

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.

[0049] 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.

[0050] 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.

[0051] 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 cruise fuel consumption relative to the thrust it produces—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 bucket cruise point.

[0052] “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.

[0053] “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.

[0054] 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 18 fan blades. Moreover, in one disclosed embodiment the low pressure turbine 46 includes no more than about 6 turbine stages schematically indicated at 34. In another non-limiting example embodiment the low pressure turbine 46 includes about 3 or more turbine stages. A ratio between the number of fan blades 42 and the number of low pressure turbine stages is between about 2.5 and about 8.5. 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 stages 34 in the low pressure turbine 46 and the number of blades 42 in the fan section 22 disclose an example gas turbine engine 20 with increased power transfer efficiency.

[0055] Increased power transfer efficiency is provided due in part to the increased use of improved turbine blade mate-

rials and manufacturing methods such as directionally solidified castings, and single crystal materials that enable increased turbine speed and a reduced number of stages. Moreover, the example low pressure turbine 46 includes improved turbine disks configurations that further enable desired durability at the higher turbine speeds.

[0056] Referring to FIGS. 2 and 3, an example disclosed speed change device is an epicyclical gearbox of a planet type, where the input is to the center “sun” gear 62. Planet gears 64 (only one shown) around the sun gear 62 rotate and are spaced apart by a carrier 68 that rotates in a direction common to the sun gear 62. A ring gear 66, which is non-rotatably fixed to the engine static casing 36 (shown in FIG. 1), contains the entire gear assembly. The fan 42 is attached to and driven by the carrier 68 such that the direction of rotation of the fan 42 is the same as the direction of rotation of the carrier 68 that, in turn, is the same as the direction of rotation of the input sun gear 62.

[0057] In the following figures nomenclature is utilized to define the relative rotations between the various sections of the gas turbine engine 20. The fan section is shown with a “+” sign indicating rotation in a first direction. Rotations relative to the fan section 22 of other features of the gas turbine engine are further indicated by the use of either a “+” sign or a “-” sign. The “-” sign indicates a rotation that is counter to that of any component indicated with a “+” sign.

[0058] Moreover, the term fan drive turbine is utilized to indicate the turbine that provides the driving power for rotating the blades 42 of the fan section 22. Further, the term “second turbine” is utilized to indicate the turbine before the fan drive turbine that is not utilized to drive the fan 42. In this disclosed example, the fan drive turbine is the low pressure turbine 46, and the second turbine is the high pressure turbine 54. However, it should be understood that other turbine section configurations that include more than the shown high and low pressure turbines 54, 46 are within the contemplation of this disclosure. For example, a three spool engine configuration may include an intermediate turbine (not shown) utilized to drive the fan section 22 and is within the contemplation of this disclosure.

[0059] In one disclosed example embodiment (FIG. 2) the fan drive turbine is the low pressure turbine 46 and therefore the fan section 22 and low pressure turbine 46 rotate in a common direction as indicated by the common “+” sign indicating rotation of both the fan 42 and the low pressure turbine 46. Moreover in this example, the high pressure turbine 54 or second turbine rotates in a direction common with the fan drive turbine 46. In another example shown in FIG. 3, the high pressure turbine 54 or second turbine rotates in a direction opposite the fan drive turbine (low pressure turbine 46) and the fan 42.

[0060] Counter rotating the low pressure compressor 44 and the low pressure turbine 46 relative to the high pressure compressor 52 and the high pressure turbine 54 provides certain efficient aerodynamic conditions in the turbine section 28 as the generated high speed exhaust gas flow moves from the high pressure turbine 54 to the low pressure turbine 46. The relative rotations in the compressor and turbine sections provide approximately the desired airflow angles between the sections, which improves overall efficiency in the turbine section 28, and provides a reduction in overall weight of the turbine section 28 by reducing or eliminating airfoils or an entire row of vanes.