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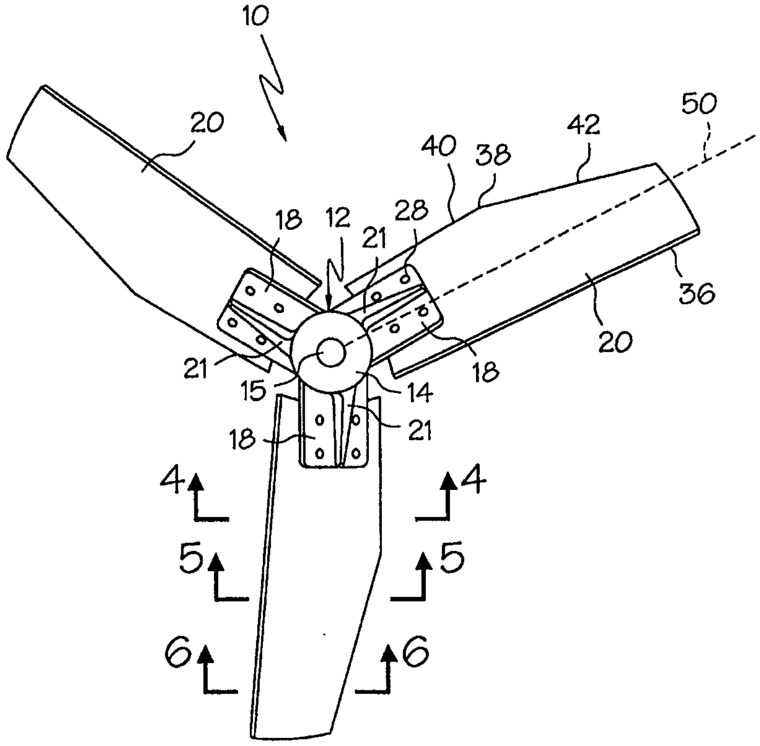
(54) Title: HIGH EFFICIENCY IMPELLER ASSEMBLY AND ASSOCIATED METHOD

(57) Abstract

An impeller assembly (10) includes a hub member (12) having a central portion (14) adapted for connection to a drive shaft. A plurality of stub blades (18) extend outwardly from the central portion (14), each stub blade (18) having an arcuate portion at least at its outer end and the arcuate portion of each stub blade including at least one opening thereon (28). A corresponding plurality of extension blades (20) each have an arcuate portion for mating with the arcuate portion of a respective one of the stub blades. The arcuate portion of each extension blade (20) includes at least first and second openings (30) thereon, each of the first and second openings selectively alignable with the opening (28) of the arcuate portion of the respective mating stub blade such that alignment of the first opening with the opening of the arcuate portion of the respective mating stub blade establishes a first selectable pitch angle and alignment of the second opening with the opening of the arcuate portion of the respective mating stub blade establishes a second selectable pitch angle. Thus, rotating the arcuate portion of the extension blade relative to the arcuate portion of the stub blade enables selection of the pitch angle. Other techniques for providing pitch angle selection and adjustment are shown. Further, the extension blades are preferably angled in the pumping direction to aid in maintaining axial flow.



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HIGH EFFICIENCY IMPELLER ASSEMBLY AND ASSOCIATED METHOD

BACKGROUND OF THE INVENTION

The present invention relates to equipment for mixing, blending and agitating liquids and suspensions of solids in liquids and, more particularly, to high efficiency impeller assemblies.

Impeller assemblies utilized for mixing, blending and agitating liquids and suspensions of solids in liquids may typically be located in the diametrical center of a cylindrical tank and are connected for rotation by a downwardly extending drive shaft. One important feature of high efficiency impellers in such applications is for such impellers to maintain an axial liquid flow in the pumping direction which does not experience significant dispersal or outward flare until near the bottom of the tank because dispersal of flow far above the bottom of the tank can result in the undesired accumulation of solids at the bottom center of the tank. Accordingly, it is always desirable to maintain good axial flow in the pumping direction. As used herein the term "pumping direction" defines the flow direction of fluid away from the impeller assembly and will typically be downward, but could likewise be upward.

Other features of high efficiency impeller assemblies which must be taken into consideration include blade chord, blade camber and blade pitch angle, which may all vary along the end to end length of the blade. The blade chord is a straight line between the leading edge and trailing edge of the blade. The blade camber is the ratio of (1) the maximum distance between the chord and a line defining the mean or midpoint of the blade thickness, and (2) the length of the blade chord. The blade pitch angle is the angle between the chord and a horizontal line which is in a plane perpendicular to the axis of the drive shaft. With respect to blade pitch angle, this feature is a particularly important structural feature that varies depending upon application parameters including viscosity of the liquid being agitated, types of solids suspended in the liquid, depth of the agitation tank, and width or radius of the agitation tank to name just a few. The power invested in the fluid and consequently the flow generated may be altered by changing the pitch angle.

Prior art impeller assemblies generally include a pre-established non-adjustable blade pitch angle or require complex mechanisms or manufacturing operations to adjust the blade pitch angle. Accordingly, it would be desirable to provide a high efficiency impeller assembly having more than one selectable blade pitch angle. It would also be desirable to provide a simple method for establishing the blade pitch angle of an impeller blade. Further, a high efficiency impeller assembly configured to maintain a good axial flow in the pumping direction would also be desirable.

SUMMARY OF THE INVENTION

The present invention is an impeller assembly which is configured to allow the blade pitch to be selected as necessary for particular different applications. In a preferred embodiment of the invention an impeller assembly includes a hub member having a central portion adapted for connection to a drive shaft. A plurality of stub blades extend outwardly from the central portion, each stub blade having an arcuate portion at least at its outer end and the arcuate portion of each stub blade including at least one opening thereon. A corresponding plurality of extension blades each have an arcuate portion for mating with the arcuate portion of a respective one of the stub blades. The arcuate portion of each extension blade includes at least first and second openings thereon, each of the first and second openings selectively alignable with the opening of the arcuate portion of the respective mating stub blade such that alignment of the first opening with the opening of the arcuate portion of the respective mating stub blade establishes a first selectable pitch angle and alignment of the second opening with the opening of the arcuate portion of the respective mating stub blade establishes a second selectable pitch angle. Thus, rotating the arcuate portion of the extension blade relative to the arcuate portion of the stub blade enables selection of the blade pitch angle.

In another preferred embodiment of the present invention a high efficiency impeller assembly includes a hub member including a central portion adapted for connection to a drive shaft and a plurality of arcuate stub blades extending outwardly from the central portion. A plurality of arcuate extension blades are provided, each placed adjacent a respective one of the arcuate stub blades. A leading edge of each extension blade sweeps forward from an inner end to an outer end thereof. Further, each of the arcuate stub blades angles in a pumping direction from a point near the hub member to an outer end thereof, such that when attached thereto its mating extension blade likewise angles in the pumping direction from an inner end to an outer end thereof. This configuration results in an outer end of the leading edge of each extension blade being positioned further in the pumping direction than an inner end of the leading edge to maintain desired axial flow in the pumping direction.

A further aspect of the present invention provides a method of establishing an operating pitch angle for an impeller blade, which method includes providing a hub connection structure having an arcuate shape. The impeller blade is likewise provided with a matching arcuate shape for mating with the hub connection structure. A desired operating pitch angle of the impeller blade is selected. The impeller blade is placed adjacent the arcuate hub connection structure and the arcuate location of the impeller blade relative to the arcuate hub connection structure is adjusted. The impeller blade is then fixed at an arcuate location relative to the arcuate hub connection structure such that the desired operating pitch angle is established.

In yet another aspect of the present invention, a method of forming a high efficiency impeller blade from a piece of sheet material involves cutting the sheet material to define a shape having a first end, a second end, a leading edge and a trailing edge, with a first portion of the trailing edge being substantially perpendicular to the first end, a second portion of the trailing edge angled relative to the first portion and toward the leading edge, and an intersection of the leading edge and the first side forming an obtuse angle. The cut planar material is then deformed into an arcuate shape, with a central axis of the arcuate shape being substantially parallel to the first portion of the trailing edge. Alternatively, blades may be rolled and then cut.

Accordingly, it is an object of the present invention to provide an impeller assembly with an adjustable blase pitch to facilitate use of the assembly in a variety of different applications; an impeller assembly configured to enable simple selection of the operating blade pitch; an impeller assembly configured to maintain good axial flow in the pumping direction; a simple method for establishing the operating pitch angle for an impeller blade; and a simple method for forming a high efficiency impeller blade from a sheet of material.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is top plan view of a preferred embodiment of an impeller assembly in accordance with the present invention;

Fig. 2 is a side elevation of the impeller assembly of Fig. 1;

Fig. 3 is an enlarged end view of a stub blade;

Fig. 4 is a section taken along line 4-4 of Fig. 1;

Fig. 5 is a section taken along line 5-5 of Fig.1;

Fig. 6 is a section taken along line 6-6 of Fig. 1; and

Fig. 7 is a top plan view of a sheet of material used to form an impeller blade in accordance with the present invention.

DETAILED DESCRIPTION

Referring to the drawings, Figs. 1 and 2 illustrate a top view and a side view of an impeller assembly 10 according to one embodiment of the present invention including a hub member 12 having a central portion 14 having an opening 15 adapted for connection to a drive shaft 16 for rotation with the drive shaft 16. Any suitable type of connection between the hub member 12 and the drive shaft 16 may be provided as is known in the art, including, but not limited to the use of a keyway type arrangement, bolts or other fasteners, and pins or clips. It is also recognized that a threaded connection could be provided between the drive shaft 16 and the hub member 12. Extending radially outward from the hub member 12 are three stub blades 18 which are utilized for connecting larger extension blades 20 to the hub member 12 for rotation with the hub member 12. Each stub blade may include one or more reinforcement ribs 21 for added strength. Although three mated stub blades 18 and extension blades 20 are shown, impeller assemblies having other numbers of blades could be provided. Further, although the stub blades 18 are preferably formed integral with the hub member in a casting operation, the stub blades 18 could be formed separate from, and then attached to the hub member 12.

The impeller assembly 10 is particularly useful in liquid agitation applications in which the impeller assembly would be placed in the diametrical center and near the top or bottom of a cylindrical tank containing a liquid with suspended solids. The impeller assembly 10 rotates via shaft 16 to created an axial flow in a pumping direction (downward or upward respectively) in the center of the tank with re-circulation taking place in the radially outer regions of the tank. As positioned in Fig. 1 the impeller assembly 10 would rotate clockwise creating a downward flow direction relative to the arrangement of Fig. 2, and such flow direction is assumed throughout the remainder of this description.

As noted above, the appropriate blade pitch angle for an impeller blade assembly varies depending upon a variety of application parameters. The impeller assembly 10 advantageously facilitates blade pitch angle selection and/or adjustment as necessary for a given application. In particular, as best seen in Fig. 2, the bottom surface of each stub blade 18 incorporates an arcuate shape. Likewise, the top surface of each extension blade 20 incorporates a matching arcuate shape for flushly mating with the bottom surface of the respective mating stub blade 18. Preferably, extension blades 20 incorporate the matching arcuate shape along their entire lengths which is defined as a "singular fixed roll radius." Because the arcuate portions of both the stub blades 18 and extension blades 20 are matching, each pair may be flushly mated together at a plurality of locations relative to each other. For example, Fig. 2 shows one relative location at which the blades could be fixed or mated together, the illustrated location resulting in a relatively low pitch angle. By rotating the extension blade 20 to the right as indicated by arrow 22 the blade pitch angle can be adjusted and selected as desired to a higher pitch angle. Preferably, top surfaces of the stub blades 18 are flat and parallel to a tangent line which intercepts the center of respective clearance holes as shown in the enlarged end view of a stub blade in Fig. 3. This configuration relieves stress concentrations of the threaded fasteners engaging the top surfaces.

The arcuate mating feature advantageously provides an impeller assembly which can be utilized to establish a large variety of blade pitch angles depending upon the application. In the manufacturing environment the system facilitates pre-manufacture of the hub member 12 with stub blades 18 and pre-manufacture of the extension blades 20. Customers may then order the assembly with their desired blade pitch angle and final manufacture can be completed once the desired blade pitch angle is known by placing each extension blade 20 adjacent a respective stub blade 18 and adjusting the relative location to achieve the desired blade pitch angle. Each extension blade 20 may then be fixed to its corresponding mating stub blade 18. Such fixation may occur utilizing a bolt 24 and nut 26 arrangement as shown in Fig. 2 in which case it would be necessary to provide one or more holes 28 through the stub blades 18 and one or more holes 30 through the extension blades 20, with bolts 24 extending through aligned stub blade holes 28 and extension blade holes 30. In such cases the stub blade hole or holes 28 could be located at predetermined locations during pre-manufacture and the extension blades 20 could be formed with no holes during pre-manufacture. Upon selection of a desired blade pitch angle for a given impeller assembly the necessary hole or holes 30 could then be formed in the extension blades at the proper location. In this regard, it would be desirable to establish a known relationship between the hole 30 location and the resulting blade pitch angle. For example, the distance of holes from one edge, such as edge portion 40, of the extension blade 20 will correspond to the resulting blade pitch angle and a chart or look-up table of the appropriate hole distance could be established and used when the desired blade pitch angle is selected, with holes 30 being formed through the extension blades 20 at the locations identified by the chart or look-up table. This type of system would advantageously also facilitate automated formation of the holes. It is also recognized that the extension blades 20 could be fixed to the stub blades 18 by other means or techniques including welding or the use of other types of fasteners.

An adjustable impeller assembly including the arcuate mating feature may also be formed. In this regard, note from Fig. 1 that four holes 28 are shown in each stub blade 18 for the connection of extension blades 20. In an adjustable assembly the extension blade 20 is formed with six or more holes 30 as shown in Fig. 6 resulting in at least two sets 32, 34 of four holes which can be used for connection to the stub blade 18. Utilizing set 32, nearer leading edge 36, for connection to the stub blade 18 would result in a higher blade pitch angle and utilizing set 34 would result in a lower blade pitch angle. The resulting impeller assembly provides for on location adjustment of the blade pitch angle if necessary when an impeller assembly is switched from one application to another. It is recognized that the number of holes utilized to connect the extension blades 20 to the stub blades could vary and therefore the invention is not limited to the use of a certain number of holes for such connection. For example, where only one hole is required for connection an extension blade 20 having two or more holes 30 selectively alignable with one stub blade hole 20 would facilitate blade pitch angle adjustment. Generally if n holes 28 are provided on the stub blade 18, at least n+1 holes 30 would be provided on the extension blade 20 to provide adjustability. It is also recognized that in some applications blade pitch angle adjustment could be facilitated by providing an elongated hole or slot on the extension blade 20 to enable movement of the extension blade 20 relative to the stub blade 18 by loosening, but not necessarily removing the nut 26 and bolt 24 combination. Likewise, the extra holes or the slot could be located on the stub blades 18 rather than the extension blades 20. All such arrangements provide suitable means for fixing the extension blade 20 at multiple locations relative to the stub blade 18.

The arcuate shape of the extension blades at the mating location with the stub blades 18 also increases the stiffness of the extension blades 20, the section modulus of the extension blades 20 being higher than blades with a flat connecting portion. In some cases this increased stiffness advantageously enables the extension blade thickness to be significantly reduced thereby reducing the extension blade weight by fifty percent or more. As noted above, each extension blade 20 is preferably arcuate along its entire length from its inner end near the hub member 12 to its outer end or tip. The cross-sectional views of Figs. 4-6 depict the arcuate shape maintained along the entire extension blade length.

Another preferred feature of the extension blade 20 is that the edge to edge width of the blade, and likewise the length of the blade chord, is smaller at the outer end or tip of the extension blade 20 than at the inner end of the extension blade 20 near the hub member 12. This feature is achieved by providing a trailing edge 38 which includes first 40 and second 42 portions, with second portion 42 extending generally forward, in the direction of intended rotation, toward leading edge 38.

Extension blades 20 in accordance with the present invention may be manufactured from a sheet 44 (Fig. 7) of suitable material, such as steel, with the particular material being chosen mainly for strength and durability depending upon the application in which the impeller assembly is to be used. The sheet 44 is cut along the dashed lines to form a the general shape of the blade. It is noted that the cut made along dashed line 46 provides a preferred blade configuration in which leading edge 36 sweeps slightly forward, in the direction of intended rotation, and thus forms an obtuse angle (ϕ) with inner end 48. The cutting step may be achieved utilizing a laser cutting device or a water jet cutting device for example, but it is recognized that other known cutting techniques could also be used. The cut sheet is then formed into an arcuate shape with a central axis of the arcuate shape, that is the central axis (shown as point 48 in Fig. 6) of an imaginary cylinder along which the arcuate shape extends, preferably extending parallel to the first portion 40 of trailing edge 38. When connected as part of an impeller assembly, the line defining the central axis of the arcuate shape of the extension blade is preferably parallel to a line (shown as dashed line 50 of Fig. 1) extending radially outward from the center of rotation of the impeller assembly and along the top surface of the extension blade. That is, the extension blade is not twisted relative to the center of rotation of the impeller. The arcuate shape forming step may be achieved using a rolling technique, a multiple parallel bend technique, or other known techniques. Any holes 30 necessary can then be formed as previously described. Alternatively, holes may be formed before rolling or cutting and cutting may take place after the rolling step.

The resulting extension blade 20 configuration, by virtue of its geometry, includes a camber which increases from the outer tip to at least the intermediate point intersection of edge portion 40 and edge portion 42. The camber at the inner end of the extension blades 20 is also greater than the camber at the outer end or tip. This increased camber of each extension blade 20 at its mating location with the stub blade 18 advantageously creates an increase in the section modulus of the extension blade at the plane of highest concentration of stress.

Referring again to Fig. 2, in order to maintain good axial flow in the pumping direction with minimal dispersal, the stub blades 18 extending from hub member 12 preferably angle slightly downward (the illustrated pumping direction) such that when attached thereto the extension blades 20 also angle slightly downward as shown. This angling in the pumping direction is particularly important in certain embodiments of the present invention where, due to the forward sweep of leading edge 36, the leading edge 36 at the blade tip would otherwise be positioned upstream, relative to the pumping direction, of the leading edge 36 near the inner end at the hub member 12 resulting in a tendency to cause dispersal rather than good axial flow in the pumping direction. With the preferred angling of the stub blades 18 in the pumping direction, the leading edge 36 at the tip is maintained slightly downstream, relative to the pumping direction, of the leading edge 36 near the inner end for good axial flow performance. In the embodiments incorporating the downstream pumping direction angle, it is preferably set in a range from about one degree to ten degrees. Importantly, the angling of the extension blades in the pumping direction is achieved without requiring a bend in the blade, thereby maintaining higher blade strength along the entire blade length.

While the form of the assembly herein described constitute a preferred embodiment of the invention, it is to be understood that the invention is not limited to this precise form of assembly, and changes may be made therein without departing from the scope of the invention.

What is claimed is:

1. An impeller assembly for providing a selectable blade pitch angle comprising:

a hub member including a central portion adapted for connection to a drive shaft;

a plurality of stub blades extending outwardly from said central portion, each stub blade having an arcuate portion at least at its outer end, said arcuate portion of each stub blade including at least one opening thereon;

a corresponding plurality of extension blades each having an arcuate portion for mating with said arcuate portion of a respective one of said stub blades, said arcuate portion of each extension blade including at least first and second openings thereon, each of said first and second openings selectively alignable with said opening of said arcuate portion of said respective mating stub blade; and

wherein, for each extension blade, alignment of said first opening with said opening of said arcuate portion of said respective mating stub blade establishes a first selectable pitch angle, and alignment of said second opening with said opening of said arcuate portion of said respective mating stub blade establishes a second selectable pitch angle.

2. The impeller assembly of claim 1 wherein said opening of said arcuate portion of each stub blade comprises a through hole, and wherein said first and second openings of each extension blade comprise through holes; and

wherein the impeller assembly further includes a plurality of fasteners, each fastener for positioning through aligned through holes of said stub blades and said extension blades.

3. The impeller assembly of claim 2 wherein said fasteners comprise bolts and the impeller assembly further comprises a plurality of nuts, each nut for attachment to one of the bolts.

4. The impeller assembly of claim 2 wherein said arcuate portion of each stub blade is located on one side thereof and an opposite side of each stub blade includes a flat surface portion around said through hole for reducing stress concentrations caused by its respective fastener.

5. The impeller assembly of claim 1 wherein each of said extension blades is arcuate along its entire length so as to include a singular fixed roll radius.

6. The impeller assembly of claim 5 wherein a trailing edge of each of said extension blades includes a first portion extending substantially parallel to a line defining a central axis of said arcuate extension blade, said first portion extending from an inner end of said extension blade to an intermediate point along the length of said extension blade.

7. The impeller assembly of claim 6 wherein said trailing edge of each extension blade further includes a second portion angled relative to said first portion and extending forwardly toward a leading edge of said extension blade.

8. The impeller assembly of claim 5 wherein a leading edge of each extension blade sweeps forward from an inner end to an outer end thereof.

9. The impeller assembly of claim 5 wherein each of said stub blades angles in a pumping direction from a point near said hub member to an outer end thereof, such that when attached thereto its mating extension blade likewise angles in the pumping direction from an inner end to an outer end thereof.

10. A high efficiency impeller assembly for providing a selectable blade pitch angle comprising:

a hub member including a central portion adapted for connection to a drive shaft;

a corresponding plurality of stub blades extending outwardly from said central portion, each stub blade having an arcuate portion at least at its outer end;

a plurality of extension blades each having an arcuate portion for mating with said arcuate portion of one of said stub blades;

wherein each extension blade and respective mating stub blade includes means thereon for fixing said extension blade at a first location relative to said arcuate portion of said respective mating stub blade and means thereon for fixing said extension blade at a second location relative to said arcuate portion of said respective mating stub blade; and

wherein, for each extension blade and respective mating stub blade, fixing said extension blade at said first location relative to said arcuate portion of said respective mating stub blade establishes a first selectable pitch angle, and fixing said extension blade at said second location relative to said arcuate portion of said respective mating stub blade establishes a second selectable pitch angle.

11. The impeller assembly of claim 10 wherein each extension blade is arcuate over its entire length, wherein a leading edge of each extension blade sweeps forward from an inner end to an outer end thereof, and wherein each of said stub blades angles in a pumping direction from a point near said hub member to an outer end thereof, such that when attached thereto its mating extension blade likewise angles in the pumping direction from an inner end to an outer end thereof.

12. The impeller assembly of claim 11 wherein a trailing edge of each of said extension blades includes a first portion extending substantially parallel to a line defining a central axis of said arcuate extension blade, said first portion extending from an inner end of said extension blade to an intermediate point along the length of said extension blade, and said trailing edge of each extension blade further includes a second portion angled relative to said first portion and extending forwardly toward said leading edge of said extension blade.

13. A method of establishing an operating pitch angle for an impeller blade comprising:

providing a hub connection structure having an arcuate shape;

providing the impeller blade with a matching arcuate shape for mating with the hub connection structure;

selecting a desired operating pitch angle of the impeller blade;

positioning the impeller blade adjacent the arcuate hub connection structure;

adjusting the arcuate location of the impeller blade relative to the arcuate hub connection structure; and

fixing the impeller blade at an arcuate location relative to the arcuate hub connection structure such that the desired operating pitch angle is established.

14. The method of claim 13 wherein the arcuate hub connection structure includes at least one hole and wherein the impeller blade includes at least one hole, said adjusting step comprising aligning the impeller blade hole with the arcuate hub connection structure hole, and said fixing step comprising passing a removable fastener through the aligned holes.

15. The method of claim 13 further comprising the steps of:

providing at least one hole in the arcuate hub connection structure;

establishing a predetermined relationship between operating pitch angle and an arcuate distance from one edge of the impeller blade;

determining an arcuate distance which corresponds to the desired operating pitch angle after selection thereof based upon the established predetermined relationship; and

forming a hole in the impeller blade at the determined arcuate distance;

said adjusting step comprising aligning the formed impeller blade hole with the arcuate hub connection structure hole; and

said fixing step comprising passing a removable fastener through the aligned holes.

16. The method of claim 13 wherein said fixing step comprises welding the extension blade to the arcuate hub connection structure.

17. A method of establishing an operating pitch angle of an impeller blade comprising:

providing a hub connection structure having an arcuate shape;

providing an impeller blade having a mating arcuate shape for placement adjacent the hub connection structure in a flush manner selectively at a plurality of positions;

selecting a desired operating pitch angle of the impeller blade;

positioning the impeller blade adjacent the arcuate hub connection structure at a particular one of the plurality of positions, which particular position corresponds to the selected operating pitch angle; and

fixing the impeller blade at the particular position relative to the arcuate hub connection structure.

18. A high efficiency impeller assembly comprising:

a hub member including a central portion adapted for connection to a drive shaft and a plurality of arcuate stub blades extending outwardly from said central portion;

a plurality of arcuate extension blades, each positioned adjacent a respective one of said arcuate stub blades, each of said extension blades having a singular fixed roll radius;

wherein a leading edge of each extension blade sweeps forward from an inner end to an outer end thereof; and

wherein each of said arcuate stub blades angles in a pumping direction from a point near said hub member to an outer end thereof, such that when attached thereto its mating extension blade likewise angles in the pumping direction from an inner end to an outer end thereof resulting in an outer end of said leading edge of each extension blade being positioned downstream, relative to the pumping direction, of an inner end of said leading edge.

19. The impeller assembly of claim 18 wherein a trailing edge of each of said extension blades includes a first portion extending substantially parallel to a line defining a central axis of said arcuate extension blade, said first portion extending from an inner end

of said extension blade to an intermediate point along the length of said extension blade, and said trailing edge of each extension blade further includes a second portion angled relative to said first portion and extending forwardly from said intermediate point toward said leading edge of said extension blade.

20. A method of forming a high efficiency impeller blade from a piece of sheet material comprising:

cutting the sheet material to define a shape having a first end, a second end, a leading edge and a trailing edge, a first portion of the trailing edge being substantially perpendicular to said first end, a second portion of the trailing edge angled relative to the first portion and toward the leading edge, an intersection of the leading edge and the first side forming an obtuse angle;

deforming the sheet material into an arcuate shape;

and wherein a central axis of the arcuate shape of the cut and deformed sheet material is substantially parallel to the first portion of the trailing edge.

21. The method of claim 20 wherein said cutting step is performed utilizing a laser.

22. The method of claim 20 wherein said cutting step is performed utilizing a waterjet.

23. The method of claim 20 further comprising the step of:

forming a plurality of holes near the first end of the cut sheet material.

24. The method of claim 20 wherein said deforming step is performed prior to said cutting step.

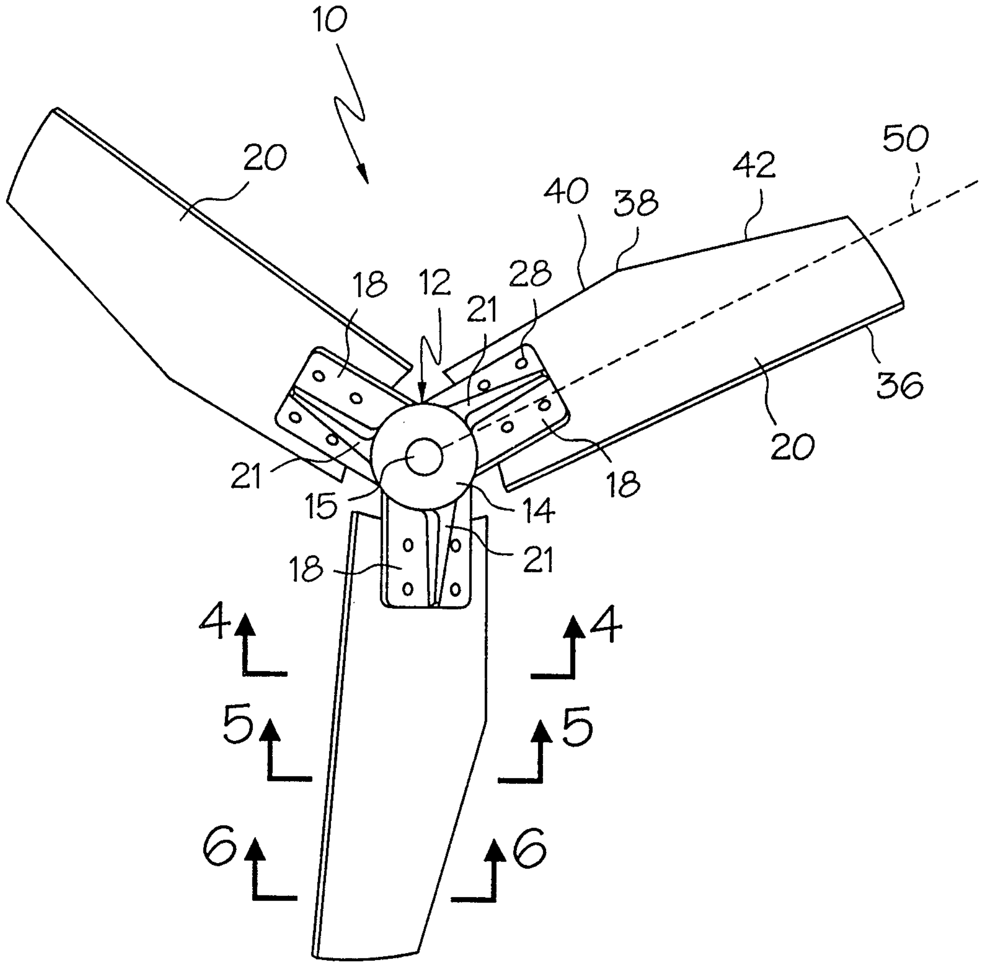
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FIG. 1

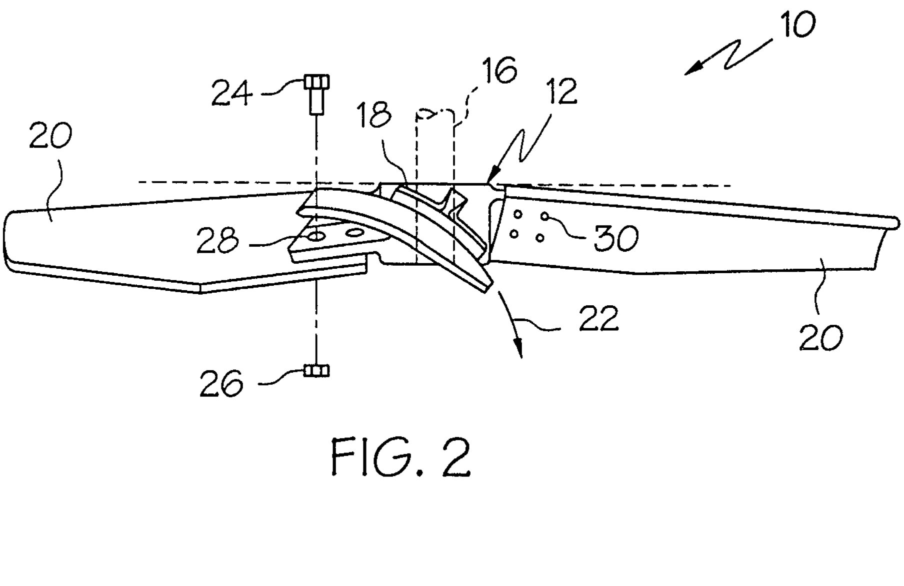
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FIG. 2

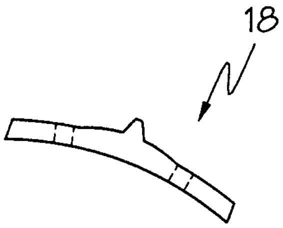

FIG. 3

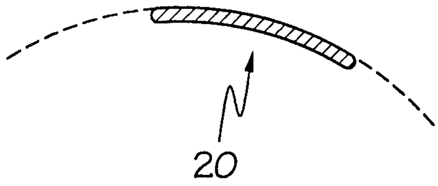

FIG. 4

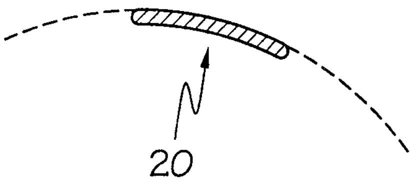

FIG. 5

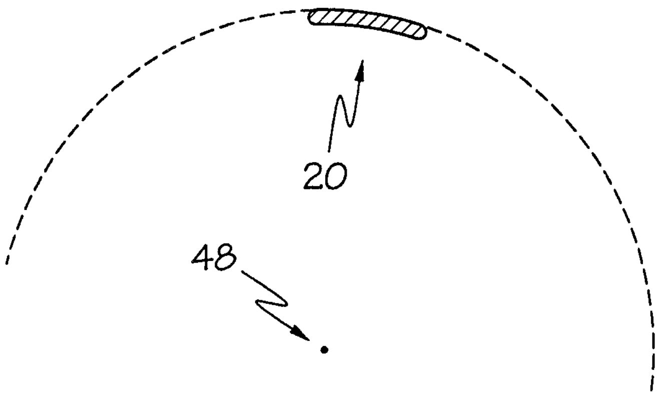

FIG. 6

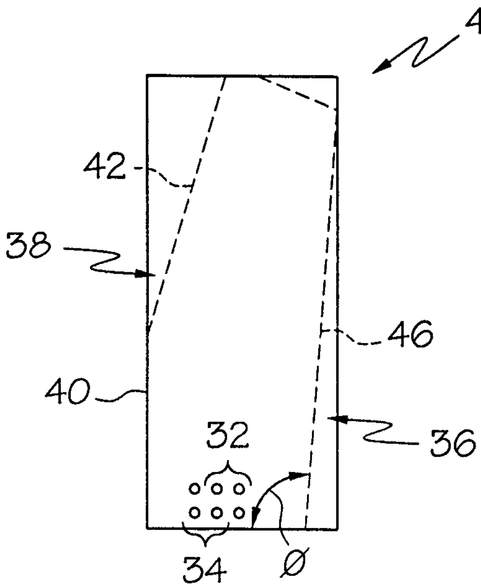

FIG. 7