

TURBINE SHROUD MILLING

BACKGROUND

This disclosure relates generally to milling and, more particularly, to
5 reducing shroud milling complexity.

Components are often machined to acquire desired dimensions. Both newly-cast and repaired components may be machined. Machining changes the dimensions of the components by removing material.

Machining relatively complex components often requires multiple
10 fixtures and multiple cutters. Machining these relatively complex components often requires significant time. Turbomachine blades, particularly the shrouds of turbomachine blades, are examples of these relatively complex components. For example, machining in particularly grinding turbomachine shrouds may require several fixtures, diamond
15 dressers, and grinding wheels. In-process repositioning the turbomachine blades for grinding may lead to machining errors.

SUMMARY

A shroud milling method according to an exemplary aspect of the present disclosure includes, among other things, milling a convex side of a
20 shroud, milling a concave side of the shroud, and holding a shroud within a common fixture when milling the convex side and when milling the concave side.

In a further non-limiting embodiment of the foregoing method, the method may include milling a knife-edge of the shroud, and holding the
25 shroud within the common fixture when milling the knife-edge of the shroud.

In a further non-limiting embodiment of either of the foregoing methods, the method may include moving a milling cutter relative to the shroud and the common fixture during the milling.

In a further non-limiting embodiment of any of the foregoing methods, milling the convex side may comprise milling a notch radius within the convex side.

5 In a further non-limiting embodiment of any of the foregoing methods, a common milling cutter may mill the convex side and the notch radius.

In a further non-limiting embodiment of any of the foregoing methods, milling the convex side may comprise side milling and end milling. The end milling may establish the notch radius.

10 In a further non-limiting embodiment of any of the foregoing methods, a common milling cutter may mill the convex side and the concave side.

In a further non-limiting embodiment of any of the foregoing methods, the shroud may be a turbine shroud of a newly-cast blade.

15 In a further non-limiting embodiment of any of the foregoing methods, the milling may include removing at least some weldment from the shroud.

A shroud according to an exemplary aspect of the present disclosure includes, among other things, a concave side of a shroud, a convex side of the shroud, and a knife-edge seal of the shroud. The concave side, the convex side, and the knife-edge seal are cut using an end mill cutter.

In a further non-limiting embodiment of the foregoing shroud, the concave side, the convex side, and the knife-edge seal may be held within a common fixture when cut using the end mill cutter.

25 In a further non-limiting embodiment of the foregoing shroud, the shroud may be a shroud of a turbine blade of a turbomachine.

In a further non-limiting embodiment of the foregoing shroud, the concave side may comprise a notch radius established by end milling.

In a further non-limiting embodiment of the foregoing shroud, the notch radius may be cut using the end mill cutter.

In a further non-limiting embodiment of the foregoing shroud, the knife edge seal may comprise at least two separate knife edge seals.

5 A method of milling a turbine blade shroud according to an exemplary aspect of the present disclosure includes, among other things securing a turbine blade within a fixture, milling a concave side of a turbine blade shroud while the turbine blade is secured within the fixture, and milling a convex side of the turbine blade shroud while the turbine blade is
10 secured within the fixture.

In a further non-limiting embodiment of the foregoing method, the method may include milling a knife-edge seal of the turbine blade shroud while the turbine blade is secured within the fixture.

In a further non-limiting embodiment of either of the foregoing
15 methods, the turbine blade may not be removed from the fixture during the milling.

In a further non-limiting embodiment of any of the foregoing methods, the method may include end milling a notch radius when milling the concave side of the turbine blade shroud.

20 In a further non-limiting embodiment of any of the foregoing methods, the method may include using the same milling cutter for milling the concave side and for milling the convex side.

DESCRIPTION OF THE FIGURES

25 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:

Figure 1 shows a shroud of a repaired blade from a turbine section of a turbomachine.

Figure 2 shows the blade of Figure 1 within a fixture.

5 Figure 3 shows a step in a method of milling the shroud of Figure 1.

Figure 4 shows another step in the method of milling the shroud of Figure 1.

Figure 5 shows yet another step in the method of milling the shroud of Figure 1.

10 Figure 6 shows the shroud of Figure 1 after the step of Figure 3.

Figure 7 shows the shroud of Figure 1 after the step of Figure 5.

Figure 8 shows the shroud of the Figure 1 within a milling cutter assembly during the step of Figure 4.

15 Figure 9 shows the shroud of Figure 1 within the milling cutter assembly during the step of Figure 5.

DETAILED DESCRIPTION

Referring to Figure 1, a shroud 60 of a blade 64 from a high-pressure turbine of a turbomachine engine is shown during a repair. In this example,
20 the shroud 60 was significantly worn during use and required repair. The initial repairs involved building up weldment in the worn areas of the shroud 60. As will be shown, the shroud 60 is then machined to desired dimensions. The shroud 60 is reinstalled within the engine after machining.

The techniques of this disclosure are described with reference to the
25 shroud 60, which is a repaired shroud 60. The techniques of this disclosure could also apply to machining shrouds of newly-cast blades to desired dimensions. That is, this disclosure is not limited to machining repaired blades.

Referring now to Figure 2, machining the shroud 60 involves placing the blade 64 within a fixture 68. The example fixture 68 includes three clamps 72a-72c. In this example, the clamp 72a is used to secure a root of the blade 64. The root held by the clamp 72a may provide a reference datum when machining the shroud 60. The clamps 72b and 72c directly contact an airfoil portion 76 of the blade 64. The clamps 72b and 72c may include a thermoset compound resin portion 74 that directly contacts the airfoil portion 76. The portions 74 dampen vibrations of the blade 64 during machining.

10 Milling is the machining process used, in this example, to shape the shroud 60 into the desired dimensions. Thus, after securing the blade 64 within the fixture 68, the blade 64 and the fixture 68 are secured to a milling table 80. In this example, the blade 64 is held by the fixture 68 during the entire shroud milling process.

15 Referring now to Figures 3-7, the shroud 60 includes a convex side 100 and a concave side 104. The convex side 100 and the concave side 104 each extend from a leading edge 108 of the shroud 60 to a trailing edge 110 of the shroud 60. The convex side 100 includes a notch radius 116. The concave side 104 includes a notch radius 118. The convex side 100 and the concave side 20 104 interface directly with circumferentially adjacent shrouds when installed within the engine.

 In this example, the convex side 100 includes three distinct planar surfaces 108a-108c. The concave side 104 also includes three distinct planar surfaces 112a-112c.

25 In this example, a first knife-edge seal 120 and a second knife-edge seal 124 extend radially from the blade 64. As is known, the knife-edge seals 120 and 124 contact a blade outer air seal within the engine (figure 1) to provide a sealing interface.

In this example, an end mill cutter 130 mills the shroud 60 to provide the convex side 100, the concave side 104, the notch radii 116 and 118, and the knife-edge seals 120 and 124. Notably, because the shroud 60 is milled while
5 held within the fixture 68, the shroud 60 is milled using a “common” fixture and a “common” end mill cutter. In the prior art, blades may be removed and reinstalled in several different fixtures when grinding a shroud.

The end mill cutter 130 rotates about an axis A during milling. When milling the convex side 100 and the concave side 104, cutting blades on the
10 sides 138 of the end mill cutter 130 are used. When milling the notch radii 116 and 118, cutting blades on the sides 138 and end 142 of the end mill cutter 130 are used. When milling the knife-edge seals 120 and 124, the sides 138 of the end mill cutter 130 are used.

When milling the convex side 100 and the concave side 104, the end
15 mill cutter 130 travels along paths P_1 and P_2 , respectively. The mill cutter 130 generally changes directions twice when moving along the paths P_1 to cut the surfaces 108a -108c. The mill cutter 130 generally changes directions twice when moving along the paths P_1 to cut the surfaces 112a -112c.

The notch radius 116 is the interface between the surface 108a and the
20 surface 108b. The notch radius 118 is the interface between the surface 112a and the surface 112b. When milling the notch radii 116 and 118, the end mill cutter 130 moves along paths along P_3 and P_4 , respectively. The paths P_3 and P_4 extend in radial directions (and outward from the page in Figure 4). Because cutting surfaces on the sides 138 and the end 142 of the end mill
25 cutter 130 are used, material can be simultaneously removed from the two surfaces that meet to form the notch radius 116 or the notch radius 118.

When milling the knife-edge seals 124 and 120, the end mill cutter 130 travels generally along the path P_5 , which requires the end mill cutter 130 to

move radially in and out as well as circumferentially across a radially outward facing surface of the shroud 60.

Referring to Figures 8 and 9, the end mill cutter 130 is controlled by a positioner 150. A controller (not shown) may include an input device utilized
5 to program movements of the position 150, and thus the end mill cutter 150.

To move the end mill cutter 130 along the paths along P_1 - P_5 the shroud 60 may be moved, the end mill cutter 130 may be moved, or some combination of the shroud 60 and the end mill cutter 130 may be moved.

Figure 8 shows the shroud 60 held by fixture 168 in a position suitable
10 for milling the convex side 100 and the concave side 104. Figure 9 shows the table 80 rotated 90° to a position suitable for moving the end mill cutter 130 along the path P_5 . The amount the table 80 is rotated may vary depending on design requirements. That is, 90° is only an example amount of rotation.

Features of the disclosed examples include encapsulating shroud
15 milling processes into a process utilizing a single or common fixture moving a shroud relative to a common milling cutter. The process of this disclosure replaces multiple fixtures, diamond dressers, and grinding wheels used in standard shroud milling processes.

The preceding description is exemplary rather than limiting in nature.
20 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

I claim:

1. A shroud milling method, comprising:
 - milling a convex side of a shroud;
 - 5 milling a concave side of the shroud; and
 - holding a shroud within a common fixture when milling the convex side and when milling the concave side.
2. The shroud milling method of claim 1, including milling a knife-edge of
10 the shroud, and holding the shroud within the common fixture when milling the knife-edge of the shroud.
3. The shroud milling method of claim 1, including moving a milling cutter relative to the shroud and the common fixture during the milling.
- 15 4. The shroud milling method of claim 1, wherein the milling the convex side comprises milling a notch radius within the convex side.
5. The shroud milling method of claim 4, wherein a common milling cutter
20 mills the convex side and the notch radius.
6. The shroud milling method of claim 4, wherein the milling the convex side comprises side milling and end milling, the end milling establishing the notch radius.
- 25 7. The shroud milling method of claim 1, wherein a common milling cutter mills the convex side and the concave side.

8. The shroud milling method of claim one, wherein the shroud is a turbine shroud of a newly-cast blade.
9. The shroud milling method of claim 1, wherein the milling comprises
5 removing at least some weldment from the shroud.
10. A shroud, comprising:
a concave side of a shroud;
a convex side of the shroud; and
10 a knife-edge seal of the shroud, wherein the concave side, the convex side, and the knife-edge seal were cut using an end mill cutter.
11. The shroud of claim 10, where in the concave side, the convex side, and the knife-edge seal were held within a common fixture when cut using the
15 end mill cutter.
12. The shroud of claim 10, wherein the shroud is a shroud of a turbine blade of a turbomachine.
- 20 13. The shroud of claim 10, wherein the concave side comprises a notch radius established by end milling.
14. The shroud of claim 13, wherein the notch radius was cut using the end mill cutter.
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15. The shroud of claim 10, the knife edge seal comprises at least two separate knife edge seals.

16. A method of milling a turbine blade shroud, comprising:
- securing a turbine blade within a fixture;
 - milling a concave side of a turbine blade shroud while the turbine
- 5 blade is secured within the fixture; and
- milling a convex side of the turbine blade shroud while the turbine
- blade is secured within the fixture.
17. The method of claim 16, including milling a knife-edge seal of the turbine
- 10 blade shroud while the turbine blade is secured within the fixture.
18. The method of claim 16, wherein the turbine blade is not removed from the fixture during the milling.
- 15 19. The method of claim 16, including end milling a notch radius when milling the concave side of the turbine blade shroud.
20. The method of claim 16, including using the same milling cutter for milling the concave side and for milling the convex side.

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