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(54) Title: GAS TURBINE ENGINE FAN BLADE AIRFOIL PROFILE

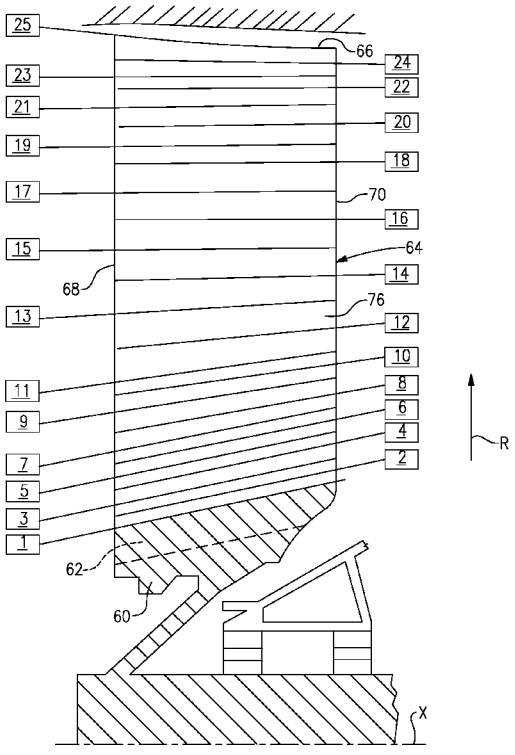


FIG.2

(57) Abstract: A fan blade for a gas turbine engine includes an airfoil that includes leading and trailing edges joined by pressure and suction sides to provide an exterior airfoil surface that extends in a radial direction to a tip. The external airfoil surface is formed in substantial conformance with multiple cross-sectional profiles of the airfoil described by a set of Cartesian coordinates set forth in Table 1. The Cartesian coordinates are provided by an axial coordinate scaled by a local axial chord. A circumferential coordinate is scaled by the local axial chord, and a span location. The local axial chord corresponds to a width of the airfoil between the leading and trailing edges at the span location.

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GAS TURBINE ENGINE FAN BLADE AIRFOIL PROFILE

[0001] This application claims priority to United States Application No. 61/706,859, which was filed on September 28, 2012.

BACKGROUND

[0002] This disclosure relates to a gas turbine engine, and more particularly to a fan blade airfoil that may be incorporated into a gas turbine engine.

[0003] Gas turbine engines typically include a compressor section, a combustor section and a turbine section. 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 are communicated through the turbine section, which extracts energy from the hot combustion gases to power the compressor section and other gas turbine engine loads.

[0004] One type of gas turbine engine incorporates a fan section driven by low pressure turbine to provide a high bypass ratio in which a significant amount of thrust is provided by the fan section through a bypass flow path. Some gas turbine engines may also use a fan drive gear system to reduce the speed of the fan section. As a result, significantly larger fan blades may be used in the fan section.

[0005] A leading edge of each fan blade is designed to align with the flow angle of air entering the bypass flow path at the fan blade's design point to minimize performance loss in the fan section. The incidence angle between the flow and the leading edge at the design point is typically optimized to provide an adequate stall margin as well as flow capacity.

SUMMARY

[0006] In one exemplary embodiment, a fan blade for a gas turbine engine includes an airfoil that includes leading and trailing edges joined by pressure and suction sides to provide an exterior airfoil surface that extends in a radial direction to a tip. The external airfoil surface is formed in substantial conformance with multiple cross-sectional profiles of the airfoil described by a set of Cartesian coordinates set forth in Table 1. The Cartesian coordinates are provided by

an axial coordinate scaled by a local axial chord. A circumferential coordinate is scaled by the local axial chord, and a span location. The local axial chord corresponds to a width of the airfoil between the leading and trailing edges at the span location.

[0007] In a further embodiment of any of the above, the airfoil includes an aluminum fan blade.

[0008] In a further embodiment of any of the above, the span locations correspond to a position from a rotational axis of the airfoil in a numerical sequence indicated in Table 1 with the last position closest to the tip.

[0009] In a further embodiment of any of the above, the Cartesian coordinates in Table 1 have a tolerance relative to the specified coordinates of ±0.050 inches (±1.27 mm).

[0010] In one exemplary embodiment, a gas turbine engine includes a compressor section. A combustor is fluidly connected to the compressor section. A turbine section is fluidly connected to the combustor. The turbine section includes a high pressure turbine coupled to the high pressure compressor via a shaft and a low pressure turbine. A fan section is operatively coupled to the turbine section. The fan section includes an array of fan blade. At least one fan blade includes an airfoil that has leading and trailing edges joined by pressure and suction sides to provide an exterior airfoil surface extending from in a radial direction to a tip. The external airfoil surface is formed in substantial conformance with multiple cross-sectional profiles of the airfoil described by a set of Cartesian coordinates set forth in Table 1. The Cartesian coordinates are provided by an axial coordinate scaled by a local axial chord. A circumferential coordinate is scaled by the local axial chord, and a span location. The local axial chord corresponds to a width of the airfoil between the leading and trailing edges at the span location.

[0011] In a further embodiment of any of the above, the airfoil includes an aluminum fan blade.

[0012] In a further embodiment of any of the above, the span locations correspond to a position from a rotational axis of the airfoil in a numerical sequence indicated in Table 1 with the last position closest to the tip.

[0013] In a further embodiment of any of the above, the Cartesian coordinates in Table 1 have a tolerance relative to the specified coordinates of ±0.050 inches (±1.27 mm).

[0014] In a further embodiment of any of the above, the array of fan blades includes less than about twenty-six (26) fan blades.

[0015] In a further embodiment of any of the above, the array of fan blades includes less than about twenty (20) fan blades.

[0016] In a further embodiment of any of the above, the fan section is driven by a geared architecture.

[0017] In a further embodiment of any of the above, the gas turbine engine is a high-bypass geared gas turbine engine.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The disclosure can be further understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0019] Figure 1 schematically illustrates a gas turbine engine embodiment.

[0020] Figure 2 is a plane view of the fan blade airfoil illustrating directional references with the span positions and local axial chords referenced in Table 1.

[0021] Figure 3 is a cross-sectional view through the fan blade airfoil illustrating the location of data points and the leading edge portion of the fan blade airfoil.

DETAILED DESCRIPTION

[0022] Figure 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.

[0023] 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 turbofans 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.

[0024] 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 X 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.

[0025] 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.

[0026] 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.

[0027] The example low pressure turbine 46 has a pressure ratio that is greater than about five. 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.

[0028] 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.

[0029] 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.

[0030] 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.

[0031] 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.

[0032] 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

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

[0033] "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.

[0034] "Low corrected fan tip speed" is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of $[(\text{Tram } ^\circ\text{R}) / 518.7)]^{0.5}$. The "Low corrected fan tip speed", as disclosed herein according to one non-limiting embodiment, is less than about 1150 ft/second.

[0035] The example gas turbine engine includes the fan 42 that comprises in one non-limiting embodiment less than about twenty-six (26) fan blades. In another non-limiting embodiment, the fan section 22 includes less than about twenty (20) fan blades.

[0036] Referring to Figure 2, the fan blade 42 is supported by a fan hub 60 that is rotatable about the axis X. Each fan blade 42 includes an airfoil 64 extending in a radial span direction R from a root 62 to a tip 66. The root 62 is received in a correspondingly shaped slot in the fan hub 60 as is known. The airfoil 64 extends radially outward of a platform, which provides the inner flow path. The platform may be integral with the fan blade or separately secured to the fan hub, for example.

[0037] The airfoil 64 has an exterior surface 76 providing a contour that extends from a leading edge 68 aftward in a chord-wise direction C to a trailing edge 70, as shown in Figure 3. Pressure and suction sides 72, 74 join one another at the leading and trailing edges 68, 70 and are spaced apart from one another in an airfoil thickness direction T. An array of the fan blades 42 are positioned about the axis X in a circumferential direction Y.

[0038] The exterior surface 76 of the airfoil 64 generates lift based upon its geometry and directs flow along the core flow path C. The fan blades 42 may be constructed from an aluminum alloy, titanium alloy and/or composite material. Abrasion-resistant coatings or other protective coatings may be applied to the fan blade 42.

[0039] With continuing reference to Figure 3, a "design point profile" is illustrated, which represents an existing fan blade profile. At part speed engine operating conditions along

the engine operating line, the flow incidence angle increases from F1 to F2. The flow can easily separate locally near the leading edge 68 at the flow incidence angle F2 during part speed conditions. To improve flutter margin and reduce noise during take-off, cutback and approach flight conditions, the design point profile of the leading edge portion of the fan blade 42 was locally changed to the "part-speed profile."

[0040] In one example, the fan blade 42 is aluminum and is provided with the design point profile. The fan blade 42 is plastically deformed, by die stamping, for example, to change the exterior surface of the fan blade 42 from the design point profile to the part-speed profile. In this manner, a new airfoil geometry may be provided while preserving the material of the originally designed blade.

[0041] The geometry of the airfoil 64 are described in terms of Cartesian coordinates defined along X, Y and R axes, which respectively correspond to the axial (X), circumferential (Y) and radial (span) R directions shown in Figures 2 and 3. The span coordinate is provided as a radial location (boxed numbers in Figure 2) from the rotational axis X of the fan blade 42. The axial (X) and circumferential (Y) coordinates are normalized by the local axial chord, which is the width of the airfoil 64 from the leading edge 68 to the trailing edge 70 for the given section. The general location of the coordinates are shown by the points illustrated in Figure 3 (some of which have been indicated by circled numbers).

[0042] The contour of the airfoil 78 is set forth in Table 1, which provides the axial (X), circumferential (Y) coordinates (in inches) and span coordinates. The axial and circumferential coordinates can be converted to metric (mm) by multiplying by 25.4. Three dimensional airfoil surfaces are formed by joining adjacent points in Table 1 in a smooth manner and joining adjacent sections or sectional profiles along the span. The manufacturing tolerance relative to the specified coordinates is ± ±0.050 inches (±1.27 mm). The coordinates define points on a cold, uncoated, stationary airfoil surface, in a plane at 0% span. Additional elements such as cooling holes, protective coatings, fillets and seal structures may also be formed onto the specified airfoil surface, or onto an adjacent platform surface, but these elements are not necessarily described by the normalized coordinates. For example, a variable coating may be applied between 0.0001 inch (0.003 mm) (trace) and 0.010 inch (0.25 mm) thick.

Table 1

Section 1

1	0.0000	-0.1051
2	-0.0001	-0.1040
3	0.0003	-0.1031
4	0.0007	-0.1026
5	0.0011	-0.1021
6	0.0016	-0.1017
7	0.0022	-0.1010
8	0.0034	-0.1000
9	0.0054	-0.0983
10	0.0083	-0.0960
11	0.0120	-0.0932
12	0.0175	-0.0893
13	0.0248	-0.0842
14	0.0339	-0.0782
15	0.0458	-0.0706
16	0.0605	-0.0616
17	0.0790	-0.0508
18	0.1015	-0.0386
19	0.1282	-0.0254
20	0.1588	-0.0117
21	0.1919	0.0014
22	0.2271	0.0134
23	0.2628	0.0237
24	0.2989	0.0322
25	0.3354	0.0391
26	0.3722	0.0442
27	0.4092	0.0475
28	0.4462	0.0493
29	0.4917	-0.0531
30	0.4561	-0.0532
31	0.4205	-0.0532
32	0.3849	-0.0537
33	0.3493	-0.0548
34	0.3138	-0.0567
35	0.2783	-0.0594
36	0.2430	-0.0628

37	0.2076	-0.0669
38	0.1739	-0.0715
39	0.1423	-0.0765
40	0.1142	-0.0814
41	0.0901	-0.0861
42	0.0701	-0.0902
43	0.0540	-0.0939
44	0.0409	-0.0970
45	0.0307	-0.0995
46	0.0225	-0.1016
47	0.0162	-0.1032
48	0.0118	-0.1042
49	0.0084	-0.1050
50	0.0059	-0.1055
51	0.0045	-0.1058
52	0.0036	-0.1059
53	0.0030	-0.1060
54	0.0024	-0.1060
55	0.0018	-0.1060
56	0.0008	-0.1058

Section 2

1	0.0000	-0.1216
2	-0.0002	-0.1205
3	0.0003	-0.1196
4	0.0007	-0.1191
5	0.0010	-0.1186
6	0.0015	-0.1181
7	0.0021	-0.1175
8	0.0032	-0.1164
9	0.0052	-0.1147
10	0.0080	-0.1123
11	0.0117	-0.1094
12	0.0171	-0.1054
13	0.0242	-0.1002
14	0.0332	-0.0939
15	0.0448	-0.0860
16	0.0593	-0.0767
17	0.0776	-0.0656
18	0.0998	-0.0530

19	0.1262	-0.0392
20	0.1564	-0.0249
21	0.1892	-0.0110
22	0.2240	0.0019
23	0.2594	0.0132
24	0.2952	0.0229
25	0.3314	0.0310
26	0.3680	0.0374
27	0.4048	0.0422
28	0.4417	0.0459
29	0.4909	-0.0506
30	0.4553	-0.0525
31	0.4196	-0.0544
32	0.3840	-0.0563
33	0.3484	-0.0589
34	0.3129	-0.0622
35	0.2774	-0.0661
36	0.2420	-0.0708
37	0.2068	-0.0762
38	0.1731	-0.0819
39	0.1416	-0.0880
40	0.1136	-0.0938
41	0.0896	-0.0992
42	0.0696	-0.1040
43	0.0536	-0.1082
44	0.0406	-0.1119
45	0.0305	-0.1148
46	0.0223	-0.1172
47	0.0161	-0.1190
48	0.0118	-0.1203
49	0.0084	-0.1212
50	0.0059	-0.1218
51	0.0045	-0.1221
52	0.0036	-0.1223
53	0.0030	-0.1223
54	0.0024	-0.1224
55	0.0018	-0.1224
56	0.0008	-0.1223

Section 3

1	0.0000	-0.1393
2	-0.0002	-0.1382
3	0.0002	-0.1373
4	0.0006	-0.1368
5	0.0010	-0.1363
6	0.0014	-0.1358
7	0.0020	-0.1352
8	0.0031	-0.1341
9	0.0050	-0.1323
10	0.0078	-0.1299
11	0.0114	-0.1269
12	0.0167	-0.1228
13	0.0238	-0.1174
14	0.0326	-0.1110
15	0.0441	-0.1030
16	0.0585	-0.0934
17	0.0765	-0.0820
18	0.0986	-0.0690
19	0.1247	-0.0547
20	0.1547	-0.0397
21	0.1871	-0.0251
22	0.2216	-0.0113
23	0.2567	0.0010
24	0.2923	0.0118
25	0.3283	0.0211
26	0.3646	0.0288
27	0.4012	0.0351
28	0.4380	0.0406
29	0.4901	-0.0486
30	0.4544	-0.0521
31	0.4187	-0.0556
32	0.3830	-0.0592
33	0.3474	-0.0630
34	0.3118	-0.0676
35	0.2763	-0.0729
36	0.2410	-0.0789
37	0.2058	-0.0856
38	0.1722	-0.0926

39	0.1407	-0.0998
40	0.1128	-0.1067
41	0.0889	-0.1130
42	0.0691	-0.1187
43	0.0532	-0.1236
44	0.0403	-0.1278
45	0.0303	-0.1311
46	0.0222	-0.1339
47	0.0160	-0.1361
48	0.0117	-0.1375
49	0.0083	-0.1386
50	0.0059	-0.1393
51	0.0045	-0.1396
52	0.0036	-0.1398
53	0.0030	-0.1399
54	0.0024	-0.1400
55	0.0018	-0.1401
56	0.0008	-0.1399

Section 4

1	0.0000	-0.1581
2	-0.0002	-0.1571
3	0.0002	-0.1562
4	0.0005	-0.1556
5	0.0009	-0.1551
6	0.0013	-0.1547
7	0.0019	-0.1540
8	0.0030	-0.1528
9	0.0049	-0.1510
10	0.0076	-0.1486
11	0.0112	-0.1456
12	0.0165	-0.1413
13	0.0235	-0.1359
14	0.0323	-0.1294
15	0.0437	-0.1211
16	0.0579	-0.1114
17	0.0759	-0.0997
18	0.0977	-0.0863
19	0.1237	-0.0716
20	0.1534	-0.0560

21	0.1856	-0.0407
22	0.2199	-0.0260
23	0.2547	-0.0128
24	0.2900	-0.0009
25	0.3258	0.0095
26	0.3620	0.0185
27	0.3984	0.0264
28	0.4350	0.0335
29	0.4892	-0.0467
30	0.4535	-0.0520
31	0.4177	-0.0573
32	0.3820	-0.0626
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40	0.1122	-0.1212
41	0.0884	-0.1284
42	0.0686	-0.1348
43	0.0529	-0.1403
44	0.0400	-0.1450
45	0.0301	-0.1488
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47	0.0159	-0.1543
48	0.0117	-0.1559
49	0.0083	-0.1571
50	0.0059	-0.1579
51	0.0045	-0.1583
52	0.0036	-0.1585
53	0.0030	-0.1587
54	0.0024	-0.1588
55	0.0018	-0.1588
56	0.0008	-0.1587

Section 5

1	0.0000	-0.1774
2	-0.0002	-0.1765

3	0.0001	-0.1755
4	0.0005	-0.1750
5	0.0008	-0.1745
6	0.0012	-0.1740
7	0.0018	-0.1733
8	0.0029	-0.1722
9	0.0048	-0.1703
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11	0.0110	-0.1648
12	0.0163	-0.1605
13	0.0233	-0.1550
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21	0.1846	-0.0572
22	0.2186	-0.0417
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24	0.2884	-0.0146
25	0.3240	-0.0032
26	0.3600	0.0071
27	0.3962	0.0166
28	0.4326	0.0251
29	0.4879	-0.0459
30	0.4522	-0.0527
31	0.4164	-0.0596
32	0.3807	-0.0666
33	0.3450	-0.0737
34	0.3095	-0.0812
35	0.2741	-0.0894
36	0.2388	-0.0982
37	0.2037	-0.1077
38	0.1703	-0.1174
39	0.1391	-0.1271
40	0.1114	-0.1361
41	0.0878	-0.1442

42	0.0681	-0.1515
43	0.0524	-0.1576
44	0.0397	-0.1629
45	0.0299	-0.1671
46	0.0219	-0.1705
47	0.0159	-0.1731
48	0.0116	-0.1749
49	0.0083	-0.1762
50	0.0059	-0.1771
51	0.0045	-0.1775
52	0.0036	-0.1778
53	0.0030	-0.1779
54	0.0024	-0.1780
55	0.0018	-0.1781
56	0.0008	-0.1781

Section 6

1	0.0000	-0.2216
2	-0.0003	-0.2207
3	0.0000	-0.2198
4	0.0004	-0.2192
5	0.0007	-0.2187
6	0.0011	-0.2182
7	0.0017	-0.2175
8	0.0027	-0.2163
9	0.0046	-0.2144
10	0.0073	-0.2118
11	0.0108	-0.2087
12	0.0160	-0.2042
13	0.0230	-0.1986
14	0.0318	-0.1917
15	0.0432	-0.1831
16	0.0573	-0.1728
17	0.0751	-0.1603
18	0.0967	-0.1459
19	0.1224	-0.1298
20	0.1517	-0.1124
21	0.1833	-0.0949
22	0.2170	-0.0776
23	0.2512	-0.0615

24	0.2860	-0.0464
25	0.3212	-0.0324
26	0.3568	-0.0193
27	0.3927	-0.0070
28	0.4288	0.0045
29	0.4846	-0.0476
30	0.4488	-0.0575
31	0.4131	-0.0676
32	0.3775	-0.0779
33	0.3418	-0.0882
34	0.3063	-0.0990
35	0.2711	-0.1102
36	0.2360	-0.1222
37	0.2012	-0.1347
38	0.1681	-0.1472
39	0.1371	-0.1596
40	0.1097	-0.1709
41	0.0863	-0.1811
42	0.0670	-0.1900
43	0.0516	-0.1975
44	0.0391	-0.2039
45	0.0295	-0.2089
46	0.0217	-0.2131
47	0.0157	-0.2162
48	0.0116	-0.2183
49	0.0083	-0.2199
50	0.0059	-0.2209
51	0.0045	-0.2215
52	0.0036	-0.2218
53	0.0030	-0.2220
54	0.0024	-0.2221
55	0.0018	-0.2222
56	0.0008	-0.2222

Section 7

1	0.0000	-0.2623
2	-0.0003	-0.2614
3	0.0000	-0.2605
4	0.0003	-0.2599
5	0.0006	-0.2594

6	0.0010	-0.2588
7	0.0016	-0.2581
8	0.0026	-0.2569
9	0.0044	-0.2549
10	0.0071	-0.2522
11	0.0106	-0.2490
12	0.0159	-0.2444
13	0.0229	-0.2385
14	0.0316	-0.2314
15	0.0431	-0.2225
16	0.0572	-0.2119
17	0.0750	-0.1988
18	0.0966	-0.1836
19	0.1221	-0.1665
20	0.1513	-0.1479
21	0.1827	-0.1289
22	0.2161	-0.1099
23	0.2501	-0.0918
24	0.2845	-0.0747
25	0.3194	-0.0584
26	0.3547	-0.0429
27	0.3902	-0.0281
28	0.4261	-0.0141
29	0.4809	-0.0512
30	0.4451	-0.0637
31	0.4095	-0.0765
32	0.3739	-0.0895
33	0.3385	-0.1027
34	0.3032	-0.1163
35	0.2681	-0.1304
36	0.2333	-0.1451
37	0.1987	-0.1603
38	0.1659	-0.1754
39	0.1353	-0.1901
40	0.1082	-0.2036
41	0.0851	-0.2154
42	0.0660	-0.2258
43	0.0509	-0.2345
44	0.0386	-0.2418

45	0.0292	-0.2476
46	0.0215	-0.2524
47	0.0157	-0.2559
48	0.0115	-0.2583
49	0.0083	-0.2601
50	0.0059	-0.2613
51	0.0045	-0.2619
52	0.0036	-0.2623
53	0.0030	-0.2625
54	0.0024	-0.2627
55	0.0018	-0.2628
56	0.0008	-0.2628

Section 8

1	0.0000	-0.2968
2	-0.0003	-0.2959
3	0.0000	-0.2950
4	0.0003	-0.2945
5	0.0007	-0.2939
6	0.0010	-0.2934
7	0.0016	-0.2926
8	0.0027	-0.2914
9	0.0045	-0.2893
10	0.0071	-0.2866
11	0.0107	-0.2832
12	0.0159	-0.2784
13	0.0229	-0.2723
14	0.0317	-0.2650
15	0.0431	-0.2557
16	0.0572	-0.2445
17	0.0750	-0.2309
18	0.0966	-0.2149
19	0.1220	-0.1967
20	0.1510	-0.1768
21	0.1822	-0.1564
22	0.2154	-0.1357
23	0.2490	-0.1158
24	0.2831	-0.0967
25	0.3177	-0.0783
26	0.3527	-0.0607

27	0.3880	-0.0437
28	0.4237	-0.0275
29	0.4776	-0.0543
30	0.4418	-0.0690
31	0.4062	-0.0841
32	0.3708	-0.0995
33	0.3355	-0.1151
34	0.3004	-0.1312
35	0.2656	-0.1477
36	0.2310	-0.1648
37	0.1968	-0.1823
38	0.1642	-0.1996
39	0.1339	-0.2163
40	0.1070	-0.2314
41	0.0842	-0.2448
42	0.0653	-0.2564
43	0.0503	-0.2660
44	0.0383	-0.2741
45	0.0289	-0.2804
46	0.0213	-0.2856
47	0.0155	-0.2895
48	0.0115	-0.2921
49	0.0082	-0.2940
50	0.0059	-0.2954
51	0.0044	-0.2961
52	0.0036	-0.2965
53	0.0030	-0.2968
54	0.0024	-0.2970
55	0.0017	-0.2972
56	0.0008	-0.2973

Section 9

1	0.0000	-0.3242
2	-0.0003	-0.3233
3	0.0000	-0.3224
4	0.0003	-0.3218
5	0.0006	-0.3212
6	0.0010	-0.3207
7	0.0016	-0.3199
8	0.0026	-0.3186

9	0.0044	-0.3165
10	0.0071	-0.3136
11	0.0106	-0.3101
12	0.0158	-0.3051
13	0.0228	-0.2988
14	0.0315	-0.2912
15	0.0430	-0.2815
16	0.0571	-0.2698
17	0.0749	-0.2555
18	0.0963	-0.2386
19	0.1216	-0.2194
20	0.1504	-0.1983
21	0.1815	-0.1764
22	0.2144	-0.1541
23	0.2478	-0.1325
24	0.2817	-0.1116
25	0.3159	-0.0913
26	0.3506	-0.0717
27	0.3857	-0.0529
28	0.4212	-0.0347
29	0.4749	-0.0555
30	0.4393	-0.0722
31	0.4037	-0.0893
32	0.3685	-0.1066
33	0.3333	-0.1244
34	0.2984	-0.1425
35	0.2638	-0.1610
36	0.2295	-0.1800
37	0.1955	-0.1995
38	0.1632	-0.2186
39	0.1330	-0.2369
40	0.1064	-0.2535
41	0.0837	-0.2680
42	0.0650	-0.2806
43	0.0501	-0.2910
44	0.0381	-0.2997
45	0.0289	-0.3065
46	0.0214	-0.3120
47	0.0156	-0.3162

48	0.0115	-0.3190
49	0.0083	-0.3211
50	0.0059	-0.3225
51	0.0045	-0.3233
52	0.0036	-0.3237
53	0.0030	-0.3240
54	0.0024	-0.3242
55	0.0018	-0.3245
56	0.0008	-0.3246

Section 10

1	0.0000	-0.3451
2	-0.0003	-0.3442
3	0.0000	-0.3433
4	0.0003	-0.3427
5	0.0006	-0.3421
6	0.0010	-0.3416
7	0.0016	-0.3407
8	0.0026	-0.3394
9	0.0044	-0.3372
10	0.0070	-0.3343
11	0.0105	-0.3306
12	0.0157	-0.3255
13	0.0227	-0.3189
14	0.0314	-0.3109
15	0.0428	-0.3008
16	0.0569	-0.2886
17	0.0746	-0.2735
18	0.0960	-0.2558
19	0.1211	-0.2356
20	0.1498	-0.2132
21	0.1806	-0.1900
22	0.2133	-0.1662
23	0.2464	-0.1430
24	0.2800	-0.1204
25	0.3140	-0.0983
26	0.3484	-0.0769
27	0.3832	-0.0562
28	0.4186	-0.0362
29	0.4732	-0.0544

30	0.4375	-0.0728
31	0.4021	-0.0916
32	0.3670	-0.1107
33	0.3320	-0.1302
34	0.2973	-0.1501
35	0.2629	-0.1704
36	0.2288	-0.1911
37	0.1949	-0.2121
38	0.1627	-0.2327
39	0.1327	-0.2524
40	0.1062	-0.2701
41	0.0835	-0.2856
42	0.0649	-0.2990
43	0.0501	-0.3100
44	0.0382	-0.3192
45	0.0289	-0.3264
46	0.0214	-0.3322
47	0.0156	-0.3366
48	0.0116	-0.3395
49	0.0084	-0.3418
50	0.0060	-0.3433
51	0.0046	-0.3441
52	0.0037	-0.3446
53	0.0031	-0.3449
54	0.0025	-0.3451
55	0.0018	-0.3454
56	0.0009	-0.3456

Section 11

1	0.0000	-0.3609
2	-0.0003	-0.3600
3	0.0000	-0.3590
4	0.0003	-0.3584
5	0.0006	-0.3578
6	0.0010	-0.3572
7	0.0015	-0.3563
8	0.0026	-0.3550
9	0.0043	-0.3527
10	0.0070	-0.3497
11	0.0104	-0.3459

12	0.0156	-0.3405
13	0.0226	-0.3337
14	0.0313	-0.3253
15	0.0426	-0.3148
16	0.0567	-0.3020
17	0.0743	-0.2863
18	0.0956	-0.2678
19	0.1207	-0.2465
20	0.1491	-0.2230
21	0.1798	-0.1984
22	0.2123	-0.1732
23	0.2452	-0.1485
24	0.2785	-0.1243
25	0.3121	-0.1006
26	0.3462	-0.0774
27	0.3808	-0.0549
28	0.4159	-0.0332
29	0.4720	-0.0504
30	0.4365	-0.0704
31	0.4012	-0.0907
32	0.3662	-0.1115
33	0.3314	-0.1326
34	0.2969	-0.1541
35	0.2626	-0.1759
36	0.2285	-0.1981
37	0.1948	-0.2205
38	0.1627	-0.2424
39	0.1327	-0.2633
40	0.1062	-0.2820
41	0.0836	-0.2984
42	0.0650	-0.3124
43	0.0502	-0.3240
44	0.0383	-0.3336
45	0.0290	-0.3412
46	0.0215	-0.3472
47	0.0158	-0.3518
48	0.0117	-0.3549
49	0.0085	-0.3572
50	0.0061	-0.3588

51	0.0046	-0.3597
52	0.0038	-0.3602
53	0.0032	-0.3605
54	0.0025	-0.3608
55	0.0019	-0.3611
56	0.0009	-0.3613

Section 12

1	0.0000	-0.3729
2	-0.0004	-0.3719
3	-0.0001	-0.3709
4	0.0002	-0.3703
5	0.0006	-0.3696
6	0.0009	-0.3690
7	0.0015	-0.3682
8	0.0025	-0.3667
9	0.0043	-0.3644
10	0.0069	-0.3613
11	0.0104	-0.3573
12	0.0155	-0.3518
13	0.0224	-0.3446
14	0.0311	-0.3360
15	0.0424	-0.3250
16	0.0564	-0.3116
17	0.0740	-0.2952
18	0.0952	-0.2759
19	0.1202	-0.2536
20	0.1486	-0.2289
21	0.1791	-0.2031
22	0.2113	-0.1765
23	0.2440	-0.1503
24	0.2771	-0.1246
25	0.3106	-0.0994
26	0.3444	-0.0746
27	0.3787	-0.0504
28	0.4135	-0.0270
29	0.4715	-0.0437
30	0.4360	-0.0652
31	0.4009	-0.0871
32	0.3659	-0.1094

33	0.3313	-0.1320
34	0.2968	-0.1549
35	0.2626	-0.1782
36	0.2287	-0.2017
37	0.1950	-0.2255
38	0.1629	-0.2486
39	0.1330	-0.2706
40	0.1065	-0.2903
41	0.0838	-0.3075
42	0.0652	-0.3222
43	0.0504	-0.3343
44	0.0385	-0.3443
45	0.0292	-0.3522
46	0.0217	-0.3585
47	0.0159	-0.3633
48	0.0118	-0.3665
49	0.0086	-0.3689
50	0.0062	-0.3706
51	0.0047	-0.3715
52	0.0039	-0.3721
53	0.0032	-0.3724
54	0.0026	-0.3727
55	0.0020	-0.3730
56	0.0010	-0.3733

Section 13

1	0.0000	-0.3823
2	-0.0004	-0.3813
3	-0.0001	-0.3803
4	0.0002	-0.3796
5	0.0006	-0.3790
6	0.0009	-0.3784
7	0.0015	-0.3775
8	0.0025	-0.3760
9	0.0043	-0.3736
10	0.0068	-0.3704
11	0.0103	-0.3663
12	0.0154	-0.3605
13	0.0223	-0.3530
14	0.0310	-0.3440

15	0.0422	-0.3325
16	0.0562	-0.3187
17	0.0737	-0.3016
18	0.0949	-0.2814
19	0.1198	-0.2581
20	0.1481	-0.2323
21	0.1784	-0.2051
22	0.2106	-0.1772
23	0.2431	-0.1496
24	0.2760	-0.1225
25	0.3092	-0.0957
26	0.3428	-0.0694
27	0.3768	-0.0435
28	0.4113	-0.0183
29	0.4713	-0.0346
30	0.4359	-0.0577
31	0.4009	-0.0812
32	0.3661	-0.1050
33	0.3315	-0.1290
34	0.2971	-0.1534
35	0.2630	-0.1780
36	0.2290	-0.2028
37	0.1954	-0.2280
38	0.1633	-0.2523
39	0.1334	-0.2754
40	0.1068	-0.2961
41	0.0842	-0.3141
42	0.0655	-0.3294
43	0.0507	-0.3420
44	0.0387	-0.3525
45	0.0294	-0.3606
46	0.0219	-0.3672
47	0.0160	-0.3722
48	0.0119	-0.3755
49	0.0087	-0.3781
50	0.0063	-0.3798
51	0.0049	-0.3808
52	0.0040	-0.3814
53	0.0033	-0.3817

54	0.0027	-0.3821
55	0.0021	-0.3824
56	0.0010	-0.3827

Section 14

1	0.0000	-0.3907
2	-0.0004	-0.3896
3	-0.0001	-0.3885
4	0.0002	-0.3879
5	0.0005	-0.3872
6	0.0009	-0.3866
7	0.0014	-0.3856
8	0.0024	-0.3841
9	0.0042	-0.3816
10	0.0067	-0.3782
11	0.0101	-0.3740
12	0.0152	-0.3680
13	0.0221	-0.3602
14	0.0307	-0.3508
15	0.0420	-0.3389
16	0.0559	-0.3244
17	0.0734	-0.3066
18	0.0946	-0.2855
19	0.1194	-0.2613
20	0.1477	-0.2342
21	0.1780	-0.2058
22	0.2100	-0.1764
23	0.2424	-0.1474
24	0.2751	-0.1188
25	0.3082	-0.0905
26	0.3416	-0.0626
27	0.3753	-0.0351
28	0.4095	-0.0081
29	0.4713	-0.0234
30	0.4360	-0.0481
31	0.4011	-0.0732
32	0.3664	-0.0985
33	0.3319	-0.1241
34	0.2976	-0.1499
35	0.2635	-0.1760

36	0.2295	-0.2023
37	0.1958	-0.2288
38	0.1638	-0.2543
39	0.1338	-0.2786
40	0.1072	-0.3003
41	0.0845	-0.3192
42	0.0657	-0.3353
43	0.0509	-0.3484
44	0.0389	-0.3593
45	0.0296	-0.3679
46	0.0220	-0.3747
47	0.0162	-0.3799
48	0.0121	-0.3834
49	0.0088	-0.3861
50	0.0064	-0.3879
51	0.0049	-0.3890
52	0.0041	-0.3896
53	0.0034	-0.3900
54	0.0028	-0.3903
55	0.0022	-0.3906
56	0.0011	-0.3910

Section 15

1	0.0000	-0.3992
2	-0.0004	-0.3981
3	-0.0001	-0.3969
4	0.0001	-0.3962
5	0.0004	-0.3955
6	0.0007	-0.3949
7	0.0013	-0.3939
8	0.0022	-0.3923
9	0.0039	-0.3897
10	0.0064	-0.3861
11	0.0098	-0.3817
12	0.0148	-0.3754
13	0.0217	-0.3673
14	0.0303	-0.3575
15	0.0416	-0.3451
16	0.0556	-0.3301
17	0.0731	-0.3115

18	0.0943	-0.2895
19	0.1192	-0.2641
20	0.1474	-0.2358
21	0.1777	-0.2060
22	0.2096	-0.1751
23	0.2420	-0.1446
24	0.2746	-0.1144
25	0.3076	-0.0846
26	0.3409	-0.0550
27	0.3745	-0.0259
28	0.4084	0.0030
29	0.4710	-0.0094
30	0.4359	-0.0360
31	0.4011	-0.0629
32	0.3665	-0.0900
33	0.3320	-0.1173
34	0.2978	-0.1447
35	0.2637	-0.1724
36	0.2298	-0.2002
37	0.1961	-0.2283
38	0.1640	-0.2554
39	0.1340	-0.2810
40	0.1074	-0.3039
41	0.0846	-0.3238
42	0.0659	-0.3407
43	0.0511	-0.3546
44	0.0390	-0.3661
45	0.0297	-0.3750
46	0.0222	-0.3822
47	0.0163	-0.3876
48	0.0122	-0.3913
49	0.0089	-0.3942
50	0.0066	-0.3961
51	0.0051	-0.3972
52	0.0042	-0.3979
53	0.0036	-0.3983
54	0.0029	-0.3987
55	0.0023	-0.3990
56	0.0012	-0.3995

Section 16

1	0.0000	-0.4076
2	-0.0005	-0.4064
3	-0.0002	-0.4052
4	0.0000	-0.4045
5	0.0003	-0.4037
6	0.0006	-0.4030
7	0.0011	-0.4020
8	0.0020	-0.4003
9	0.0036	-0.3976
10	0.0060	-0.3939
11	0.0094	-0.3892
12	0.0144	-0.3826
13	0.0212	-0.3742
14	0.0299	-0.3640
15	0.0413	-0.3511
16	0.0554	-0.3355
17	0.0730	-0.3161
18	0.0943	-0.2931
19	0.1192	-0.2666
20	0.1475	-0.2369
21	0.1778	-0.2057
22	0.2098	-0.1733
23	0.2421	-0.1412
24	0.2748	-0.1094
25	0.3077	-0.0779
26	0.3409	-0.0467
27	0.3744	-0.0159
28	0.4082	0.0147
29	0.4707	0.0066
30	0.4358	-0.0219
31	0.4011	-0.0507
32	0.3665	-0.0796
33	0.3322	-0.1087
34	0.2980	-0.1380
35	0.2639	-0.1674
36	0.2300	-0.1970
37	0.1964	-0.2268
38	0.1643	-0.2555
39	0.1342	-0.2827

40	0.1075	-0.3069
41	0.0848	-0.3279
42	0.0660	-0.3458
43	0.0512	-0.3604
44	0.0392	-0.3725
45	0.0299	-0.3819
46	0.0223	-0.3895
47	0.0165	-0.3953
48	0.0124	-0.3992
49	0.0091	-0.4021
50	0.0067	-0.4042
51	0.0052	-0.4054
52	0.0043	-0.4061
53	0.0037	-0.4065
54	0.0031	-0.4069
55	0.0024	-0.4073
56	0.0013	-0.4079

Section 17

1	0.0000	-0.4165
2	-0.0005	-0.4153
3	-0.0003	-0.4140
4	-0.0001	-0.4133
5	0.0002	-0.4125
6	0.0005	-0.4118
7	0.0010	-0.4107
8	0.0018	-0.4090
9	0.0034	-0.4061
10	0.0059	-0.4022
11	0.0092	-0.3974
12	0.0142	-0.3905
13	0.0210	-0.3817
14	0.0297	-0.3711
15	0.0412	-0.3576
16	0.0554	-0.3412
17	0.0731	-0.3210
18	0.0945	-0.2969
19	0.1196	-0.2691
20	0.1479	-0.2381
21	0.1784	-0.2053

22	0.2105	-0.1712
23	0.2428	-0.1375
24	0.2755	-0.1040
25	0.3085	-0.0708
26	0.3417	-0.0379
27	0.3752	-0.0052
28	0.4090	0.0273
29	0.4705	0.0245
30	0.4358	-0.0062
31	0.4011	-0.0370
32	0.3667	-0.0679
33	0.3323	-0.0990
34	0.2982	-0.1302
35	0.2641	-0.1616
36	0.2303	-0.1931
37	0.1966	-0.2248
38	0.1645	-0.2553
39	0.1344	-0.2841
40	0.1077	-0.3098
41	0.0849	-0.3321
42	0.0662	-0.3510
43	0.0513	-0.3665
44	0.0393	-0.3793
45	0.0300	-0.3893
46	0.0225	-0.3973
47	0.0166	-0.4034
48	0.0125	-0.4075
49	0.0092	-0.4106
50	0.0068	-0.4128
51	0.0053	-0.4141
52	0.0044	-0.4148
53	0.0038	-0.4153
54	0.0032	-0.4157
55	0.0025	-0.4162
56	0.0013	-0.4168

Section 18

1	0.0000	-0.4259
2	-0.0006	-0.4247
3	-0.0004	-0.4233

4	-0.0001	-0.4225
5	0.0001	-0.4218
6	0.0004	-0.4210
7	0.0009	-0.4199
8	0.0017	-0.4181
9	0.0033	-0.4151
10	0.0057	-0.4110
11	0.0090	-0.4059
12	0.0140	-0.3987
13	0.0209	-0.3895
14	0.0297	-0.3784
15	0.0412	-0.3642
16	0.0555	-0.3471
17	0.0733	-0.3259
18	0.0949	-0.3007
19	0.1201	-0.2715
20	0.1487	-0.2389
21	0.1792	-0.2044
22	0.2115	-0.1686
23	0.2440	-0.1331
24	0.2768	-0.0978
25	0.3098	-0.0627
26	0.3431	-0.0279
27	0.3766	0.0067
28	0.4104	0.0411
29	0.4706	0.0440
30	0.4360	0.0112
31	0.4015	-0.0218
32	0.3671	-0.0549
33	0.3328	-0.0881
34	0.2986	-0.1215
35	0.2646	-0.1550
36	0.2307	-0.1886
37	0.1970	-0.2223
38	0.1648	-0.2547
39	0.1347	-0.2854
40	0.1079	-0.3127
41	0.0851	-0.3363
42	0.0664	-0.3564

43	0.0516	-0.3729
44	0.0396	-0.3864
45	0.0303	-0.3969
46	0.0227	-0.4055
47	0.0168	-0.4119
48	0.0127	-0.4163
49	0.0094	-0.4196
50	0.0070	-0.4219
51	0.0055	-0.4233
52	0.0046	-0.4241
53	0.0039	-0.4245
54	0.0033	-0.4250
55	0.0026	-0.4255
56	0.0014	-0.4261

Section 19

1	0.0000	-0.4369
2	-0.0006	-0.4356
3	-0.0004	-0.4342
4	-0.0002	-0.4334
5	0.0000	-0.4325
6	0.0003	-0.4318
7	0.0007	-0.4306
8	0.0016	-0.4287
9	0.0031	-0.4256
10	0.0055	-0.4213
11	0.0088	-0.4160
12	0.0139	-0.4084
13	0.0208	-0.3988
14	0.0296	-0.3871
15	0.0412	-0.3722
16	0.0556	-0.3542
17	0.0736	-0.3319
18	0.0953	-0.3053
19	0.1208	-0.2746
20	0.1495	-0.2402
21	0.1802	-0.2038
22	0.2126	-0.1660
23	0.2452	-0.1284
24	0.2781	-0.0910

25	0.3113	-0.0539
26	0.3447	-0.0169
27	0.3782	0.0198
28	0.4121	0.0563
29	0.4710	0.0651
30	0.4364	0.0298
31	0.4019	-0.0055
32	0.3675	-0.0410
33	0.3332	-0.0766
34	0.2991	-0.1123
35	0.2650	-0.1480
36	0.2311	-0.1839
37	0.1974	-0.2200
38	0.1652	-0.2546
39	0.1351	-0.2872
40	0.1082	-0.3164
41	0.0853	-0.3416
42	0.0666	-0.3630
43	0.0518	-0.3804
44	0.0398	-0.3948
45	0.0305	-0.4060
46	0.0229	-0.4151
47	0.0170	-0.4219
48	0.0129	-0.4265
49	0.0096	-0.4301
50	0.0071	-0.4325
51	0.0056	-0.4340
52	0.0047	-0.4348
53	0.0040	-0.4353
54	0.0034	-0.4359
55	0.0027	-0.4363
56	0.0014	-0.4371

Section 20

1	0.0000	-0.4491
2	-0.0007	-0.4478
3	-0.0005	-0.4463
4	-0.0003	-0.4454
5	-0.0001	-0.4446
6	0.0002	-0.4438

7	0.0006	-0.4426
8	0.0014	-0.4406
9	0.0030	-0.4373
10	0.0054	-0.4328
11	0.0087	-0.4272
12	0.0137	-0.4193
13	0.0207	-0.4091
14	0.0296	-0.3967
15	0.0413	-0.3811
16	0.0558	-0.3621
17	0.0740	-0.3385
18	0.0958	-0.3104
19	0.1213	-0.2778
20	0.1501	-0.2413
21	0.1809	-0.2027
22	0.2134	-0.1626
23	0.2461	-0.1226
24	0.2791	-0.0829
25	0.3124	-0.0435
26	0.3459	-0.0043
27	0.3797	0.0347
28	0.4137	0.0736
29	0.4715	0.0878
30	0.4369	0.0500
31	0.4024	0.0122
32	0.3679	-0.0258
33	0.3335	-0.0638
34	0.2993	-0.1020
35	0.2653	-0.1403
36	0.2314	-0.1788
37	0.1977	-0.2174
38	0.1655	-0.2545
39	0.1354	-0.2894
40	0.1085	-0.3206
41	0.0856	-0.3475
42	0.0669	-0.3703
43	0.0521	-0.3890
44	0.0401	-0.4043
45	0.0308	-0.4162

46	0.0232	-0.4258
47	0.0173	-0.4331
48	0.0131	-0.4380
49	0.0098	-0.4418
50	0.0073	-0.4444
51	0.0058	-0.4460
52	0.0048	-0.4468
53	0.0042	-0.4474
54	0.0035	-0.4479
55	0.0028	-0.4485
56	0.0015	-0.4492

Section 21

1	0.0000	-0.4619
2	-0.0007	-0.4605
3	-0.0006	-0.4590
4	-0.0004	-0.4581
5	-0.0002	-0.4572
6	0.0000	-0.4563
7	0.0005	-0.4551
8	0.0013	-0.4530
9	0.0028	-0.4496
10	0.0052	-0.4449
11	0.0084	-0.4390
12	0.0135	-0.4306
13	0.0204	-0.4199
14	0.0293	-0.4068
15	0.0411	-0.3903
16	0.0557	-0.3703
17	0.0740	-0.3454
18	0.0958	-0.3157
19	0.1215	-0.2813
20	0.1505	-0.2428
21	0.1815	-0.2020
22	0.2142	-0.1596
23	0.2471	-0.1175
24	0.2804	-0.0755
25	0.3139	-0.0338
26	0.3477	0.0076
27	0.3817	0.0488

28	0.4159	0.0900
29	0.4734	0.1085
30	0.4387	0.0683
31	0.4040	0.0281
32	0.3693	-0.0122
33	0.3347	-0.0526
34	0.3003	-0.0931
35	0.2660	-0.1338
36	0.2320	-0.1746
37	0.1981	-0.2156
38	0.1658	-0.2550
39	0.1356	-0.2921
40	0.1087	-0.3253
41	0.0857	-0.3539
42	0.0670	-0.3781
43	0.0522	-0.3979
44	0.0403	-0.4142
45	0.0310	-0.4268
46	0.0234	-0.4370
47	0.0175	-0.4447
48	0.0133	-0.4500
49	0.0099	-0.4540
50	0.0074	-0.4568
51	0.0059	-0.4584
52	0.0049	-0.4594
53	0.0042	-0.4600
54	0.0036	-0.4606
55	0.0029	-0.4611
56	0.0015	-0.4620

Section 22

1	0.0000	-0.4798
2	-0.0008	-0.4784
3	-0.0007	-0.4768
4	-0.0005	-0.4759
5	-0.0003	-0.4750
6	-0.0001	-0.4741
7	0.0003	-0.4727
8	0.0011	-0.4706
9	0.0026	-0.4670

10	0.0049	-0.4620
11	0.0082	-0.4558
12	0.0132	-0.4470
13	0.0202	-0.4356
14	0.0291	-0.4219
15	0.0409	-0.4044
16	0.0556	-0.3831
17	0.0740	-0.3568
18	0.0959	-0.3254
19	0.1217	-0.2889
20	0.1509	-0.2481
21	0.1821	-0.2048
22	0.2149	-0.1599
23	0.2481	-0.1152
24	0.2815	-0.0707
25	0.3152	-0.0264
26	0.3492	0.0176
27	0.3833	0.0615
28	0.4176	0.1052
29	0.4763	0.1270
30	0.4414	0.0841
31	0.4064	0.0413
32	0.3715	-0.0016
33	0.3367	-0.0446
34	0.3021	-0.0878
35	0.2676	-0.1311
36	0.2333	-0.1745
37	0.1992	-0.2180
38	0.1667	-0.2599
39	0.1362	-0.2994
40	0.1092	-0.3346
41	0.0861	-0.3650
42	0.0673	-0.3908
43	0.0525	-0.4118
44	0.0405	-0.4291
45	0.0312	-0.4425
46	0.0236	-0.4533
47	0.0177	-0.4615
48	0.0134	-0.4671

49	0.0100	-0.4714
50	0.0075	-0.4743
51	0.0060	-0.4761
52	0.0050	-0.4771
53	0.0043	-0.4777
54	0.0036	-0.4784
55	0.0029	-0.4790
56	0.0016	-0.4798

Section 23

1	0.0000	-0.5023
2	-0.0009	-0.5010
3	-0.0008	-0.4994
4	-0.0006	-0.4984
5	-0.0005	-0.4974
6	-0.0002	-0.4965
7	0.0002	-0.4951
8	0.0010	-0.4928
9	0.0024	-0.4890
10	0.0048	-0.4838
11	0.0080	-0.4772
12	0.0131	-0.4678
13	0.0200	-0.4558
14	0.0290	-0.4412
15	0.0409	-0.4226
16	0.0557	-0.4001
17	0.0742	-0.3721
18	0.0963	-0.3387
19	0.1223	-0.3000
20	0.1516	-0.2566
21	0.1830	-0.2106
22	0.2161	-0.1628
23	0.2494	-0.1152
24	0.2830	-0.0678
25	0.3168	-0.0205
26	0.3508	0.0265
27	0.3850	0.0734
28	0.4194	0.1201
29	0.4795	0.1452
30	0.4444	0.0994

31	0.4093	0.0536
32	0.3742	0.0077
33	0.3392	-0.0383
34	0.3043	-0.0844
35	0.2696	-0.1306
36	0.2351	-0.1769
37	0.2007	-0.2234
38	0.1679	-0.2680
39	0.1372	-0.3101
40	0.1099	-0.3477
41	0.0867	-0.3801
42	0.0677	-0.4075
43	0.0529	-0.4299
44	0.0409	-0.4483
45	0.0315	-0.4626
46	0.0239	-0.4741
47	0.0179	-0.4828
48	0.0136	-0.4888
49	0.0102	-0.4933
50	0.0077	-0.4965
51	0.0061	-0.4983
52	0.0051	-0.4994
53	0.0044	-0.5001
54	0.0037	-0.5008
55	0.0030	-0.5014
56	0.0016	-0.5024

Section 24

1	0.0000	-0.5283
2	-0.0009	-0.5270
3	-0.0009	-0.5253
4	-0.0007	-0.5243
5	-0.0005	-0.5233
6	-0.0003	-0.5223
7	0.0002	-0.5208
8	0.0010	-0.5184
9	0.0025	-0.5144
10	0.0048	-0.5089
11	0.0081	-0.5019
12	0.0132	-0.4920

13	0.0203	-0.4793
14	0.0293	-0.4637
15	0.0413	-0.4439
16	0.0562	-0.4199
17	0.0748	-0.3900
18	0.0971	-0.3544
19	0.1233	-0.3131
20	0.1528	-0.2667
21	0.1845	-0.2176
22	0.2178	-0.1665
23	0.2512	-0.1156
24	0.2849	-0.0648
25	0.3188	-0.0142
26	0.3528	0.0364
27	0.3869	0.0867
28	0.4212	0.1370
29	0.4826	0.1661
30	0.4473	0.1169
31	0.4120	0.0676
32	0.3768	0.0183
33	0.3416	-0.0312
34	0.3066	-0.0807
35	0.2716	-0.1303
36	0.2368	-0.1800
37	0.2021	-0.2298
38	0.1691	-0.2776
39	0.1381	-0.3226
40	0.1107	-0.3629
41	0.0873	-0.3976
42	0.0682	-0.4270
43	0.0533	-0.4509
44	0.0413	-0.4706
45	0.0319	-0.4858
46	0.0242	-0.4981
47	0.0182	-0.5075
48	0.0139	-0.5138
49	0.0104	-0.5187
50	0.0078	-0.5221
51	0.0062	-0.5241

52	0.0052	-0.5252
53	0.0045	-0.5260
54	0.0038	-0.5267
55	0.0030	-0.5274
56	0.0016	-0.5283

Section 25

1	0.0000	-0.5566
2	-0.0010	-0.5553
3	-0.0009	-0.5536
4	-0.0007	-0.5525
5	-0.0005	-0.5515
6	-0.0002	-0.5504
7	0.0002	-0.5489
8	0.0011	-0.5463
9	0.0027	-0.5421
10	0.0052	-0.5363
11	0.0086	-0.5290
12	0.0137	-0.5185
13	0.0209	-0.5049
14	0.0300	-0.4883
15	0.0421	-0.4672
16	0.0571	-0.4415
17	0.0758	-0.4096
18	0.0984	-0.3715
19	0.1248	-0.3273
20	0.1547	-0.2777
21	0.1866	-0.2252
22	0.2202	-0.1705
23	0.2539	-0.1158
24	0.2877	-0.0613
25	0.3217	-0.0069
26	0.3557	0.0474
27	0.3898	0.1017
28	0.4238	0.1559
29	0.4864	0.1894
30	0.4507	0.1366
31	0.4151	0.0836
32	0.3796	0.0305
33	0.3441	-0.0226

34	0.3087	-0.0758
35	0.2734	-0.1291
36	0.2383	-0.1825
37	0.2033	-0.2361
38	0.1699	-0.2874
39	0.1388	-0.3359
40	0.1112	-0.3791
41	0.0877	-0.4165
42	0.0687	-0.4481
43	0.0538	-0.4738
44	0.0418	-0.4949
45	0.0324	-0.5112
46	0.0247	-0.5244
47	0.0186	-0.5344
48	0.0142	-0.5412
49	0.0107	-0.5464
50	0.0080	-0.5500
51	0.0064	-0.5522
52	0.0053	-0.5534
53	0.0046	-0.5542
54	0.0038	-0.5550
55	0.0030	-0.5557
56	0.0017	-0.5567

[0043] In general, the airfoil 64, as described herein, has a combination of axial sweep and tangential lean. Depending on configuration, the lean and sweep angles sometimes vary by up to ±10° or more. In addition, the airfoil 64 is sometimes rotated with respect to a radial axis or a normal to the platform or shroud surface, for example by up to ±10° or more.

[0044] Novel aspects of the turbine blade and associated airfoil surfaces described herein are achieved by substantial conformance to specified geometries. Substantial conformance generally includes or may include a manufacturing tolerance of about ±0.050 inches (±1.27 mm), in order to account for variations in molding, cutting, shaping, surface finishing and other manufacturing processes, and to accommodate variability in coating thicknesses. This tolerance is generally constant or not scalable, and applies to each of the specified blade surfaces, regardless of size.

[0045] Substantial conformance is based on sets of points representing a three-dimensional surface with particular physical dimensions, for example in inches or millimeters, as determined by selecting particular values of the scaling parameters. A substantially conforming airfoil, blade or vane structure has surfaces that conform to the specified sets of points, within the specified tolerance.

[0046] Alternatively, substantial conformance is based on a determination by a national or international regulatory body, for example in a part certification or part manufacture approval (PMA) process for the Federal Aviation Administration, the European Aviation Safety Agency, the Civil Aviation Administration of China, the Japan Civil Aviation Bureau, or the Russian Federal Agency for Air Transport. In these configurations, substantial conformance encompasses a determination that a particular part or structure is identical to, or sufficiently similar to, the specified airfoil, blade or vane, or that the part or structure is sufficiently the same with respect to a part design in a type-certified or type-certificated airfoil, blade or vane, such that the part or structure complies with airworthiness standards applicable to the specified blade, vane or airfoil. In particular, substantial conformance encompasses any regulatory determination that a particular part or structure is sufficiently similar to, identical to, or the same as a specified blade, vane or airfoil, such that certification or authorization for use is based at least in part on the determination of similarity.

[0047] 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.

CLAIMS

What is claimed is:

1. A fan blade for a gas turbine engine comprising:

an airfoil including leading and trailing edges joined by pressure and suction sides to provide an exterior airfoil surface extending in a radial direction to a tip; and

wherein the external airfoil surface is formed in substantial conformance with multiple cross-sectional profiles of the airfoil described by a set of Cartesian coordinates set forth in Table 1, the Cartesian coordinates provided by an axial coordinate scaled by a local axial chord, a circumferential coordinate scaled by the local axial chord, and a span location, wherein the local axial chord corresponds to a width of the airfoil between the leading and trailing edges at the span location.

2. The fan blade according to claim 1, wherein the airfoil includes an aluminum fan blade.

3. The fan blade according to claim 1, wherein the span locations correspond to a position from a rotational axis of the airfoil in a numerical sequence indicated in Table 1 with the last position closest to the tip.

4. The fan blade according to claim 1, wherein the Cartesian coordinates in Table 1 have a tolerance relative to the specified coordinates of ±0.050 inches (±1.27 mm).

5. A gas turbine engine comprising:

a compressor section;

a combustor fluidly connected to the compressor section;

a turbine section fluidly connected to the combustor, the turbine section comprising:

a high pressure turbine coupled to the high pressure compressor via a shaft;

a low pressure turbine; and

a fan section operatively coupled to the turbine section, wherein the fan section includes an array of fan blades, wherein at least one fan blade includes an airfoil having leading and trailing edges joined by pressure and suction sides to provide an exterior airfoil surface extending from in a radial direction to a tip; and

wherein the external airfoil surface is formed in substantial conformance with multiple cross-sectional profiles of the airfoil described by a set of Cartesian coordinates set forth in Table 1, the Cartesian coordinates provided by an axial coordinate scaled by a local axial chord, a circumferential coordinate scaled by the local axial chord, and a span location, wherein the local axial chord corresponds to a width of the airfoil between the leading and trailing edges at the span location.

6. The gas turbine engine according to claim 5, wherein the airfoil includes an aluminum fan blade.

7. The gas turbine engine according to claim 5, wherein the span locations correspond to a position from a rotational axis of the airfoil in a numerical sequence indicated in Table 1 with the last position closest to the tip.

8. The gas turbine engine according to claim 5, wherein the Cartesian coordinates in Table 1 have a tolerance relative to the specified coordinates of ±0.050 inches (±1.27 mm).

9. The gas turbine engine according to claim 5, wherein the array of fan blades includes less than about twenty-six (26) fan blades.

10. The gas turbine engine according to claim 5, wherein the array of fan blades includes less than about twenty (20) fan blades.

11. The gas turbine engine according to claim 5, wherein the fan section is driven by a geared architecture.

12. The gas turbine engine according to claim 5, wherein the gas turbine engine is a high-bypass geared gas turbine engine.

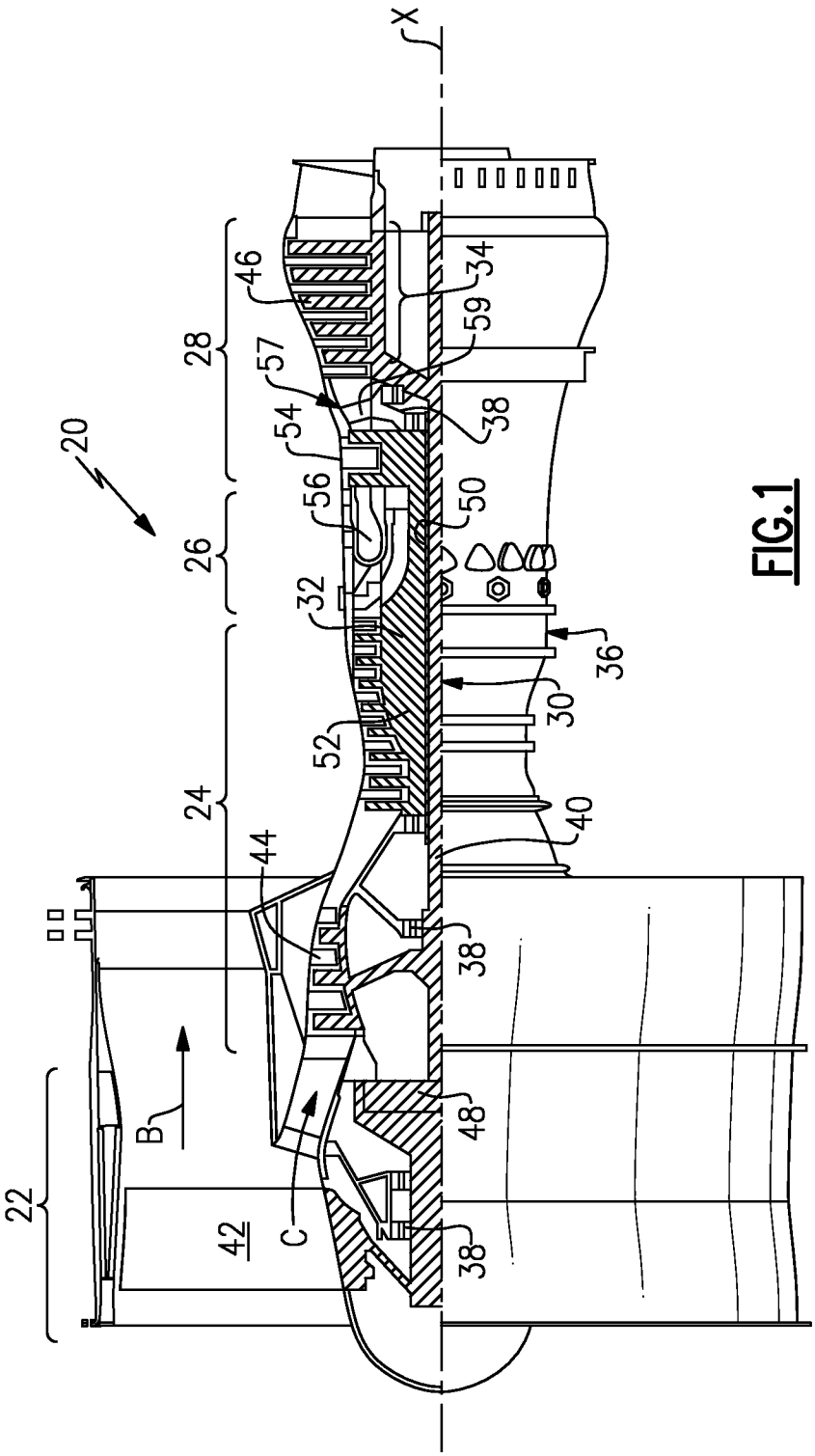


FIG.1

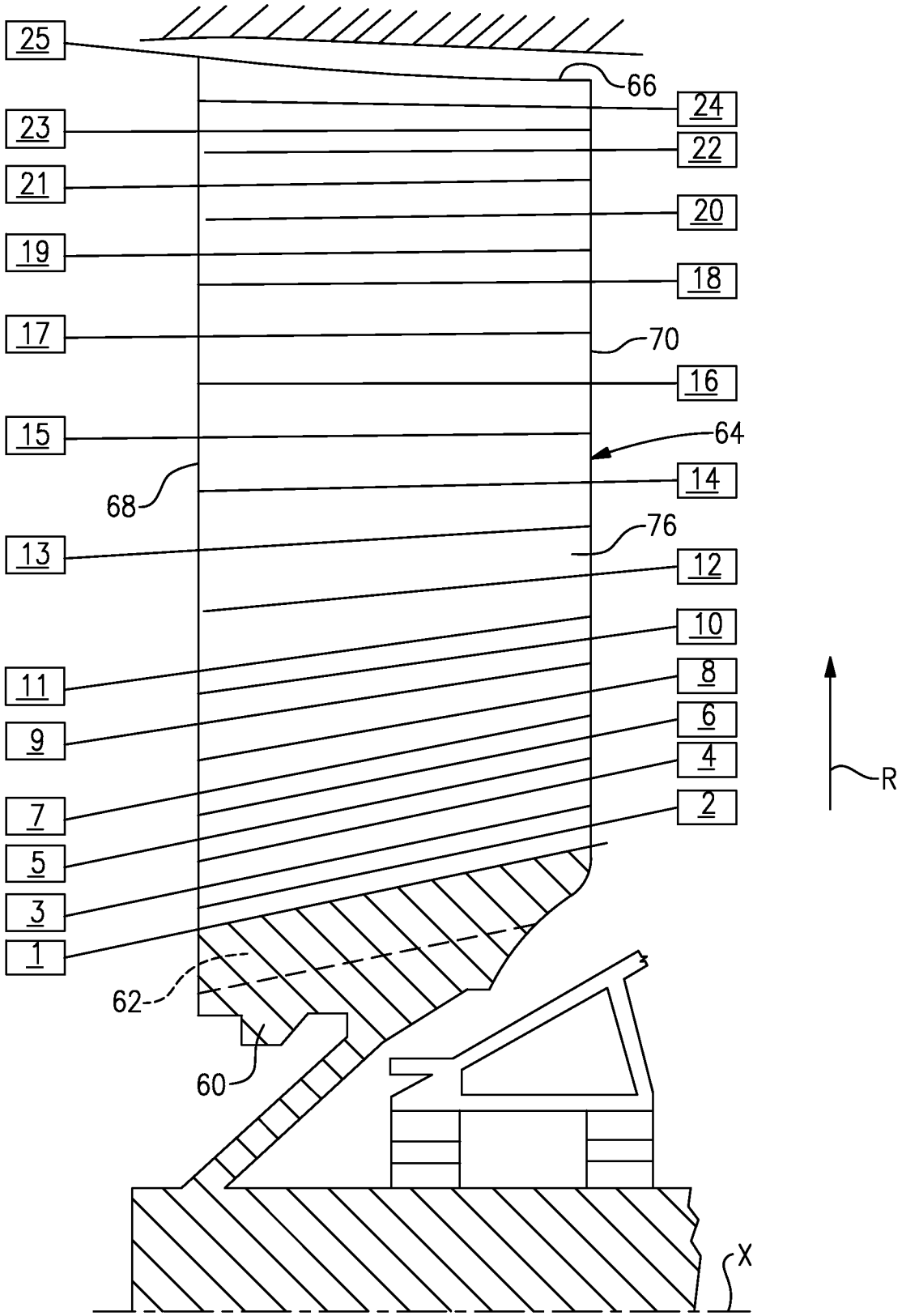

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FIG.2

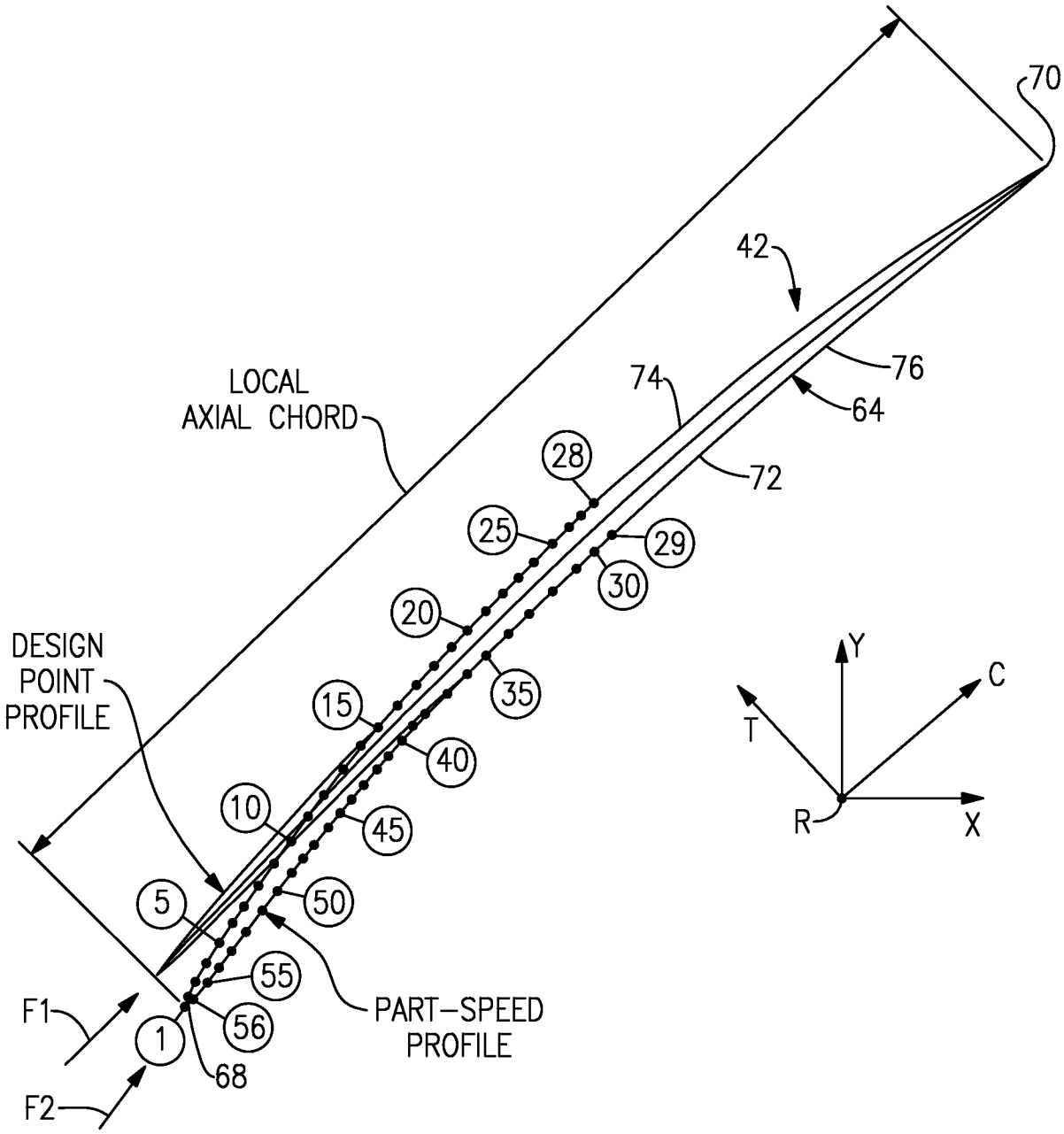

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DESIGN
POINT
PROFILE
PART-SPEED
PROFILE
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F2
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FIG.3