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(54) Title: RELATIONSHIP BETWEEN FAN AND PRIMARY EXHAUST STREAM VELOCITIES IN A GEARED GAS TURBINE ENGINE

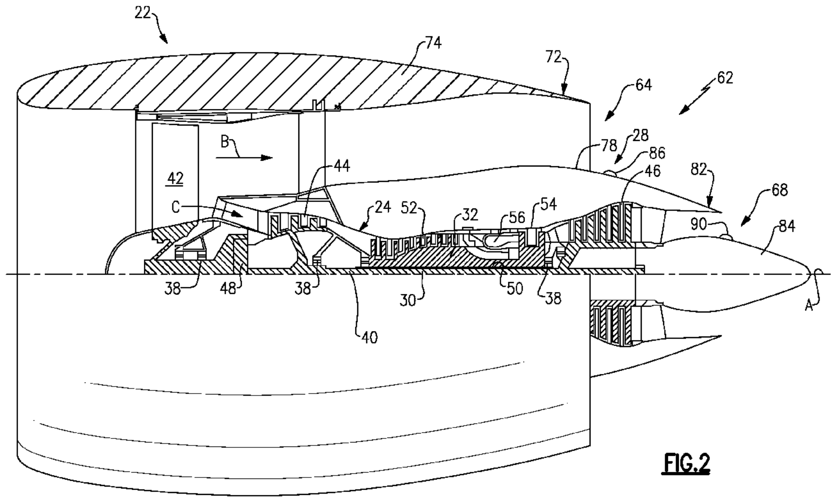

FIG.2

(57) **Abstract**: An example gas turbine engine includes, among other things, a geared architecture rotatably coupling a fan drive shaft to an engine fan, the geared architecture having a speed reduction ratio that is approximately in a first range of 2.4 to 4.2. The gas turbine engine is configured so that an Exhaust Velocity Ratio, defined by a ratio of a fan stream exhaust velocity to primary stream exhaust velocity, is approximately in a second range of 0.75 to 0.90.

RELATIONSHIP BETWEEN FAN AND PRIMARY EXHAUST STREAM VELOCITIES IN A GEARED GAS TURBINE ENGINE

BACKGROUND

[0001] A gas turbine engine typically includes a fan section, a compressor section, a combustor section, and a turbine section. Air entering the compressor section is compressed and delivered into the combustion section where it is mixed with fuel and ignited to generate a high-temperature exhaust gas flow. The high-temperature exhaust gas flow expands through the turbine section to drive the compressor and the fan section. The compressor section typically includes low and high pressure compressors, and the turbine section includes low and high pressure turbines.

[0002] The high pressure turbine drives the high pressure compressor through an outer shaft to form a high spool, and the low pressure turbine drives the low pressure compressor through an inner shaft to form a low spool. The fan section may also be driven by the low inner shaft. A speed reduction device such as an epicyclical gear assembly may be utilized to drive the fan section such that the fan section may rotate at a speed different than the turbine section so as to increase the overall propulsive efficiency of the engine. In such engine architectures, a shaft driven by one of the turbine sections provides an input to the epicyclical gear assembly that drives the fan section at a reduced speed such that both the turbine section and the fan section can rotate at closer to optimal speeds.

[0003] Although geared architectures have improved propulsive efficiency, turbine engine manufacturers continue to seek further improvements to engine performance including improvements to thermal, transfer, and propulsive efficiencies.

SUMMARY

[0004] A gas turbine engine according to an exemplary aspect of the present disclosure includes, among other things, a geared architecture rotatably coupling a fan drive shaft to an engine fan, the geared architecture having a speed reduction ratio that is approximately in a first range of 2.4 to 4.2. The gas turbine engine is configured so that an Exhaust Velocity Ratio, defined by a ratio of a fan stream exhaust velocity to primary stream exhaust velocity, is approximately in a second range of 0.75 to 0.90.

[0005] In a further non-limiting embodiment of the foregoing gas turbine engine, the engine may be configured so that the Exhaust Velocity Ratio is in the second range when cruising at 35,000 feet and when operating at a 0.80 Mach number cruise power condition.

[0006] In a further non-limiting embodiment of either of the foregoing gas turbine engines, a Fan Pressure Ratio for the engine may be less than 1.45 at 35,000 feet and when operating at a 0.80 Mach number cruise power condition.

[0007] In a further non-limiting embodiment of any of the foregoing gas turbine engines, a Bypass Ratio of the engine may be greater than 8.0.

[0008] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the engine may be configured so that the Exhaust Velocity Ratio is in the second range when the fan stream exhaust velocity is less than 1175 feet per second.

[0009] A gas turbine engine according to another exemplary aspect of the present disclosure includes, among other things, a geared architecture rotatably coupling a fan drive shaft to a fan of a gas turbine engine, the geared architecture having a speed reduction ratio that is approximately in a first range of 2.4 to 4.2, a fan stream exhaust of the gas turbine engine, and a primary stream exhaust of the gas turbine engine. The gas turbine engine is configured so that an Exhaust Velocity Ratio, defined by a ratio of a fan stream exhaust velocity to primary stream exhaust velocity, is approximately in a second range of 0.75 to 0.90.

[0010] In a further non-limiting embodiment of the foregoing gas turbine engine, the engine may be configured so that the Exhaust Velocity Ratio is in the second range when cruising at 35,000 feet and when operating at a 0.80 Mach number cruise power condition.

[0011] In a further non-limiting embodiment of either of the foregoing gas turbine engines, a Fan Pressure Ratio for the engine may be less than 1.45 at 35,000 feet and when operating at a .80 Mach number cruise power condition.

[0012] In a further non-limiting embodiment of any of the foregoing gas turbine engines, a Bypass Ratio of the engine may be greater than 8.0.

[0013] In a further non-limiting embodiment of any of the foregoing gas turbine engines, the engine may be configured so that the Exhaust Velocity Ratio is in the second range when the fan stream exhaust velocity is less than 1175 feet per second.

[0014] A method of providing a gas turbine engine having a fan stream exhaust velocity and a primary stream exhaust velocity, according to yet another exemplary aspect of the present disclosure includes, among other things, providing a geared architecture that rotatably couples a fan drive shaft to a fan of a gas turbine engine, the geared architecture having a speed reduction ratio that is approximately in a first range of 2.4 to 4.2, providing a fan stream exhaust configured to provide exhaust at a fan stream exhaust velocity, and providing a primary exhaust configured to provide exhaust at a primary stream exhaust velocity. The gas turbine engine is configured so that an Exhaust Velocity Ratio, defined by a ratio of the fan stream exhaust velocity to primary stream exhaust velocity, is approximately in a second range of 0.75 to 0.90.

[0015] In a further non-limiting embodiment of the foregoing method, the engine may be configured so that the Exhaust Velocity Ratio is in the second range at 35,000 feet and operating at a 0.80 Mach number cruise power condition.

[0016] In a further non-limiting embodiment of either of the foregoing methods, the Fan Pressure Ratio for the engine may be less than 1.45 at 35,000 feet and when operating at a 0.80 Mach number cruise power condition.

[0017] In a further non-limiting embodiment of any of the foregoing methods, the method may include providing a Bypass Ratio of the engine that is greater than 8.0.

[0018] In a further non-limiting embodiment of any of the foregoing methods, the engine may be configured so that the Exhaust Velocity Ratio is in the second range when the fan stream exhaust velocity is less than 1175 feet per second.

[0019] Although the different examples have the specific components shown in the illustrations, embodiments of this disclosure are not limited to those particular combinations. It is possible to use some of the components or features from one of the examples in combination with features or components from another one of the examples.

DESCRIPTION OF THE FIGURES

[0020] The various features and advantages of the disclosed examples will become apparent to those skilled in the art from the detailed description. The figures that accompany the detailed description can be briefly described as follows:

[0021] Figure 1 shows a section view of an example gas turbine engine.

[0022] Figure 2 shows an example embodiment of the gas turbine engine of Figure 1.

DETAILED DESCRIPTION

[0023] 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 temperature 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.

[0024] Although the disclosed non-limiting embodiment depicts a gas turbine gas turbine engine, it should be understood that the concepts described herein are not limited to use with gas turbines 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.

[0025] The example engine 20 generally includes a low speed spool 30 and a high speed spool 32 mounted for rotation about an engine central longitudinal axis A relative to an engine static structure 36 via several bearing systems 38. It should be understood that various bearing systems 38 at various locations may alternatively or additionally be provided.

[0026] 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 A.

[0027] 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.

[0028] The example low pressure turbine 46 has a pressure ratio that is greater than about 5. The pressure ratio of the example low pressure turbine 46 is measured prior to an inlet of the low pressure turbine 46 as related to the pressure measured at the outlet of the low pressure turbine 46 prior to an exhaust nozzle.

[0029] A mid-turbine frame 58 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 58 further supports bearing systems 38 in the turbine section 28 as well as setting airflow entering the low pressure turbine 46.

[0030] 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 temperature exhaust gases that are then expanded through the high pressure turbine 54 and low pressure turbine 46. The mid-turbine frame 58 includes vanes 60, which are in the core airflow path and may function as an inlet guide vane for the low pressure turbine 46. Utilizing the vane 60 of the mid-turbine frame 58 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 58. 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.

[0031] 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.

[0032] 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.

[0033] 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.

[0034] "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.

[0035] “Low corrected fan tip speed” is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of [(Tram °R)/ (518.7°R)]^0.5. The “Low corrected fan tip speed”, as disclosed herein according to one non-limiting embodiment, is less than about 1150 ft/second.

[0036] The example gas turbine engine includes the fan 42 that comprises in one non-limiting embodiment less than about 26 fan blades. In another non-limiting embodiment, the fan section 22 includes less than about 20 fan blades. Moreover, in one disclosed embodiment the low pressure turbine 46 includes no more than about 6 turbine rotors schematically indicated at 34. In another non-limiting example embodiment, the low pressure turbine 46 includes about 3 turbine rotors. A ratio between the number of fan blades and the number of low pressure turbine rotors is between about 3.3 and about 8.6. The example low pressure turbine 46 provides the driving power to rotate the fan section 22 and therefore the relationship between the number of turbine rotors 34 in the low pressure turbine 46 and the number of blades in the fan section 22 disclose an example gas turbine engine 20 with increased power transfer efficiency.

[0037] Referring now to Figure 2, an engine 62 is a variation of the engine 20. The engine 62 has a fan stream exhaust 64 and a primary stream exhaust 68. Generally, the bypass flow B exits through the fan stream exhaust 64, and the core flow C exits through the primary stream exhaust 68.

[0038] The fan stream exhaust 64 is provided between a nacelle nozzle 72 (at an aft area of a nacelle 74) and an engine casing 78. The primary stream exhaust 68 is provided between a casing nozzle 82 (at an aft area of the casing 78) and a tailcone 84. Flow through the primary stream exhaust 68 has been expanded through the low pressure turbine 46.

[0039] During operation, a ratio of a velocity of flow through the fan stream exhaust 64 to a velocity of flow through the primary stream exhaust 68, termed the “Engine Exhaust Stream Velocity Ratio,” (or the “Exhaust Velocity Ratio”) is in a range from approximately 0.75 to 0.90. Particularly in geared engine designs having a speed reduction ratio of from 2.4 to 4.2, an Exhaust Velocity Ratio in the stated, desired range has been found to reduce overall fuel consumption compared to engines having this relationship falling outside of this range.

[0040] The geometries of the engine 62 and the nacelle 74 could be selected to achieve the stated range for the Exhaust Velocity Ratio during cruise operation. The fan pressure ratio, total fan inlet flow, and bypass ratio could be selected to achieve the desired Exhaust Velocity Ratio.

[0041] Changes to the fan pressure ratio could be achieved by changing the geometry of the blades of the fan 42. The fan stream nozzle throat area is the minimum flow area at the exit of the fan nozzle 72. The primary stream nozzle throat area is the minimum flow area at the exit of the primary nozzle 82 over the tail cone 84. These areas could be designed for values to achieve a selected total fan flow and bypass ratio. Selection of a combination of these geometries would cause the engine 62 to operate at the desired Exhaust Velocity Ratio.

[0042] Notably, an engine designed to operate within the stated envelope for the Exhaust Velocity Ratio falls within the scope of the disclosure, even if the engine is not continuously operating within that envelop. A person having skill in this art and the benefit of this disclosure could calculate, for example, an engine exhaust stream velocity ratio during a particular operating condition based on the designed fan stream exhaust and other parameters.

[0043] In one example, the engine 62 exhibits a relationship of a fan stream exhaust velocity to primary stream exhaust velocity within this range when the engine 62 is cruising at 35,000 feet and operating at a 0.80 Mach number cruise power condition. Probes 86 and 90 may be located at or near the fan stream exhaust 64 and the primary stream exhaust 68 to measure the respective pressure and temperature of the flows, from which exhaust velocities can be determined in order to verify that the designed fan and primary stream exhausts result in the desired ratio.

[0044] One characteristic of the engine 62 is that a fan pressure ratio of the engine 62 is less than 1.45 when the engine 62 is cruising at 35,000 feet and operating at a 0.80 Mach number cruise power condition.

[0045] Another characteristic of the engine 62 is that a designed bypass ratio of the engine 62 is greater than 8.0. Flow need not be actively moving through the engine 62 for the engine 62 to have a designed bypass ratio that is greater than 8.0.

[0046] Yet another characteristic of the engine 62 is that the geared architecture 48 has a speed reduction ratio of from 2.4 to 4.2.

[0047] In one example, the fan stream exhaust velocity is less than 1175 ft/s (358 m/s) when the engine is cruising at 35,000 feet and operating at a 0.80 Mach number cruise power condition.

[0048] Features of the disclosed examples include a fan stream to primary stream exhaust velocity relationship that advantageously results in reduced fuel consumption by improving propulsive efficiency and overall engine efficiency.

[0049] 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 this disclosure. For that reason, the following claims should be studied to determine the scope and content of this disclosure.

CLAIMS

I claim:

1. A gas turbine engine comprising:

a geared architecture rotatably coupling a fan drive shaft to a fan of a gas turbine engine, the geared architecture having a speed reduction ratio that is approximately in a first range of 2.4 to 4.2,

wherein the gas turbine engine is configured so that an Exhaust Velocity Ratio, defined by a ratio of a fan stream exhaust velocity to primary stream exhaust velocity, is approximately in a second range of 0.75 to 0.90.

2. The gas turbine engine of claim 1, wherein the engine is configured so that the Exhaust Velocity Ratio is in the second range when cruising at 35,000 feet and when operating at a 0.80 Mach number cruise power condition.

3. The gas turbine engine of claim 1, wherein a Fan Pressure Ratio for the engine is less than 1.45 at 35,000 feet and when operating at a 0.80 Mach number cruise power condition.

4. The gas turbine engine of claim 1, wherein a Bypass Ratio of the engine is greater than 8.0.

5. The gas turbine engine of claim 1, wherein the engine is configured so that the Exhaust Velocity Ratio is in the second range when the fan stream exhaust velocity is less than 1175 feet per second.

6. A gas turbine engine comprising:

a geared architecture rotatably coupling a fan drive shaft to a fan of a gas turbine engine, the geared architecture having a speed reduction ratio that is approximately in a first range of 2.4 to 4.2;

a fan stream exhaust of the gas turbine engine; and

a primary stream exhaust of the gas turbine engine, wherein the gas turbine engine is configured so that an Exhaust Velocity Ratio, defined by a ratio of a fan stream exhaust velocity to primary stream exhaust velocity, is approximately in a second range of 0.75 to 0.90.

7. The gas turbine engine of claim 6, wherein the engine is configured so that the Exhaust Velocity Ratio is in the second range when cruising at 35,000 feet and when operating at a 0.80 Mach number cruise power condition.

8. The gas turbine engine of claim 6, wherein a Fan Pressure Ratio for the engine is less than 1.45 at 35,000 feet and when operating at a .80 Mach number cruise power condition.

9. The gas turbine engine of claim 6, wherein a Bypass Ratio of the engine is greater than 8.0.

10. The gas turbine engine of claim 6, wherein the engine is configured so that the Exhaust Velocity Ratio is in the second range when the fan stream exhaust velocity is less than 1175 feet per second.

11. A method of providing a gas turbine engine having a fan stream exhaust velocity and a primary stream exhaust velocity, the method comprising:

providing a geared architecture that rotatably couples a fan drive shaft to a fan of a gas turbine engine, the geared architecture having a speed reduction ratio that is approximately in a first range of 2.4 to 4.2;

providing a fan stream exhaust configured to provide exhaust at a fan stream exhaust velocity; and

providing a primary exhaust configured to provide exhaust at a primary stream exhaust velocity,

wherein the gas turbine engine is configured so that an Exhaust Velocity Ratio, defined by a ratio of the fan stream exhaust velocity to primary stream exhaust velocity, is approximately in a second range of 0.75 to 0.90.

12. The method of claim 11, wherein the engine is configured so that the Exhaust Velocity Ratio is in the second range at 35,000 feet and operating at a 0.80 Mach number cruise power condition.

13. The method of claim 11, wherein a Fan Pressure Ratio for the engine is less than 1.45 at 35,000 feet and when operating at a 0.80 Mach number cruise power condition.

14. The method of claim 11, including providing a Bypass Ratio of the engine that is greater than 8.0.

15. The method of claim 11, wherein the engine is configured so that the Exhaust Velocity Ratio is in the second range when the fan stream exhaust velocity is less than 1175 feet per second.

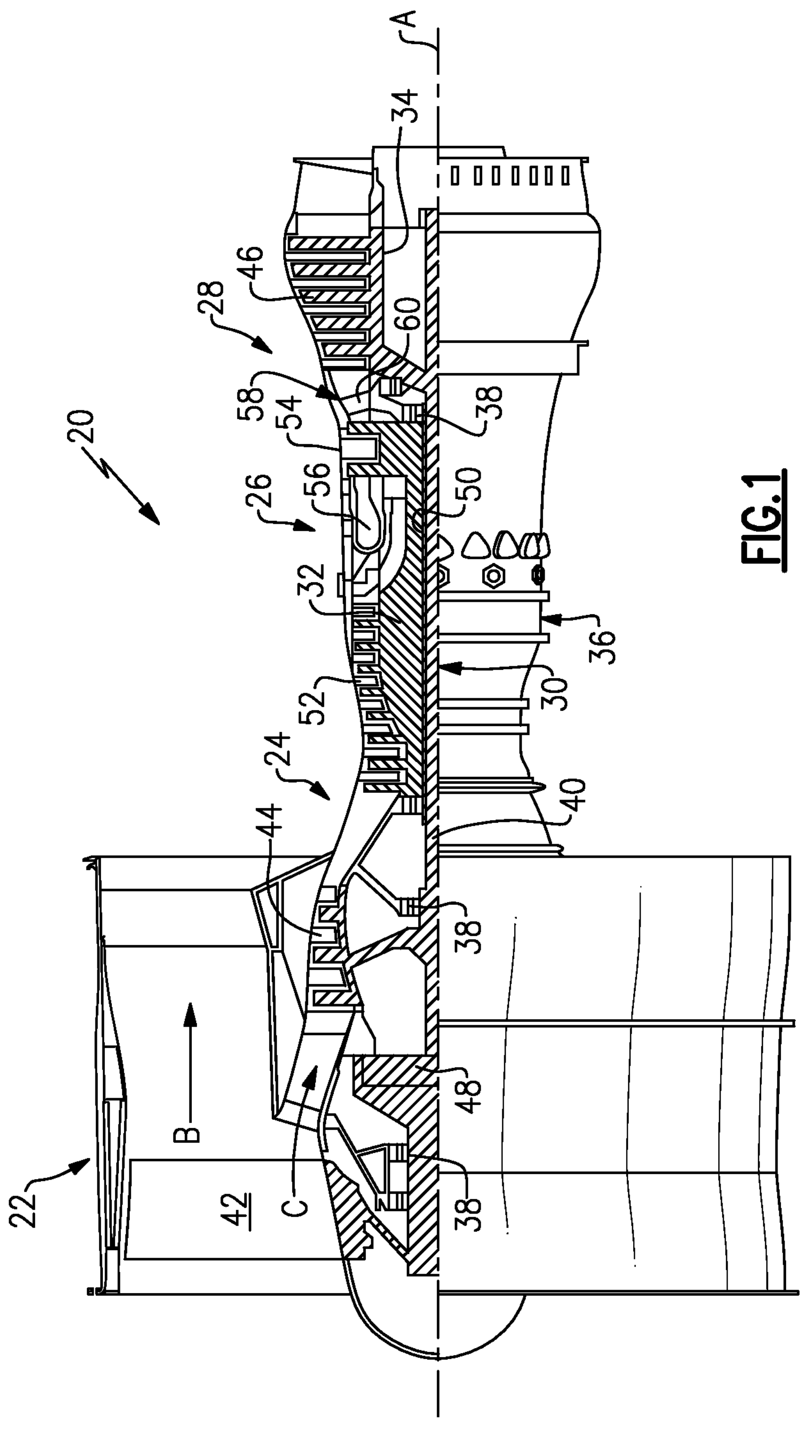

FIG.1

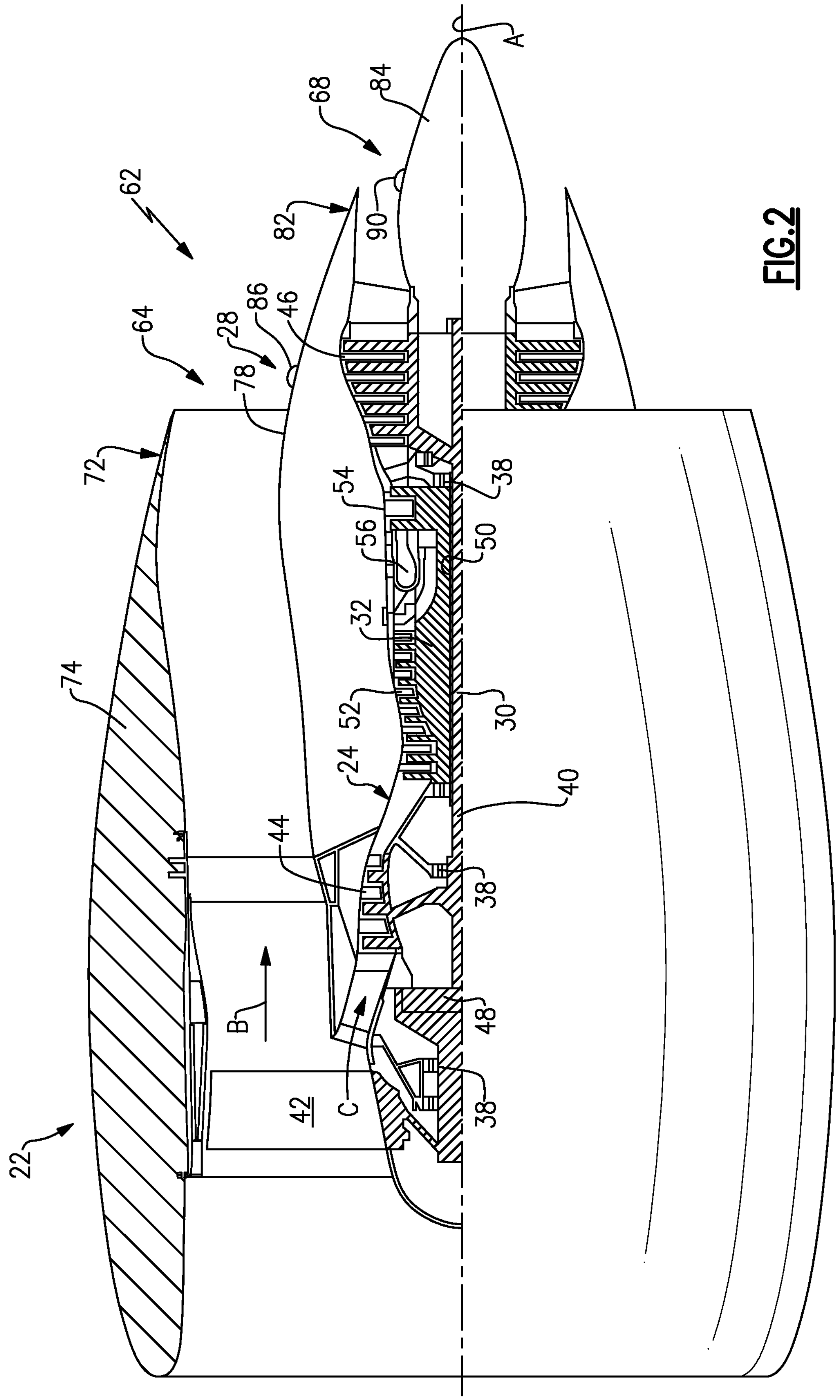
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FIG.2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/022402

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F02K 3/02 (2013.01)
USPC - 60/226.3
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)
IPC(8) - F02K 1/38, 3/02, 3/075 (2013.01)
USPC - 60/204, 226.3, 262; 181/220; 415/144

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - F02K 1/386, 3/02, 3/075 (2013.01)

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012/0171018 A1 (HASEL et al) 05 July 2012 (05.07.2012) entire document	1-15
Y	US 3,100,627 A (WILDE) 13 August 1963 (13.08.1963) entire document	1-15
Y	US 2012/0124964 A1 (HASEL et al) 24 May 2012 (24.05.2012) entire document	5, 10, 15

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 September 2013	19 SEP 2013
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774