US005141400A

United States Patent [19]

Murphy et al.

[11] **Patent Number: 5,141,400**

[45] **Date of Patent: Aug. 25, 1992**

[54] **WIDE CHORD FAN BLADE**

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[21] Appl. No.: **645,774**

[22] Filed: **Jan. 25, 1991**

[51] **Int. Cl.**[5] **B63H 1/20**; B63H 1/26

[52] **U.S. Cl.** .... **416/204 A**; 416/219 R; 416/229 R; 416/241 A; 416/229 A; 416/248

[58] **Field of Search** .... 416/204 R, 204 A, 219 R, 416/229 R, 229 A, 241 R, 223 R, 224, 248, 241 A; 29/889.7, 889.71, 527.1, 527.4; 156/263, 267, 309.6, 307.3

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,600,103	8/1971	Gray et al.	416/224
3,637,325	1/1972	Morley	416/230
3,649,425	3/1972	Alexander	416/229 A
3,679,324	7/1972	Stargardter	416/229
3,699,623	10/1972	Kreider	29/156.8
4,029,838	6/1977	Chamis et al.	428/301
4,416,949	11/1983	Gabellieri	428/461
4,594,761	6/1986	Murphy et al.	29/156.8
5,018,271	5/1991	Bailey et al.	416/219 R
5,049,036	9/1991	Bailey et al.	29/889.71

OTHER PUBLICATIONS

Wide Chord Fan Club; 23-29, May, 1990.

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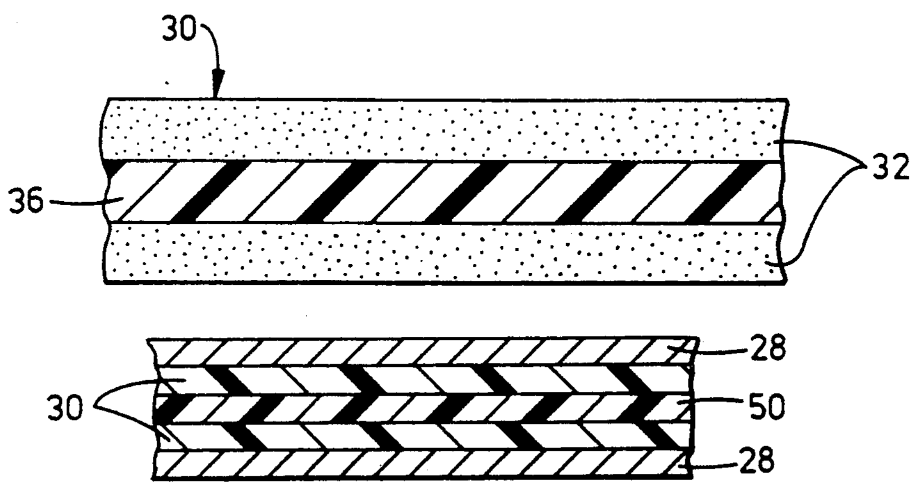
[57] **ABSTRACT**

A laminated airfoil for use in a high bypass engine. The airfoil preferably has a large tip chord and is comprised of alternating layers of thin metallic foil and elastomeric layers. The exterior surfaces of the airfoil are comprised of a thin, metallic foil. The airfoil also has a metal sheath secured to the leading edge. High strength metal members extend through the dovetail root sections.

31 Claims, 2 Drawing Sheets



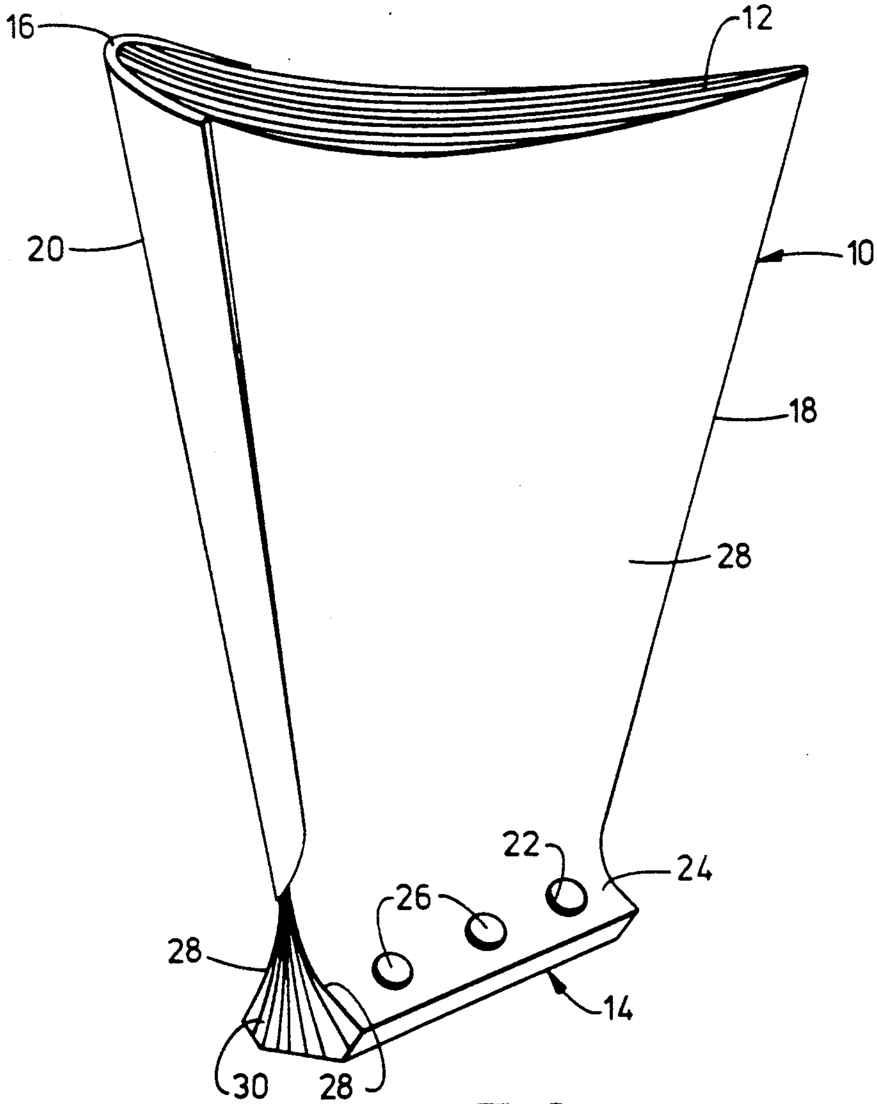


FIG. 1

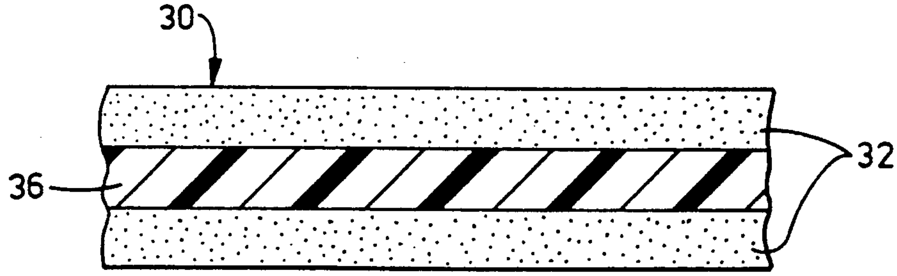


FIG. 2

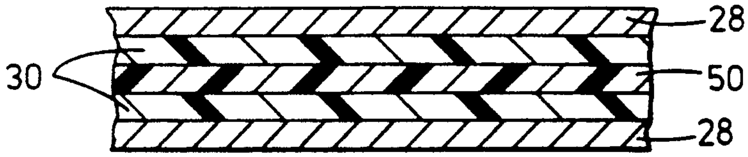


FIG. 3

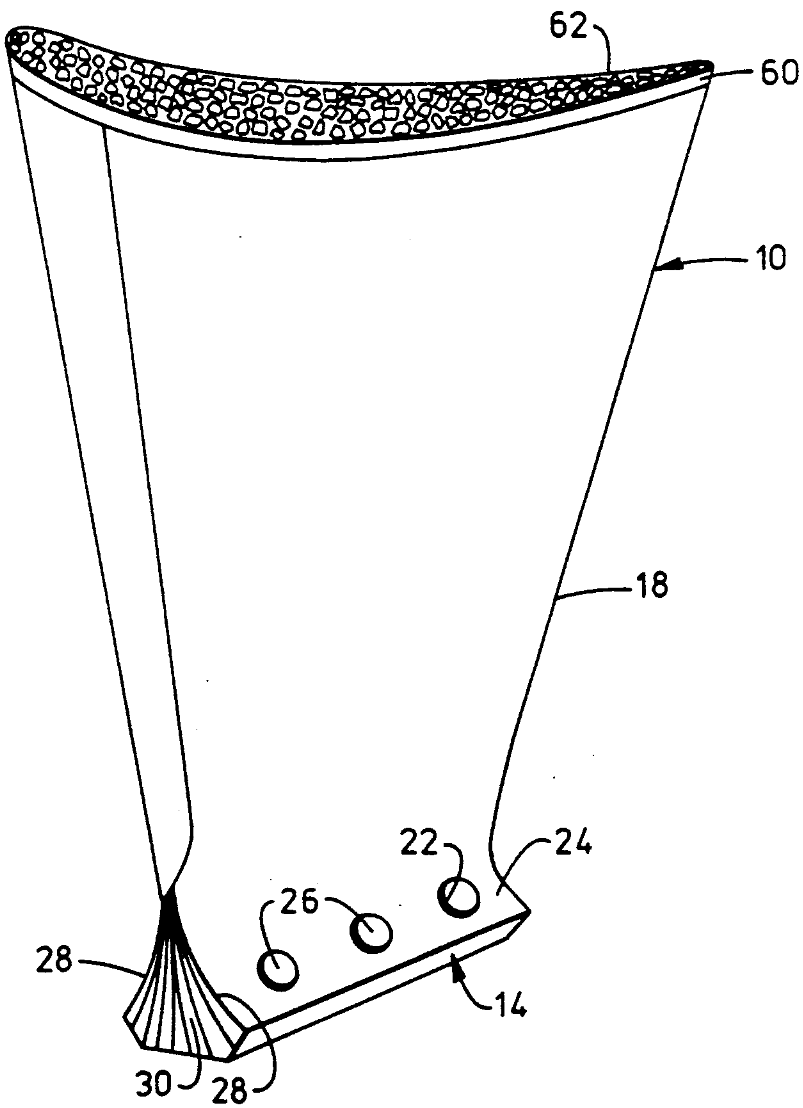


FIG. 4

WIDE CHORD FAN BLADE

BACKGROUND OF THE INVENTION

Aircraft and aircraft engine design have always strived for reduced weight and greater efficiency. Other factors affecting aircraft and engine design involve cost and size, including the maintenance of the aircraft and the engines. With increased emphasis in these areas, future aircraft are growing in size, requiring either more thrust from the engines or additional engines. Reduced maintenance costs and initial costs can be achieved by enlarging the engines, increasing the thrust developed by the engines rather than by increasing the number of engines on a particular aircraft. However, as the engines grow larger, weight reduction becomes paramount as all the engine components are required to grow.

The next generation of commercial high thrust engines will have fan diameters ranging in size from 106 inches to 124 inches. The increased fan diameters will require longer blades. The longer blades will have wider chords for increased efficiency. The chord, which is the axial straight line dimension between the trailing edge and the leading edge of the airfoil, will grow with the increased blade size. Typical fan blades currently have tip chords of about 8 to 12 inches, while the wide chord fan blades for the larger engines will have tip chords in the range of about 20 to 28 inches. The wider chord blades offer the increased efficiency because they have greater stability margins and move the air more efficiently across the blade face due to their longer chords. The increased stability allows the blade to be manufactured without a mid-span shroud, which on current Titanium blades causes a decrease in blade efficiency. Increased blade efficiency is important in high bypass turbine engines because about 75% to 80% of the air bypasses the core engine combustor and is used to provide direct thrust.

The majority of the current fan blades in turbofan engines are solid titanium construction. Another fan blade construction utilizes titanium skin over a titanium honeycomb core. The manufacture of a solid titanium wide chord fan blade is prohibitive because of the initial cost of the materials and the ultimate weight of the blade upon completion. Thus, a solid fan blade for a larger engine would probably be more of a standard chorded blade with a mid span shroud.

A proposed solution to the problem of weight and cost for blades in larger engines is an all-composite wide chord fan blade. A large engine having all-composite wide chord fan blades has a projected weight savings of about 800 pounds over a large engine having standard chorded fan blades. The all-composite wide chord fan blade would also display a somewhat smaller, but nevertheless substantial, weight savings over titanium skin/titanium honeycomb blades.

The concept of all-composite blades has been attempted in the past. However, these blades have never been successfully implemented for several reasons. One early program developed erosion problems due to the poor erosion characteristics of the applied coating and to the lack of a metallic leading edge. The coating could not withstand rain droplet impacts without sustaining damage. Once the exterior coating was damaged, exposing the underlying laminated composite structure, the underlying composite structure was subjected to water damage from water ingestion and further impacts.

These conditions caused severe delaminations in the blades and led to blade failure in relatively short times.

Another composite fan blade program was discontinued when the blades could not withstand small bird impacts (bird size of about 2.0-4.0 ounces) without delaminations under the leading edge. Although the blade could pass FAA requirements at the time, maintainability of the blades was projected to be a problem because these delaminations were "invisible", that is undetectable by visual inspection, and could propagate, causing potentially serious blade failures. It was believed that engines would always see impacts in this size range that would not be detected, so that the incident would go unnoticed, even though internal damage would have occurred to the blade.

Thus, there exists a need to provide a composite wide chord fan blade which can withstand typical impacts and operating conditions experienced by modern turbofan engines. The composite blade should offer stiffness and light weight, which are important as engine size and thrust continue to increase. However, the composite fan blade must be capable of equivalent or better performance at all operating conditions, including impact, of current metallic fan blades. Maintenance requirements should be comparable to current fan blades, and desirably should be reduced.

SUMMARY OF THE INVENTION

The present invention is a damped, energy absorbing, laminated airfoil. The airfoil, of wide chord configuration, has a tip portion, a dovetail root section, the dovetail root section having flank surfaces, a leading edge extending from the tip portion to the root section, and a trailing edge oppositely disposed to the leading edge and extending from the tip portion to the root section. The tip chord is larger than the conventional chords of current engines, being at least about 20 inches, and as large as 28 inches. The airfoil is comprised of alternating layers of thin metallic foil and elastomeric layers, thereby forming a laminated composite airfoil. The metallic foil forms the first and the last layers of the laminated structure, so that the outer surfaces of the airfoil are made from metallic foil. The alternating elastomeric layers provide the means of bonding the metallic foil layers, while providing inherent energy absorbing characteristics to the structure. At least one hole or aperture, and preferably a plurality of holes or apertures, are drilled into each dovetail flank surface extending at least partially through of the dovetail. A high strength metal member is then disposed through each of the dovetail root section apertures across the alternating layers and secured in place by adhesive bonding, thereby further securing the layers and providing additional strength. The adhesive bonding agent is preferably the same material used to secure the metallic foil layers together. A metal sheath is secured to the leading edge of the airfoil by adhesive bonding. In a preferred embodiment, the high strength metal member is a titanium-base pin, while the metallic foil in the airfoil is a titanium alloy foil or a stainless steel alloy foil having a uniform thickness of about 0.005 to about 0.015 inches. The leading edge sheath is a nickel alloy foil having a thickness of about 0.008 to about 0.012 inches on each of the edges and increasing to a thickness of about 0.040 to about 0.060 inches at the airfoil leading edge. Alternatively, the leading edge sheath is a stainless steel alloy or a titanium alloy foil having a uniform thickness of about 0.008 to about 0.015 inches.

The laminated airfoil is formed by preshaping the metallic foil. This may be conveniently done by superplastic forming, which is accomplished under stress at elevated temperature. The preshaped metallic foil having a thickness of from 0.005–0.015 inches is then trimmed to a predetermined size by conventional cutting or trimming techniques. The metallic foil and a heat flowable elastomeric film are then assembled into an assembly of alternating layers of each material and placed into a die. The die has a cavity which accepts the foil assembly and may also accept a metal leading edge sheath. The die cavity is further designed so that the final part produced will be a net shape or near net shape airfoil. The assembly, when placed into the die cavity, has a metallic foil first layer and last layer, so that the outer surfaces of final part are metal. After placing the assembly into the die, sufficient heat and pressure are applied to the ply assembly to cause the elastomeric film to flow by conventionally die pressing the assembly. This operation causes the elastomeric film to simultaneously bond to the alternating metal layers and to cure.

After removal of the cured airfoil from the die, subsequent finishing operations, such as drilling of dovetail root flank holes and insertion of high strength metal members coated with adhesive, final machining of the dovetail root section, final trimming, if necessary, and attachment of a leading edge sheaths, if not accomplished during die pressing, may be performed.

The present invention permits the use of alternating plies of materials to form airfoils, such as fan blades, and in particularly, wide chord fan blades, as well as compressor vanes. The advantages of airfoils formed in this manner is that they are lighter in weight than conventional airfoils, but retain strength and toughness required for such demanding applications. The reduced weight becomes more important in jet engine design as engines become larger and more powerful, requiring ever larger fans and vanes.

Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention itself, however, both as to its organization and its method of practice, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a perspective view of a fan blade airfoil having a dovetail root section and a metal sheath leading edge.

FIG. **2** is a cross section of an elastomeric layer in which a polyurethane film is coated on each side with an adhesive layer or alternatively, a combined elastomeric adhesive.

FIG. **3** is a partial cross-section of a laminated blade having alternating layers of metallic foil, elastomeric material and polymeric composite ply.

FIG. **4** is a perspective view of a fan blade airfoil having a dovetail root, a metal tip cap, a metal leading edge and an abrasive tip applied to the metal tip cap.

DETAILED DESCRIPTION OF THE INVENTION

Pursuant to the present invention, a laminated airfoil having alternating layers of a metallic foil and lightweight film, with the metallic foil forming the first layer and the last layer so that the outer surfaces of the airfoil are metal is provided.

The present invention also encompasses methods for forming laminated airfoils from metallic foils and energy-absorbing elastomeric films or polymeric composite materials and combinations thereof. The energy-absorbing elastomeric films provide impact resistance and vibration damping to the composite blades, which is an important feature in preventing blade damage due to foreign object ingestion and fatigue.

Referring now to FIG. **1**, a perspective view of the laminated airfoil in the form of the wide chord fan blade **10** is shown. The fan blade has a tip portion **12**, dovetail root section **14**, a leading edge **16** extending from the tip portion **12** to the root section **14**, a trailing edge **18** oppositely disposed to the leading edge **16** and extending from the tip portion **12** to the root section **14**. The fan blade has a metal sheath **20** attached to the leading edge **16**, apertures **22** extending through the flank surfaces **24** of the dovetail root section **14** and a high strength metal member **26** disposed through each dovetail root section aperture **22**. The metal sheath **20** attached to the leading edge helps provide the fan blade with additional impact resistance, erosion resistance and improved resistance of the composite structure to delamination. The high strength metal member **26** improves delamination resistance and provides a wear resistant surface for the dovetail, which has some restricted movement in the dovetail slot of the rotor or fan disk. The metal member **26** also improves the compressive strength of the dovetail flank by becoming the primary load bearing portion of the composite fan blade. This feature of the metal member is significant since forces in the dovetail region are high during engine operation. The stresses in the fan blade due to rotation have components radially outward as well as axial. These stresses are sufficient to cause a fan blade without a stress-bearing metal member to flow outwardly and deform, resulting in potential blade separation from the disk or delamination of the composite. The fan blade is composed of alternating layers of metallic foil **28** and energy-absorbing elastomeric layers **30** forming the laminated composite fan blade **10** of FIG. **1**. The metallic foil **28** forms the first and last layers of the alternating layers so that the outside surface of the fan blade **10** is metal.

The metallic foil may be any metallic foil suitable for use in aircraft engine applications. It is preferred that the metallic foil be selected from a group consisting of titanium alloys, nickel-base superalloys or stainless steels. It is preferred that the metallic foil be produced by superplastic forming. Superplastic forming is well known in the art. The superplastic forming method subjects certain metals which exhibit superplastic behavior to a low strain rate at high temperatures. Under these conditions, the metals can undergo unusually large amounts of plastic deformation, so that thin metallic films may be formed.

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