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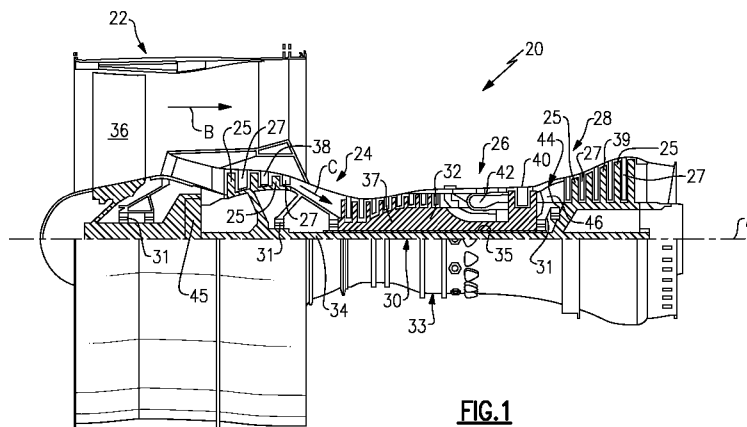


FIG. 1

(57) Abstract: A rotor blade for a gas turbine engine according to an exemplary aspect of the present disclosure includes, among other things, an airfoil extending in span between a root region and a tip region and a tip portion extending at an angle from the tip region of the airfoil.



GAS TURBINE ENGINE ROTOR BLADE

BACKGROUND

[0001] This disclosure relates to a gas turbine engine, and more particularly to a rotor blade for a gas turbine engine that provides improved aerodynamic performance.

[0002] Gas turbine engines typically include a compressor section, a combustor section and a turbine section. In general, during operation, air is pressurized in the compressor section and is mixed with fuel and burned in the combustor section to generate hot combustion gases. The hot combustion gases flow through the turbine section, which extracts energy from the hot combustion gases to power the compressor section and other gas turbine engine loads.

[0003] Some gas turbine engines sections may utilize multiple stages to obtain the pressure levels necessary to achieve desired thermodynamic cycle goals. For example, the compressor and turbine sections of a gas turbine engine typically include alternating rows of moving airfoils (i.e., rotor blades) and stationary airfoils (i.e., stator vanes). Each stage consists of a row of rotor blades and a row of stator vanes.

[0004] One design feature of a rotor blade that can affect gas turbine engine performance is the airflow gap that extends between the tips of each rotor blade and a surrounding shroud assembly or engine casing. Airflow that escapes through these gaps can result in gas turbine engine performance losses.

SUMMARY

[0005] A rotor blade for a gas turbine engine according to an exemplary aspect of the present disclosure includes, among other things, an airfoil extending in span between a root region and a tip region and a tip portion extending at an angle from the tip region of the airfoil.

[0006] In a further non-limiting embodiment of the foregoing rotor blade, a span axis of the tip portion forms a dihedral angle relative to a span axis of the airfoil.

[0007] In a further non-limiting embodiment of either of the foregoing rotor blades, the dihedral angle is greater than or equal to 90° relative to the span axis of the airfoil.

[0008] In a further non-limiting embodiment of any of the foregoing rotor blades, the dihedral angle is less than or equal to 90° relative to the span axis of the airfoil.

[0009] In a further non-limiting embodiment of any of the foregoing rotor blades, the dihedral angle is between 45° and 135° degrees relative to the span axis of the airfoil.

[00010] In a further non-limiting embodiment of any of the foregoing rotor blades, the tip portion extends from a pressure side of the airfoil.

[00011] In a further non-limiting embodiment of any of the foregoing rotor blades, the tip portion extends in span between a root and a tip and extends in chord between a leading edge and a trailing edge, and the tip portion defines a plurality of cross-sectional slices that extend between the leading edge and the trailing edge along the span of the tip portion.

[00012] In a further non-limiting embodiment of any of the foregoing rotor blades, the tip portion is not tapered between the root and the tip of the tip portion.

[00013] In a further non-limiting embodiment of any of the foregoing rotor blades, the tip portion includes a converging taper between the root and the tip of the tip portion.

[00014] In a further non-limiting embodiment of any of the foregoing rotor blades, the tip portion includes a diverging taper between the root and the tip of the tip portion.

[00015] In a further non-limiting embodiment of any of the foregoing rotor blades, the tip portion forms a sweep angle that is defined between a chord axis and a span axis of the tip portion.

[00016] In a further non-limiting embodiment of any of the foregoing rotor blades, the tip portion includes an aft sweep.

[00017] In a further non-limiting embodiment of any of the foregoing rotor blades, the tip portion includes a forward sweep.

[00018] In a further non-limiting embodiment of any of the foregoing rotor blades, the tip portion defines a sweep angle and a dihedral angle that extend across an entire span of the tip portion.

[00019] In a further non-limiting embodiment of any of the foregoing rotor blades, a tip of the tip portion is rotated in a direction toward the root region.

[00020] In a further non-limiting embodiment of any of the foregoing rotor blades, a tip of the tip portion is rotated in a direction away from the root region.

[00021] A gas turbine engine according to an exemplary aspect of the present disclosure includes, among other things, a compressor section, a combustor section in fluid communication with the compressor section and a turbine section in fluid communication with the combustor section. A plurality of rotor blades positioned within at least one of the compressor section and the turbine section, and each of the plurality of rotor blades includes an airfoil extending in span between a root region and a tip region and a tip portion extending at an angle from the tip region of the airfoil.

[00022] In a further non-limiting embodiment of the foregoing gas turbine engine, the plurality of rotor blades are at least partially radially surrounded by a shroud assembly.

[00023] In a further non-limiting embodiment of either of the foregoing gas turbine engines, the tip portion includes a dihedral angle and a sweep angle that extend across an entire span of the tip portion.

[00024] The various features and advantages of this disclosure will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[00025] Figure 1 illustrates a schematic, cross-sectional view of a gas turbine engine.

[00026] Figure 2 illustrates a portion of a gas turbine engine.

[00027] Figure 3 illustrates an exemplary rotor blade that can be incorporated into a gas turbine engine.

[00028] Figure 4 illustrates a tip portion of a rotor blade.

[00029] Figures 5A, 5B and 5C illustrate various design characteristics that can be incorporated into a tip portion of a rotor blade.

[00030] Figures 6A, 6B and 6C illustrate additional design characteristics of a rotor blade tip portion.

[00031] Figures 7A and 7B illustrate other design features that can be incorporated into a tip portion of a rotor blade.

DETAILED DESCRIPTION

[00032] Figure 1 schematically illustrates a gas turbine engine 20. The exemplary gas turbine engine 20 is a two-spool turbofan engine 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 for features. The fan section 22 drives air along a bypass flow path B, while the compressor section 24 drives air along a core flow path C for compression and communication into the combustor section 26. The hot combustion gases generated in the combustor section 26 are expanded through the turbine section 28. Although depicted as a turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to turbofan engines and these teachings could extend to other types of engines, including but not limited to, three-spool engine architectures.

[00033] The gas turbine engine 20 generally includes a low speed spool 30 and a high speed spool 32 mounted for rotation about an engine centerline longitudinal axis A. The low speed spool 30 and the high speed spool 32 may be mounted relative to an engine static structure 33 via several bearing systems 31. It should be understood that other bearing systems 31 may alternatively or additionally be provided.

[00034] The low speed spool 30 generally includes an inner shaft 34 that interconnects a fan 36, a low pressure compressor 38 and a low pressure turbine 39. The inner shaft 34 can be connected to the fan 36 through a geared architecture 45 to drive the fan 36 at a lower speed than the low speed spool 30. The high speed spool 32 includes an outer shaft 35 that interconnects a high pressure compressor 37 and a high pressure turbine 40. In this embodiment, the inner shaft 34 and the outer shaft 35 are supported at various axial locations by bearing systems 31 positioned within the engine static structure 33.

[00035] A combustor 42 is arranged between the high pressure compressor 37 and the high pressure turbine 40. A mid-turbine frame 44 may be arranged generally between the high pressure turbine 40 and the low pressure turbine 39. The mid-turbine frame 44 can support one or more bearing systems 31 of the turbine section 28. The mid-turbine frame 44 may include one or more airfoils 46 that extend within the core flow path C.

[00036] The inner shaft 34 and the outer shaft 35 are concentric and rotate via the bearing systems 31 about the engine centerline longitudinal axis A, which is co-linear with their longitudinal axes. The core airflow is compressed by the low pressure compressor 38 and the high pressure compressor 37, is mixed with fuel and burned in the combustor 42, and is then expanded over the high pressure turbine 40 and the low pressure turbine 39. The high pressure turbine 40 and the low pressure turbine 39 rotationally drive the respective high speed spool 32 and the low speed spool 30 in response to the expansion.

[00037] The pressure ratio of the low pressure turbine 39 can be pressure measured prior to the inlet of the low pressure turbine 39 as related to the pressure at the outlet of the low pressure turbine 39 and prior to an exhaust nozzle of the gas turbine engine 20. In one non-limiting embodiment, the bypass ratio of the gas turbine engine 20 is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor 38, and the low pressure turbine 39 has a pressure ratio that is greater than about five (5:1). It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present disclosure is applicable to other gas turbine engines, including direct drive turbofans.

[00038] In one embodiment of the exemplary gas turbine engine 20, a significant amount of thrust is provided by the bypass flow path B due to the high bypass ratio. The fan section 22 of the gas turbine engine 20 is designed for a particular flight condition--typically cruise at about 0.8 Mach and about 35,000 feet. This flight condition, with the gas turbine engine 20 at its best fuel consumption, is also known as bucket cruise Thrust Specific Fuel Consumption (TSFC). TSFC is an industry standard parameter of fuel consumption per unit of thrust.

[00039] Fan Pressure Ratio is the pressure ratio across a blade of the fan section 22 without the use of a Fan Exit Guide Vane system. The low Fan Pressure Ratio according to one non-limiting embodiment of the example gas turbine engine 20 is less than 1.45. Low Corrected Fan Tip Speed is the actual fan tip speed divided by an industry standard temperature correction of $[(T_{\text{amb}} \text{ } ^\circ\text{R}) / (518.7 \text{ } ^\circ\text{R})]^{0.5}$, where T represents the ambient temperature in degrees Rankine. The Low Corrected Fan Tip Speed according to one non-limiting embodiment of the example gas turbine engine 20 is less than about 1150 fps (351 m/s).

[00040] Each of the compressor section 24 and the turbine section 28 may include alternating rows of rotor assemblies and vane assemblies (shown schematically) that carry airfoils that extend into the core flow path C. For example, the rotor assemblies can carry a plurality of rotor blades 25, while each vane assembly can carry a plurality of vanes 27 that extend into the core flow path C.

[00041] Figure 2 schematically illustrates a portion 100 of a gas turbine engine, such as the gas turbine engine 20 of Figure 1. The portion 100 may be representative of a section of either the compressor section 24 or the turbine section 28 of the gas turbine engine 20. The portion 100 includes a plurality of stages that each include alternating rows of rotor blades 25 and stator vanes 27. Although two stages are illustrated by Figure 2, it should be understood that the portion 100 could include a greater or fewer number of stages.

[00042] The rotor blades 25 rotate about the engine centerline longitudinal axis A in a known manner to either create or extract energy (in the form of pressure) from the core airflow that is communicated through the gas turbine engine 20 along the core flow path C. The stator vanes 27 convert the velocity of airflow into pressure, and turn the airflow in a desired direction to prepare the airflow for the next set of rotor blades 25.

[00043] The rotor blades 25 are at least partially radially surrounded by a shroud assembly 50 (i.e., an outer casing of the engine static structure 33 of Figure 1). A gap 52 can extend between each rotor blade 25 and the shroud assembly 50 to provide clearance for accommodating the rotation of the rotor blades 30.

[00044] Figure 3 illustrates an exemplary rotor blade 25 that can be incorporated into a gas turbine engine. For example, one or more rotor blades of the compressor section 24 and/or the turbine section 28 of the gas turbine engine 20 may include a design similar to the exemplary rotor blade 25. The teachings of this disclosure could also extend to other portions of a gas turbine engine 20. The rotor blade 25 can include one or more design characteristics that provide improved aerodynamic performance, thereby improving gas turbine engine performance.

[00045] In this exemplary embodiment, the rotor blade 25 includes an airfoil 56 that axially extends in chord between a leading edge portion 60 and a trailing edge portion 62. The airfoil 56 also extends in span across a span axis SA between a root region 64 and a tip region 54. The airfoil 56 may also circumferentially extend between a pressure side 66 and a suction side 68.

[00046] A tip portion 58 may extend from the airfoil 56 of the rotor blade 25. In one embodiment, the tip portion 58 extends from the tip region 54 at an angle relative to the airfoil 56. In this embodiment, the tip portion 58 extends from the pressure side 66 of the airfoil 56. That is, the tip portion 58 only extends from a single side of the airfoil 56. The tip portion 58 may extend from the airfoil 56 such that it is parallel to the shroud assembly 50, which radially surrounds the rotor blade 25.

[00047] Although not shown in Figure 3, the rotor blade 25 may also include platform and root portions for attaching the rotor blade 25 to a rotor disk (see feature 39 of Figure 2, for example).

[00048] Figure 4 illustrates the tip portion 58 of the rotor blade 25 of Figure 3. The tip portion 58 can form a dihedral angle α relative to a span axis SA of the airfoil 56.

[00049] In one embodiment, the tip portion 58 forms a dihedral angle α_1 that is 90° relative to the span axis SA. In other words, the tip portion 58 can extend across a span axis SA-T that is perpendicular to the span axis SA of the airfoil 56. In another embodiment, the tip portion 58 forms a dihedral angle α_2 is less than 90° relative to the span axis SA. The tip portion 58 could also form a dihedral angle α_3 that is greater than 90° relative to the span axis SA. In yet another embodiment, the dihedral angle is between 45° and 135° relative to the span axis SA of the airfoil 56.

[00050] Figures 5A, 5B and 5C illustrate possible variations in the chord length over the span of a tip portion 58 of a rotor blade 25. The tip portion 58 extends in span between a root 70 (near the airfoil 56) and a tip 72 (spaced from the airfoil 56) and extends in chord between a leading edge 74 and a trailing edge 76. A plurality of cross-sectional chord slices CL extend between the leading edge 74 and the trailing edge 76 across the span between the root 70 and tip 72.

[00051] Figure 5A illustrates one possible configuration that can be embodied by the tip portion 58. In this embodiment, the tip portion 58 is not tapered between the root 70 and the tip 72. In other words, a chord CL1 that extends through the root 70 (between the leading edge 74 and the trailing edge 76) is the same length as a chord CL2 that extends through the tip 72 (between the leading edge 74 and the trailing edge 76).

[00052] In another embodiment, the tip portion 58 includes a converging taper between the root 70 and the tip 72. In other words, as shown in Figure 5B, a chord

CL1 that extends through the root 70 can include greater length than a chord CL2 that extends through the tip 72. A converging taper such as illustrated by Figure 5B defines taper angles β_1 , β_2 relative to reference axes A1, A2 that extend axially through a leading edge 75 and a trailing edge 77 of the root 70. The taper angles β_1 , β_2 may be the same or different angles. In this configuration, the leading edge 74 of the tip portion 58 extends toward the trailing edge 76 of the tip portion 58 and the trailing edge 76 extends toward the leading edge 74 to define the converging taper.

[00053] Figure 5C illustrates a tip portion 58 having a diverging taper between the root 70 and the tip 72. The diverging taper establishes a larger chord CL2 at the tip 72 as compared to a chord CL1 that extends through the root 70. The diverging taper illustrated by Figure 5C defines taper angles β_1 , β_2 relative to reference axes A1, A2 that extend axially from the leading edge 75 and trailing edge 77 of the root 70. In this configuration, the leading edge 74 of the tip portion 58 extends away from the trailing edge 76 and the trailing edge 76 extends away from the leading edge 74 to define the diverging taper. The taper angles β_1 , β_2 may be the same or different angles.

[00054] Figures 6A, 6B and 6C illustrate additional design features that can be incorporated into a tip portion 58 of a rotor blade 25. For example, the tip portion 58 can also form a sweep angle μ . The sweep angle μ is defined between a chord axis CL1 and a span axis SP1 of the tip portion 58. In one non-limiting embodiment, the span axis SP1 intersects the chord axis CL1 at 25% of the length of the chord axis CL1 between the leading edge 74 and the trailing edge 76.

[00055] The tip portion 58 can include no sweep (see Figure 6A), an aft sweep (see Figure 6B) or a forward sweep (see Figure 6C). The aft sweep extends in a downstream direction DD relative to the airfoil 56 (i.e., toward the trailing edge 62). A forward sweep extends in an upstream direction UD relative to the airfoil 56 (i.e., toward the leading edge 60).

[00056] Figures 7A and 7B illustrate additional characteristics that can be designed into the tip portion 58 of a rotor blade 25. The tip portion 58 may include an airfoil tip rotation. As shown in Figure 7A, the tip 72 of the tip portion 58 may be rotated by an angle Δ_1 toward the root region 64 (see Figure 3) of the airfoil 56. Alternatively, as shown in Figure 7B, the tip 72 of the tip portion 58 can be rotated by an angle Δ_2 in a direction away from the root region 64. In other words, the tip 72 of the tip portion 58 can include a nose down or a nose up configuration.

[00057] Although the design characteristics described above and illustrated in Figures 4, 5A, 5B, 5C, 6A, 6B, 6C, 7A and 7B of this application are shown individually, it should be understood that any given tip portion of a rotor blade can include any combination of these design configurations. For example, one exemplary rotor blade can include a tip portion having a dihedral angle that is greater than 90°, a converging taper, no sweep and a nose down configured tip. In another configuration, a tip portion of a rotor blade can include a normal dihedral angle, a diverging taper, forward sweep and no tip rotation. It should be understood that the specific design characteristics for any given rotor blade can vary depending upon design specific parameters, including but not limited to, the aerodynamic and performance requirements of a gas turbine engine.

[00058] Although the different non-limiting embodiments are illustrated as having specific components, the embodiments of this disclosure are not limited to those particular combinations. It is possible to use some of the components or features from any of the non-limiting embodiments in combination with features or components from any of the other non-limiting embodiments.

[00059] It should be understood that like reference numerals identify corresponding or similar elements throughout the several drawings. It should also be understood that although a particular component arrangement is disclosed and illustrated in these exemplary embodiments, other arrangements could also benefit from the teachings of this disclosure.

[00060] The foregoing description shall be interpreted as illustrative and not in any limiting sense. A worker of ordinary skill in the art would understand that certain modifications could come within the scope of this disclosure. For these reasons, the following claims should be studied to determine the true scope and content of this disclosure.

CLAIMS

What is claimed is:

1. A rotor blade for a gas turbine engine, comprising:
an airfoil extending in span between a root region and a tip region; and
a tip portion extending at an angle from said tip region of said airfoil.
2. The rotor blade as recited in claim 1, wherein a span axis of said tip portion forms a dihedral angle relative to a span axis of said airfoil.
3. The rotor blade as recited in claim 2, wherein said dihedral angle is greater than or equal to 90° relative to said span axis of said airfoil.
4. The rotor blade as recited in claim 2, wherein said dihedral angle is less than or equal to 90° relative to said span axis of said airfoil.
5. The rotor blade as recited in claim 2, wherein said dihedral angle is between 45° and 135° degrees relative to said span axis of said airfoil.
6. The rotor blade as recited in claim 1, wherein said tip portion extends from a pressure side of said airfoil.
7. The rotor blade as recited in claim 1, wherein said tip portion extends in span between a root and a tip and extends in chord between a leading edge and a trailing edge, and said tip portion defines a plurality of cross-sectional slices that extend between said leading edge and said trailing edge along said span of said tip portion.
8. The rotor blade as recited in claim 7, wherein said tip portion is not tapered between said root and said tip of said tip portion.
9. The rotor blade as recited in claim 7, wherein said tip portion includes a converging taper between said root and said tip of said tip portion.
10. The rotor blade as recited in claim 7, wherein said tip portion includes a diverging taper between said root and said tip of said tip portion.

11. The rotor blade as recited in claim 1, wherein said tip portion forms a sweep angle that is defined between a chord axis and a span axis of said tip portion.
12. The rotor blade as recited in claim 11, wherein said tip portion includes an aft sweep.
13. The rotor blade as recited in claim 11, wherein said tip portion includes a forward sweep.
14. The rotor blade as recited in claim 1, wherein said tip portion defines a sweep angle and a dihedral angle that extend across an entire span of said tip portion.
15. The rotor blade as recited in claim 1, wherein a tip of said tip portion is rotated in a direction toward said root region.
16. The rotor blade as recited in claim 1, wherein a tip of said tip portion is rotated in a direction away from said root region.

17. A gas turbine engine, comprising:
 - a compressor section;
 - a combustor section in fluid communication with said compressor section;
 - a turbine section in fluid communication said combustor section;
 - a plurality of rotor blades positioned within at least one of said compressor section and said turbine section, and each of said plurality of rotor blades includes:
 - an airfoil extending in span between a root region and a tip region; and
 - a tip portion extending at an angle from said tip region of said airfoil.

18. The gas turbine engine as recited in claim 17, wherein said plurality of rotor blades are at least partially radially surrounded by a shroud assembly.

19. The gas turbine engine as recited in claim 17, wherein said tip portion includes a dihedral angle and a sweep angle that extend across an entire span of said tip portion.

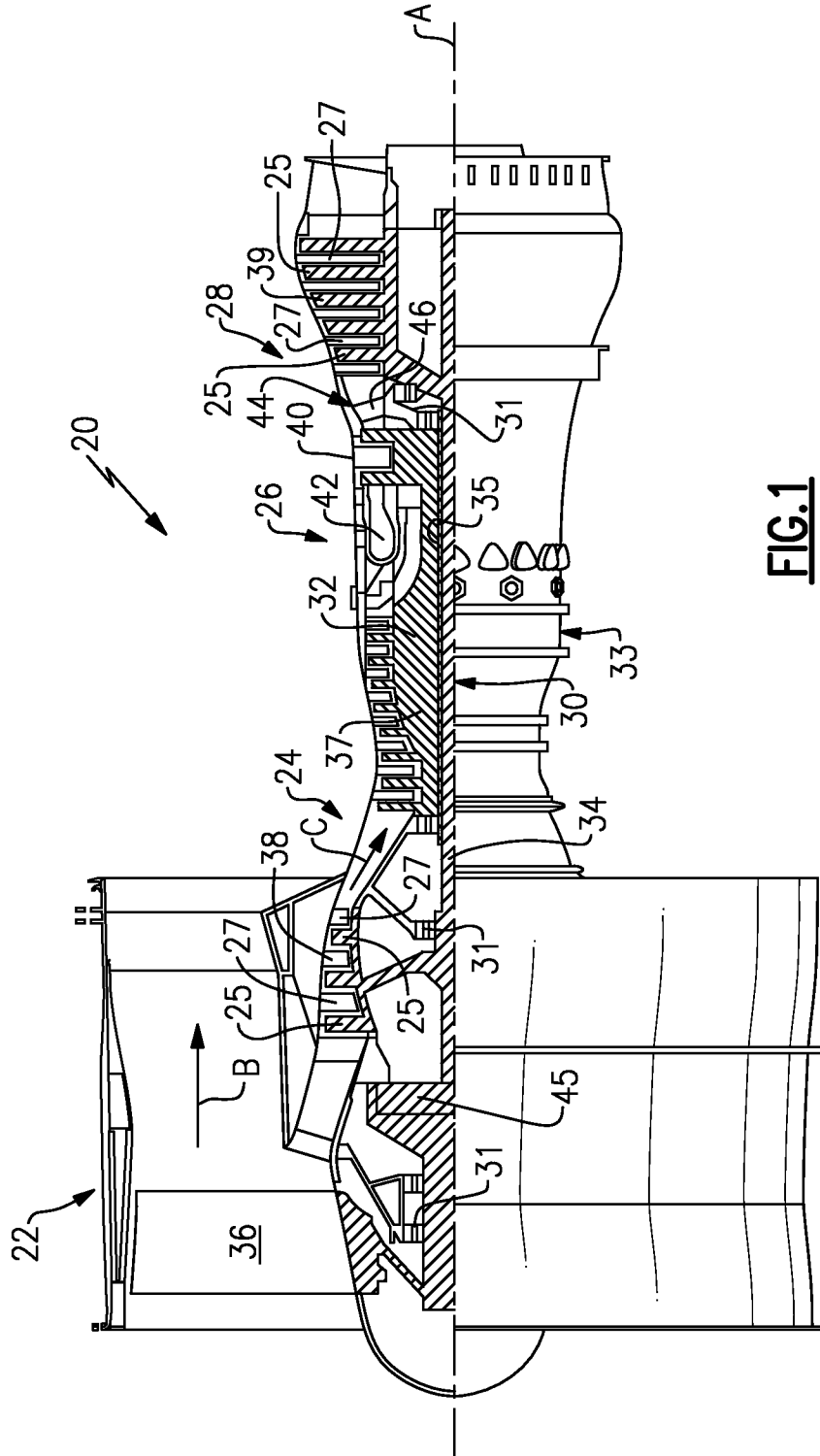


FIG. 1

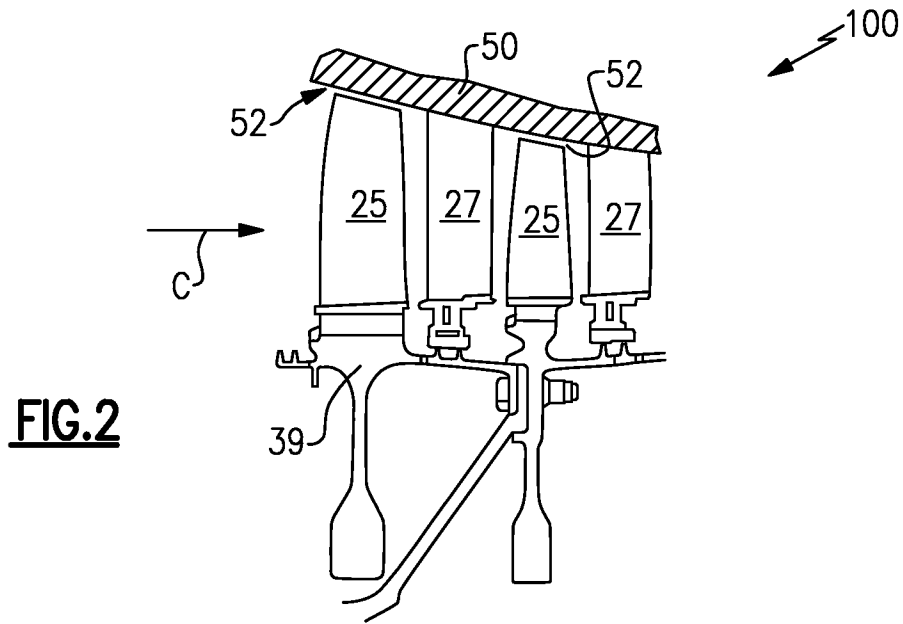


FIG. 2

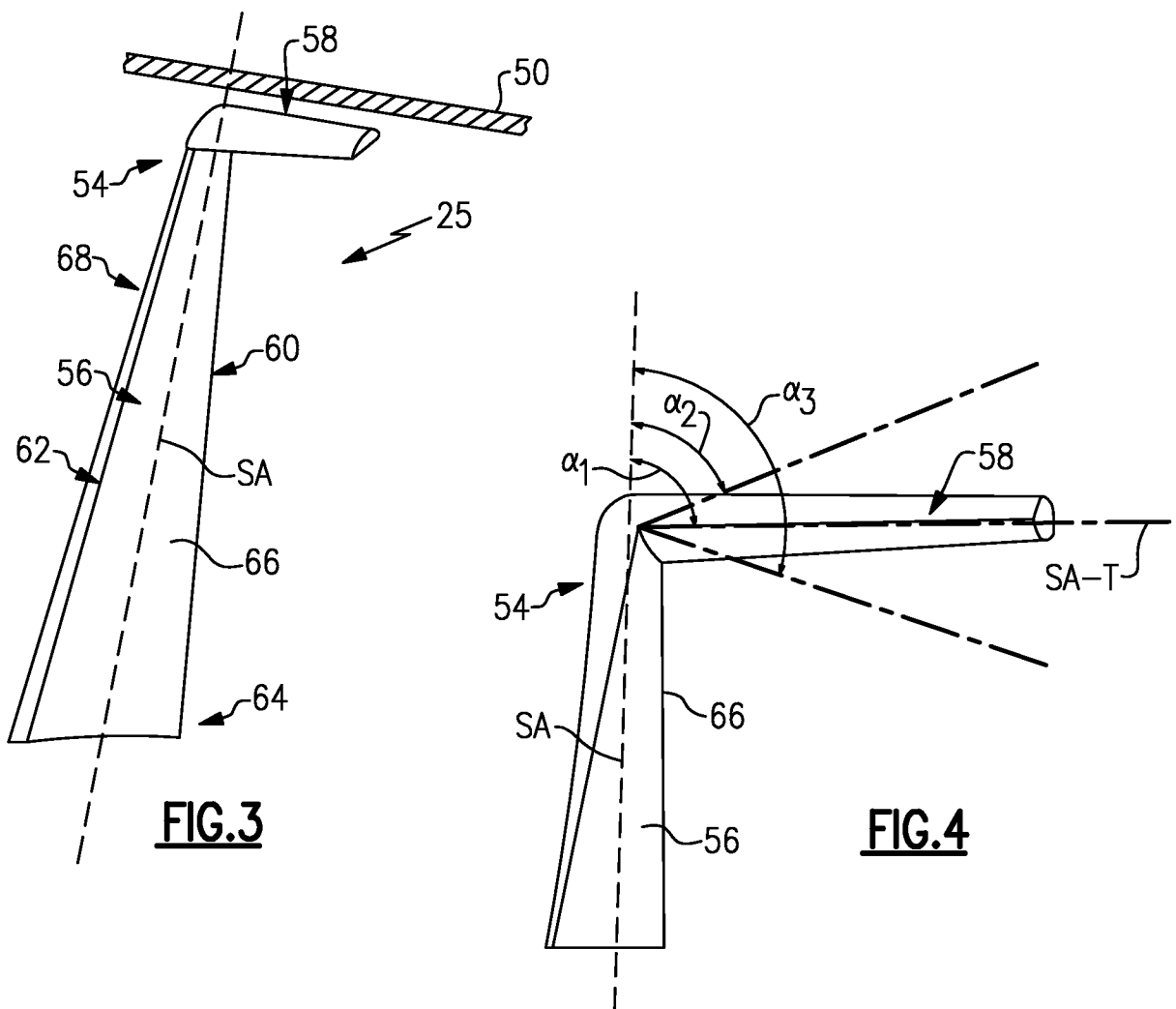
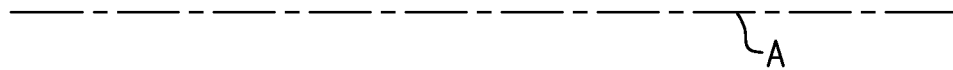


FIG. 3

FIG. 4

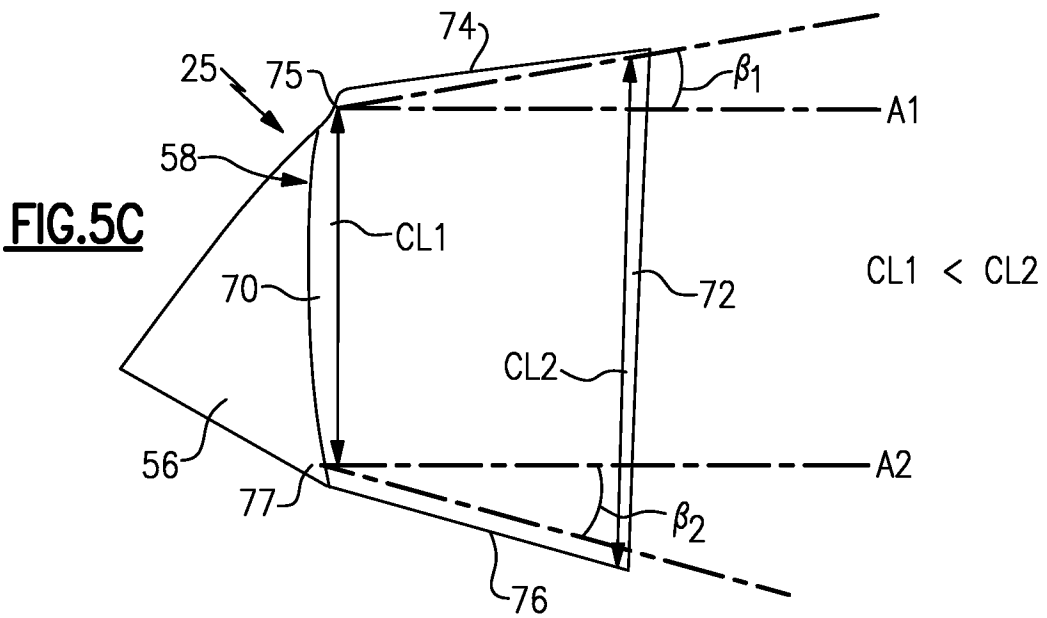
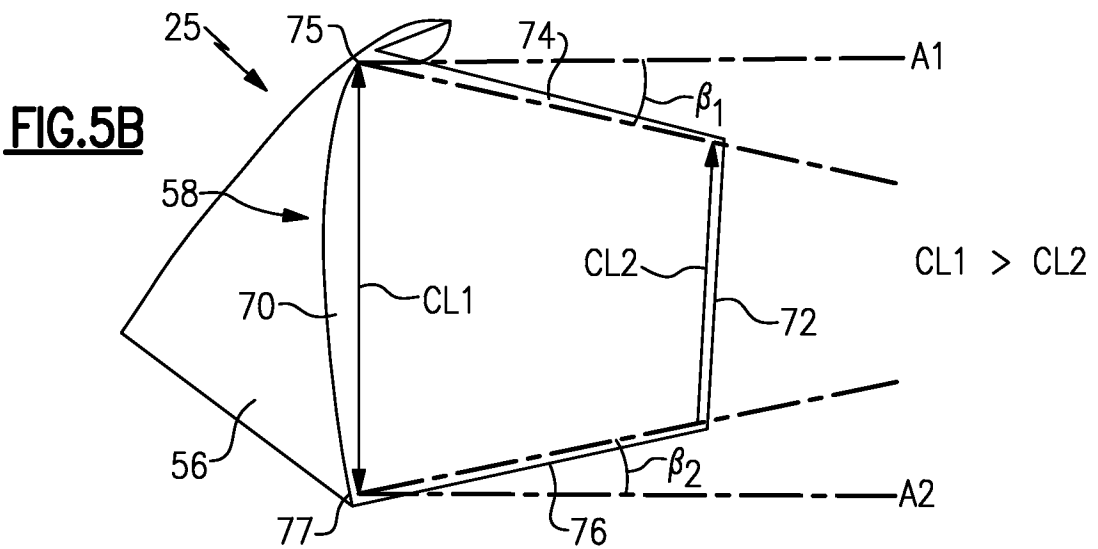
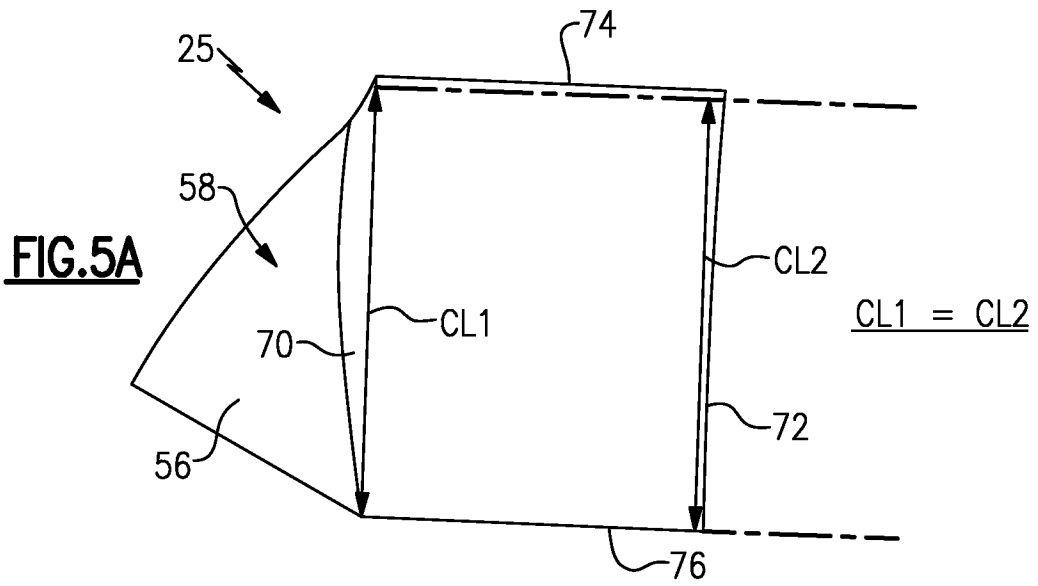


FIG. 6A

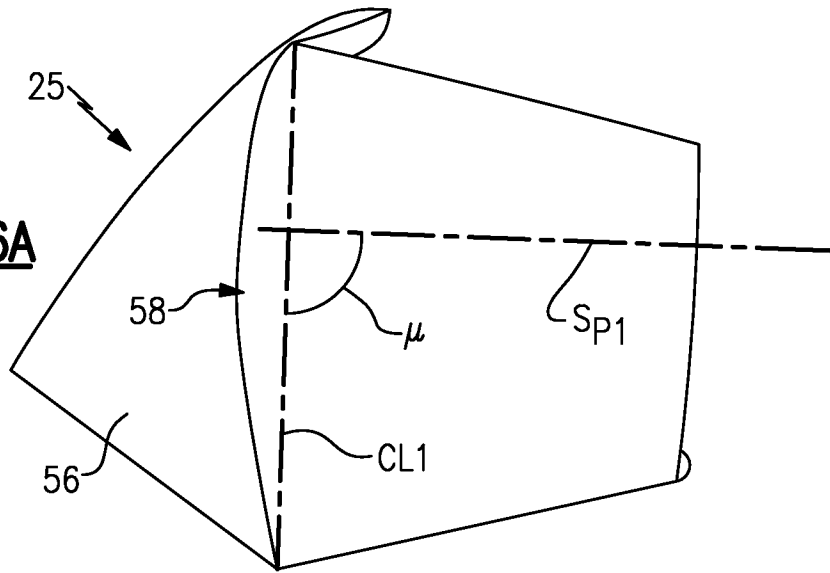


FIG. 6B

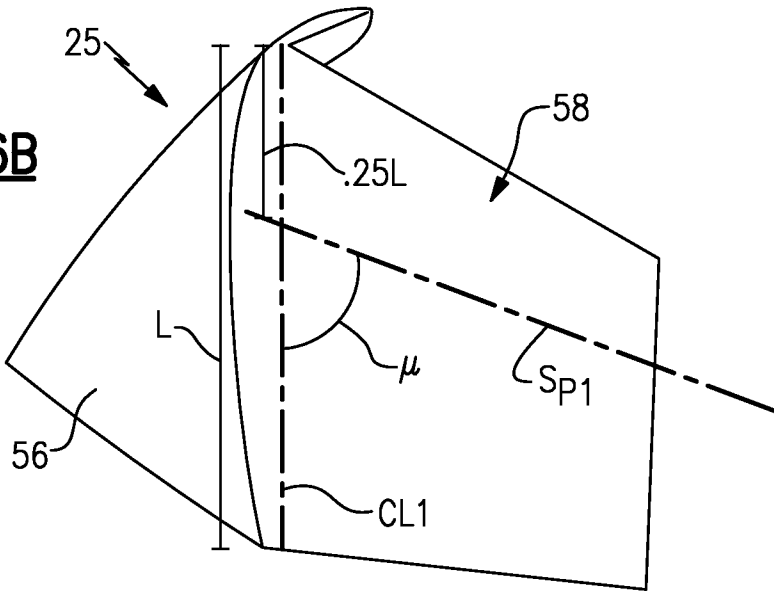
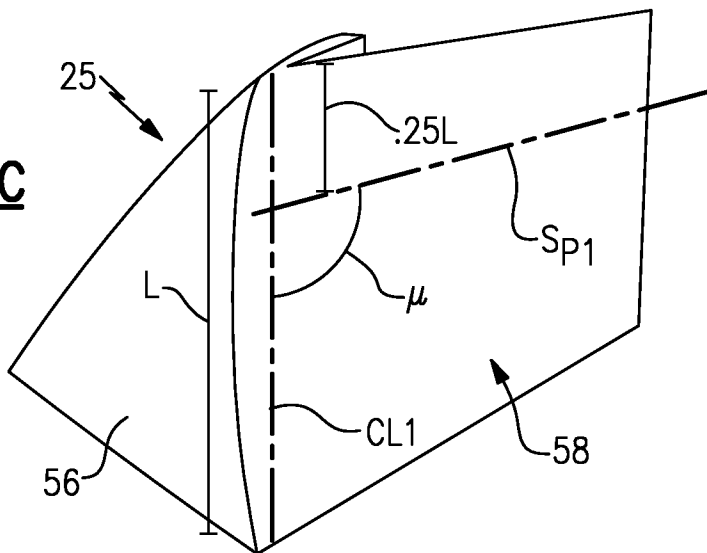


FIG. 6C



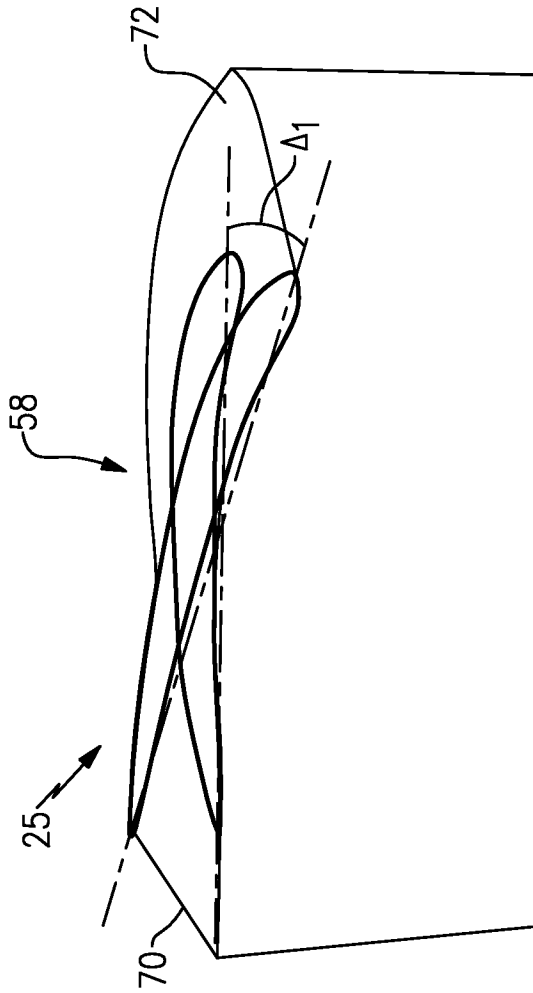


FIG. 7A

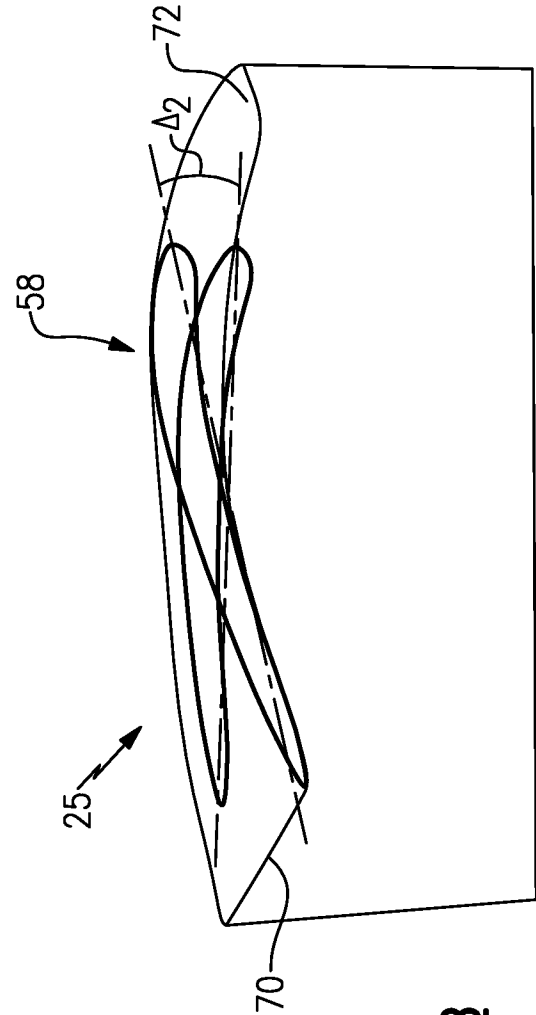


FIG. 7B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/010175**A. CLASSIFICATION OF SUBJECT MATTER****F01D 5/14(2006.01)i, F01D 5/12(2006.01)i, F02C 7/00(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F01D 5/14; F01D 25/00; F01D 11/08; F16J 15/40; F01D 11/04; F04D 29/08; F01D 5/12; F02C 7/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: turbine engine, blade, airfoil, tip, gap, clearance, and seal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009-0252602 A1 (DIAKUNCHAK, IHOR S.) 08 October 2009 See abstract; paragraphs [0002],[0017]-[0021]; and figures 1-4.	1-19
A	US 4,161,318 A (STUART et al.) 17 July 1979 See abstract; column 1, lines 60-64, column 2, lines 8-14,51-67; and figures 1-4.	1-19
A	US 2011-0002777 A1 (SMITH, BRUCE L.) 06 January 2011 See abstract; paragraphs [0030]-[0033],[0037]-[0040]; and figures 1-3,6-9,11,12.	1-19
A	US 5,234,318 A (BRANDON, RONALD E.) 10 August 1993 See abstract; column 2, lines 36-65; and figures 1-9.	1-19
A	US 2009-0269189 A1 (BOTTOME, KRISTOFER JOHN) 29 October 2009 See abstract; paragraphs [0024],[0025],[0027]-[0030],[0033]-[0035]; and figures 1-7.	1-19

 Further documents are listed in the continuation of Box C. See patent family annex.

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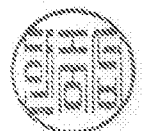
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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