

SUPPORT COLLAR GEOMETRY FOR LINEAR FRICTION WELDING

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5 has certain rights in this invention.

BACKGROUND

This disclosure relates generally to turbomachine airfoils and, more particularly, to repairing or replacing airfoils using linear friction welding techniques.

10 As known, gas turbine engines, and other turbomachines, include multiple sections, such as a fan section, a compressor section, a combustor section, a turbine section, and an exhaust section. The compressor section and the turbine section include airfoil arrays mounted for rotation about an engine axis. The airfoil arrays include multiple individual airfoils (i.e., blades) that extend radially from a mounting
15 platform to an airfoil tip. The blade arrays and mounting platform may form a one piece, integrally bladed rotor or bladed disk/blisk.

Air moves into the engine through the fan section. Rotating the airfoil arrays in the compressor section compresses the air. The compressed air is then mixed with fuel and combusted in the combustor section. The products of combustion are
20 expanded to rotatably drive airfoil arrays in the turbine section. Rotating the airfoil arrays in the turbine section drives rotation of the fan and compressor sections. Airfoils in the gas turbine engine may become damaged. Replacing the damaged airfoils in a conventionally bladed rotor is relatively simple. Replacing the damaged airfoils in an integrally bladed rotor is often significantly more difficult (sometimes
25 not feasible) and expensive.

SUMMARY

An example method of attaching an airfoil for an integrally bladed rotor includes placing a support collar in an installed position around at least a leading edge
30 and trailing edge of an airfoil stub to be repaired in an integrally bladed rotor. The support collar and the airfoil stub together have a midline that is positioned between opposing, laterally outer surfaces of the airfoil stub when the support collar is in the

installed position. The method performs linear friction welding to add an airfoil to the airfoil stub.

Another example method of attaching an airfoil for an integrally bladed rotor includes placing a support collar in an installed position around at least a leading edge and a trailing edge of an airfoil stub to be repaired in an integrally bladed rotor. The support collar and the airfoil stub together have a midline that does not extend laterally past a laterally outer surface of the blade stub. The method includes performing linear friction welding to add an airfoil to the airfoil stub.

An example integrally bladed rotor includes a rotor hub and a plurality of blades extending radially outwardly of the rotor hub. At least one of the blades is attached by a linear friction welding operation. The blade includes an airfoil stub portion that was associated with the rotor hub prior to the attachment and an airfoil portion that has been linear friction welded to the airfoil stub as part of the attachment. A collar supported the airfoil stub during the linear friction welding and is then machined away. The collar includes a consumable portion that is consumed during the linear friction welding. The consumable portion and the blade stub have a midline that is bounded by opposing laterally outer surfaces of the blade stub during the linear friction welding.

These and other features of the disclosed examples can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a schematic view of an example gas turbine engine.

Figure 2 shows an integrally bladed rotor in a repair tooling fixture from the Figure 1 engine.

Figure 3 schematically shows a top view of an airfoil stub ready for a linear friction welding operation.

Figure 4 shows a perspective view of the Figure 3 airfoil stub.

Figure 5 shows a close up view of a trailing edge of an airfoil stub in the Figure 3 linear friction welding operation.

Figure 6 shows a section view at line 6 of Figure 5 with an airfoil.

Figure 7 shows the Figure 6 section view after partially linear friction welding the airfoil to an airfoil stub.

Figure 8 shows the Figure 6 section view after linear friction welding the airfoil to an airfoil stub.

5 Figure 9 shows the Figure 6 section view after machining away excess material.

DETAILED DESCRIPTION

Figure 1 schematically illustrates an example gas turbine engine 10 including
10 (in serial flow communication) a fan 14, a low pressure compressor 18, a high pressure compressor 22, a combustor 26, a high pressure turbine 30, and a low pressure turbine 34. The gas turbine engine 10 is circumferentially disposed about an engine axis X. The gas turbine engine is an example turbomachine.

During operation, air is pulled into the gas turbine engine 10 by the fan 14,
15 pressurized by the compressors 18 and 22, mixed with fuel, and burned in the combustor 26. The turbines 30 and 34 extract energy from the hot combustion gases flowing from the combustor 26. In a two-spool design, the high pressure turbine 30 utilizes the extracted energy from the hot combustion gases to power the high pressure compressor 22 through a high speed shaft 38. The low pressure turbine 34
20 utilizes the extracted energy from the hot combustion gases to power the low pressure compressor 18 and the fan 14 through a low speed shaft 42.

The examples described in this disclosure are not limited to the two-spool engine architecture described and may be used in other architectures, such as a single spool axial design, a three-spool axial design, and still other architectures. That is,
25 there are various types of engines, and other turbomachines, that can benefit from the examples disclosed herein.

Referring to Figures 2-5 with continuing reference to Figure 1, an example integrally bladed rotor 50 includes a plurality of airfoils 52 extending radially away from a rotor hub. The example integrally bladed rotor 50 includes a damaged airfoil
30 stub 56. During operation, the integrally bladed rotor 50 typically forms part of the low pressure compressor 18 and/or high pressure compressor 22 of the gas turbine engine 10. The integrally bladed rotor 50 is made of a titanium alloy, in this example, but may be made of nickel alloy or other materials.

The damaged airfoil stub 56 is to be repaired. During repair, the integrally bladed rotor 50 is mounted within a linear friction welding machine incorporating a fixture 54. The airfoil stub 56 is supported by a collar assembly 100. In this example, the collar 100 includes a sub-collar 64 associated with a leading edge 40 of the airfoil stub 56 and a sub-collar 68 associated with a trailing edge 41 of the airfoil stub 56. The sub-collars 64 and 68 each include a base portion 90 and a consumable portion 86. The consumable portion 86 is consumed during the linear friction welding. Although the example describes replacing a damaged airfoil stub, another example may include attaching an airfoil during initial assembly of the rotor 50.

10 The example airfoil stub 56 includes a convex (or suction) side 74 and a concave (or pressure) side 78. The consumable portion 86 is defined by a surface 75 that is typically aligned with the convex side 74, and a surface 79 that is typically aligned with the concave side 78. The consumable portion 86 of the sub-collar 68 thus has a lateral profile that matches the geometry of an airfoil stub 56.

15 A midline 82 of the consumable portion 86 and the portion of the airfoil stub 56 within the sub-collar 68 is centered between the surface 75 and the surface 79. That is, at a given chord position X, the distance D1 between the surface of the surface 75 and the midline 82 is the same as the distance D2 between the surface of the concave side surface 79 and the midline 82. In this example, the midline 82 is positioned between (or bounded by) the surface 74 and the surface 78.

20 During the linear friction welding process, the consumable portion 86 is consumed while the base portion 90 remains. A person having skill in the art of linear friction welding, and the benefit of this disclosure, would understand how material is consumed during the linear friction welding.

25 The sub-collars 64 and 68 are the same material as the airfoil stub 56 and the replacement airfoil 94 in this example. In another example, one or both of the sub-collars 64 and 68 is a different material than the airfoil stub 56, the replacement airfoil 94, or both.

30 Referring now to Figures 6-9 with continuing reference to Figure 5, a replacement airfoil 94 is positioned against the airfoil stub 56 and the consumable portion 86 of the sub-collar 64 at an interface 96. During the linear welding process, the replacement airfoil 94 oscillates back and forth in a weld direction D that is generally parallel to a chord of the airfoil stub 56.

By moving the replacement airfoil 94 and the airfoil stub 56 rapidly relative to each other, heat is built up, and will weld the two together. The linear friction welding technique is known.

5 In this example, the consumable portion 86 and a portion of the airfoil stub 56 are consumed during the linear friction welding. Again, the consumable portion 86 is sized such that the midline 82 is positioned between the surface 74 and the surface 78. This arrangement causes material in the consumable portion 86 to flow away from, rather than toward, the airfoil stub 56 as the material in the consumable portion 86 is consumed. As can be appreciated, the midline is radially extending relative to the
10 engine axis X, in this example.

In this example, the midline 82 represents the circumferential center of the section of the consumable portion 86 and the blade stub 56. That is, the midline is centered between the surface 74 and the surface 78, and the distance D1 is about the same as the distance D2. The consumable portion 86 includes substantially the same
15 amount of material (within 5%, for example) on either side of the midline.

In other examples, the midline 82 is not centered between the surface 74 and the surface 78. However, in such examples, the midline still does not extend laterally past the surface 74 or the surface 78. Thus, it is possible that the distance D1 is not the same as the distance D2. After securing the airfoil 94 to the airfoil stub 56 and the
20 consumable portion 86, the consumable portion 86 is machined away along with a portion of the replacement airfoil 94 and some of the airfoil stub 56.

Features of the disclosed examples include laterally balancing the amount of consumable material during a linear friction weld to avoid polluting desired welds with the material that would otherwise be expelled from the resultant linear friction
25 weld joint. In the prior art, the consumable portion may contain more material on the concave side than on the convex side, or vice versa. Significantly more material on one of the sides could cause material intended for expulsion from the consumable portion to flow back toward the airfoil stub during the linear friction welding, which can pollute or otherwise foul the weld bond.

30 The surface of the consumable portion of the collar in contact with the airfoil matches with the profile of the airfoil to provide intimate structural support during welding. The size of the airfoil is used to determine the size of the convex side of the

collar and the size of the concave side of the collar resulting the flow of material away from the airfoil during the linear friction welding.

The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this disclosure. Thus, the scope of legal protection given to this disclosure can only be determined by studying the following claims.

CLAIMS

1. A method of attaching an airfoil for an integrally bladed rotor comprising:
placing a support collar in an installed position around at least a leading edge
5 and trailing edge of an airfoil stub for an integrally bladed rotor, a consumable portion
of the support collar and the airfoil stub together having a midline that is positioned
between opposing, laterally outer surfaces of the airfoil stub when the support collar is
in the installed position; and
performing linear friction welding to add an airfoil to the airfoil stub.
10
2. The method of claim 1, including oscillating the airfoil relative to the airfoil
stub in a first direction during the linear friction welding.
3. The method of claim 2, wherein the midline corresponds to the circumferential
15 center of a section of the consumable portion and the airfoil stub, the section taken
along a plane that is perpendicular to the first direction.
4. The method of claim 1, wherein the airfoil stub is centered between a first
outer edge of the airfoil stub and an opposing, second outer edge of the airfoil stub.
20
5. The method of claim 1, wherein a convex side of the consumable portion is
circumferentially spaced from the midline a first distance, and a concave side of the
consumable portion is circumferentially spaced from the midline a second distance
that is the same as the first distance.
25
6. The method of claim 1, wherein the midline extends radially.
7. The method of claim 1, including machining away the collar after the linear
friction welding is complete.
30
8. The method of claim 1, including consuming the consumable portion of the
support collar during the linear friction welding.

9. The method of claim 1, wherein the support collar and the airfoil stub are formed of the same material.
10. The method of claim 9, wherein the same material is a titanium material.
- 5 11. The method of claim 1, wherein the method comprises a repair operation.
12. A method of attaching an airfoil for an integrally bladed rotor comprising:
placing a support collar in an installed position around at least a leading edge
10 and a trailing edge of an airfoil stub in an integrally bladed rotor, the support collar and the airfoil stub together having a midline that does not extend laterally past a laterally outer surface of the airfoil stub; and
performing linear friction welding to add an airfoil to the airfoil stub.
- 15 13. The method of claim 12, including machining away the support collar after the linear friction welding.
14. The method of claim 12, wherein the linear friction welding occurs generally in a direction between the leading edge and the trailing edge of the airfoil stub.
- 20 15. The method of claim 12, wherein the airfoil stub and the collar are formed of different materials.
16. The method of claim 12, wherein the support collar is formed of a first sub-collared configured to support the leading edge of the airfoil stub and a second sub-collared configured to support the trailing edge of the airfoil stub, and with unsupported positions between the first sub-collared and the second sub-collared.
- 25 17. The method of claim 12, including consuming a first amount of material from a first lateral side of the midline during the linear friction welding; and
30 consuming a second amount of material from an opposing, second side of the support collar during the linear friction welding, the first amount of material substantially the same as the second amount of material.

18. An integrally bladed rotor comprising:
a rotor hub; and
a plurality of blades extending radially outwardly of the rotor hub, with at least one of the blades being secured to the rotor hub by a linear friction welding operation, the at least one blade including an airfoil stub portion that was associated with the rotor hub prior to the attachment, and
an airfoil portion that has been linear friction welded to the airfoil stub,
wherein a collar supported the airfoil stub during the linear friction welding and is then machined away, the collar includes a consumable portion that is consumed during the linear friction welding, and the consumable portion and the blade stub have a midline that is bounded by opposing laterally outer surfaces of the blade stub during the linear friction welding.
19. The integrally bladed rotor of claim 18, wherein the integrally bladed rotor is formed of a titanium alloy.
20. The integrally bladed rotor of claim 18, wherein the collar is formed of a titanium alloy.
21. The integrally bladed rotor of claim 18, wherein the integrally bladed rotor is formed of a nickel alloy.