

SETTING TWIST ANGLE OF TURBINE ENGINE BLADE COMPONENTS

BACKGROUND

5 [0001] The present disclosure relates generally to blade components used in gas turbine engines and more particularly to methods and apparatuses for setting blade twist in such components.

 [0002] Gas turbine engines generally include a fan, a compressor, a combustor, a turbine, and an exhaust nozzle. A portion of the incoming air is compressed in the compressor
10 section of the engine and then mixed with fuel and burned in the combustor section to produce a high energy, high temperature gas stream. The hot gas stream exits the combustor and subsequently passes through the turbine section that extracts energy from the hot gas stream to power the compressor and provide useful work such as powering an aircraft in flight.

 [0003] The compressor and turbine commonly include alternating stages of rotor
15 blades and stator vanes. Turbine blades and vanes often include complex, contoured blade geometries designed to optimally interact with the working medium gas passing through the engine. One common feature of turbine blade geometries is the blade twist angle.

 [0004] Through normal engine operations, the twist angle may decrease over time due to thermo-mechanical cycling and aerodynamic loading of the blades. The amount of twist
20 that effects each individual turbine blade is unlikely to be identical as each blade may experience different engine run conditions and repair cycles.

 [0005] Blades are routinely inspected for maintenance purposes, and a wide variety of repair processes have been developed to restore the twist angle but these processes may typically require tedious quality control processes. Furthermore, rework of overtwisted blades is
25 impossible as base alloy plastic deformations disallow further rework.

SUMMARY

 [0006] A method for setting or correcting a twist angle of a blade according to one disclosed non-limiting embodiment of the present disclosure includes applying a first torque to
30 twist a blade to produce a first displacement, the first displacement less than a second

displacement , measuring the first torque to provide a measured first torque, measuring the first displacement to provide a measured first displacement, determining a specific torque to produce the second displacement from the measured first torque and the measured first displacement and applying the specific torque to the blade to twist the blade to produce the second displacement .

5 [0007] In a further embodiment of the foregoing embodiment, the method includes limiting the first torque to less than the specific torque.

 [0008] In a further embodiment of any of the foregoing embodiments, the method includes limiting the first torque to about 20%-30% of the specific torque.

10 [0009] In a further embodiment of any of the foregoing embodiments, the method includes defining the second displacement as an original pre-twist angle.

 [0010] In a further embodiment of any of the foregoing embodiments, measuring the first torque includes measuring by a torque wrench.

 [0011] In a further embodiment of any of the foregoing embodiments, applying the first torque includes driving an electric motor connected to the wrench.

15 [0012] In the alternative or additionally thereto, the first torque includes connecting the electric motor to the wrench through a gear system.

 [0013] In the alternative or additionally thereto, the first torque includes connecting the electric motor to the wrench through a pulley system.

20 [0014] A repair system for adjusting a twist angle of a blade according to another disclosed non-limiting embodiment of the present disclosure includes a fixture configured to engage a root of a blade, a wrench configured to apply a first torque to twist the blade to produce a first displacement, the first displacement less than a second displacement , a gauge to measure the first torque, a gauge to measure the first displacement and a controller to determine a specific torque to produce the second displacement from the measured first torque and the measured first displacement.

25 [0015] In a further embodiment of the foregoing embodiment, the system includes a drive system connected to the wrench, the drive system in communication with the controller.

 [0016] In a further embodiment of the foregoing embodiment, the controller is operable to drive a drive system connected to the wrench.

30 [0017] In a further embodiment of the foregoing embodiment, the controller is operable to drive a drive system to generate the specific torque.

[0018] In a further embodiment of the foregoing embodiment, the controller is operable to drive a drive system to generate the first torque.

[0019] In a further embodiment of the foregoing embodiment, the controller is operable to limit the first torque to about 20%-30% of the specific torque.

5 [0020] A system for adjusting a twist angle of a blade according to another disclosed non-limiting embodiment of the present disclosure includes a fixture configured to engage a root of a blade, a wrench configured to apply a first torque to twist the blade to produce a first displacement, the first displacement less than a second displacement, a gauge to measure the first torque, a gauge to measure the first displacement, a controller to determine a specific torque to
10 produce the second displacement from the measured first torque and the measured first displacement, and a drive system connected to the wrench, the drive system in communication with the controller.

[0021] In a further embodiment of the foregoing embodiment, the gauge to measure the first torque is contained within the wrench.

15 [0022] In a further embodiment of the foregoing embodiment, the gauge to measure the first displacement is mounted to the fixture.

[0023] In a further embodiment of the foregoing embodiment, the controller is operable to limit the first torque to about 20%-30% of the specific torque.

20 BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Various features will become apparent to those skilled in the art from the following detailed description of the disclosed non-limiting embodiment. The drawings that accompany the detailed description can be briefly described as follows:

25 [0025] Figures 1A and 1B are top and side views respectively of a twisted gas turbine blade;

[0026] Figure 2 is a perspective view of a repair system for correcting the twist angle of the turbine blade;

[0027] Figure 3 is schematic block diagram of an algorithm for correcting the twist angle of the turbine blade;

30 [0028] and

[0029] Figure 4 is graphical representation of the torque and displacement of the turbine blade when the algorithm of Figure 3 is operated.

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DETAILED DESCRIPTION

[0030] Figures 1A and 1B are top and side views respectively of a gas turbine blade 10, that includes a root 12, a platform 14, an airfoil 16, a tip shroud 18, and knife edges 20. The blade 10 may be, for example, a shrouded high pressure turbine blade, but is not limited thereto and may include vanes and other blade structures.

10 [0031] The root 12 may be a dovetail or fir tree root and is configured for receipt in a slot in the rim of a rotor disc (not shown). The platform 14 is integral (unitary) with and radially outboard of the root 12. The airfoil 16 extends radially outward from the platform 14 to the shroud 18 that includes knife edges 20 designed to engage, for example, a stationary honeycomb seal (not shown) arranged radially outward of blade 10 mounted in the rim of the rotor disc.

15 [0032] A twist angle 22 of the blade 10 is equal to the angular displacement of the airfoil 16 about a spanwise axis, such as the stacking axis 24 of the airfoil 16, between the root 12 and the shroud 18. For example only, the twist angle 22 is represented by an angle defined between a vertical plane R through the root 12 and a line W perpendicular to knife edge 20. That is, the twist angle 22 may be defined as the angle between plane R and line W. It should be
20 appreciated that the twist angle 22 may change along the span of the airfoil 16.

[0033] Through normal engine operation, the twist angle 22 of the blade 10 may change from a desired original manufactured condition twist angle 22 due to, for example, thermo-mechanical cycling and aerodynamic loading on the blade 10. In order to extend the useful life of the blade 10, the twist angle 22 may be restored to the original manufactured
25 condition.

[0034] In another disclosed, non-limiting embodiment, the twist angle 22 may be roughly set during a manufacturing or casting process that still requires fine adjustment. That is, the twist angle 22 of the blade 10 is finalized through the method as disclosed herein.

[0035] With respect to Figure 2, a repair or twist setting system 30 for adjustment of
30 the twist angle 22 of the blade 10 generally includes a base plate 32, a fixture 34, a twist angle gauge 36, a wrench 38 shown displaced from the blade 10, a drive system 40 and a controller 42.

The controller 42 is in communication with the drive system 40, the angle gauge 36 and the wrench 38. It should be appreciated that the repair system is schematically illustrated and that various configurations may alternatively or additionally be provided. For further understanding of other aspects of twist angle adjustment and associated modes thereof, attention is directed to
5 United States Patent Application No. 2009/0255307 entitled Turbine Blade Twist Angle Correction Tooling that is assigned to the assignee of the present disclosure and that is hereby incorporated herein in its entirety.

[0036] The fixture 34 is mounted to the base plate 32 and configured to engage the root 12 of the blade 10. The fixture 34 may include, for example, a multiple of blocks 34a, 34b
10 in which the blocks 34a, 34b may be configured to engage two sides of the root 12 of the blade 10. The blocks 34a, 34b may be adapted to engage varying root geometries, such as a fir tree root geometry.

[0037] The twist angle gauge 36 is connected to the base plate 32 and configured to measure the twist angle 22 of the blade 10. The twist angle gauge 36 may be adjustably
15 connected to, for example, gauge stand 36A. The gauge stand 36A may be configured to adjustably position the gauge 36 vertically with respect to the base plate 32 and laterally with respect to the blade 10 to cause the twist angle gauge 36 to engage, for example, one or more portions of blade 10, such as contacting shroud 18 of blade 10 to measure twist angle 22.

[0038] The wrench 38 is configured to engage the shroud 18 and the drive system 40
20 is configured to engage the wrench 38 to apply a measured load to the blade 10 to adjust the twist angle 22 in response to the controller 42. The wrench 38 includes a torque gauge 38A that may be, for example, an electronic or electromechanical gauge configured to measure the load applied to blade 10 by wrench 38 during twist correction operations. The torque gauge 38 may be mounted within the wrench 38 communicate with the controller 42 and measure the load
25 applied to blade 10.

[0039] The drive system 40 may include various subsystems such as an electric motor 40A, and a pulley or gear system 40B (illustrated schematically) to apply a measured torque to the wrench 38. It should be appreciated that the drive system 40 may be of various forms to include, for example, combinations of the wrench 38, the drive system 40 and the
30 controller 42. For example only, an automated torque wrench with electronic feedback control to the controller 42 may be provided.

[0040] The controller 42 executes a strategic twist correction algorithm 44 (Figure 3). The functions of the algorithm 44 are disclosed in terms of functional block diagrams, and it should be understood by those skilled in the art with the benefit of this disclosure that these functions may be enacted in either dedicated hardware circuitry or programmed software routines capable of execution in a microprocessor based electronics control embodiment. The controller 42 typically includes a processor 42A, a memory 42B, and an interface 42C. The processor 42A may be any type of known microprocessor having desired performance characteristics. The memory 42B may, for example only, include UVPROM, EEPROM, FLASH, RAM, ROM, DVD, CD, a hard drive, or other computer readable medium that stores the data and control algorithms described herein. The interface 42C facilitates communication with the twist angle gauge 36, the wrench 38, the drive system 40, as well as other systems such as input/output devices and displays.

[0041] With respect to Figure 3, the repair system 30 may be used to adjust the twist angle 22 as well as minimize or eliminate possible human contributed errors. The system 30 thereby provides accuracy and consistency for the adjustment of the twist angle 22 to directly improve the quality of the repaired blade 10 through assurance that the twist angle 22 is adjusted to the pre-twist angle of the blade 10 as originally manufactured. The system 30 further prevents over-twisting that will require scrapping of the blade 10.

[0042] The strategic twist correction algorithm 44 first requires clamping of the root 12 of the blade 10 in the fixture 34 and the twist angle gauge 36 positioned to measure an initial pre-repair twist angle of the blade 10 through contact with, for example, the shroud 18 (Step 100). The wrench 38 is then clamped to the shroud 18 (Step 102). The wrench 38 may be configured in alternative embodiments to engage turbine blades with varying tip configurations, such as shrouded and unshrouded blades and blades having squealer tips.

[0043] The controller 42 activates the drive system 40 to apply a first torque (R ; in N mm) to the wrench 38 to produce an angle displacement (d ; in mm) which is measured and communicated to the controller 42 (Step 104). The first torque as well as the displacement is measured and communicated to the controller 42 (Step 106).

[0044] The first torque (N mm) is significantly less than that required to re-twist the blade 10 to a desired original manufacture corrected twist angle 22. In one disclosed, non-limiting embodiment, the first torque is only 20%-30% of the expected torque required to re-

twist the blade 10 to the desired original manufacture corrected twist angle 22. The particular first torque applied need only be less than that required to produce a second displacement to re-twist the blade 10 to a desired original manufacture corrected twist angle 22. In other words, the first torque is utilized only to calibrate the torque required to re-twist the blade 10 to the desired original manufacture corrected twist angle 22 (Step 108; as specified in Figure 3 and the result of which is indicated in Figure 4).

[0045] The controller 42 then again activates the drive system 40 to apply a specific torque (R_d) to the blade 10 to twist the blade 10 to produce the desired original manufacture corrected twist angle 22 (Step 110; as specified in Figure 3 and the result of which is indicated in Figure 4). As utilized herein, "specific torque" is the torque required to increase displacement by distance "d". As such, by determining and applying the specific torque R_d , the system can readily determine the amount of torque required (R_d) to rework the blade 10 to an original pre-twist angle.

[0046] It should be appreciated, that the controller 42 may operate to apply the specific torque R_d in steps to twist the blade 10 to initially produce less than the desired original manufacture corrected twist angle 22 then step to the desired original manufacture corrected twist angle 22 to assure the blade 10 is not twisted past the desired pre-twist angle. Alternatively, or in addition, the controller 42 may gradually slow down the drive system 40 when the blade 10 approaches the desired twist angle 22 to avoid over twisting. In addition, the controller 42 can also immediately stop the applied torque if a feedback control indicates the blade correction achieves original pre-twist angle. The strategic twist correction algorithm 44 thereby prevents over-twisting of the blade 10 to minimize or eliminate blade scrap rates.

[0047] Turbine blade repairs employing embodiments of that disclosed herein therefore reduce repair time and cost, and simultaneously improve repair quality as turbine blades with original pre-twist angles provide greater engine efficiency and fuel usage.

[0048] It should be understood that relative positional terms such as "forward," "aft," "upper," "lower," "above," "below," and the like are with reference to the normal operational attitude of the vehicle and should not be considered otherwise limiting.

[0049] It should be understood that like reference numerals identify corresponding or similar elements throughout the several drawings. It should also be understood that although a particular component arrangement is disclosed in the illustrated embodiment, other arrangements will benefit herefrom.

[0050] Although particular step sequences are shown, described, and claimed, it should be understood that steps may be performed in any order, separated or combined unless otherwise indicated and will still benefit from the present disclosure.

5 [0051] The foregoing description is exemplary rather than defined by the limitations within. Various non-limiting embodiments are disclosed herein, however, one of ordinary skill in the art would recognize that various modifications and variations in light of the above teachings will fall within the scope of the appended claims. It is therefore to be understood that within the scope of the appended claims, the disclosure may be practiced other than as specifically described. For that reason the appended claims should be studied to determine true
10 scope and content.

CLAIMS

What is claimed is:

1. A method for setting a twist angle of a blade comprising:
5 applying a first torque to twist a blade to produce a first displacement, the first displacement being less than a second displacement;
measuring the first torque to provide a measured first torque;
measuring the first displacement to provide a measured first displacement;
determining a specific torque to produce the second displacement from the measured first
10 torque and the measured first displacement; and
applying the specific torque to the blade to twist the blade to produce the second displacement.
2. The method as recited in claim 1, further comprising:
15 limiting the first torque to less than the specific torque.
3. The method as recited in claim 1, further comprising:
limiting the first torque to about 20%-30% of the specific torque.
- 20 4. The method as recited in claim 1, further comprising:
defining the second displacement as an original pre-twist angle.
5. The method as recited in claim 1, wherein said measuring the first torque includes
measuring by a torque wrench.
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6. The method as recited in claim 1, wherein said applying the first torque includes
driving an electric motor connected to the wrench.
7. The method as recited in claim 6, wherein said applying the first torque includes
30 connecting the electric motor to the wrench through a gear system.

8. The method as recited in claim 6, wherein said applying the first torque includes connecting the electric motor to the wrench through a pulley system.

9. A system for adjusting a twist angle of a blade, comprising:

a fixture configured to engage a root of a blade;

a wrench configured to apply a first torque to twist the blade to produce a first displacement, the first displacement less than a second displacement;

a gauge to measure the first torque;

a gauge to measure the first displacement; and

a controller to determine a specific torque to produce the second displacement from the measured first torque and the measured first displacement.

10. The system as recited in claim 9, further comprising a drive system connected to said wrench, said drive system in communication with said controller.

11. The system as recited in claim 10, wherein said controller is operable to drive a drive system connected to said wrench.

12. The system as recited in claim 10, wherein said controller is operable to drive a drive system to generate the specific torque.

13. The system as recited in claim 10, wherein said controller is operable to drive a drive system to generate the first torque.

14. The system as recited in claim 9, wherein said controller is operable to limit the first torque to about 20%-30% of the specific torque.

15. A system for setting a twist angle of a blade, comprising:
a fixture configured to engage a root of a blade;
a wrench configured to apply a first torque to twist the blade to produce a first
5 displacement, the first displacement less than a second displacement;
a gauge to measure the first torque;
a gauge to measure the first displacement;
a controller to determine a specific torque to produce the second displacement from the
measured first torque and the measured first displacement; and
10 a drive system connected to said wrench, said drive system in communication with said
controller.

16. The system as recited in claim 15, wherein said gauge to measure the first torque
is contained within said wrench.

17. The system as recited in claim 15, wherein said gauge to measure the first
displacement is mounted to said fixture.

18. The system as recited in claim 15, wherein said controller is operable to limit the
first torque to about 20%-30% of the specific torque.