May 23, 1961 R. P. MALOOF 2,985,245

PROPELLER FAN

Filed Aug. 1, 1958

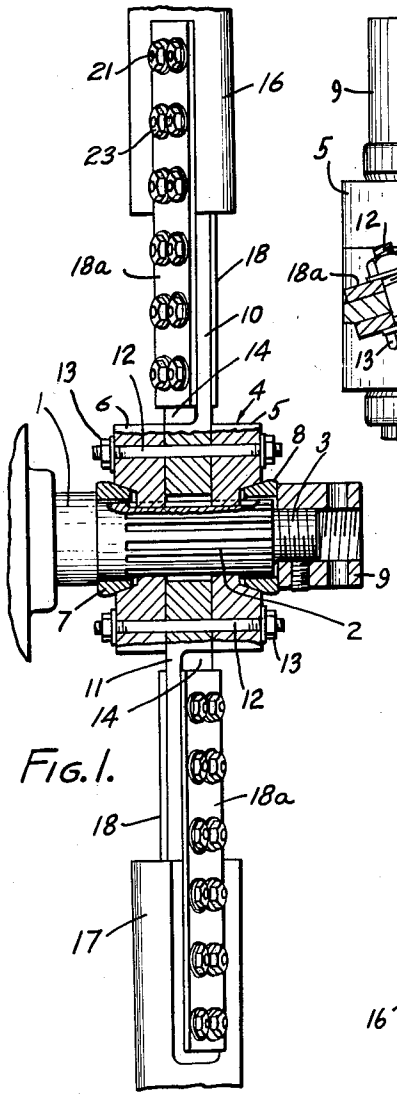


FIG. 1.

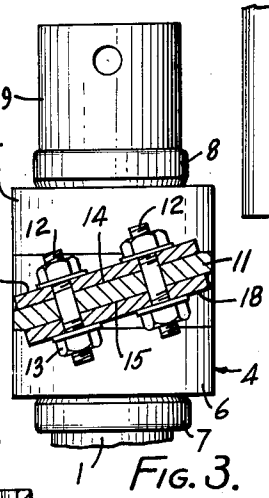


FIG. 3.

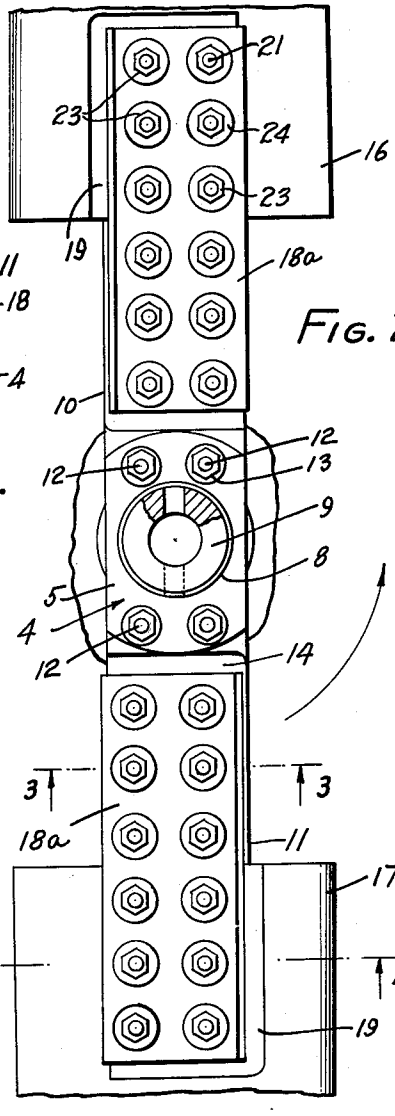


FIG. 2.

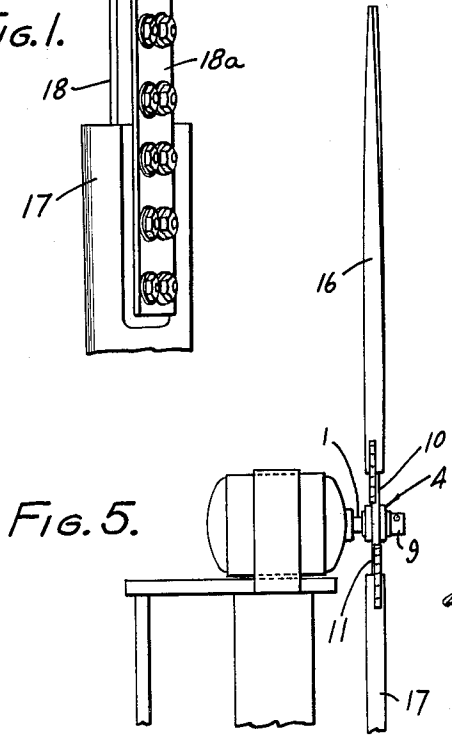


FIG. 5.

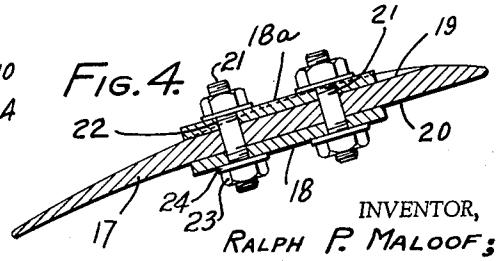


FIG. 4.

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PROPELLER FAN

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3 Claims. (Cl. 170—173)

The present invention relates to a propeller fan construction of large size, of high aerodynamic efficiency and low cost. The propeller fan of the invention is adapted for use on wind machines, air exhausters, and air inducers.

I have found that I may use an aluminum alloy extrusion of constant cross section, so shaped that propeller fan blading could be made directly simply by cutting off lengths of extruded stock as the design required.

It is known that, while aluminum and other alloys, capable of being extruded, can be quite strong for the weight, there are limits to the stresses these alloys can endure, and such limits may be too low to allow the use of extruded blading of a practical cross section.

In any propeller fan, an impulse or thrust is produced by the action of the moving blades on the air impelled. This impulse is directly related to the change in energy level of the air passing through the plane of the fan. The impulse must be restrained completely in order to prevent axial travel of the entire fan mechanism. Therefore, the aerodynamic forces on the blading, must be balanced out by reacting forces in the blades and fan structure.

The geometric arrangement giving the best aerodynamic efficiency is one that becomes well suited to a slender, thin, smooth, moderately twisted metal extrusion, except for the structural properties required of the region where the propeller fan blade joins the hub. In this connecting zone, large moments may appear which produce bending stress that actually exceed the tension stresses caused by centrifugal force. It becomes necessary then to provide a mechanism which would make use of centrifugal force to overcome or relieve the bending moment. The connection between the hub and each blade forms a continuous, elastic, deflectable joint.

The technique of using hinged connections to sever the bending moment transfer path on aerodynamic lifting rotors has long been known. The result of such a connection is a rotor whose blades are allowed to "cone" in the direction of lift. The cone angle is automatically stabilized by the balance of centrifugal restoring moment and aerodynamic lifting moment. The pin of the connecting hinge has only the centrifugal force to contend with. However desirable the hinge connection may be from a stress standpoint, the problems which attend are such that low cost is not possible, and inspection must be dependable and frequent. I have discovered that a bolted connection of very high strength and relatively low bending stiffness may be used to join hub and blade and whereby no moving parts such as hinges or auxiliary structure is required to produce a propeller fan rigid enough to support itself when not revolving.

An object of the invention is to provide an air propeller fan of superior mechanical design, economical to fabricate, of determined aerodynamic efficiency, and having long trouble-free life.

With the above mentioned and other aspects in view, the invention consists in the novel and useful provision,

formation, construction association and relative arrangement of parts, members and features all as disclosed in the drawing, described generally, and finally set forth in the claims.

In the drawing:

Figure 1 is a fragmentary partially sectional view showing the connection between the hub and the blades,

Figure 2 is a view, partially in section and in fragment, revolved substantially 90° from the showing of Figure 1,

Figure 3 is a fragmentary sectional view on the line 3—3 of Figure 2,

Figure 4 is a sectional view on the line 4—4 of Figure 2, and

Figure 5 is a fragmentary view, in side elevation showing a motor and the improved blade construction with its hub secured to the shaft of the motor.

Referring now to the drawing, and specifically to Figure 1, I have shown by way of illustration, an engine shaft **1** having the usual splined portion **2**, and screw threaded end **3**. The hub, designated generally as **4**, includes two annular plates **5** and **6**, provided with the usual annular tapered keys **7** and **8** for securing the hub to the splined portion **2**, particularly when the nut **9** is tightened on the screw-threaded end **3**. In this hub construction, there is interposed between the plates **5** and **6**, tangs **10** and **11** which, in the present construction, are diametrically opposed. These tangs, in each instance, have end portions of a given thickness secured between the plates **5** and **6**, by means of bolts designated generally as **12**, passed through aligned bores in both the tangs and the plates. In the present instance, four bolts are utilized, with ends of said bolts carrying nuts **13**. Each tang has a reduced thickness portion provided with a pair of opposed flat surfaces **14** and **15** (Fig. 3) which are parallel and at an angle to a plane normal to the axis of the hub and engine shaft. As stated, in the present illustration, I use a pair of blades, **16** and **17**, of identical construction, and the blades, in the present instance, have a constant cross section. A constant cross section blade can be formed by extrusion and at low cost both in tooling and production expense. I contemplate the use of a solid, extruded, aluminum blading of uniform cross-section, which permits blades of different lengths to be cut therefrom. To mount each blade to a tang, I have provided a pair of splice plates **18** and **18***a*. These splice plates are of uniform thickness and length.

As shown in Figure 4, each blade at its hub connecting end is provided with a substantially plane or flat top surface **19** which is parallel to the flat bottom surface **20**, with the splice plates receiving said blade surface therebetween. Both splice plates, top and bottom, as well as the blade, are provided with a series of spaced apart bores, designated generally as **22**, for receiving bolts **21** carrying end nuts **23** and washers **24** whereby pairs of splice plates will secure a blade therebetween. The number of bolts between the splice plates and a blade, as well as the number of bolts between the splice plates and a tang may vary from that shown in the drawing.

The reason for providing the parallel flat surfaces **19** and **20** for each blade, is that this construction allows the blade to be joined to a hub tang with bolts or pins in double shear. Thus the bolt bending moments caused by a centrifugal force carried in the splice plates are equal and opposite, on each side, leaving a net moment of zero to be transmitted to the tang and blade. This construction reduces the number of machine operations, and provides a reference surface to use for machining and measuring.

In considering the type of hub employed, it is quite obvious that the extruded aluminum blades would not

have sufficient strength to absorb the high bending moment from blade lift if it were not for the relieving moment produced by centrifugal force. The centrifugal moment does not develop, however, until the blade "cone" is established by forward deflection of the blade. If the blade were hinged with respect to an axis perpendicular to the rotation axis, that is, parallel to a blade chord, free coning would take place and all moments would balance to zero at the edge, but because of mechanical difficulties arising from hinge bearings, etc., and because of manufacturing costs of such machinery, an attachment having low bending stiffness which includes the tangs with the splice plates for hub to blade connection was devised. The thickness of the blade attachment tang is established so that the high bending stresses would be limited by restrained coning of the blades. The aerodynamic bending moment is now only partially absorbed by elastic deformation of the hub tangs because the bending deformation of the blade provides a forward shift in the blade mass, allowing centrifugal force to act on the displaced mass in such a way as to counteract the aerodynamic force to balance out the moment produced by them. While, from an ideal standpoint, the flexible connection of the hub appendage should have a neutral elastic plane lying exactly perpendicular to the rotation axis, I do not practice this, because the marginal advantage in dynamic stability is overbalanced by the cost advantage of allowing the tang to deflect in the blade inclination plane which is displaced from perpendicular about 17°. The details described are the ones that make it possible to produce these propeller fans at a low cost and without sacrifice of performance.

When I speak of a flexible connection between the hub and a blade I am referring to low bending stiffness in the hub to blade connection such as may be accomplished by providing a steel bar tang having a width five to ten times its thickness.

A practical limit to the art of extruding large shapes is taken advantage of in the design of the blades for this propeller fan. It is known that the use of very slender, thin blade on propeller fans produces high aerodynamic efficiency. But such blades tend to flutter destructively if the torsional stiffness is not kept at a maximum, particularly if the blade chord-wise center of gravity moves too far toward the trailing edge. With extruded blades of solid shape, a very thin airfoil can be used without the need for auxiliary chord-wise balancing or artificial stabilizing means, because of the high torsion stiffness. The blade thickness ratio can be made as thin as a practical hub connection will allow.

The propeller fan described herein may or may not have twisted blades. In the case of a wind machine propeller fan, a twisted blade is used; however, certain air inducers need not have twisted blades.

I claim:

1. In a two-blade propeller-fan construction, a hub comprising two annular plates for mounting on a driving shaft, a pair of tanks 180° apart, each tang having a portion bolted between the plates and having beyond the hub a reduced thickness portion with parallel sides making an angle of about 17° with a plane at right angles to the axis of the hub and shaft, a pair of elongated slender propeller blades located at the outer ends of the tangs, a pair of elongated splice plates at both sides of the hub for receiving therebetween the reduced thickness portion of the tang, and a portion of the blade to provide a flexible connection between the hub and the blade, and means for securing each pair of splice plates together in double shear.

2. A propeller fan of large size for wind machines including a pair of diametrically disposed blades formed from a metal alloy extruded stock of uniform cross section, a tang for each blade including a thicker end portion with parallel sides and a reduced thickness portion with opposed flat surfaces parallel to each other and at an acute angle to a plane normal to the axis about which the fan revolves, said reduced thickness portion being from five to ten times as wide as it is thick, a hub including a pair of annular hub plates secured together with the thicker end portions of the two tangs between them, four splice plates of uniform thickness and length securing together the blades and the reduced thickness portions of the tangs with the inner ends of the splice plates spaced from the hub, and means for mounting the hub on an engine shaft.

3. A propeller fan of large size for two-bladed wind machines having long thin flexible blades, including a pair of diametrically disposed blades formed from an aluminum alloy extruded stock of uniform cross section having a curved upper face and a lower centrally plane face, a tang for each blade including a thicker inner portion with parallel sides and a reduced thickness portion with opposed flat surface parallel to each other and at an acute angle of about 17° to a plane normal to the axis about which the fan revolves, said reduced thickness portion being from five to ten times as wide as it is thick, with its outer end proximate the inner end of a blade, a hub including a pair of annular hub plate disks bolted together with the thicker inner portions of the two tangs between them, two pairs of elongated splice plates securing together the inner end portions of the blades and the reduced thickness portions of the two tangs with the inner ends of the splice plates spaced from the hub, the upper face of each blade having a flat portion adjacent the proximate splice plate, and means for mounting the hub on an engine shaft.

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