



(43) International Publication Date
2 October 2014 (02.10.2014)

- (51) International Patent Classification:
F01D 5/20 (2006.01) *F01D 9/02* (2006.01)
F01D 5/12 (2006.01)
- (21) International Application Number:
PCT/US2013/069095
- (22) International Filing Date:
8 November 2013 (08.11.2013)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
61/777,413 12 March 2013 (12.03.2013) US
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: CANTILEVER STATOR WITH VORTEX INITIATION FEATURE

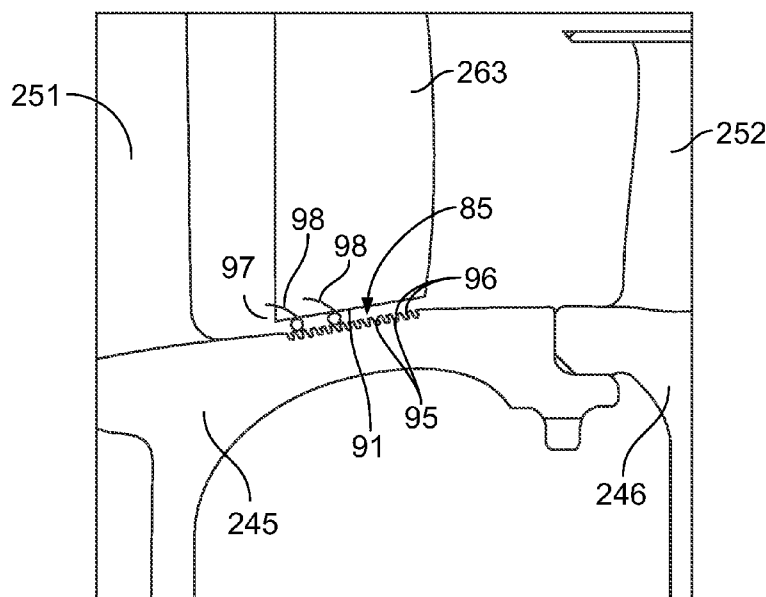


FIG. 5

(57) Abstract: An axial flow compressor is disclosed with a plurality of rotors. Each rotor includes a disk having an outer rim. Each outer rim is coupled to a radially outwardly extending rotor blade. The case is coupled to a plurality of radially inwardly extending stator vanes, i.e. cantilever-type stator vanes. Each stator vane is disposed between two rotor blades and extends towards one of the outer rims and terminates at a tip disposed in close proximity to one of the outer rims. At least one of the outer rims includes a serrated outer surface that faces the tip of a stator vane which results in a vortex flow causing air that would normally leak through the clearance between the stator vane and the outer rim to engage the stator vane to a greater degree thereby increasing the efficiency of the compressor.

CANTILEVER STATOR WITH VORTEX INITIATION FEATURE**TECHNICAL FIELD**

[0001] This disclosure relates to gas turbine engines and, more specifically, to compressors of gas turbine engines. The disclosed compressors reduce leakage between a cantilevered stator vane and an outer rim of a rotating disk.

BACKGROUND

[0002] A sectional view of a gas turbine engine 10 of the turbo fan type is shown in FIG. 1. While not shown, the engine 10 may also be a geared turbofan engine. The engine 10 includes a nacelle 11 that surrounds the fan 12. The fan 12 may be connected to a nose 13 for aerodynamic purposes and, as the fan 12 rotates, it generates two primary air flows including a bypass airflow indicated by the arrow 14 and that flows between the nacelle 11 and the engine case 15 which serves as a housing for the primary engine components. The fan 12 also helps to generate an air flow that passes through the engine case 15 as indicated by the arrow 16. A low-pressure compressor 17 is disposed aft of the fan 12 and is coupled to a low-pressure turbine 18 by the shaft 21. A high-pressure compressor 22 is disposed aft of the low-pressure compressor 17 and forward of the combustor 23. The combustor 23 is disposed between the high-pressure compressor 22 and the high-pressure turbine 24. The high-pressure turbine 24 and the high-pressure compressor 22 are coupled together by the outer shaft 25.

[0003] Air enters the engine 10 via the fan 12 before being compressed by the low-pressure compressor 17 and before being compressed again by the high-pressure compressor 22 before being combusted in the combustor 23. The combustion gasses then rotate the high-pressure turbine 24 and low-pressure turbine 18 (which drive the high-pressure compressor 22 and low-pressure compressor 17 respectively) before exiting the engine 10 through the nozzle 26.

[0004] One primary problem associated with gas turbine engines 10 is leakage, especially in the compressors 17, 22. For example, a high-pressure compressor 22 is illustrated in FIG. 2. The high-pressure compressor 22 is surrounded by the case 15 and includes a plurality of rotors 27-32. Each rotor 27-32 includes a disk 33-38. Each disk 33-38 may include a radially inwardly end 39-44 which may serve as a hub for connecting the disks 33-38 to the shaft 25 (see FIG. 1). Each disk 33-38 may also include a radially outward end 45-50. The radially outward ends 45-50 are typically coupled to rotor blades 51-56. The rotor blades include distal tips 57-62 which are disclosed in close proximity to interior surfaces of the case 15. The clearance between the rotor blade tips 57-62 and the interior surfaces of the case 15 are one source of leakage in such a high-pressure compressor. Another source of leakage involves the stators 63-67 which are coupled to the case 15 as well as shrouds 68-72. As shown in FIG. 2, the shrouds 68-72 may be of a fixed dimension (see the shrouds 70, 71 and 72) or the shrouds may be variable (see the shrouds 68, 69). Either way, clearance between the variable stators 63, 64 and the rotors 27, 28 and clearance between the non-variable stators 65-67 and the rotors 29-32 is another source of leakage.

[0005] The compressor 22 of FIG. 2 includes stators 63-67 of the shrouded type. Turning to FIG. 3, another high-pressure compressor 122 is disclosed with “cantilevered” stator 163-167. The reader will note that the cantilevered stators 163-167 are secured to the case 115 and are not physically connected to nor engaging the rotors 127-131. Instead, there is clearance between the radially inwardly directed tips 76-79 and the radially outward ends 145, 147, 149 of the rotors 127, 129, 131. The clearances between the tips 76-79 and the radially outward ends 145, 147, 149 of the rotors 127, 129, 131 are another source of leakage for the compressor 122.

[0006] The negative impacts of such leakage between rotor blades and the case or between stator vanes and the hubs are well documented. An increase in the rotor tip clearance leakage leads to a reduction in stage pressure rise, efficiency and flow range. For example, rotor blades with normal operating clearances generate a 1.5 % reduction in efficiency for every 1% increase in the clearance to blade-height ratio. Such leakage also increases the stall margin. Similar effects are caused by leakage at the stator vane tip, whether the stator vanes are of the shrouded type as shown in FIG. 2 or of the cantilevered type shown in FIG. 3. Another option that is not shown in FIGS. 2 or 3 is to employ an abradable rub system which is expensive, prone to wear or deterioration and therefore results in a loss in effectiveness.

[0007] Therefore, there is a need for an improved stator vane design which minimizes leakage and forces more air flow to pass across the body of the stator vane.

SUMMARY

[0008] In one aspect, an axial flow compressor is disclosed which includes a plurality of rotors coaxially disposed within a case and coupled together. Each rotor includes a disk having a radially outward end that includes an outer rim. Each outer rim is coupled to a radially outwardly extending rotor blade. Each radially outwardly extending rotor blade terminates at a tip. The case is also coupled to a plurality of radially inwardly extending stator vanes. Each stator vane may be disposed between two rotor blades and may extend towards one of the outer rims before terminating at a tip disposed in close proximity to one of the outer rims. At least one of the outer rims includes a serrated outer surface that faces the tip of one of the stator vanes.

[0009] In another aspect, a high-pressure compressor for a gas turbine engine is disclosed. The compressor may include a plurality of rotors coaxially disposed within a case. Each rotor may include a disk having a radially inward end that includes a hub and a radially outward end

that includes an outer rim. Each outer rim may be coupled to at least one radially outwardly extending rotor blade and each outer rim may also be coupled to at least one other outer rim of at least one adjacent disk. Each radially outwardly extending rotor blade may terminate at a tip disposed in close proximity with an interior surface of the case. The case may be coupled to a plurality of radially inwardly extending stator vanes. Each stator vane may be disposed between two rotor blades and may extend towards one of the outer rims before terminating at a tip disposed in close proximity to one of the outer rims. A plurality of the outer rims may include a serrated outer surface that faces the tip of one of the stator vanes. The serrated outer surfaces may each include a plurality of coaxial and adjacent grooves spaced apart by coaxial lands.

[0010] And yet in another aspect, a gas turbine engine is disclosed. The engine may include a high-pressure compressor disposed between a low-pressure compressor and a combustor. The high-pressure compressor may be coaxially coupled to a high-pressure turbine for rotation with the high-pressure turbine. The high-pressure compressor may include a plurality of rotors coaxially disposed within the case. Each rotor may include a disk having a radially inward end and a radially outward end that includes an outer rim. Each outer rim may be coupled to a radially outwardly extending rotor blade and at least one other outer rim of at least one adjacent disk. Each radially outwardly extending rotor blade may terminate at a tip disposed in close proximity with an interior surface of the case. The case may be coupled to a plurality of radially inwardly extending stator vanes. Each stator vane may be disposed between two rotor blades and may extend toward one of the outer rims and may further terminate at a tip disposed in close proximity to one of the outer rims. A plurality of the outer rims may include a serrated outer surface wherein each serrated outer surface faces a tip of one of the stator vanes.

[0011] In any one or more of the aspects described above, the serrated outer surface may include a plurality of adjacent grooves.

[0012] In any one or more of the aspects described above, the serrated outer surface may include a plurality of coaxial grooves separated by lands with each land disposed between two grooves. The grooves may be defined by a bottom surface disposed between two sidewalls. The side walls may be slanted in the fore direction. In a further refinement of this concept, the lands may be flat.

[0013] In any one or more of the aspects described above, the stator vane that faces the serrated outer surface has a width. Further, the serrated outer surface also has a width, however, the width of the serrated outer surface may be smaller than the width of the stator vane that faces the serrated outer surface.

[0014] In any one or more of the aspects described above, the tip of the stator vane that faces the serrated outer surface may be free of an abradable coating.

[0015] In any one or more of the aspects described above, at least one outer rim includes two serrated outer surfaces disposed on either side of a rotor blade. The rotor blade may be disposed axially between two stator vanes with each of the two stator blades being in alignment with one of the two serrated outer surfaces.

[0016] In any one or more of the aspects described above, at least one outer rim may not include a serrated outer surface and may be disposed between and coupled to two outer rims that each include at least one serrated outer surface.

[0017] In any one or more of the embodiments described above, the compressor may be a high-pressure compressor of a gas turbine engine that also includes a low-pressure compressor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. 1 is a sectional view of a prior art turbofan gas turbine engine.

[0019] FIG. 2 is a sectional view of a prior art high-pressure compressor that may be utilized in the gas turbine engine shown in FIG. 1.

[0020] FIG. 3 is a sectional view of another prior art high-pressure compressor that may be utilized in the gas turbine engine of FIG. 1.

[0021] FIG. 4 is a sectional view of a disclosed high-pressure compressor.

[0022] FIG. 5 is an enlarged and partial sectional view of the high-pressure compressor shown in FIG. 4.

[0023] FIG. 6 illustrates, graphically, a comparison of efficiency versus clearance for prior art cantilever stator vane with a rub system early in the life cycle of the rub system, a cantilever stator vane without a rub system and the disclosed cantilever stator operating with the serrated outer rim that creates the vortex flow across the body of the stator vane.

DESCRIPTION

[0024] Turning to FIGS. 4 and 5, a disclosed high-pressure, and axial-flow compressor 222 is shown in a sectional view and that also includes the plurality of rotors 227-231. Each rotor includes a disk 233-237. Each disk 233-237 includes a radially inward end 239-243, that may serve as a hub for coupling the disk 233-237 and the high-pressure compressor 222 to a shaft 25 like that shown in FIG. 1. Each disk 233-237 also includes a radially outward end 245-249. Each radially outward end 245-249 may be coupled to a rotor blade 251-255. The rotor blades 251-254 may be integrally connected to their respective disks 233-236 while the rotor blade 255

of the last stage may be connected to the disk 237 by way of a dovetail connection. The rotor 231 also serves as a final stage to the high-pressure compressor 222 and therefore includes a seal mechanism 81 to keep the compressed air from leaking radially inwardly before it reaches the combustor 23 (see FIG. 1). The case 215 is coupled to a plurality of stator vanes 263-266 that are of the cantilever-type, or in other words, stators that are suspended from the case 215 and extend radially inward towards the disks 233-236. An additional shrouded stator 267 is coupled to the case 215 and the shroud 270 which engages the seal 81.

[0025] Referring to the stators 263, 264 and 265 and to FIGS. 4-5, the stator vanes 263, 264, 265 extend radially inwardly towards serrated surfaces 85-87. The serrated surface 85 that is disposed in close proximity to the distal tip 91 of the stator vane 263 is more clearly illustrated in FIG. 5. It will be noted that the relationship between the serrated surface 85 and the distal tip 91 of the stator vane 263 is analogous to the relationships between the serrated surfaces 86, 87 and the distal tips 92, 93 of the stator vanes 264, 265 respectively. Each serrated surface 85-87 includes a plurality of grooves 95 disposed between lands 96. As shown in FIG. 5, the grooves 95 are defined by opposing sidewalls that terminate in a land 96 and the grooves 95 are slanted in the fore direction. As compressed air is traveling through the high-pressure compressor 222 in the aft direction, any leakage in the clearance 97 between the stator vane 263 and the serrated surface 85 will create multiple vortices shown schematically at 98 in FIG. 5. The multiple vortices 98 act to force the majority of the gas pass flow to pass the body of the stator 263 as opposed to passing along the distal tip 91. As a result, the effective clearance is tighter than the physical clearance 97 thereby increasing the efficiency of the stator vane 263 and the high-pressure compressor 222. The high-pressure compressor 222 may include a plurality of serrated

surfaces 85-87 thereby decreasing efficiency losses caused by clearances between the stator vanes 263, 264, 265 and the radially outward ends 245 and 247.

[0026] A non-dimensional comparison of three different stator vane styles is shown in FIG. 6. The line 101 represents a baseline efficiency for shrouded stator vanes, like that shown in FIG. 2. The data point 102 represents a cantilevered stator vane without abradable material on its distal tip so the stator vane does not rub up against the disk. The data point 103 represents the disclosed stator vane that is of a cantilever-type that has clearance between it and its respective disk that includes a serrated surface in alignment with the distal tip of the stator vane. The data point 103 represents a substantially increased efficiency for the disclosed stator vanes/serrated surfaces in comparison to the data point 102 and the baseline 101 which represents typical shrouded stator vanes. The data point 104 represents a cantilever-type stator with abradable material at its distal tip so that it engages its respective disk. While the data point 104 represents an increase in efficiency over the data point 103, the abradable material that rubs against the disk must be replaced with relative frequency and therefore the data point 104 represents a stator vane that is substantially more costly to employ than the disclosed stator vanes of the data point 103.

INDUSTRIAL APPLICABILITY

[0027] A high-pressure compressor 222 is disclosed that includes a plurality of disks 233 and 235 that may include one or more serrated surfaces 85, 86, 87 that are in alignment with cantilever-type stator vanes 263, 264, 265. The serrated surfaces 85, 86, 87 create a vortex flow as air leaks between the distal tips 91, 92, 93 of the stator vanes 263, 264, 265. The vortex flow causes the air to rotate upward and engage the stator vanes 263, 264, 265 as opposed to passing through the clearance between the distal tips 91, 92, 93 and the radially outward ends 245, 247 of the disks 233, 235. While the high-pressure compressor 222 utilizes only three such serrated

surfaces 85, 86, 87 that are in alignment with three stator vanes 263, 264, 265, more or fewer stator vanes/serrated surface combinations may be employed. The vortex flow caused by the serrated surfaces 85, 86, 87 causes more air to engage the stator vanes 263, 264, 265 as opposed to merely passing along the clearance between the distal tips 91, 92, 93 of the stator vanes 263, 264, 265 and the radially outward surfaces 244, 247 of the disks 233, 235. Hence, efficiency is improved without resorting to the use of an abradable material disposed on the distal tips 91, 92, 93 of the stator vanes 263, 264, 265. By avoiding the use of such abradable rub material, maintenance is reduced and the efficiencies between the disclosed serrated surface/stator vane distal tip combination and stator vanes with abradable rub material disposed on their distal tips is comparable, even when the abradable rub material is early in its life cycle. Thus, an efficient high-pressure compressor 222 is disclosed that is more efficient than many existing designs, maintains its efficiency longer than other existing designs and is cheaper to operate due to the reduced maintenance.

CLAIMS

1. An axial flow compressor, comprising:

a plurality of rotors coaxially disposed within a case and coupled together, each rotor including a disk having a radially outward end that includes an outer rim, each outer rim is coupled to a radially outwardly extending rotor blade, each radially outwardly extending rotor blade terminating at a tip;

the case being coupled to a plurality of radially inwardly extending stator vanes, each stator vane extending towards one of the outer rims and terminating at a tip disposed in close proximity to one of the outer rims;

at least one outer rim including a serrated outer surface that faces the tip of one of the stator vanes.

2. The compressor of claim 1 wherein the serrated outer surface includes a plurality of adjacent grooves.

3. The compressor of claim 1 wherein the serrated outer surface includes a plurality of coaxial grooves separated by lands with each land disposed between two grooves, the grooves being defined by a bottom surface disposed between two side walls, the sidewalls being slanted in a fore direction.

4. The compressor of claim 3 wherein the lands are flat.
5. The compressor of claim 1 wherein that stator vane that faces the serrated outer surface has a width and the serrated outer surface has a width that is smaller than the width of the stator vane that faces the serrated outer surface.
6. The compressor of claim 1 wherein the tip of the stator vane that faces the serrated outer surface is free of an abradable coating.
7. The compressor of claim 1 wherein at least one outer rim includes two serrated outer surfaces disposed on either side of a rotor blade, the rotor blade being disposed axially between two stator blades, each of the two stator blades being in alignment with one of the two serrated outer surfaces.
8. The compressor of claim 1 wherein at least one outer rim does not include a serrated outer surface and is disposed between and coupled to two outer rims that each include at least one serrated outer surface.

9. The compressor of claim 1 wherein the compressor is a high-pressure compressor of a gas turbine engine that also includes a low-pressure compressor.

10. A compressor for a gas turbine engine, the compressor comprising:

a plurality of rotors coaxially disposed within a case, each rotor including a disk having a radially inward end that includes a hub and a radially outward end that includes an outer rim, each outer rim is coupled to at least one radially outwardly extending rotor blade and each outer rim is also coupled to at least one other outer rim of at least one adjacent disk, each radially outwardly extending rotor blade terminating at a tip disposed in close proximity with an interior surface of the case;

the case being coupled to a plurality of radially inwardly extending stator vanes, each stator vane extending towards one of the outer rims and terminating at a tip disposed in close proximity to one of the outer rims;

a plurality of the outer rims including a serrated outer surface, each serrated outer surface facing the tip of one of the stator vanes; and

the serrated outer surfaces each including a plurality of coaxial and adjacent grooves spaced apart by coaxial lands.

11. The compressor of claim 9 wherein the grooves are defined by a bottom surface disposed between two side walls, the sidewalls being slanted in a fore direction.

12. The compressor of claim 9 wherein the lands are flat.

13. The compressor of claim 10 wherein the stator vanes that face the serrated outer surfaces have widths and the serrated outer surfaces have a widths that are smaller than the widths of the stator vanes that face the serrated outer surfaces.

14. The compressor of claim 10 wherein the tips of the stator vanes that face the serrated outer surfaces are free of an abradable coating.

15. A gas turbine engine, comprising:

a high-pressure compressor disposed between a low-pressure compressor and a combustor, the high-pressure compressor being coaxially coupled to a high-pressure turbine for rotation with the high-pressure turbine;

the high-pressure compressor including a plurality of rotors coaxially disposed within a case, each rotor including a disk having a radially inward end and a radially outward end that includes an outer rim, each outer rim is coupled to a radially outwardly extending rotor blade and to at least one other outer rim of at least one adjacent disk, each radially outwardly extending rotor blade terminating at a tip disposed in close proximity with an interior surface of the case;

the case being coupled to a plurality of radially inwardly extending stator vanes, each stator vane extending towards one of the outer rims and terminating at a tip disposed in close proximity to one of the outer rims;

a plurality of the outer rims including a serrated outer surface, each serrated outer surface facing the tip of one of the stator vanes.

16. The engine of claim 15 wherein the serrated outer surface includes a plurality of adjacent and coaxial grooves.

17. The engine of claim 15 wherein the serrated outer surface includes a plurality of coaxial grooves separated by lands with each groove disposed between two lands, the grooves being defined by a bottom surface disposed between two side walls, the sidewalls being slanted in a fore direction.

18. The engine of claim 17 wherein the lands are flat.

19. The engine of claim 15 wherein each stator vane that faces one of the serrated outer surfaces has a width and each serrated outer surface has a width that is smaller than the width of the stator vane that faces the serrated outer surface.

20. The engine of claim 15 wherein the tips of the stator vanes that face the serrated outer surfaces are free of abradable coatings.

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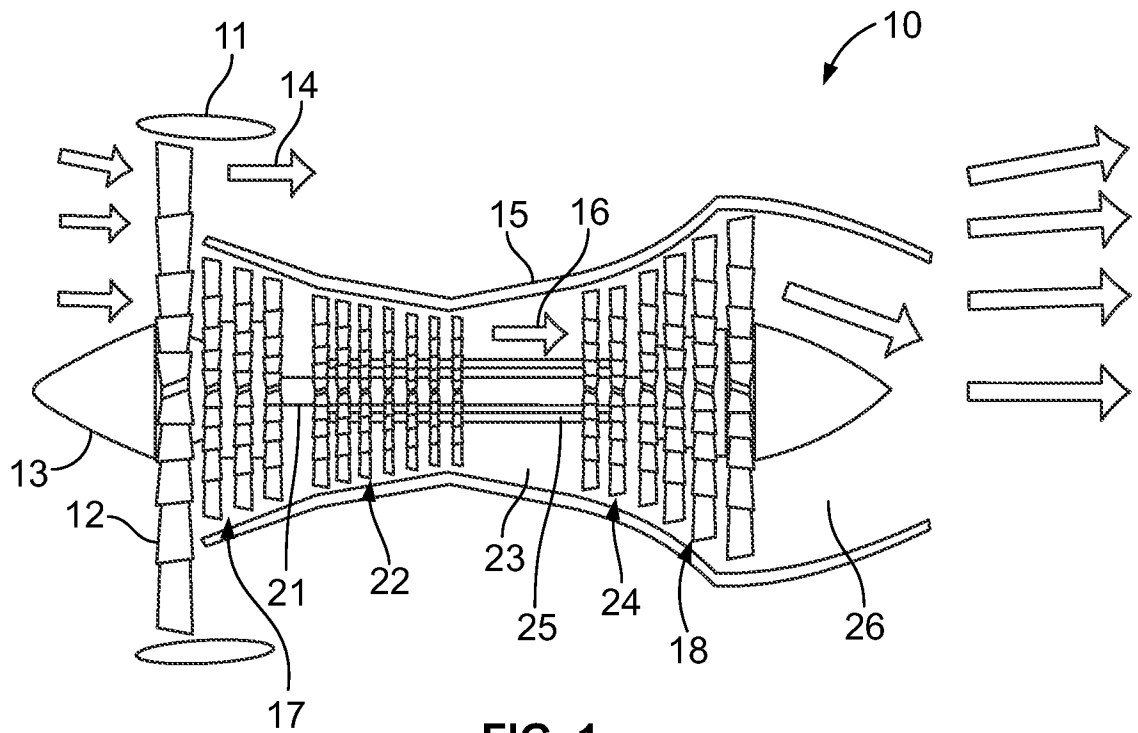


FIG. 1
PRIOR ART

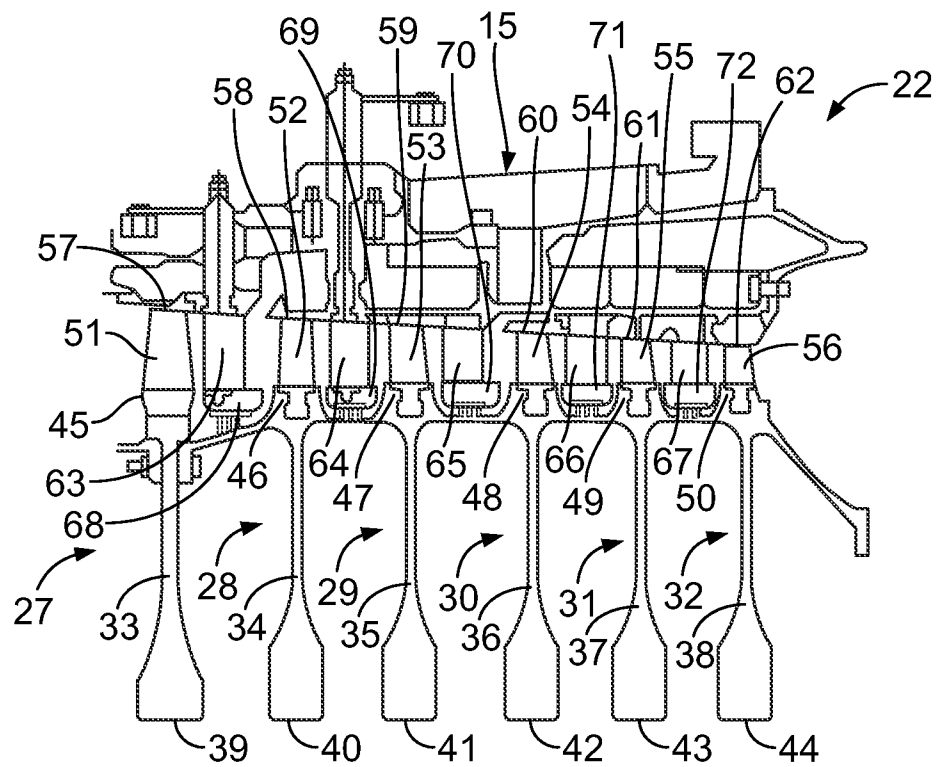
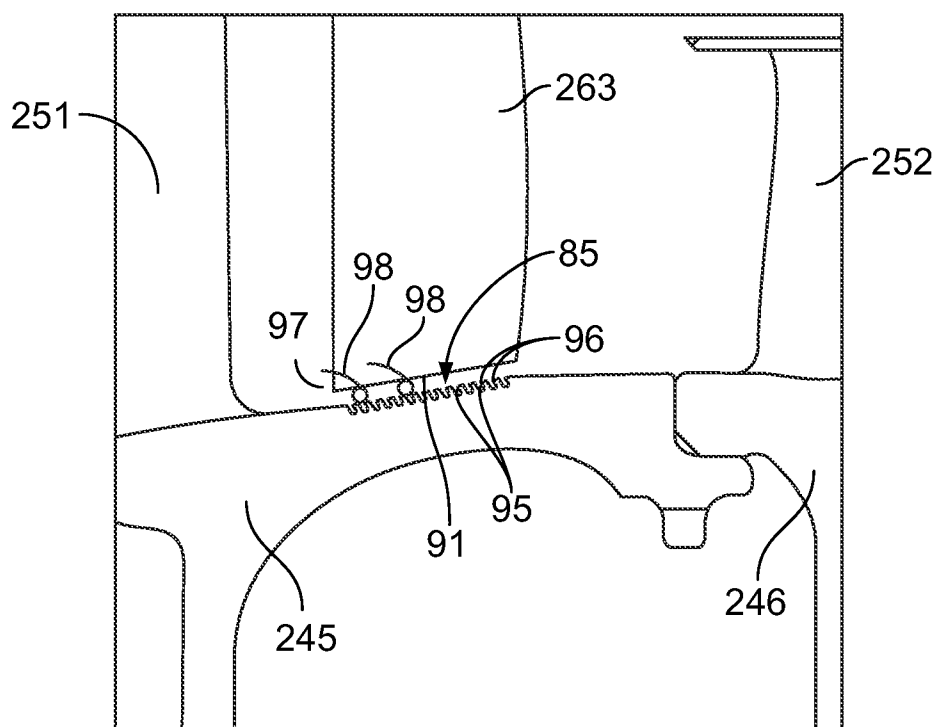
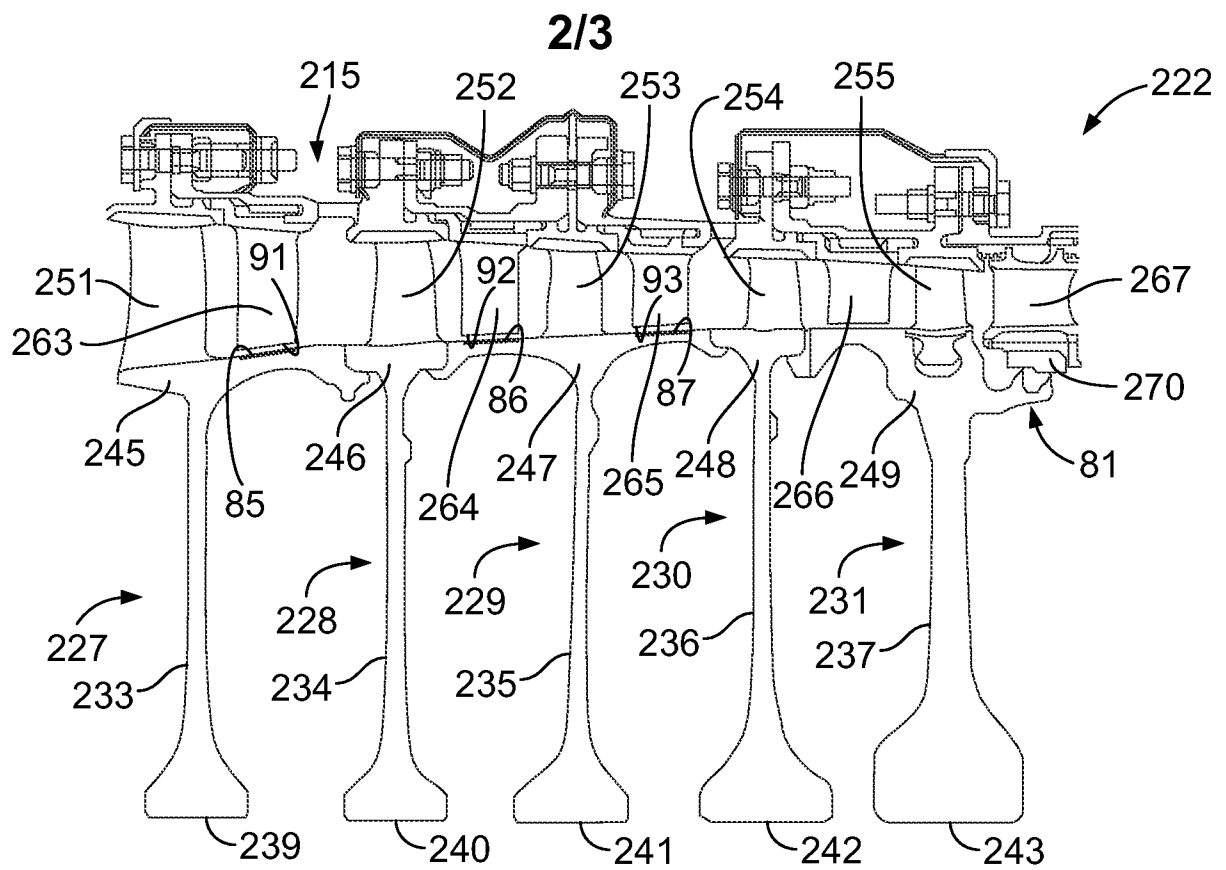


FIG. 2
PRIOR ART



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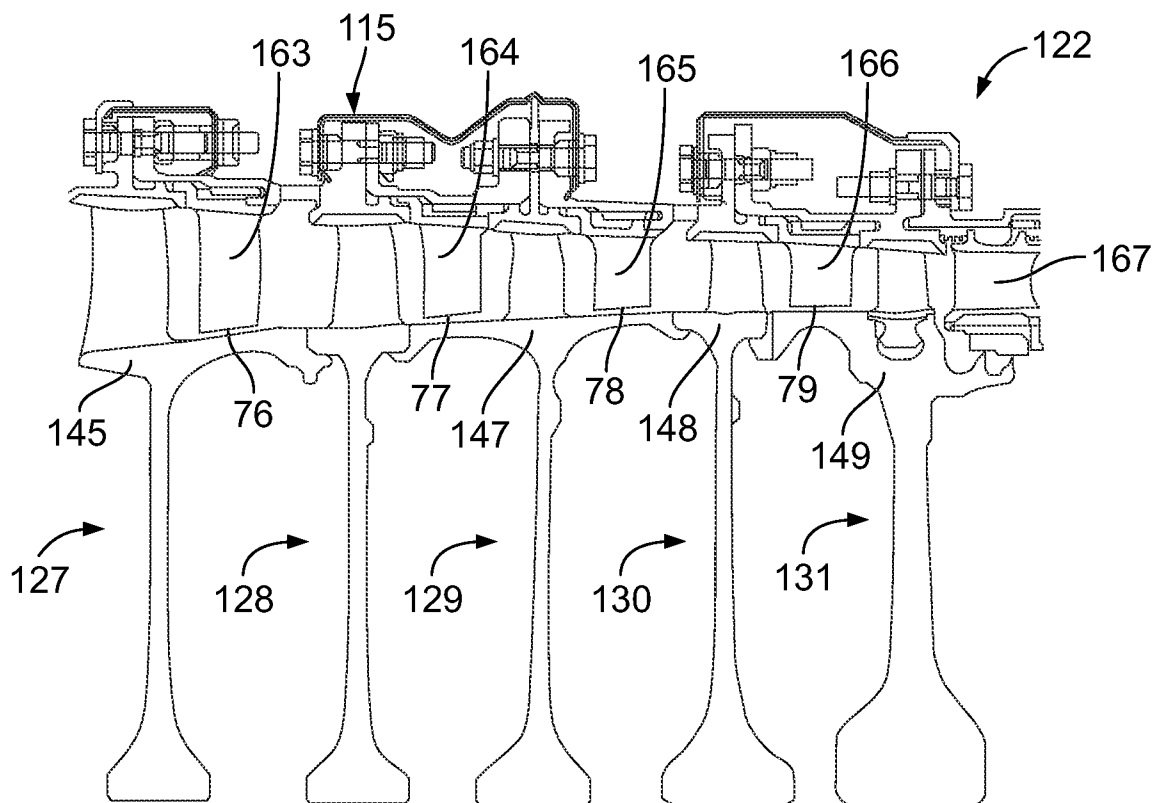


FIG. 3
PRIOR ART

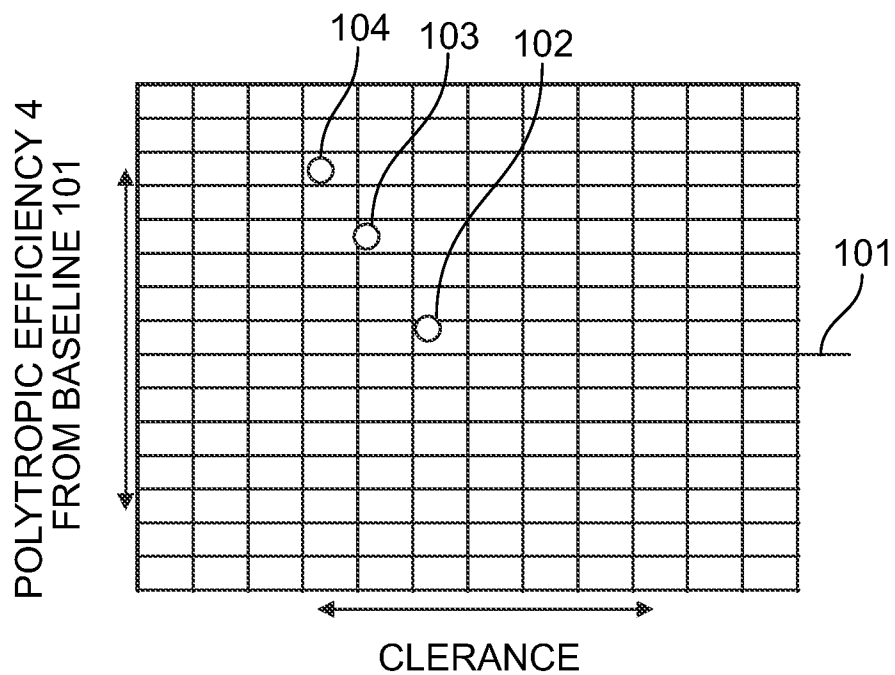


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/069095**A. CLASSIFICATION OF SUBJECT MATTER****F01D 5/20(2006.01)i, F01D 5/12(2006.01)i, F01D 9/02(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 5/20; F16J 15/447; F01D 25/24; F04D 29/28; F04D 29/16; F01D 5/14; F04D 29/40; F01D 11/02; F01D 5/12; F01D 9/02

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: gas turbine, compressor, rotor, stator, serration, rim, and leakage

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2008-0219835 A1 (FRELING et al.) 11 September 2008 See paragraphs [0014]-[0025] and figures 1-4	1-20
Y	US 2009-0160135 A1 (TURINI et al.) 25 June 2009 See paragraphs [0020]-[0027] and figures 4-5.	1-20
A	EP 1937979 B1 (INGERSOLL-RAND COMPANY) 23 June 2010 See paragraphs [0011]-[0042] and figures 1-9.	1-20
A	US 2009-0246007 A1 (JOHANN, ERIK) 01 October 2009 See paragraphs [0004]-[0018] and figures 1-8.	1-20
A	EP 0292250 A1 (UNION CARBIDE CORPORATION) 23 November 1988 See column 4, line 55 - column 5, line 37 and figures 1-8.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

26 February 2014 (26.02.2014)

Date of mailing of the international search report

26 February 2014 (26.02.2014)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/069095

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