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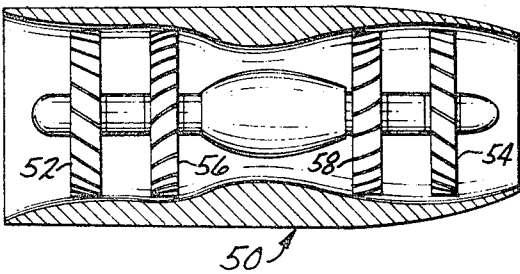
[54] NOISE ATTENUATING SYSTEM FOR ROTARY
 ENGINES
 9 Claims, 8 Drawing Figs.

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 415/119, 181/33, 181/58, 181/64
[51] Int. Cl. F01d 5/10,
 F01d 25/00
[50] Field of Search 230/120,
 119, 122, 134.2, 232; 415/119, 60; 181/64, 33.22,
 33.21, 58

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ABSTRACT: A plurality of angularly arranged baffles or blades which are radially mounted to form a fan type construction. The fan is mounted for free rotation in the fluid stream of a rotary engine in the path of the propagating sound waves emitted from the engine. During operation the rotating fan will present a barrier to the sound waves and cause them to be either reflected or scattered towards an area having sound absorbing characteristics while offering a minimum obstruction to the fluid flow. A further sound attenuation and an improvement in engine performance is achieved through a predetermined air pressure profile which is obtained by fairing the blade angle configuration, whereby the inlet air drives the outer portion of the rotating blades and the inner portion of the blades compresses the inlet air. Any engine performance loss which is experienced by the fan type apparatus is offset by the improved air pressure profile at the first stage engine inlet area.



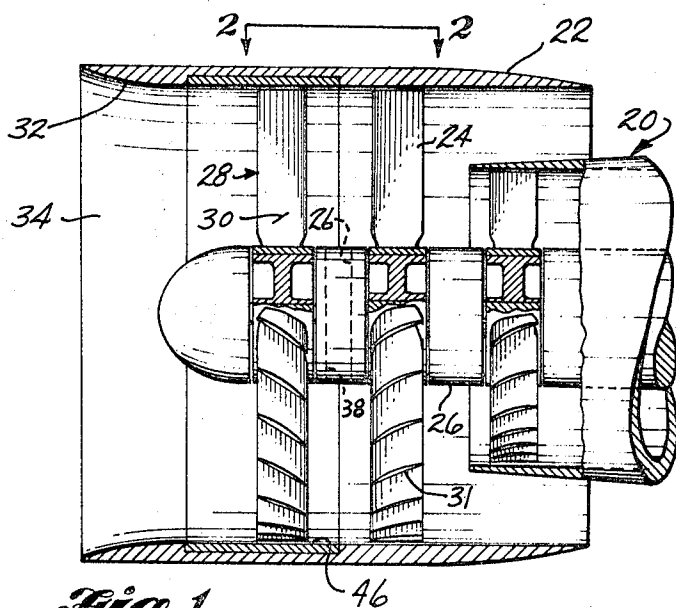


Fig. 1.

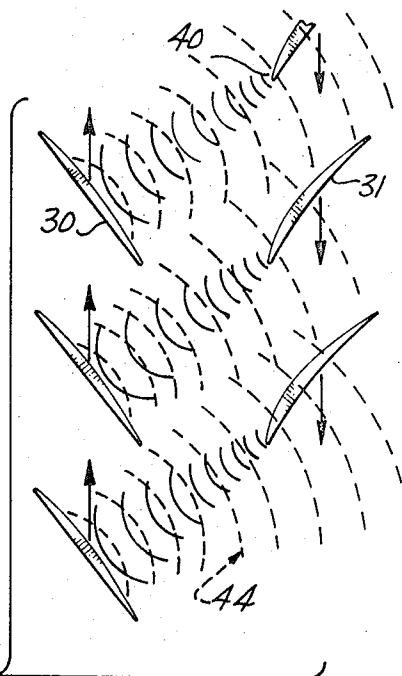


Fig. 2.

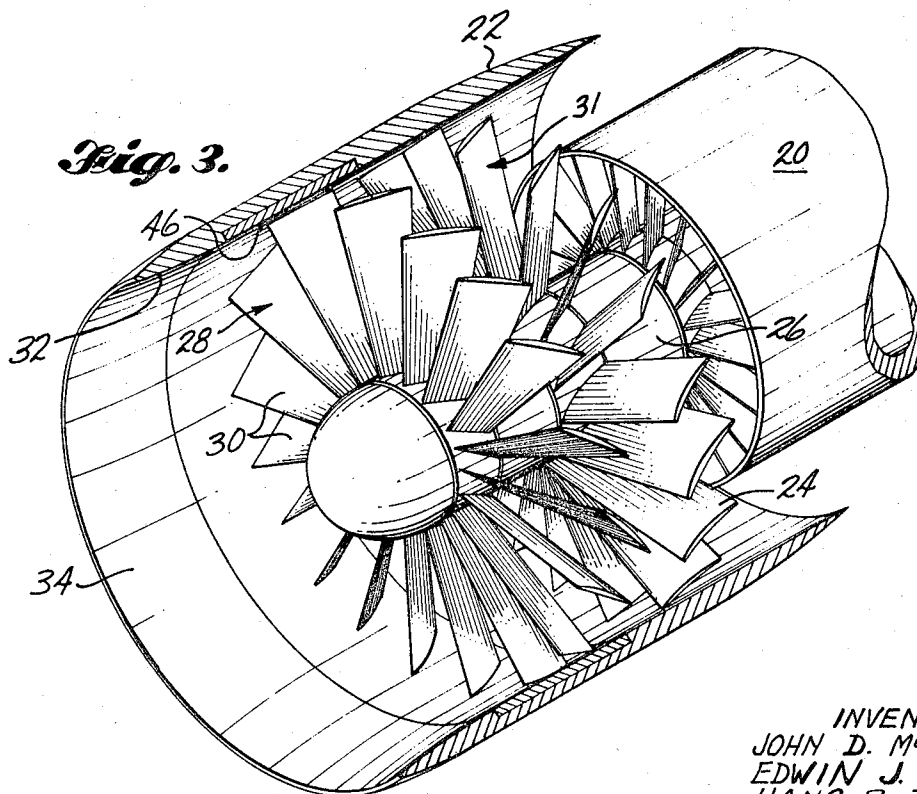


Fig. 3.

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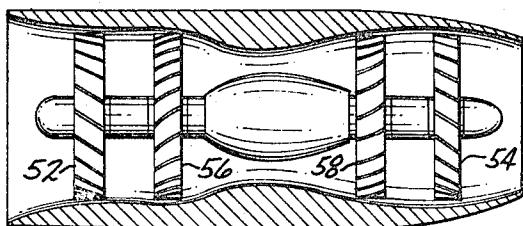


Fig. 4.

Fig. 5.

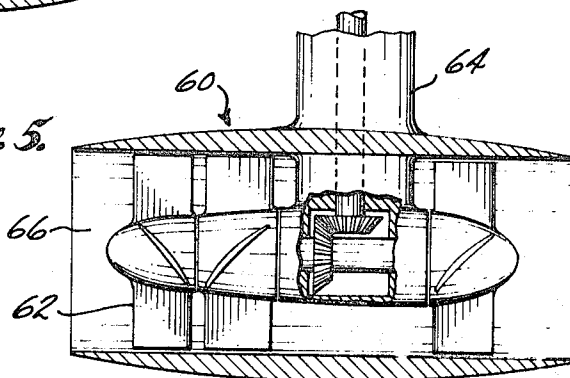


Fig. 6.

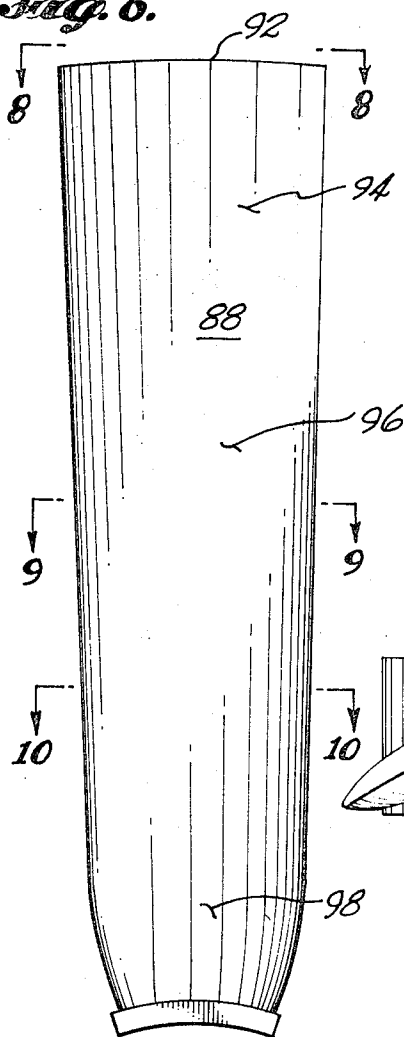
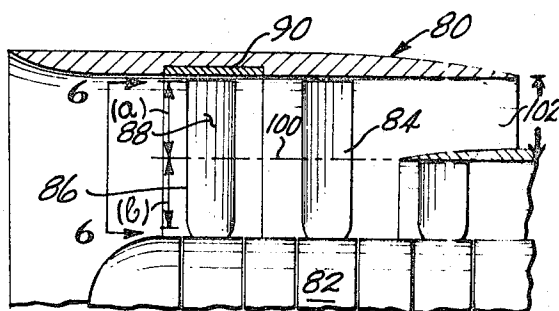


Fig. 7.

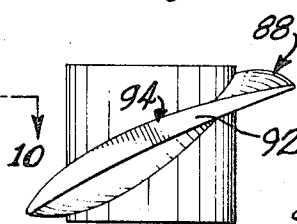


Fig. 8.



Fig. 9.

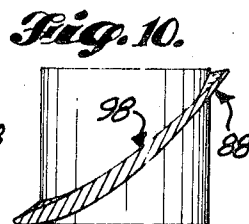


Fig. 10.

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NOISE ATTENUATING SYSTEM FOR ROTARY ENGINES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a noise suppressing apparatus which resides in the placement of freely rotating fan blades in front of and/or behind the rotating vanes of a rotating engine and more particularly to a free rotating fan positioned in the intake of turbo engines for regulating intake and reflecting sound waves which together will sequentially diminish and suppress the emitted sound waves or noise.

2. Description of the Prior Art

Noise suppressor and sound attenuating techniques that have been developed so far all achieve their effect at the expense of a decrease in efficiency of to which they are applied. Specifically in the case of modern aircraft gas turbine engines where, for instance, the inlet silencing devices add weight and drag to the propulsion installation, the effective thrust of the engines is reduced and/or complexities are added which endanger the safe operation of the aircraft. The performance loss sustained through conventional devices impairs the economic viability of air transportation and little use of such devices is therefore made. The performance loss sustained further changes power levels required for safe flight and alters the flight paths unfavorably such that much or all of the static sound attenuation is lost for the community below the flight path.

Many concepts relate to a system where the noise is guided into a sound-absorbing material, but by achieving this objective, a masking, reflecting or shielding is constructed that will not only diminish the noise but also cause a restriction to the incoming air which, accordingly, will result in a loss of total pressure at the engine face and thus a power loss to the engine. For instance, in the U.S. Pat. No. 2,869,670 to Hoffmann both an acoustic noise absorbing material is used in combination with a reflecting shielding intake passage, and thus, the aforementioned advantages as well as disadvantages are achieved. In the U.S. Pat. No. 3,194,487 to Tyler, deflecting means are used, which again provide a resistance to the intake air, and in the French patent to Planair No. 1,234,151 absorbent material is used on the stator vanes of the engine. Also, the British Pat. Nos. 226,203 and 44,206 by Maschinenfabrik Oerlikon and Poole, respectively, disclose certain improvements for reducing noise from the compressor or fan blades by providing suitable elements, such as special stator blades or screens adjacent to the blades with a shroud to minimize transmission of the noise or to smooth out pulsations in the air.

Thus, the prior art shows many contributions and improvements in the noise attenuation field. However, none of the prior mentioned improvements in the noise attenuation field have the uniqueness of the present invention.

The present invention provides noise attenuation without significantly restricting the flow of the working medium or fluid, flow of air in the case of aircraft engines, and with a minimum of pressure drop across the device. Even with an unsophisticated execution of the present invention, the sound attenuating apparatus suffers an insignificant performance loss. Applied to aircraft engines proper execution of the present invention can offset this insignificant loss and may even improve the overall operation of the aircraft engine while retaining its full sound attenuation capability.

SUMMARY OF THE INVENTION

Noise, defined as unwanted sound, consists of pressure fluctuations of random or periodic frequency and amplitude propagating from the noise source as waves through the medium surrounding the noise source with a velocity characteristic for the particular medium, said velocity being termed the velocity of sound. Frequency of sound f , velocity of sound c and wavelength λ are related according to $\lambda = c/f$. Audible sound in air thus has wavelengths from 2 centimeters to 20 meters; a sound in the frequency region of 3000 cycles

per second, where the human ear is most sensitive has wavelengths of the order of 10 centimeters.

Noise propagating in air or liquid, is subjected to all the well-known phenomena of wave mechanics, such as reflection, absorption and interference.

By the present invention there is provided a device which makes use of one, several or all of these phenomena, as required to attain the type and degree of noise attenuation considered best for the particular application as set forth herein.

Aircraft gas turbine engines traditionally originate noise from three distinct sources: the primary jet leaving the tailpipe at high velocity, noise generated by the compressor and/or fan leaving the engine through the exhaust duct and noise generated by the compressor and/or fan emanating from the air inlet. The introduction of the high bypass ratio turbofan engine of large power has reduced the community annoyance by primary jet noise but, in spite of great design advances, little if any relief can be expected from the noise generated by the large diameter highly loaded fan blades with supersonic tip velocities.

The vast increase in aircraft movements over airport communities with ever increasing population densities subjects more and more people to the annoying and health endangering noise hazard on one hand and requires spreading of aircraft operations around the clock and ever increasing use of fixed ILS glidepaths during the approach with no noise abating options open to the pilot on the other hand.

The present invention has as its first objective the attenuation and/or suppression of the fan generated noise emanating from the inlet of the aircraft gas turbine engine. It is in this application where this invention can make use of all the phenomena of wave mechanics listed above. The device according to the invention has, even in its simplest form, less of a detrimental effect on airplane performance for a given amount of attenuation than devices known to the prior art.

The device according to the present invention consists of a number of baffles or blades arranged on a supporting body which is mounted on a support within a duct in front of the noise source by means which allow it to rotate freely with a minimum of friction about an axis coincident with the axis of the duct. In its simplest form the device has blades with a twist linearly proportional to the radius of the blade station. In operation the blades of the device with their body of attachment are set into rotary motion by the inflowing air.

In this elementary execution the only work performed by the incoming air is overcoming the friction of the means of mounting which is insignificant and overcoming the skin friction along the surface of the blades which is very small. Proper shaping of the leading and trailing edges of the blades to account for area ratio changes due to blade blockage which are otherwise symmetrical, avoids all turning of the air, thus does not affect the normal operation of the basic engine and creates a minimum velocity deficiency or wake behind the blades of the device, which, if significant and too closely spaced to the support, could become a noise generating mechanism in itself.

The amount of twist of the blades is selected to obtain a rotational speed of the free wheeling rotor which is optimum for the particular engine. In general the rotational speed will be selected as high as possible in order to obtain a high relative velocity of the incoming air relative to the rotating blades. Relative velocities in excess of the velocity of sound will effectively block the direct propagation of sound through the channels formed by the blades.

Number of blades and chord length of the blades is selected in combination with the blade pitch in such a fashion that all sound waves propagating forward are effectively intercepted and reflected, dispersed or absorbed. The intercepting and reflecting of the forward propagating sound waves is the basic means of sound suppression of this simplest form of execution of the present invention.

In addition, the device improves the operation of aircraft gas turbine engines under conditions of nonuniform inlet airflow velocities such as commonly occur due to aircraft pitching, yawing, sideslipping, crosswind or gusts. The improvement is caused by the capability of the rotating device to absorb energy from areas of high air inflow velocity and to impart this energy to the air in regions of low inflow velocity. The reduction in velocity profile distortion at the face of the basic engine resulting from this energy transfer capability of the invention can be utilized to improve engine surge margin and to reduce the length of the engine inlet for equal distortion, thus reducing the propulsion installation weight, and to orient the direction of the inlet to minimize cruise drag without limiting aircraft maneuvers, such as rotation or pullout.

While only a few examples have been given for attenuating the noises by the free rotating fan blades in rotary engines, it will be apparent to those skilled in the art that on the basis of the schematic drawings and the explanation given herein, various other sound or noise attenuating combinations can be developed.

The sound attenuating effect of the device can be enhanced by refurbishing the walls of the duct in the areas to which the reflected sound waves are directed with sound-absorbing absorbing linings. Similar linings can be applied to the means supporting the baffles and to the baffles themselves. Depending on the character of the noise source, that is its frequency spectrum, such sound-absorbing linings can be designed as selective or broadband absorber or any combination thereof. While such sound-absorbing linings are used in conventional devices, the effect of these linings applied to the inlet duct walls is less than optimum because too much noise can propagate forward without being affected by the lining. In the present invention, however, such direct propagation is more or less eliminated and the reflected sound waves strike the duct lining at a favorable incidence angle, thus enhancing its absorbing qualities.

Where pure tone components are a major contributing source to the noise, the present invention offers the option of spacing the baffles at the half wavelength of the annoying pure tone, thus making use of the interference phenomenon of wave mechanics which will cause mutual extinction of the original and reflected wave. Combinations of spacing and linings can be used to obtain broadband and selective suppression of noise.

It is characteristic of axial fans with small hub to tip ratios that the ability of the fan to do work on the air decreases towards the hub, resulting in a lower total pressure near the hub than near the tip. The prior art recognizes this characteristic and tries to counteract it by blade design and by adding additional fan stages in the hub region. The present invention has the capability of performing such a function or at least to assist this function by using an airfoil at the periphery which extracts work from the working medium and transfers this work to the working medium in the hub region by giving the airfoils of the baffles in this area compressor characteristics. The device according to the present invention, further disclosed as second embodiment hereinafter, can thus perform the double task of attenuating noise and of improving the total pressure profile after the first fan stage.

A single set of rotating baffles will suffice to provide the desired noise attenuating effect in many instances. However, there may arise occasions where a greater degree of attenuation warrants additional efforts. The present invention is uniquely suited for such applications. Rotating independently of any other components under the driving force of the working medium, the direction and speed of rotation being determined solely by the angle of the blades, the axial dimension and weight and performance penalty of the device all being small, it is perfectly feasible to install more than one such device in series. The individual devices in such a case can be identical or they can differ in pitch, direction of rotation and material. Properly spaced, their sound

attenuating effect will be at least additive, rather more if suitable lining is applied in the correct locations.

The present noise attenuating system is most ideally suited to block the propagation of sound in the upstream direction; that is, toward the inlet of a gas turbine engine, where sound and flow of the working medium are going in opposing directions. The system can also be used downstream of the noise source for attenuation of sound propagating towards the exit of the duct. Longer chords and multiple sets of the described free rotating fan can be used to obtain satisfactory attenuation under the more unfavorable conditions on the downstream side of the noise source.

Accordingly, it is one of the objects of this invention to provide a noise attenuating apparatus which will by its rotational speed prevent noise from passing and simultaneously improve the incoming airflow pattern for the next stage.

Another object of the present invention is to provide a noise attenuating apparatus for a turbine engine inlet where the incoming air drives the apparatus and the apparatus compresses the incoming air so that a regulated incoming airstream is presented to said noise propagating areas, thereby preventing increase of noise and improving engine performance, as well as subduing noise output.

Thus, a noise attenuating apparatus for rotating engines is presented which comprises a fan having a plurality of angularly arranged and radially mounted blades, wherein the fan, freely rotating about the axis of rotation, is mounted adjacent the engine noise propagating origin. In the preferred embodiment relating in particular to bypass turbine engines, the free rotating fan is mounted at the inlet in front of the first compressor stage fan assembly or arrangement. Each blade has an identical configuration whereby said blades when rotating are able to regulate the incoming air into a predetermined air pressure column. As a result, the incoming air will drive the outer portions of said blades and the incoming air is compressed by the inner portions of said blades, so that the airstream profile after passing said free rotating blades has a higher pressure at the center area. The next fan, being normally the bypass fan, will receive this pressure and at the exit thereof produce a substantial uniformly shaped pressure for the first stage of the engine.

Each said free rotating blade as viewed from the incoming air side, comprises from tip to root an outer portion, middle portion and inner portion. Starting from the tip the blade surface has a convex curvature which decreases toward the middle portion and thereafter increases to a concave curvature from the middle portion towards the root.

Besides the objects mentioned above, many other objects, advantages and features which are herein disclosed will become fully apparent when following the hereinafter detailed description in conjunction with the accompanying drawings, which illustrate and clarify the preferred embodiments of this invention.

THE DRAWINGS

FIG. 1 is a longitudinal cross section of the inlet portion of a bypass turbine engine with bypass fan and a first compressor stage. A free rotating shield of blades or baffles forming a fan is incorporated into the inlet area in front of the bypass fan.

FIG. 2 is a schematic sketch which shows the direction of the free rotating blades and the first compressor stage as well as the noise and noise-reflected waves.

FIG. 3 is an isometric illustration of the turbine engine inlet section shown in FIG. 1.

FIG. 4 is a schematic sectional view of a rotary engine having inlet and exhaust noise attenuating means.

FIG. 5 is a schematic sectional view of a rotary engine used for all types of fluids and wherein free rotating blades are used at the inlet or, upon rotation of the complete engine arrangement, outlet area.

FIG. 6 to 10 are illustrations which relate to the second preferred embodiment of this invention.

FIG. 6 is a side view of a free rotating blade.

FIG. 7 is a sectional view taken along the radius of the turbine front fan engine inlet portion.

FIG. 8, 9 and 10 are sectional perpendicular views taken along the lines 8-8, 9-9, and 10-10 from FIG. 6.

DESCRIPTION OF THE DRAWINGS

Referring to FIG. 1, a sectional view of the inlet portion of a rotational engine 20 having bypass duct 22 is illustrated. A first stage compressor 24 including bypass fan is mounted for rotation on axle 26 and is driven thereby. A free rotating fan 28 mounted for rotation independent of the axle 26 is positioned adjacent to the first stage compressor fan 24. The blades 30 of the free rotating fan 28 are positioned at an angle which is opposite the angle of the blades 31 of the first fan of the compressor 24. The free rotating fan 28 comprises the basic construction of the noise attenuating apparatus. However, in addition thereto is a layer of acoustic material 32 which is inserted and mounted in the inlet duct area or cowl interior 34 of the rotational engine 20 bypass duct 22. The free rotational fan 28 is positioned on an independent bearing and axle construction 38 which is supported within the cowl 34 by support means (not shown).

In FIG. 1 the blades of the free rotating fan 28 and the blades of the first fan in the first stage compressor 24 are positioned in an opposed angular relationship which produces a result that is schematically explained in FIG. 2. The sound waves 40 or noise that originates mainly at the edge portions of the blades 31, propagates in various directions and as illustrated in FIG. 2 the direction towards the inlet opening 34 is to be obstructed in order to attenuate noise output. As shown by the arrows in FIG. 2, the blades 30 of the free rotating fan 28 rotate in an opposite direction and have their blades positioned at an angle which is perpendicular to the propagating noise traveling towards the exit area. When the rotation speed of the rotating fan blades 28 is faster than the speed of the sound waves or the noise, it is practically impossible for the noise to find an exit through the fast rotating fan blades 30. As illustrated in the diagram in FIG. 2 the noise waves are reflected in the direction illustrated by the pattern of interrupted lines 44. Thus, the noise experiences a closed shield and reflects scatters, and diffuses in various directions. Also, it can be seen that no restriction is experienced to the incoming air. It will be noted in FIG. 1 and 3 that the tip portion of the blades 30 passes the acoustic material 32 at a slight distance 46. This gap or distance 46 forms a small exit, and any sound waves that are propagated in this direction will thus be absorbed to a certain extent by the acoustic material 32 mounted inside the interior cowl 34. As mentioned herein, the noise attenuating apparatus finds its basic application in rotary engines and in particular to turbine engines used for aircraft or the like.

In FIG. 4 and FIG. 5 two additional applications are shown where, for instance, in the schematic sectional view of the jet engine 50 in FIG. 4, a free rotational fan 52 and 54 are used. As shown, the fan 52 is positioned at the inlet duct section in front of the first compressor stage 56 of the engine 50 and the second rotational fan 54 is mounted for free rotation at the exhaust compressor stage 58 of the engine 50. Noise that is propagated by the first compressor stage 56 and by the exhaust compressor stage 58 is prevented by the free rotational noise attenuating fan system 52 and 54 respectively from leaving the engine inlet or exhaust openings.

In reference to FIG. 5 it should be noted that the engine assembly 60 herein illustrated is basically used for propulsion power through the 14 medium of a fluid. For instance, this type of rotational propulsion engine 60 is in particular suitable for for marine vessels or the like. Also, here noises are originated by the fast rotating screw and a free type rotating fan for noise or sound attenuation might be desirable. The free rotating fan 62 is used as a free rotating inlet noise attenuating shield. However, upon rotation of the engine assembly 60 about the axis 64, the inlet 66 could be reversed to an outlet. It

can be visualized that a typical noise attenuating system could be applied for submarines as an antisound detection system.

In reference to FIG. 7 there is illustrated a portion of an inlet bypass duct of a turbofan engine 80. The first stage compressor assembly 82, including bypass fan, is provided with blades 84. A free rotating fan arrangement 86 having a plurality of blades 88 is mounted in front of the blades 84. The free rotating fan 86 is mounted in coincidence with the axis of rotation of the engine 80. The inlet of this engine 80 is also provided with an inserted sheet of acoustic material 90, which is approximately positioned adjacent the tips 92 of the rotating blades 88.

The principle of operation of the absorbing or sound attenuating apparatus is basically the same as the one described herein before, with the exception of the free rotating blades 88 and its configuration providing additional advantageous results. As explained, the majority of the most objectionable noises originate from the compressor blade tip edge and support regions in the rotating parts of the engine, and most of the noise is caused by speeds, pressures and other parameters. Irregular inflow of air will cause disturbing variations at various components in the system and an irregular air intake would cause an irregular sound wave pattern which will have its various frequencies and harmonics. It can thus be seen, besides the fact that a regular or even inflow of air would cause an improved engine performance, a more constant noise wave pattern would also be achieved. Thus, in other words, the variations of intake air at different angles of attack will provoke higher and more irritating and disturbing sound effects. By changing the blade configuration (as illustrated in FIG. 6 and its cross-sectional views in FIGS. 8, 9 and 10), it will be possible to shape the irregular incoming air into a constant even flow column at the first stage compressor arrangement 82. As shown in FIG. 8, the section has at its tip portion 92 a convex contour 94 so that the incoming air is met at the outer circumferential blade portion of the free rotating fan by a fan profile which intends to drive the fan, while simultaneously spreading the air towards the center portion 96 of the rotating fan and there being compressed through the rotation. A sectional view of the profile 96 of the fan blade 88 as illustrated in FIG. 9 will have a configuration that resembles the profile of blades 30 of the free rotating fan described in the prior FIGS. 1-5.

Thus, a noise attenuating apparatus for a rotating engine is presented which comprises a plurality of angularly arranged and radially mounted blades. The blades are mounted for free rotation about an axis which is incident with the rotational axis of the rotating engine. In addition, a sound or noise absorbing material has been mounted at the inlet cowl for subduing and absorbing additional spreading noises which may escape via the open exit area between the free rotating tip and the cowl surface. To further attenuate and subdue the noise propagated by the engine, and to enhance engine performance to thereby offset the small performance losses caused by the presence of the free rotating fan, the free rotating blades have been shaped in a twisted configuration whereby the incoming air is regulated into a desired effective air pressure column for the first compressor stage. As a result, the incoming air will drive the outer portions of the free rotating blades and be spread toward the center of the free rotating blades so that the incoming air is at that point compressed by the inner portions of the blades. As disclosed, the blade surface starts from the tip as a convex curvature which slowly decreases towards a flatter or straight surface at the middle portion and thereafter successively increases to a concave curvature, ending at the root section.

Comparing the blade configuration in reference to FIGS. 7-10, the blade 88 surface 94 starts from the tip 92 with a convex curvature which slowly decreases to a flat surface at the approximate point intersected by the phantom line 100. The distance *a* or outer portion of blade 88 is in length substantially equal to the bypass duct exit 102. The inner portion of blade 88 is indicated by the distance *b* which is

substantially equal to the length measured from line 100 to the root of blade 88. The flat or substantially straight surface 96 corresponds to the middle portion shown at the 100 intersection line.

While only a few examples have been give for attenuating the noises by the free rotating fan blades in rotary engines, it will be apparent to those skilled in the art that on the basis of the schematic drawings and the explanation given herein, various other sound or noise attenuating combinations can be developed. And it should be also understood that the specific embodiments herein illustrated and described are not limited thereto, but may be used in other ways without departure from the spirit of the invention as defined by the following claims.

We claim:

1. A noise attenuating apparatus for rotating engines comprising:
 - a. a plurality of angularly arranged and radially positioned blades;
 - b. said blades mounted for free rotation about said engine axis of rotation in said engine fluid inlet and exit passageways in front and aft of said engine, respectively.
2. A noise attenuating apparatus for rotating engines as claimed in claim 1 wherein said plurality of blades form a fan assembly structure.
3. A noise attenuating apparatus for rotating engines as claimed in claim 2 wherein said rotating engine comprises a bypass turbine engine with an inlet duct and wherein said fan assembly structure is mounted for free rotation therein.
4. A noise attenuating apparatus as claimed in claim 3 wherein said plurality of angularly arranged and radially mounted blades in said fan assembly structure comprises blades having each a twisted configuration for regulating said inlet air towards said engine.

5. A noise attenuating apparatus as claimed in claim 4 wherein each said twisted blade comprises a tip and a root, and from said tip to said root, an outer portion, a middle portion and an inner portion.

6 A noise attenuating apparatus as claimed in claim 5 wherein said twisted blade configuration for each said blade from said tip to said root comprises a blade surface wherein said outer portion is provided with a convex contour which gradually decreases to a flat surface at said middle portion and which surface gradually increases to a concave contour from said middle portion via via said inner portion towards said root.

7. A noise attenuating apparatus as claimed in claim 6 wherein said fan assembly structure upon rotation covers a circular shielding area wherein an outer concentric ring of said circular area corresponds to said blades outer portion positioned parallel to said bypass fan duct exit opening and wherein an inner concentric ring of said circular area corresponds to said blades inner portion and is positioned parallel to said engine first stage inlet area.

8 A noise attenuating apparatus as claimed in claim 7 wherein said blade configuration upon rotation of said fan assembly structure is adapted to be driven by said inlet air at said outer portions and wherein said inlet air will be compressed at said inner portions of said fan assembly structure so that a predetermined air pressure column is produced by said free rotating fan structure.

9. A noise attenuating apparatus as claimed in claim 8 wherein said inlet duct of said turbine bypass engine and said blades of said free rotating fan structure are covered by a material having sound absorbing characteristics.

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