A method of manufacturing a fan blade includes providing a metallic fan blade body, and applying at least a 200 volt potential to the fan blade body in a solution to produce a crystalline oxidation layer. A fan blade for a gas turbine engine includes a metallic fan blade body having a tip with a crystalline oxidation layer. A fan blade for a gas turbine engine includes a metallic fan blade body having a tip with a titanium dioxide layer.
GAS TURBINE ENGINE FAN BLADE TIP TREATMENT

BACKGROUND

[0001] This disclosure relates to a fan blade for a gas turbine engine. In more particularly, the disclosure relates to a fan blade having a treated tip.

[0002] Composite fan blades have been proposed for gas turbine engines. One example fan blade includes an aluminum substrate or fan blade body having a titanium sheath adhered to a leading edge of the fan blade body. A polyurethane coating is applied over the fan blade body and forms a fan blade contour with the sheath.

[0003] During operation of the gas turbine engine, a tip of the fan blade may rub with an adjacent sealing structure. During the rub event, the tip may wear and heat may be generated. To this end, the tip of the fan body has been anodized to create a hardened layer. One typical sealing structure has a hardness greater than that of the tip. Thus, during rub events the tip may still become undesirably worn. In some instances, sufficient heat may be generated to delaminate the coating from the fan blade body.

SUMMARY

[0004] In one exemplary embodiment, a method of manufacturing a fan blade includes providing a metallic fan blade body, and applying at least a 200 volt potential to the fan blade body in a solution to produce a crystalline oxidation layer.

[0005] In a further embodiment of any of the above, the fan blade body includes a tip. The method includes the step of masking the fan blade body to leave at least the tip exposed. The tip having the crystalline oxidation layer.

[0006] In a further embodiment of any of the above, the fan blade body provides an electrode in an alkaline solution.

[0007] In a further embodiment of any of the above, the method includes generating a plasma discharge on a surface of the fan blade body.

[0008] In a further embodiment of any of the above, the crystalline oxidation layer is aluminum oxide.

[0009] In a further embodiment of any of the above, the crystalline oxidation layer has a thickness of at least 0.0005 inch (0.013 mm).

[0010] In a further embodiment of any of the above, the crystalline oxidation layer has a hardness of at least 1700 HV.

[0011] In a further embodiment of any of the above, the fan blade body is one of a 7000 series and a 2000 series aluminum alloy.

[0012] In a further embodiment of any of the above, the method includes the steps of removing the masking and adhering a sheath to a leading edge of the fan blade body.

[0013] In a further embodiment of any of the above, the adhering step includes arranging an adhesive-saturated scrim between the sheath and the leading edge.

[0014] In a further embodiment of any of the above, the method includes the step of coating the fan blade body with polyurethane to provide a fan blade contour along with the sheath.

[0015] In a further embodiment of any of the above, the crystalline oxidation layer is left exposed subsequent to the coating step.

[0016] In another exemplary embodiment, a fan blade for a gas turbine engine includes a metallic fan blade body having a tip with a crystalline oxidation layer.

[0017] In a further embodiment of any of the above, the crystalline oxidation layer has a thickness of at least 0.005 inch (0.12 mm).

[0018] In a further embodiment of any of the above, the crystalline oxidation layer has a hardness of at least 1700 HV.

[0019] In a further embodiment of any of the above, the fan blade body is one of a 7000 series and a 2000 series aluminum alloy.

[0020] In a further embodiment of any of the above, the fan blade includes a sheath adhered to a leading edge of the fan blade body.

[0021] In a further embodiment of any of the above, the fan blade includes a polyurethane coating arranged over the fan blade body and adjoining the sheath to provide a fan blade contour.

[0022] In another exemplary embodiment, a fan blade for a gas turbine engine includes a metallic fan blade body having a tip with a titanium dioxide layer.

[0023] In a further embodiment of any of the above, the tip includes a plasma spray coating arranged on the titanium dioxide layer, which is provided between the plasma spray coating and the metallic fan blade body.

[0024] In a further embodiment of any of the above, the amorphous titanium oxidation layer has a thickness of at least 0.0005 inch (0.13 mm).

[0025] In a further embodiment of any of the above, the amorphous titanium oxidation layer has a hardness of at least 640 HV.

[0026] In a further embodiment of any of the above, the fan blade body is one of a 7000 series and a 2000 series aluminum alloy.

[0027] In a further embodiment of any of the above, the fan blade includes a sheath adhered to a leading edge of the fan blade body.

[0028] In a further embodiment of any of the above, the fan blade includes a polyurethane coating arranged over the fan blade body and adjoining the sheath to provide a fan blade contour.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The disclosure can be further understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0030] FIG. 1 schematically illustrates a gas turbine engine embodiment.

[0031] FIG. 2 is a perspective view of an embodiment of a fan blade of the engine shown in FIG. 1.

[0032] FIG. 3 is a perspective view of a blade body for the fan blade shown in FIG. 2.

[0033] FIG. 4 is a flowchart depicting an example manufacturing process used to produce the fan blade shown in FIG. 2.

[0034] FIG. 5 is an end view of the fan blade shown in FIG. 2 produced by the manufacturing process depicted in FIG. 4.

[0035] FIG. 6 is a schematic cross-sectional view of an example fan blade produced by another manufacturing process.

DETAILED DESCRIPTION

[0036] FIG. 1 schematically illustrates an example gas turbine engine 20 that includes a fan section 22, a compressor section 24, a combustor section 26 and a turbine section 28. Alternative engines might include an augmenter section (not
shown) among other systems or features. The fan section 22 drives air along a bypass flow path B while the compressor section 24 draws air in along a core flow path C where air is compressed and communicated to a combustor section 26. In the combustor section 26, air is mixed with fuel and ignited to generate a high pressure exhaust gas stream that expands through the turbine section 28 where energy is extracted and utilized to drive the fan section 22 and the compressor section 24.

[0037] Although the disclosed non-limiting embodiment depicts a turbofan gas turbine engine, it should be understood that the concepts described herein are not limited to use with turbfans as the teachings may be applied to other types of turbine engines; for example a turbine engine including a three-spool architecture in which three spools concentrically rotate about a common axis and where a low spool enables a low pressure turbine to drive a fan via a gearbox, an intermediate spool that enables an intermediate pressure turbine to drive a first compressor of the compressor section, and a high spool that enables a high pressure turbine to drive a high pressure compressor of the compressor section.

[0038] The example 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.

[0039] The low speed spool 30 generally includes an inner shaft 40 that connects a fan 42 and a low pressure (or first) compressor section 44 to a low pressure (or first) turbine section 46. The inner shaft 40 drives the fan 42 through a speed change device, such 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 (or second) compressor section 52 and a high pressure (or second) turbine section 54. The inner shaft 40 and the outer shaft 50 are concentric and rotate via the bearing systems 38 about the engine central longitudinal axis X.

[0040] A combustor 56 is arranged between the high pressure compressor 52 and the high pressure turbine 54. In one example, the high pressure turbine 54 includes at least two stages to provide a double stage high pressure turbine 54. In another example, the high pressure turbine 54 includes only a single stage. As used herein, a “high pressure” compressor or turbine experiences a higher pressure than a corresponding “low pressure” compressor or turbine.

[0041] The example low pressure turbine 46 has a pressure ratio that is greater than about 5. The pressure ratio of the example low pressure turbine 46 is measured prior to an inlet of the low pressure turbine 46 as related to the pressure measured at the outlet of the low pressure turbine 46 prior to an exhaust nozzle.

[0042] 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 as well as setting airflow entering the low pressure turbine 46.

[0043] The core airflow C is compressed by the low pressure compressor 44 then by the high pressure compressor 52 mixed with fuel and ignited in the combustor 56 to produce high speed exhaust gases that are then expanded through the high pressure turbine 54 and low pressure turbine 46. The mid-turbine frame 57 includes vanes 59, which are in the core airflow path and function as an inlet guide vane for the low pressure turbine 46. Utilizing the vane 59 of the mid-turbine frame 57 as the inlet guide vane for low pressure turbine 46 decreases the length of the low pressure turbine 46 without increasing the axial length of the mid-turbine frame 57. Reducing or eliminating the number of vanes in the low pressure turbine 46 shortens the axial length of the turbine section 28. Thus, the compactness of the gas turbine engine 20 is increased and a higher power density may be achieved.

[0044] The disclosed gas turbine engine 20 in one example is a high-bypass geared aircraft engine. In a further example, the gas turbine engine 20 includes a bypass ratio greater than about six (6), with an example embodiment being greater than about ten (10). The example geared architecture 48 is an epicyclical gear train, such as a planetary gear system, star gear system or other known gear system, with a gear reduction ratio of greater than about 2.3.

[0045] In one disclosed embodiment, the gas turbine engine 20 includes a bypass ratio greater than about ten (10:1) and the fan diameter is significantly larger than an outer diameter of the low pressure compressor 44. It should be understood, however, that the above parameters are only exemplary of one embodiment of a gas turbine engine including a geared architecture and that the present disclosure is applicable to other gas turbine engines.

[0046] 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 pound-mass (lbf) of fuel per hour being burned divided by pound-force (lbf) of thrust the engine produces at that minimum point.

[0047] “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 1.50. In another non-limiting embodiment the low fan pressure ratio is less than about 1.45.

[0048] “Low corrected fan tip speed” is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of [1 + 0.00059 * (T - 68)] where T is the “temperature” at sea level. The “Low corrected fan tip speed”, as disclosed herein according to one non-limiting embodiment, is less than about 1150 ft/second.

[0049] The example gas turbine engine includes the fan 42 that comprises in one non-limiting embodiment less than about twenty (26) fan blades. In another non-limiting embodiment, the fan section 22 includes less than about twenty (20) fan blades. Moreover, in one disclosed embodiment the low pressure turbine 46 includes no more than about six turbine rotors schematically indicated at 34. In another non-limiting example embodiment the low pressure turbine 46 includes about three turbine rotors. A ratio between the number of fan blades 42 and the number of low pressure turbine rotors is between about 3.3 and about 8.6. The example low pressure turbine 46 provides the driving power to rotate the fan section 22 and therefore the relationship between the number of turbine rotors 34 in the low pressure turbine 46 and the number of blades 42 in the fan section 22 disclose an example gas turbine engine 20 with increased power transfer efficiency.

[0050] Referring to FIGS. 2 and 3, a fan blade 60 of the fan 42 includes a root 62 supporting a platform 64. An airfoil 66
extends from the platform 64 to a tip 67. The airfoil 66 includes spaced apart leading and trailing edges 68, 70. Pressure and suction sides 72, 74 adjoin the leading and trailing edges 68, 70 to provide a fan blade contour 86. It should be understood that the fan blade 60 is exemplary, and "platform-less" fan blades may also be used.

[0051] The tip 67 is arranged adjacent to a sealing structure 83, which is typically arranged in relation to the tip 67 to provide a clearance 84. One example sealing structure may have embedded glass particles with a hardness of 650 HV. During certain engine operating conditions, the tip 67 may be prone to rubbing with the sealing structure 83, which can generate heat and undesirably wear the tip 67.

[0052] Each fan blade 60 includes an aluminum fan blade body 80, which may be hollow or solid. A leading edge sheath 76 is applied to a leading edge 78 of the fan blade body 80. In one example, the fan blade body 80 is constructed from a 7000 series aluminum alloy, such as 7255. In another example, a 2000 series aluminum is used.

[0053] The fan blade body 80 has a leading edge 78. A sheath 76 is secured to the fan blade body 80 over the leading edge 78 with adhesive 82. In one example, the sheath 76 and the fan blade body 80 are constructed from first and second metals that are different from one another. In one example, the sheath 76 is constructed from a titanium alloy. It should be understood that other metals or materials may be used.

[0054] The adhesive 82 provides a barrier between the fan blade body 80 and the sheath 76 to prevent galvanic corrosion. Referring to FIG. 8, the adhesive 82 includes a scrim 88 (e.g., a glass scrim) that carries the adhesive 82. Examples of the adhesive 82 include a variety of commercially available aerospace-quality metal-bonding adhesives, including several epoxy- and polyurethane-based adhesive films. In some embodiments, the adhesive 82 is heat-cured via autoclave or other similar means. Examples of suitable bonding agents include type EA9628 epoxy adhesive available from Henkel Corporation, Hysol Division, Bay View, Calif. and type AF163K epoxy adhesive available from 3M Adhesives, Coatings & Sealants Division, St. Paul, Minn. The adhesive 82 may be cured using a vacuum bag and autoclave.

[0055] Certain adhesives 82, including the example film-based adhesives above, are compatible with scrim 88. Scrim 88 provides dielectric separation between blade body 80 and sheath 76, preventing galvanic corrosion between the two different metal surfaces of blade body 80 and sheath 76. One example scrim 88 is a flexible nylon-based layer with a thickness between about 0.003 inch (0.078 mm) and about 0.010 inch (0.25 mm) thick. Other examples of the adhesive 82 and other aspects of the fan blade 60 are set forth in U.S. Patent Application Publication 2011/0211967 to the Applicant, which is incorporated herein by reference in its entirety.

[0056] A polymer coating 90 is applied over the fan blade body 80 adjacent to the sheath 76 to provide a fan blade contour 86. The coating 90 is polyurethane in one example.

[0057] An example method 100 of manufacturing the fan blade 60 is illustrated in the flow chart shown in FIG. 4. The substrate provided by the fan blade body 80 may be masked to leave at least the tip 67 exposed, as depicted in block 102. A chemical masking, mechanical masking tape, lacquer, or other painted on coating may be used and temporarily deposited upon the exterior surface of the fan blade body 80. Since the oxidation process employed by the example method 100 requires significant voltage, reducing the area to be oxidized greatly reduces the necessary power and cost of oxidizing the tip 67.

[0058] The tip 67 is oxidized using a high voltage process, such as micro-arc oxidation (MAO), which may also be referred to as plasma electrolytic oxidation (PEO) or plasma arc oxidation (PAO). Such a process employs an at least a 200 volt potential, and as high as 2000 volts. One example process is available from Keromite International Ltd. in the United Kingdom. During the MAO process, a plasma is generated on the surface of the fan blade body, which forms a crystalline aluminum oxide structure having a hardness of at least 1700 HV. A typical anodized aluminum hardness is 450 HV, and the oxidation layer produced by anodizing is non-crystalline. The crystalline oxidation layer 92 (FIG. 5) may have a thickness of at least 0.005 inch (0.12 mm), which is significantly thicker than a typical anodized layer thickness of 0.002 inch (0.05 mm). However, the layer may be thinner than 0.005 inch (0.12 mm) since the crystalline oxidation layer 92 is harder than typical anodizing.

[0059] Since the crystalline oxidation layer 92 is significantly harder than the sealing structure 83, which has embedded particles around 650 HV in one example, the tip 67 more easily cuts through the sealing structure 83 during a rub event, ultimately generating less heat. The reduced heat minimizes the possibility of the coating 90 from delaminating from the fan blade body 80. The thicker crystallized oxidation layer also better insulates the substrate of the fan blade body 80, reducing the that reaches the interface of the fan blade body 80 and the coating 90. The coating is also more wear resistant than a conventional anodize. It also provides superior corrosion protection than a conventional anodize.

[0060] The mask may be removed following the oxidation process 104. The fan blade 60 may be assembled, as indicated at block 106, by securing the sheath 76 over the leading edge 78 using the adhesive 82 and scrim 88. The fan blade body 80 is covered with the coating 90 to provide the fan blade contour 86, as best shown in FIG. 5.

[0061] Another example fan blade 160 is illustrated in FIG. 6. The fan blade 160 includes an aluminum alloy substrate of the fan blade body 180. A titanium dioxide layer 192 is deposited on the end of the fan blade body 180 using, for example, an EC2 process available from Henkel. The EC2 process applies a current to the fan blade body 180, which is immersed in a neutral solution. The EC2 process adds a titanium dioxide layer 192 to the aluminum alloy substrate and provides a sufficient bond. The titanium dioxide layer 192 is 0.0005-0.001 inch (0.013-0.25 mm) thick. If additional wear resistance is desired, a plasma-sprayed coating 110 may be applied to the titanium dioxide layer 192. Example plasma spray coatings are alumina or metal. The titanium dioxide layer 192 and plasma spray coating 110, if used, provides a wear resistant tip 167 that also thermally insulates the fan blade body 180. The coating is also more wear resistant and provides superior corrosion protection than a conventional anodize.

[0062] Although an example embodiment has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of the claims. For that reason, the following claims should be studied to determine their true scope and content.
What is claimed is:

1. A method of manufacturing a fan blade comprising:
   providing a metallic fan blade body; and
   applying at least a 200 volt potential to the fan blade body
   in a solution to produce a crystalline oxidation layer.

2. The method according to claim 1, wherein the fan blade body includes a tip, and comprising the step of masking the fan blade body to leave at least the tip exposed, the tip having the crystalline oxidation layer.

3. The method according to claim 1, wherein the fan blade body provides an electrode in an alkaline solution.

4. The method according to claim 3, comprising generating a plasma discharge on a surface of the fan blade body.

5. The method according to claim 1, wherein the crystalline oxidation layer is aluminum oxide.

6. The method according to claim 5, wherein the crystalline oxidation layer has a thickness of at least 0.0005 inch (0.013 mm).

7. The method according to claim 5, wherein the crystalline oxidation layer has a hardness of at least 1700 HV.

8. The method according to claim 5, wherein the fan blade body is one of a 7000 series and a 2000 series aluminum alloy.

9. The method according to claim 2, comprising the steps of removing the masking and adhering a sheath to a leading edge of the fan blade body.

10. The method according to claim 9, wherein the adhering step includes arranging an adhesive-saturated scrim between the sheath and the leading edge.

11. The method according to claim 10, comprising the step of coating the fan blade body with polyurethane to provide a fan blade contour along with the sheath.

12. The method according to claim 11, wherein the crystalline oxidation layer is left exposed subsequent to the coating step.

13. A fan blade for a gas turbine engine comprising:
   a metallic fan blade body having a tip with a crystalline oxidation layer.

14. The fan blade according to claim 13, wherein the crystalline oxidation layer has a thickness of at least 0.005 inch (0.12 mm).

15. The fan blade according to claim 14, wherein the crystalline oxidation layer has a hardness of at least 1700 HV.

16. The fan blade according to claim 15, wherein the fan blade body is one of a 7000 series and a 2000 series aluminum alloy.

17. The fan blade according to claim 16, comprising a sheath adhered to a leading edge of the fan blade body.

18. The fan blade according to claim 17, comprising a polyurethane coating arranged over the fan blade body and adjoining the sheath to provide a fan blade contour.

19. A fan blade for a gas turbine engine comprising:
   a metallic fan blade body having a tip with a titanium dioxide layer.

20. The fan blade according to claim 19, wherein the tip includes a plasma spray coating arranged on the titanium dioxide layer, which is provided between the plasma spray coating and the metallic fan blade body.

21. The fan blade according to claim 19, wherein the amorphous titanium oxidation layer has a thickness of at least 0.0005 inch (0.13 mm).

22. The fan blade according to claim 21, wherein the amorphous titanium oxidation layer has a hardness of at least 640 HV.

23. The fan blade according to claim 22, wherein the fan blade body is one of a 7000 series and a 2000 series aluminum alloy.

24. The fan blade according to claim 23, comprising a sheath adhered to a leading edge of the fan blade body.

25. The fan blade according to claim 24, comprising a polyurethane coating arranged over the fan blade body and adjoining the sheath to provide a fan blade contour.

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