly securing the blades to the hub in such manner that the centrifugal force of said blades is transmitted through said means to said hub, and the rotational torque force is transmitted through the abutting of said flanges on the hub and blades.

17. A propeller blade of solid steel having an airfoil section of the character described, with the leading edge portion having sufficient mass to improve the aerodynamic properties of the propeller by diminishing the prejudicial deformation due to thrust and torque stresses exerted on the blade, said airfoil so constructed and arranged to resist bending or flexion of the blade from the ensuing thrust and torque loadings.

18. A propeller blade of solid steel having an airfoil section of the character described with the leading edge portion having sufficient mass to provide rigidity from the root portion of the blade to the tip portion to improve the aerodynamic properties of the propeller by diminishing the prejudicial deformation due to thrust and torque stresses exerted on the blade, said airfoil so constructed and arranged to resist bending or flexion of the blade from the ensuing thrust and torque loadings.

19. A propeller blade of solid steel having an airfoil section of the character described, so constructed and arranged that a distribution of the material throughout the blade length along the leading edge portion, and by arching the trailing edge portion is of such proportion for utmost strength and rigidity to withstand the combined loading of centrifugal force and thrust force to prevent excessive flutter of the blade and provide a silent propeller.

20. A propeller blade of solid steel having an airfoil section of the character described, so constructed and arranged that a distribution of the material throughout the blade length along the leading edge portion, and by arching the trailing edge portion is of such proportion for utmost strength and rigidity from the root portion of the blade to the tip portion to withstand the combined loading of centrifugal force, thrust and torque forces, to prevent excessive flutter of the blade and provide a silent propeller.

21. A propeller blade having an airfoil section throughout the length of the blade substantially from the root portion to the tip, so constructed and arranged that the leading edge portion is formed with a double convex surfaces, and the trailing edge portion is formed with a concavo-convex surfaces, the point of tangency of the convex and concave portions on the lower surface of the airfoil occuring approximately one-third of the chord length of the airfoil section from the leading edge.

22. A propeller blade having an airfoil section throughout the length of the blade substantially from the root portion to the tip, so constructed and arranged that the leading edge portion is formed with a double convex surfaces, and the trailing edge portion is formed with a concavo-convex surfaces, the point of tangency of the convex and concave portions on the lower surface of the airfoil occurring approximately one-third of the chord length of the airfoil section from the leading edge, said portion of the blade sections confined within the double convex surfaces whose width and thickness gradually decreases from root to tip comprises a tapering beam along the entire leading edge portion of the blade to add rigidity against rearward deflection of the blade in the path of rotation against the forces of torque.

23. A propeller blade having an airfoil section throughout the length of the blade substantially from the root portion to the tip, so constructed and arranged that the leading edge portion is formed with a double convex surface, and the trailing edge portion is formed with a concavo-convex surface, the point of tangency of the convex and concave portions on the lower surfaces of the airfoil occurring approximately one-third of the chord length of the airfoil section from the leading edge, said portion of the blade sections confined within the concavo-convex surfaces and approximately two-thirds of the chord length of the sections comprises an arched construction of varying width and thickness along the trailing edge sections of the blade, to provide rigidity against forward deflection of the blade in the path of rotation against the forces of thrust.

24. A propeller blade having an airfoil section throughout the length of the blade substantially from the root portion to the tip, so constructed and arranged that the leading edge portion is formed with a double convex surface, and the trailing edge portion is formed with a concavo-convex surface, the point of tangency of the convex and concave portions on the lower surface of the airfoil occurring approximately one-third of the chord length of the airfoil section from the leading edge, said sections gradually decreasing in area from the root portion to the tip of the blade for the purpose described.

25. In a propeller blade, a planform profile, of such a character that the contour of the leading edge and the trailing edge of the outer portion of the blade from the tip inward are formed of convex curved profiles, and merge into concave curved profiles at the inner shank portion, and terminate into a cylidrical profile at the root end portion of the blade.

26. In a propeller blade, a planform profile, of such a character that the contour of the leading edge and the trailing edge of the outer portion of the blade from the tip inward are formed by convex curved profiles, and merge into concave curved profiles at the inner shank portion, and terminate into a cylindrical profile at the root end portion of the blade, said planform profile having the maximum width of the blade at a point substantially midway from the axis of rotation.

27. In a propeller blade, an airfoil of the character described comprising concavo-convex surfaces, a planform profile, of such a character that the contour of the leading edge and the trailing edge of the outer portion of the blade from the tip inward are formed by convex curved profiles, and merge into concave curved profiles at the inner shank portion, and terminate into a cylindrical profile at the root end portion of the blade.

28. In a propeller blade of solid steel, having a shank portion at the inner end, and an airfoil

portion extending therefrom, said airfoil portion having a concavo-convex lower surface of relative similar proportions throughout the length thereof.

29. In a propeller blade of solid steel, having an end projection, a cylindrical flanged root end adjoining said projection, a shank portion adjoining said root end, and an airfoil portion adjoining said shank portion, said airfoil portion having a concavo-convex lower surface of relative similar proportions throughout the length thereof.

30. In a propeller blade, a planform profile, of such a character that the contour of the leading edge and the trailing edge of the outer portion of the blade from the tip inward are formed of convex curved profiles, and merge into concave curved profiles at the inner shank portion, and terminate into a cylindrical flanged profile at the root end portion of the blade provided with a cylindrical projection at the innermost end of the blade.

31. In a propeller blade, a planform profile, of such a character that the contour of the leading edge and the trailing edge of the outer portion of the blade from the tip inward are formed of convex curved profiles, and merge into concave curved profiles at the inner shank portion, and terminate into a cylindrical flanged profile at the root end portion, and a cylindrical projection adjoining the flanged profile at the innermost end of the blade.

32. In a propeller blade, a planform profile, of such a character that the contour of the leading edge and the trailing edge of the outer portion of the blade from the tip inward are formed by convex curved profiles, and merge into concave curved profiles at the shank portion, and terminate into a cylindrical profile at the root end portion of the blade, said planform profile having the maximum width of the blade at a point intermediate the tip and root end portion.

33. In a propeller blade, having a shank portion at the inner end, and an airfoil portion extending therefrom, said airfoil portion having a concavo-convex lower surface for a greater portion of the blade length, and merging into a relatively flat lower surface substantially throughout the outer extremity of the blade.

34. In a propeller blade, having a hollow shank portion at the inner end, and an airfoil portion extending therefrom, said airfoil portion having a concavo-convex lower surface for a greater portion of the blade length, and merging into a relatively flat lower surface substantially throughout the outer extremity of the blade.

35. In a propeller blade, having a cylindrical root end, a shank portion adjoining said root end, and an airfoil portion extending therefrom, said airfoil portion having a concavo-convex lower surface for a greater portiton of the blade lenth, and merging into a relatively flat lower surface substantially throughout the outer extremity of the blade.

36. In a propeller blade, having a cylindrical flanged root end, a shank portion adjoining said root end, and an airfoil portion extending therefrom, said airfoil portion having a concavo-convex lower surface for a greater portion of the blade length, and merging into a relatively flat lower surface throughout the outer extremity of the blade.

37. In a propeller blade, having a cylindrical flanged root end and projection, a shank portion adjoining said root end, and an airfoil portion extending therefrom, said airfoil portion having a concavo-convex lower surface for a greater length of the blade, and merging into a relatively flat lower surface throughout the outer extremity of the blade.

38. A propeller blade having two opposite faces, one face having a convex surface for the entire length of the blade, the other face having a concavo-convex surface for a substantial portion of the length of the blade and having a relatively flat surface for the portion adjacent the extremity of said blade.

39. A propeller blade having two opposite faces, one face having a convex surface for the entire length of the blade, the other face having a concavo-convex surface for a substantial portion of the length of the blade and having a relatively flat surface for that portion of its length where the air velocity traversing said surface will approach or exceed, in normal operation, the velocity of 950 feet per second.

40. In a propeller blade having a hollow root and shank formation and an airfoil portion with surfaces of the character described, said outer portion gradually increasing in area from the tip inward to the root end, the thrust surface having both concave and convex portions merging into each other.

41. In an aircraft propeller blade detachable from a driving hub, having a hollow root portion and a solid airfoil portion extending therefrom, said airfoil portion increasing in area from the tip inward to the root portion with the thrust surface part concave and part convex each merging into the other in varying proportions.

42. In a solid metal propeller blade having an airfoil portion with thin airfoil sections gradually increasing in thickness throughout the length of said airfoil portion of the blade, which are formed by arching to provide a high strength-weight ratio in the airfoil portion of the blade.

43. In a solid metal propeller blade having an airfoil portion with thin airfoil sections gradually increasing in thickness throughout the length of said airfoil portion of the blade, which are formed by arching of said airfoil sections to provide a high strength-weight ratio of sufficient rigidity and stiffness to withstand deflection against the stresses imposed in service operation of the blade.

44. In a solid metal propeller blade having an airfoil portion for the greater length of the blade, said airfoil portion so constructed and arranged that rigidity is built into a portion of the airfoil portion by arching the section to withstand deflection against the thrust forces in service operation of the blade.

45. In a solid metal propeller blade having an airfoil portion for the greater length of the blade, said airfoil portion so constructed and arranged that rigidity is built into one of the surfaces of the airfoil portion by arching the section to withstand deflection against the thrust and torque forces in service operation of the blade.

46. A propeller having a hub provided with a plurality of solid bases and a cylindrical socket within said bases, blades having flanges and projections interfitting and in abutting engagement with said bases and sockets, and means for attaching said blades to said hub to rigidly hold said blades.

47. A propeller blade having a rounded leading edge with a radius whose curvature gradually increases from the tip to the root portion of the blade, and a leading edge portion confined within oppositely curved convexed upper and lower surfaces and merging with said rounded leading

edge, a trailing edge portion having upper convex and lower concave surfaces merging with the convexed surfaces of the leading edge portion at a point substantially one-third of the chord of the blade section, said trailing edge portion having a trailing edge with a rounded trailing edge, the radius of curvature gradually increasing from the tip to the root of the blade.

48. A propeller blade having a cylindrical flanged root portion, a shank portion, and an outer portion of airfoil section, said outer portion having rounded leading and trailing edges, with a leading edge portion confined within oppositely curved convexed upper and lower surfaces, and a trailing edge portion having convexed upper and concaved lower surfaces that merge with the upper and lower convex surfaces of the leading edge portion respectively at a point substantially one-third the chord of the blade.

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