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(54) **GEARED TURBOFAN WITH FAN BLADES DESIGNED TO ACHIEVE LAMINAR FLOW**

(71) Applicant: **United Technologies Corporation**, Hartford, CT (US)

(72) Inventors: **Edwin M. Worth**, Northville, MI (US); **Thomas G. Tillman**, West Hartford, CT (US); **Frederick M. Schwarz**, Glastonbury, CT (US)

(73) Assignee: **United Technologies Corporation**, Harford, CT (US)

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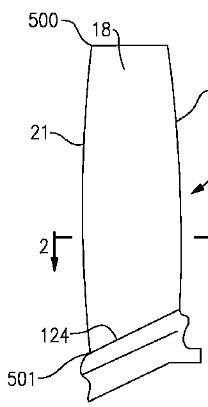
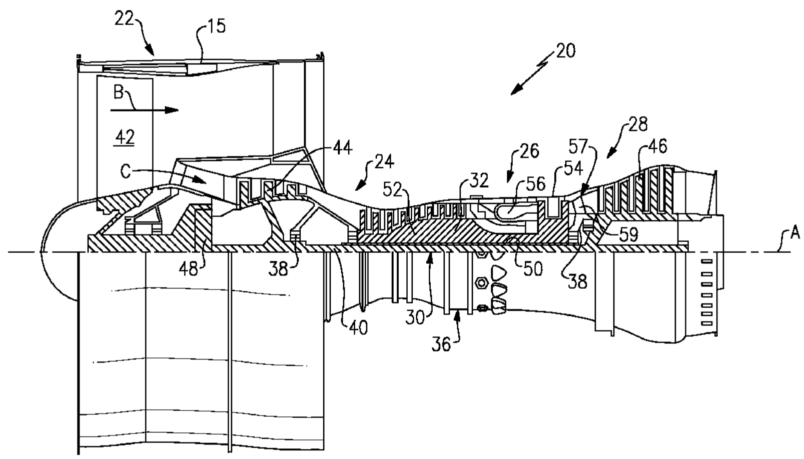
(57) **ABSTRACT**

A fan blade comprises a main body having an airfoil extending between a leading edge and a trailing edge. The fan blade has at least one of a channel closed by a cover, and an end cap covering at least one of the leading and trailing edges. At least one of a cover and an end cap has a pair of opposed ends. A step is defined extending from at least one of a suction wall and a pressure wall of the airfoil, to an outer surface of the one of a cover and an end cap at one of the opposed ends, and the step being less than or equal to about 0.010 inch (0.0254 centimeter) in dimension.





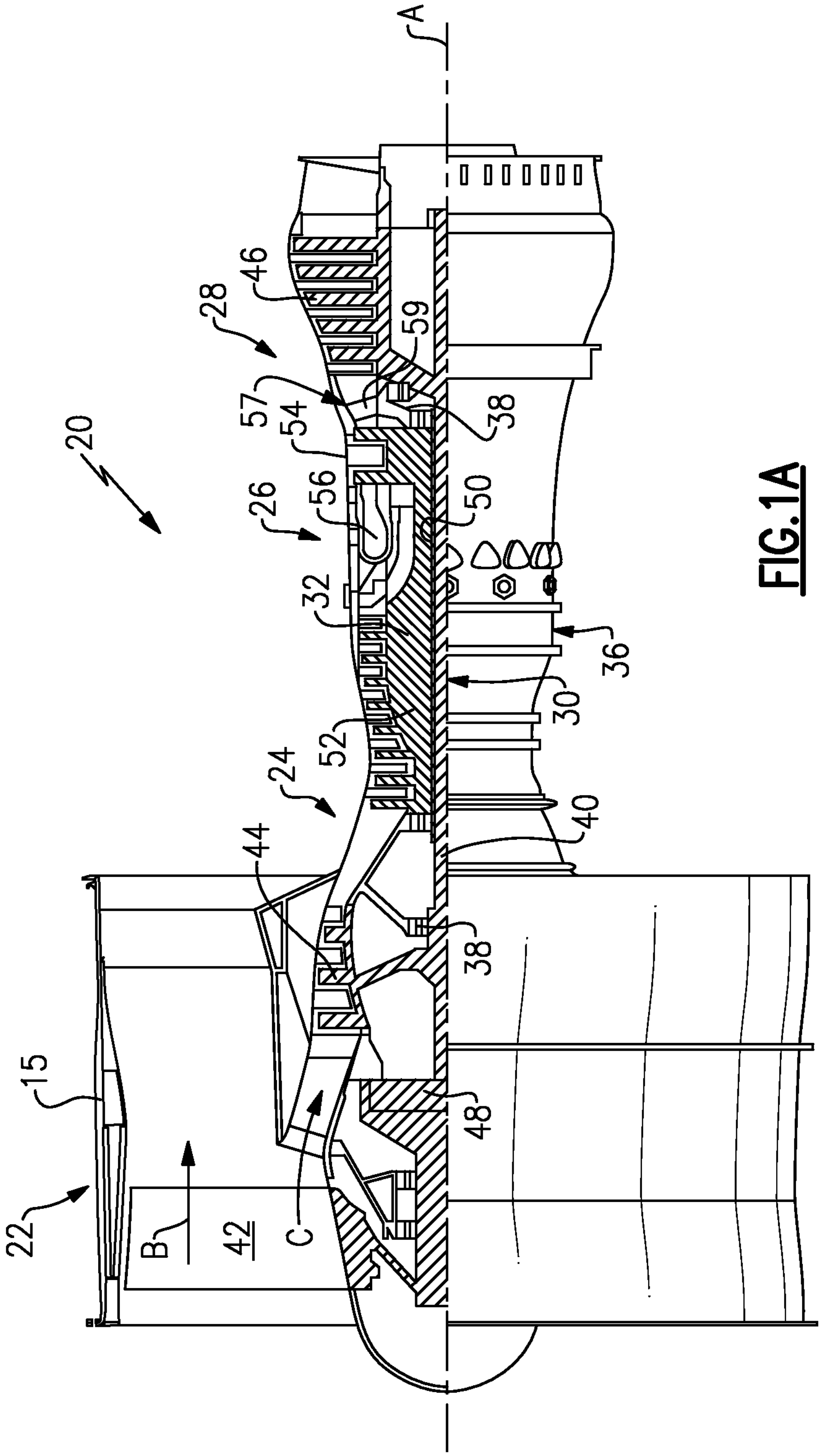


FIG.1A

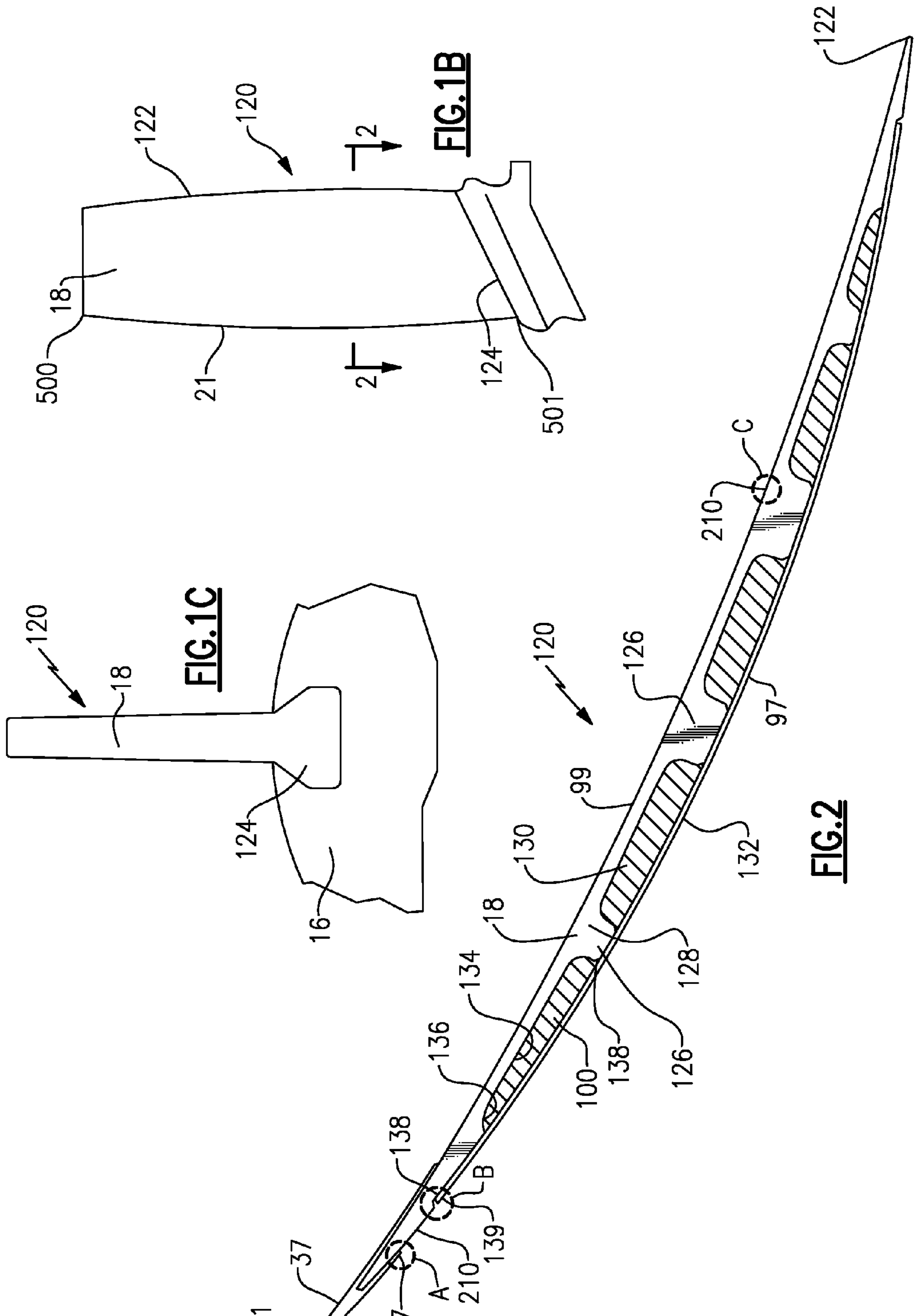


FIG.1B

FIG.1C

FIG.2

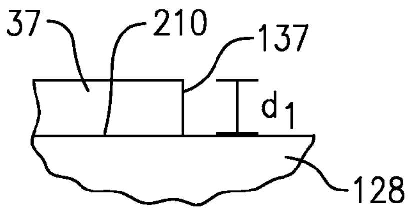


FIG.3A

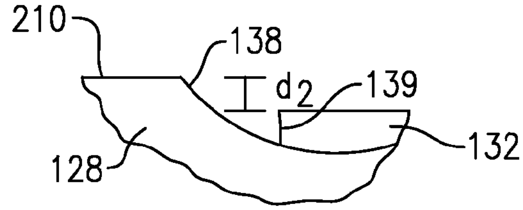


FIG.3BA

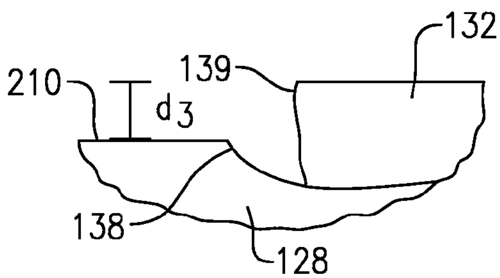


FIG.3BB

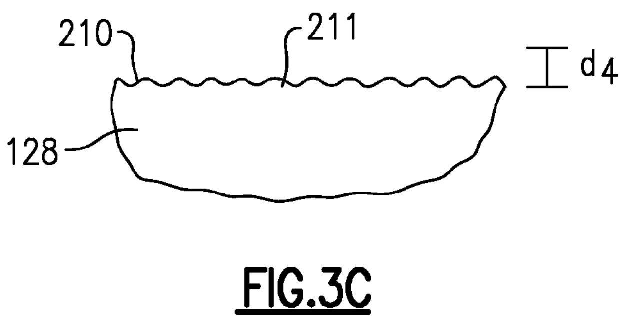


FIG.3C

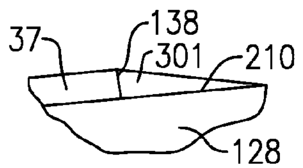


FIG.4A

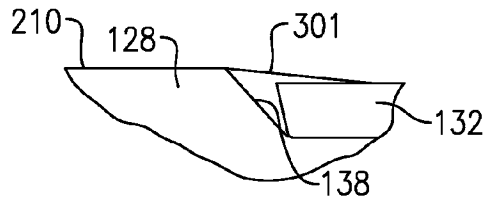


FIG.4BA

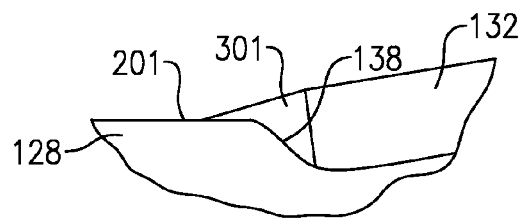


FIG.4BB

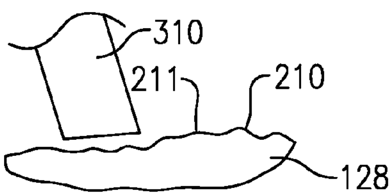


FIG.4C

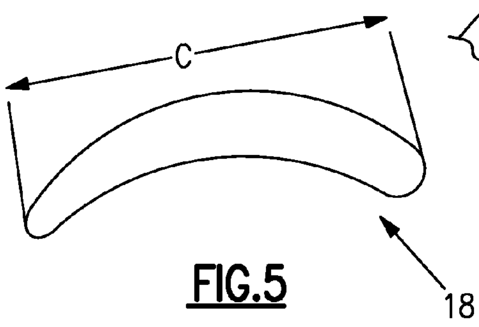


FIG.5

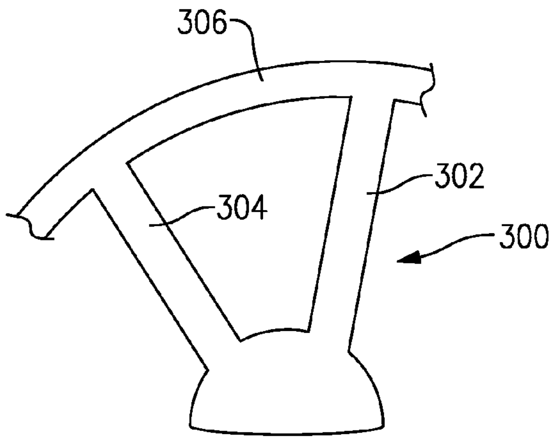


FIG.6

GEARED TURBOFAN WITH FAN BLADES DESIGNED TO ACHIEVE LAMINAR FLOW

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application 61/727,786 filed Nov. 19, 2012, and U.S. Provisional Application 61/884,295, filed Sep. 30, 2013.

BACKGROUND

[0002] Gas turbine engines may be provided with a fan for delivering air to a compressor section and into a bypass section. From the compressor section, the air is compressed and delivered into a combustion section. The combustion section mixes fuel with the air and combusts the combination. Products of the combustion pass downstream over turbine rotors which are driven to rotate and, in turn, drive the compressor and the fan.

[0003] Historically, a single turbine rotor may have driven a lower pressure compressor and a fan at the same speed. More recently, a gear reduction has been proposed such as intermediate the lower pressure compressor and the fan, such that the fan can rotate at lower speeds relative to the lower pressure compressor. With this change, the diameter of the fan has increased dramatically and its speed has decreased.

[0004] As the fan blade diameter increases, its weight be expected to increase. To address this increase, hollow fan blades have been developed. One type of hollow fan blade has at least one channel and an outer cover attached over a main fan blade body to contain the channel. In addition, an end cap may be placed on the fan body.

[0005] The interface of the ends of the end cap and the cover skin, relative to the main fan body, provides an interface that may be in the form of a step.

SUMMARY

[0006] In a featured embodiment, a fan blade comprises a main body having an airfoil extending between a leading edge and a trailing edge. The fan blade has at least one of a channel closed by a cover, and an end cap covering at least one of the leading and trailing edges. At least one of a cover and an end cap has a pair of opposed ends. A step is defined extending from at least one of a suction wall and a pressure wall of the airfoil, to an outer surface of the one of a cover and an end cap at one of the opposed ends, and the step being less than or equal to about 0.010 inch (0.0254 centimeter) in dimension.

[0007] In another embodiment according to the previous embodiment, the main body includes both the cover and the end cap, the end cap at the leading edge, wherein the steps are defined at each of the opposed ends of the cover on one of the suction wall and the pressure wall, and wherein the steps are defined at each of the opposed ends of the end cap on both the suction and pressure walls, and wherein all of the step dimensions are less than or equal to about 0.010 inch (0.0254 centimeter).

[0008] In another embodiment according to any of the previous embodiments, an outer surface of the fan blade has a surface roughness. The surface roughness has a root means square value of less than about 60×10^{-6} inch on at least a portion of a radial length of the main body.

[0009] In another embodiment according to any of the previous embodiments, a filler material is provided between each of the opposed ends of the end caps and cover and the main body, with the filler material reducing the size of the steps, and the filler material being part of the cover and the end cap for purposes of measuring the dimensions of the steps.

[0010] In another embodiment according to any of the previous embodiments, an outer surface of the fan blade has a surface roughness. The surface roughness has a root means square value of less than about 60×10^{-6} inch on at least a portion of a radial length of the main body.

[0011] In another embodiment according to any of the previous embodiments, a filler material is provided between the end of the one of an end cap and a cover and the main body, with the filler material reducing the size of the steps, and the filler material being part of the cover and the end cap for purposes of measuring the dimensions of the steps.

[0012] In another embodiment according to any of the previous embodiments, the fan blade has a chord length. A ratio of the step dimension to the chord length is less than or equal to about 0.001.

[0013] In another embodiment according to any of the previous embodiments, the step occurs over at least from 20% of a blade span, measured from a platform to a radially outer tip of the airfoil.

[0014] In another embodiment according to any of the previous embodiments, the fan blade is designed to rotate with a fan tip corrected speed below 1225 ft/second (368 meters/second) at bucket cruise.

[0015] In another embodiment according to any of the previous embodiments, a shroud connects the fan blade to an adjacent fan blade.

[0016] In another embodiment according to any of the previous embodiments, at least one of the main body, cover, and cap is formed of aluminum or an aluminum alloy.

[0017] In another embodiment according to any of the previous embodiments, at least one of the main body, cover, and cap is formed of titanium or a titanium alloy.

[0018] In another embodiment according to any of the previous embodiments, at least one of the main body, cover, and cap is formed of composite.

[0019] In another embodiment according to any of the previous embodiments, at least one of the main body is formed of composite, a metal, or an alloy, and wherein the cover or the cap is formed of titanium or a titanium alloy.

[0020] In another featured embodiment, a gas turbine engine comprises a fan drive turbine driving a fan rotor having a plurality of blades through a gear reduction. The blades include a main body having an airfoil extending between a leading edge, and a trailing edge and the blades having a chord length. The fan blade has at least one of a channel closed by a cover and an end cap covering at least one of the leading and trailing edges. At least one of a cover and an end cap has a pair of opposed ends. A step is defined extending from at least one of a suction wall and a pressure wall of the airfoil, to an outer surface of the one of a cover and an end cap at one of the opposed ends. A ratio of the step dimension to the chord length is less than or equal to about 0.001.

[0021] In another embodiment according to the previous embodiment, the main body includes both the cover and the end cap, the end cap at the leading edge, wherein the steps are defined at each of the opposed ends of the cover on one of the suction wall and the pressure wall. The steps are defined at each of the opposed ends of the end cap on both the suction and pressure walls. All of the step dimensions have a ratio of less than or equal to about 0.001.

[0022] In another embodiment according to any of the previous embodiments, a filler material is provided between each of the opposed ends of the end caps and cover and the main body. The filler material reduces the size of the step dimensions, and is part of the cover and the end cap.

[0023] In another embodiment according to any of the previous embodiments, an outer surface of the fan blade has a surface roughness. The surface roughness has a root means square value of less than about 60×10^{-6} inch on at least a portion of a radial length of the main body.

[0024] In another embodiment according to any of the previous embodiments, a filler material is provided between the end of the one of an end cap and a cover and the main body. The filler material reduces the size of the step dimensions, and is part of the one of the cover and the end cap.

[0025] In another embodiment according to any of the previous embodiments, the step occurs over at least from 20% of a blade span, measured from the platform to a radially outer tip of the airfoil.

[0026] In another embodiment according to any of the previous embodiments, the fan blade is designed to rotate with a fan tip corrected speed below 1225 ft/second (368 meters/second) at bucket cruise.

[0027] In another embodiment according to any of the previous embodiments, a shroud connects adjacent ones of the blades.

[0028] In another featured embodiment, a method of manufacturing a fan blade comprising the steps of providing a main body extending between a leading edge and a trailing edge, and having a suction wall and a pressure wall. The main body has at least one of a channel enclosed by a cover, and an end cap covering at least one of the leading and trailing edges. At least one of a cover and an end cap is assembled to the main body, and defines a step between at least one of the suction and pressure walls and an end of the at least one of a cover and an end cap. The step is made to be less than or equal to about 0.010 inch (0.0254 centimeter) in dimension.

[0029] In another embodiment according to the previous embodiment, the size of the step is reduced by adding a filler material which is considered part of the at least one of an end cap and a cover for purposes of measuring the step dimension.

[0030] In another embodiment according to any of the previous embodiments, the main body includes both a cover and an end cap. There are at least four steps associated with ends of the cover spaced toward both the leading and trailing edges and ends of the end cap on each of the pressure and suction walls. All of the dimensions of the steps are made to be less than or equal to about 0.010 inch (0.0254 centimeter).

[0031] In another embodiment according to any of the previous embodiments, a surface roughness of the outer surface of the main body, and the at least one of the cover and the end cap is made to be less than about 60×10^{-6} inch over at least a portion of a radial length of the main body.

[0032] In another embodiment according to any of the previous embodiments, a machining step is utilized to reduce the surface roughness.

[0033] In another embodiment according to any of the previous embodiments, the fan blade defines a chord length. A ratio of the step dimension to the chord length is less than or equal to about 0.001.

[0034] In another featured embodiment, a method of designing a fan blade comprising providing a main body having an airfoil extending between a leading edge and a trailing edge, and the fan blade having a chord length. The airfoil extends radially outwardly from a platform. The fan blade has at least one of a channel closed by a cover, and an end cap covering at least one of the leading and trailing edges. At least one of a cover and an end cap has a pair of opposed ends. A step is defined extending from at least one of a suction wall and a pressure wall of the airfoil to an outer surface of the one of a cover and an end cap at one of the opposed ends. A ratio of the step dimension to the chord length is less than or equal to about 0.001.

[0035] In another embodiment according to the previous embodiment, an outer surface of the fan blade has a surface roughness which has a root means square value of less than about 60×10^{-6} inch on at least a portion of a radial length of the main body.

[0036] These and other features may be best understood from the following drawings and specification.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] FIG. **1**A schematically shows a gas turbine engine.

[0038] FIG. **1**B is a side view of a removed fan blade.

[0039] FIG. **1**C shows the fan blade of FIG. **1**B in an installed condition.

[0040] FIG. **2** is a cross-sectional view of the fan blade of FIGS. **1**B, **1**C.

[0041] FIG. **3**A is a detail of a location identified by A in FIG. **2**.

[0042] FIG. **3**BA is a first possibility at an area identified by B in FIG. **2**.

[0043] FIG. **3**BB shows a second possibility.

[0044] FIG. **3**C shows a possibility at an area identified by C in FIG. **2**.

[0045] FIG. **4**A shows a corrective method at the location of FIG. **3**A.

[0046] FIG. **4**BA shows a corrective method at the location of FIG. **3**BA.

[0047] FIG. **4**BB shows a corrective method at the location of FIG. **3**BB.

[0048] FIG. **4**C shows a corrective method at the location of FIG. **3**C.

[0049] FIG. **5** explains a feature of the fan blade of FIGS. **1**B-**4**C.

[0050] FIG. **6** shows another embodiment.

DETAILED DESCRIPTION

[0051] FIG. **1**A schematically illustrates a gas turbine engine **20**. The gas turbine engine **20** is disclosed herein as a two-spool turbofan that generally incorporates a fan section **22**, a compressor section **24**, a combustor section **26** and a turbine section **28**. Alternative engines might include an augmentor section (not shown) among other systems or features. The fan section **22** drives air along a bypass flow path B in a bypass duct defined within a nacelle **15**, while the compressor section **24** drives air along a core flow path C for compression and communication into the combustor section **26** then expansion through the turbine section **28**. Although depicted as a two-spool turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with two-spool turbofans as the teachings may be applied to other types of turbine engines including three-spool architectures.

[0052] The exemplary engine **20** generally includes a low speed spool **30** and a high speed spool **32** mounted for rotation about an engine central longitudinal axis A relative to an engine static structure **36** via several bearing systems **38**. It should be understood that various bearing systems **38** at various locations may alternatively or additionally be provided, and the location of bearing systems **38** may be varied as appropriate to the application.

[0053] The low speed spool **30** generally includes an inner shaft **40** that interconnects a fan **42**, a low pressure compressor **44** and a low pressure turbine **46**. The inner shaft **40** is connected to the fan **42** through a speed change mechanism, which in exemplary gas turbine engine **20** is illustrated as a geared architecture **48** to drive the fan **42** at a lower speed than the low speed spool **30**. The high speed spool **32** includes an outer shaft **50** that interconnects a high pressure compressor **52** and high pressure turbine **54**. A combustor **56** is arranged in exemplary gas turbine **20** between the high pressure compressor **52** and the high pressure turbine **54**. A mid-turbine frame **57** of the engine static structure **36** is arranged generally between the high pressure turbine **54** and the low pressure turbine **46**. The mid-turbine frame **57** further supports bearing systems **38** in the turbine section **28**. The inner shaft **40** and the outer shaft **50** are concentric and rotate via bearing systems **38** about the engine central longitudinal axis A which is collinear with their longitudinal axes.

[0054] The core airflow is compressed by the low pressure compressor **44** then the high pressure compressor **52**, mixed and burned with fuel in the combustor **56**, then expanded over the high pressure turbine **54** and low pressure turbine **46**. The mid-turbine frame **57** includes airfoils **59** which are in the core airflow path C. The turbines **46**, **54** rotationally drive the respective low speed spool **30** and high speed spool **32** in response to the expansion. It will be appreciated that each of the positions of the fan section **22**, compressor section **24**, combustor section **26**, turbine section **28**, and fan drive gear system **48** may be varied. For example, gear system **48** may be located aft of combustor section **26** or even aft of turbine section **28**, and fan section **22** may be positioned forward or aft of the location of gear system **48**.

[0055] The engine **20** in one example is a high-bypass geared aircraft engine. In a further example, the engine **20** bypass ratio is greater than about six (6), with an example embodiment being greater than about ten (10), the geared architecture **48** is an epicyclic gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3 and the low pressure turbine **46** has a pressure ratio that is greater than about five. In one disclosed embodiment, the engine **20** bypass ratio is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor **44**, and the low pressure turbine **46** has a pressure ratio that is greater than about five 5:1. Low pressure turbine **46** pressure ratio is pressure measured prior to inlet of low pressure turbine **46** as related to the pressure at the outlet of the low pressure turbine **46** prior to an exhaust nozzle. The geared architecture **48** may be an epicycle gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3:1. It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present invention is applicable to other gas turbine engines including direct drive turbofans.

[0056] A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The fan section **22** of the engine **20** is designed for a particular flight condition—typically cruise at about 0.8 Mach and about 35,000 feet. The flight condition of 0.8 Mach and 35,000 ft, with the engine at its best fuel consumption—also known as "bucket cruise Thrust Specific Fuel Consumption ('TSFC')"—is the industry standard parameter of lbm of fuel being burned divided by lbf of thrust the engine produces at that minimum point. "Low fan pressure ratio" is the pressure ratio across the fan blade alone, without a Fan Exit Guide Vane ("FEGV") system. The low fan pressure ratio as disclosed herein according to one non-limiting embodiment is less than about 1.45. "Low corrected fan tip speed" is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of $[(\text{Tram}\ ^\circ \text{R})/(518.7^\circ \text{R})]^{0.5}$. The "Low corrected fan tip speed" as disclosed herein according to one non-limiting embodiment is less than about 1150 ft/second.

[0057] A fan blade **120** which may be utilized in the gas turbine engine **20** is illustrated in FIG. **1**B having an airfoil **18** extending radially outwardly from a platform **124**, which may include, as shown, a dovetail. A leading edge **21** and a trailing edge **122** define the forward and rear limits of the airfoil. As shown in FIG. **1**B, the airfoil **18** extends from a radially inner end **501** adjacent the platform **124** to a radially outer end **500**.

[0058] As shown in FIG. **1**C, a fan rotor **16** will receive the platform **124** to mount the fan blade with the airfoil **18** extending radially outwardly. As the rotor **16** is driven to rotate, it carries the fan blade **120** with it.

[0059] FIG. **2** shows a cross-section of the fan blade **120** at the airfoil **18**. As shown, the leading edge **21** receives a cap **37** secured to a main body **128**. A cover **132** closes off cavities or channels **130** in the main body **128**. The main body **128**, the cap **37** and the cover **132** may all be formed of aluminum or various aluminum alloys. Other materials, such as titanium, titanium alloys or other appropriate metals, may alternatively be utilized for any one or more of the cap **37**, the cover **132**, and/or the main body **128**. Further, other, non-metallic materials, such as composites or plastics, may alternatively and/or additionally be utilized for any one or more of the cap **37**, the cover **132**, and/or the main body **128**.

[0060] In addition, while the fan blade **120** is shown having one cover **132** and channels **130** having a closed inner end, it is also possible that the main body **128** would provide a channel extending across its entire thickness with covers at each side. As shown, a plurality of ribs **126** separate the channels **130** in the cross-section illustrated in FIG. **2**. Filler material **100** may be deposited within the channels **130** and would typically be of a lighter weight than the main body **128**.

[0061] Applicant has discovered that with the increasing diameter of the fan blade **120** when utilized in geared gas turbine engine, surface smoothness becomes important. If a laminar flow can be achieved at the surface of the airfoil, the fuel burn efficiency and the fan efficiency can be increased dramatically. However, it is challenging to achieve laminar flow on fan blades **120** and, in particular, as their diameter increases and their speed decreases.

[0062] In fact, the fan blades mentioned above having a cover **132**, or an end cap **37**, could be defined as assembled fan blades. These assembled fan blades, applicant has recognized, create steps which could move the actual flow further from laminar than it might be with a solid fan blade.

[0063] As shown in FIG. **3**A, an area identified by A in FIG. **2** is enlarged. As shown, the cap **37** has an end **137**, which is spaced above an outer surface **210** of the main body **128**. There is a step of a dimension d_1 between the two.

[0064] Similarly, FIG. **3**BA shows one possibility at the location B in FIG. **2**. Here, the cover **132** has its end **139**

spaced from the outer surface **210** by a step of a dimension d_2. This would be a "negative" step.

[0065] FIG. 3BB shows the opposite wherein the cover **132** extends above the surface **210** by a dimension d_3. This might be called a positive step.

[0066] Applicant has discovered that these steps must be minimized to achieve laminar flow. In particular, the steps should be less than or equal to about 0.010 inch (0.0254 centimeter). This requirement can be performed as part of a quality control step and, if any of the dimensions d_1-d_3 are outside of this dimension, then corrective steps may be taken. As an example, as shown in FIGS. **4**A, **4**BB and **4**BA, a putty **301** may be included to take up the step and reduce the sudden change between the two surfaces.

[0067] Stated another way, a chord length C for the blade airfoils **18** may be defined as shown in FIG. **5**. In one embodiment, rather than the 0.010 inch (0.0254 centimeter) maximum, the dimensions d_1-d_3 could be defined as being kept within a maximum ratio with regard to the chord length C. In one embodiment, the maximum allowable step was 0.010 inch (0.0254 centimeter), and the chord length C was 10 inches (25.14 centimeters). In this embodiment, a ratio of d_1-d_3 to C is less than or equal to about 0.001. For this embodiment, C is measured at a tip of the airfoil **18**, and between its leading and trailing edges.

[0068] As mentioned above, the reduction of the steps may be provided on each of the suction side **99** and pressure side **97** (see FIG. **2**) of the airfoil at all positions wherein there is a step. In addition, the corrective measure may be more important at different radial locations between the radial ends **500** and **501** of the airfoil **18** (see FIG. **1**B).

[0069] For purposes of measuring the step height after the corrective steps of FIGS. **4**A, **4**BA, and **4**BB, the putty **301** is considered part of the cover **132** or end cap **37**. While putty is disclosed, other filler materials may be used.

[0070] FIG. **3**C shows yet another concern. A surface roughness at the surface **210** may be identified as surface irregularities **211** and may have a highest dimension d_4. It would be desirable that this surface roughness be minimized Applicant has found that maintaining a surface roughness with a root means square value of less than about 60×10^{-6}- inch would result in a fan blade providing more laminar flow.

[0071] As shown in FIG. **4**C, this may be achieved by machining such as applying a polishing or smoothing tool **310** to the irregularities **211**.

[0072] Applicant has also discovered that the most important portion of the fan blade to have the required smoothness are from about 20% of the blade span radially outwardly, measured along a length of airfoil **18** to 100% of the airfoil **18**, at its tip.

[0073] In addition, applicant has determined that the results achieved by a fan blade having the disclosed characteristics are most beneficial when a fan tip corrected speed is below about 1225 ft/second at bucket cruise, and even more beneficial when the fan speed is below 1150 ft/second. Further, the benefits are more pronounced when the fan rotor carries **26** or fewer fan blades.

[0074] Now, an assembled fan blade having either the small step size or the very smooth outer surface will achieve laminar flow over a greater percentage of its surface area. These treatments can be applied at any radial location between ends **501** and **500** or over all of those portions. In addition, they may be provided on only the suction side **99**, only the pressure side **97** or both.

[0075] FIG. **6** shows an alternate embodiment fan rotor **300** wherein blades **302** and **304** have a shroud **306** extending between them. The shroud **306** provides additional rigidity to the structure to enhance laminar flow across the fan blades **302**, **304**. The shroud of this embodiment may be used in conjunction with any of the foregoing surface treatments described with respect to the embodiments of FIGS. **2**-**5**.

[0076] Although an embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this disclosure. For that reason, the following claims should be studied to determine the true scope and content of this disclosure.

1. A fan blade comprising:

a main body having an airfoil extending between a leading edge and a trailing edge and the fan blade having at least one of:

(a) a channel closed by a cover, and

(b) an end cap covering at least one of the leading and trailing edges; and

the at least one of the cover and the end cap having a pair of opposed ends, and a step defined by at least one of a suction wall and a pressure wall of the airfoil, to an outer surface of said one of the cover and the end cap at one of said opposed ends, and said step being less than or equal to about 0.010 inch (0.0254 centimeter) in dimension.

2. The fan blade as set forth in claim **1**, wherein said main body including both said cover and said end cap, the end cap at said leading edge, wherein there are a plurality of said step defined at each of said opposed ends of said cover on one of said suction wall and said pressure wall, and wherein said steps are defined at each of said opposed ends of said end cap on both said suction and pressure walls, and wherein all of said step dimensions are less than or equal to about 0.010 inch (0.0254 centimeter).

3. The fan blade as set forth in claim **2**, wherein an outer surface of said fan blade having a surface roughness and said surface roughness having a root means square value of less than about 60×10^{-6} inch on at least a portion of a radial length of the main body.

4. The fan blade as set forth in claim **2**, wherein a filler material is provided between each of said opposed ends of said end caps and cover and said main body, with said filler material reducing the size of said steps, and said filler material being part of said cover and said end cap for purposes of measuring said dimensions of said steps.

5. The fan blade as set forth in claim **1**, wherein an outer surface of said fan blade having a surface roughness and said surface roughness having a root means square value of less than about 60×10^{-6} inch on at least a portion of a radial length of the main body.

6. The fan blade as set forth in claim **1**, wherein a filler material is provided between at least one of said ends of said one of the end cap and the cover and said main body, with said filler material reducing the size of said step, and said filler material being part of said cover and said end cap for purposes of measuring said dimensions of said steps.

7. The fan blade as set forth in claim **1**, wherein said fan blade having a chord length, and a ratio of said step dimension to said chord length being less than or equal to about 0.001.

8. The fan blade as set forth in claim **1**, wherein said step occurring over at least from 20% of a blade span, measured from a platform to a radially outer tip of said airfoil.

9. The fan blade as set forth in claim **1**, wherein said fan blade is designed to rotate with a fan tip corrected speed below 1225 ft/second (368 meters/second) at bucket cruise.

10. The fan blade as set forth in claim **1**, comprising a shroud for connecting the fan blade to an adjacent fan blade.

11. The fan blade as set forth in claim **1**, wherein at least one of the main body, cover, and cap is formed of aluminum or an aluminum alloy.

12. The fan blade as set forth in claim **1**, wherein at least one of the main body, cover, and cap is formed of titanium or a titanium alloy.

13. The fan blade as set forth in claim **1**, wherein at least one of the main body, cover, and cap is formed of composite.

14. The fan blade as set forth in claim **1**, wherein at least one of the main body is formed of composite, a metal, or an alloy, and wherein the cover or the cap is formed of titanium or a titanium alloy.

15. A gas turbine engine comprising:

a fan drive turbine driving a fan rotor having a plurality of blades through a gear reduction;

each of said plurality of blades including a main body having an airfoil extending between a leading edge, and a trailing edge and each of said plurality of blades having a chord length, and each of said plurality of blades having at least one of:

(a) a channel closed by a cover, and

(b) an end cap covering at least one of the leading and trailing edges; and

the at least one of the cover and the end cap having a pair of opposed ends, and a step defined by at least one of a suction wall and a pressure wall of the airfoil, to an outer surface of said one of the cover and the end cap at one of said opposed ends, and a ratio of said step dimension to said chord length being less than or equal to about 0.001.

16. The gas turbine engine as set forth in claim **15**, wherein said main body including both said cover and said end cap, the end cap at said leading edge, wherein there are a plurality of said step defined at each of said opposed ends of said cover on one of said suction wall and said pressure wall, and wherein said steps are defined at each of said opposed ends of said end cap on both said suction and pressure walls, and wherein all of said step dimensions having said ratio being less than or equal to about 0.001.

17. The gas turbine engine as set forth in claim **16**, wherein a filler material is provided between each of said opposed ends of said end caps and cover and said main body, with said filler material reducing the size of said step dimensions, and said filler material being part of said cover and said end cap.

18. The gas turbine engine as set forth in claim **15**, wherein an outer surface of said fan blade having a surface roughness and said surface roughness having a root means square value of less than about 60×10^{-6} inch on at least a portion of a radial length of the main body.

19. The gas turbine engine as set forth in claim **15**, wherein a filler material is provided between at least one of said ends of said one of the end cap and the cover and said main body, with said filler material reducing the size of said step dimensions, and said filler material being part of said one of said cover and said end cap.

20. The gas turbine engine as set forth in claim **15**, wherein said step occurring over at least from 20% of a blade span, measured from the platform to a radially outer tip of said airfoil.

21. The gas turbine engine as set forth in claim **15**, wherein said fan blade is designed to rotate with a fan tip corrected speed below 1225 ft/second (368 meters/second) at bucket cruise.

22. The gas turbine engine as set forth in claim **15**, comprising a shroud connecting adjacent ones of said blades.

23. A method of manufacturing a fan blade comprising the steps of:

providing a main body extending between a leading edge and a trailing edge, and having a suction wall and a pressure wall, with said main body having at least one of a channel enclosed by a cover, and an end cap covering at least one of said leading and trailing edges, with said at least one of the cover and the end cap being assembled to said main body, and defining a step by at least one of the suction and pressure walls and an end of the at least one of the cover and the end cap, and the step being made to be less than or equal to about 0.010 inch (0.0254 centimeter) in dimension.

24. The method as set forth in claim **23**, wherein the size of the step is reduced by adding a filler material which is considered part of the at least one of the end cap and the cover for purposes of measuring said step dimension.

25. The method as set forth in claim **23**, wherein the main body includes both the cover and the end cap and there are at least four of said steps associated with ends of the cover having one spaced toward the leading edge and one spaced towards the trailing edges and ends of the end cap on each of the pressure and suction walls, and all of said dimensions of said steps being made to be less than or equal to about 0.010 inch (0.0254 centimeter).

26. The method as set forth in claim **23**, wherein a surface roughness of an outer surface of the main body, and the at least one of the cover and the end cap is made to be less than about 60×10^{-6} inch over at least a portion of a radial length of the main body.

27. The method as set forth in claim **23**, wherein a machining step is utilized to reduce the surface roughness.

28. The method as set forth in claim **23**, wherein the fan blade defining a chord length, and a ratio of said step dimension to said chord length being less than or equal to about 0.001.

29. A method of designing a fan blade comprising:

providing a main body having an airfoil extending between a leading edge and a trailing edge, and the fan blade having a chord length, the airfoil extending radially outwardly from a platform, and the fan blade having at least one of:

(a) a channel closed by a cover; and

(b) an end cap covering at least one of the leading and trailing edges; and

the at least one of the cover and the end cap having a pair of opposed ends, and a step defined by at least one of a suction wall and a pressure wall of the airfoil to an outer surface of said one of the cover and the end cap at one of said opposed ends, and a ratio of said step dimension to said chord length being less than or equal to about 0.001.

30. The method as set forth in claim **29**, wherein an outer surface of said fan blade having a surface roughness and said surface roughness having a root means square value of less than about 60×10^{-6} inch on at least a portion of a radial length of the main body.

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