**Honeycomb seal for abradable angel wing**

An abradable honeycomb is integrally formed in a turbine nozzle (11) sealing flange (16) for engagement with a bucket angel wing (14) to reduce the leakage of air into the turbine’s hot gas path. The honeycomb is integrally formed in a turbine nozzle sealing flange (16) using a sinker EDM method to directly sink the honeycomb into the sealing flange (16) itself so that the honeycomb is an integral part of the flange (16). For repair, an entirely new honeycomb flange can be made and welded or brazed on to the turbine nozzle (11).

**FIG. 1**
Description

The present invention relates to turbines, and more particularly, to a method of fabricating an abradable honeycomb as an integral part of a nozzle sealing flange which is engaged by an angel wing of a rotating bucket in a gas turbine to limit cooling air from leaking into the gas turbine’s high temperature combustion gas passage.

BACKGROUND OF THE INVENTION

A gas turbine is a rotary engine that extracts energy from the flow of combustion gas through the turbine. It has an upstream air intake or inlet, a compressor coupled to a combustor, a downstream turbine that receives combustion gas from the combustor, and a gas outlet or exhaust nozzle.

The compressor and turbine sections include at least one circumferential row of rotating rotor blades or buckets. The free ends or tips of the buckets are surrounded by a stator casing. The base portions of the rotor blades are flanked by the inner shrouds of stator blades or nozzles located upstream and downstream of the rotating buckets.

Seal assemblies are typically used to prevent or limit cooling air from leaking into a gas turbine’s high temperature combustion gas passage from between moving buckets and stationary nozzles. These seal assemblies typically include seal plates, referred to as “angel wings”, which extend axially from the upstream and downstream surfaces of the shank portions of the moving buckets, and which terminate in radially outwardly extending tips or teeth. The seal assemblies also include sealing structures or flanges projecting axially from upstream and downstream from stationary nozzle assemblies to define seals with the angel wings of the moving bucket shanks. However, the sealing performance of these seal assemblies is not always good, such that more than a desired amount of the cooling air tends to leak into the high temperature combustion gas passage so that the amount of cooling air is increased, causing deterioration in the performance of the gas turbine.

The efficiency of the turbine depends, in part, on the radial clearance or gap between the angel wings and the adjacent sealing structures. If the clearance is too small, the angel wings will strike the adjacent sealing structures during certain turbine operating conditions. If the clearance is too large, excessive valuable cooling air will leak from the rotor wheelspace into the hot gas path, decreasing the turbine’s efficiency.

An abradable seal can be used to improve turbine performance by physically reducing the clearance between the sealing flange of a nozzle and an opposed angel wing seal plate of a bucket. An abradable seal material is sometimes located on the radially inner surface of the seal of the stationary nozzle, so as to be located within the annular gap between the inner surface of the nozzle seal and the end tips of the angel wing of the rotating bucket.

Angel wing abradable seals using honeycomb on the nozzle have been shown to provide significant sealing improvement. However, attaching a honeycomb piece reliably to an angel wing is difficult, since brazing thin pieces of metal ribbon means a very small attachment region. Currently, the honeycomb is sometimes brazed directly to a part with the hope that it will stay on. One alternative to this is to braze the honeycomb to a plate and then braze or weld the plate onto the angel wing.

BRIEF DESCRIPTION OF THE INVENTION

The present invention uses sinker electrical discharge machining (“EDM”) to plunge/burn a honeycomb device to plunge the electrode directly into the block of material so that when a turbine bucket angel wing in the turbine’s sealing assembly rubs the nozzle sealing flange, there is improved sealing between the nozzle sealing flange and the bucket angel wing with less risk of honeycomb failure. Optionally, the honeycomb resulting from the electrode with the sinker electrical discharge machining device being plunged into the block of material can be coated with a coating suitable for corrosion resistance and/or improved abradability. In addition, the block of material in which the honeycomb is formed can be either an integral part of the turbine nozzle or separate from the turbine nozzle. In the latter case, the block of material is welded or brazed to the turbine nozzle after the honeycomb has been formed in such block.

In an first aspect of the invention, a method of making a turbine nozzle sealing flange with a plurality of abradable cavities formed in the sealing flange comprises the steps of providing a block of material suitable for serving as a nozzle sealing flange, providing a sinker electrical discharge machining device for machining features into the block of material, providing an electrode for use with the sinker electrical discharge machining device to perform the machining of the features in the block of material, the electrode being shaped to form the plurality of cavities in the block of material, and using the electrode with the sinker electrical discharge machining device to plunge the electrode directly into the block of material, to thereby form the nozzle sealing flange with the plurality of abradable cavities.

In another aspect of the invention, a method of limiting cooling air from leaking into a gas turbine’s high temperature combustion gas passage comprises the steps of providing one or more blocks of material suitable for forming one or more corresponding turbine nozzle
In a further aspect of the invention, a method of making a part with a predetermined integral abradable shape comprises the steps of providing a block of material suitable for making the part, providing a sinker electrical discharge machining device for machining features into the block of material, providing an electrode for use with the sinker electrical discharge machining device to perform the machining of the features into the block(s) of material, the electrode having a series of crisscrossing negative grooves which form a positive honeycomb pattern that can be formed directly into the block(s) of material by the positive electrode burning the honeycomb pattern into each of the one or more blocks of material when the electrode is pressed into the block of material.

Detailed Description of the Invention

FIG. 1 illustrates the concept of attaching a abradable honeycomb seal to an angel wing to seal the path into a turbine hot gas path from the wheelspace.

FIGS. 2A and 2B are perspective views of two embodiments of an abradable angel wing seal in which is directly formed the abradable honeycomb so as to be an integral part of the angel wing seal.

FIG. 3 is an enlarged perspective view of a portion of the abradable honeycomb formed in an angel wing seal according to the present invention.

FIG. 4 is a sketch depicting the multiple layers resulting from the honeycomb being coated with a material for corrosion resistance/improved abradability.

FIG. 5 is an enlarged perspective view of a sketch depicting the preferable diamond shape of each of the hexagonal cells comprising the abradable honeycomb formed in an angel wing seal according to the present invention.

FIG. 6 is a simplified sketch of a Sinker EDM (Electrical Discharge Machining) machine used in the process of making the honeycomb impression formed in an angel wing seal according to the present invention.

FIG. 7 is an enlarged perspective view of an electrode used in the Sinker EDM machine to make the honeycomb impression formed in an angel wing seal according to the present invention.

Sealing flanges, providing a sinker electrical discharge machining device for machining features into the block(s) of material, and providing an electrode for use with the sinker electrical discharge machining device to perform the machining of the features into the block(s) of material, the electrode having a series of crisscrossing negative grooves which form a positive honeycomb pattern that can be formed directly into the block(s) of material by the positive electrode burning the honeycomb pattern into each of the one or more blocks of material when the electrode is pressed into the block of material.

In a further aspect of the invention, a method of making a part with a predetermined integral abradable shape comprises the steps of providing a block of material suitable for making the part, providing a sinker electrical discharge machining device for machining features into the block of material, providing an electrode for use with the sinker electrical discharge machining device to perform the machining of the features in the block of material, the electrode being shaped to form the predetermined shape in the block of material, using the electrode with the sinker electrical discharge machining device to bum the predetermined integral abradable shape directly into the block of material, and optionally coating the resulting predetermined integral abradable shape burned into the block of material with a coating suitable for corrosion resistance and/or improved abradability.
After the honeycomb 18 has been formed, it can optionally be coated with a coating suitable for oxidation and corrosion resistance and/or improved abradability. An example of such a coating would be an aluminide intermetallic coating.

It should be noted that although FIG. 2 preferably shows a honeycomb 18 with a plurality of cells 20 formed in the nozzle sealing flange 16, other abradable patterns, which include a plurality of cavities interconnected by a plurality of side walls, could be formed in the sealing flange 16. These cavities could be similar to, or different from, the cells 20 of honeycomb 18, for example, in shape and/or construction.

FIG. 3 is an enlarged perspective view of a portion of the abradable honeycomb 18 formed in sealing flange 16 according to the present invention. FIG. 4 depicts a portion 30 of a single honeycomb cell 20 that has been coated with a coating 36. The dimensions of the cells 20 can be of any size and any wall thickness. Preferably, the goal dimensions for the diamond shaped cells 20 comprising the abradable honeycomb 18 formed in sealing flange 16 are a length of between 0.05 and 0.2 inches, a width of between 0.05 and 0.2 inches, a depth of about 0.1 to 0.6 inches, and a wall thickness of about 0.004 to 0.015 inches.

As can be seen from FIG. 3, preferably, each of the individual cells 20 forming the honeycomb 18 are diamond shaped hexagons, although it should be noted that other suitable geometric shapes could be used. FIG. 5 is an enlarged perspective view of a sketch depicting the preferable diamond shape of each of the hexagonal cells 20 comprising the abradable honeycomb 18 formed in sealing flange 16. The dimensions of the cells 20 can be of any size and any wall thickness. Preferably, the goal dimensions for the diamond shaped cells 20 are a length of between 0.05 and 0.2 inches, a width of between 0.05 and 0.1 inches, a depth of about 0.1 to 0.6 inches, and a wall thickness of about 0.004 to 0.015 inches.

FIG. 6 is a simplified sketch of a Sinker EDM (Electrical Discharge Machining) machine 40 used in the process of making a honeycomb impression 18 integrally formed in sealing flange 16 according to the present invention. FIG. 7 is an enlarged perspective view of an electrode 42 used in the Sinker EDM machine 40 to press the honeycomb impression 18 in a sealing flange 16 according to the present invention. The electrode 42 includes a press assembly on which the electrode 42 is mounted to press the honeycomb 18 directly into the sealing flange 16, as shown in FIG. 6. Using the Sinker EDM machine 40 to directly sink the diamond honeycomb 18 into the sealing flange 16 allows the honeycomb to become an integral part of the sealing flange 16. In this regard, casting for sealing flange 16 could be thickened to allow pressing the honeycomb 18 directly into the flange at any desired location, after which a coating can be added. For repair, or as an alternative for new construction, an entire sealing flange 16 can have the honeycomb 18 sunken into it, which can then be welded, brazed, or mechanically attached to the nozzle 11.

Sinkerd EDM (Electrical Discharge Machining) is a process that lends itself to precision machining of features when conventional machining is inappropriate. For instance, complex features, small precise features and tight tolerance features are all examples of operations well suited for sinker EDM, in which a "positive" shaped electrode can be machined and then "sunk" (burned) into a desired part. With EDM, no pressure is applied to the material being machined, as the features are burned to their shape, rather than abraded. A more complicated electrode shape than the diamond shaped honeycomb of the electrode 42 shown in FIG. 7 could do either a more complicated honeycomb pattern or other, more complicated patterns.

In one alternative embodiment, a thicker sidewall along the leading edge 19 and/or the trailing edges 21 (where no rub occurs) could be retained to improve strength. Additional embodiments could include the formation of varied shapes and sizes. The EDM technology enables having certain walls thicker in one axis or location than another, which could allow improved sealing, while not impacting abradability (thicker in the flow direction, than in the rub direction, for example). The EDM technology can also enable angling of the honeycomb in a preferred direction, again to improve sealing. The thickness of honeycomb could be varied in one direction versus another preferential direction. The sunken shape, such as a honeycomb, could also have another non-normal orientation that could not easily be made any other way.

The use sinker electrical discharge machining ("EDM") to directly plunge the honeycomb 18 into the nozzle sealing flange 16 itself, so that the honeycomb becomes an integral part of the nozzle sealing flange, enables the abradable angel wing seal by providing a...
reliable method for putting honeycomb on a nozzle sealing flange. It also results in a sealing flange that provides improved sealing between the angel wing and the sealing flange.

[0027] The use of the sinker electrical discharge machining enables a new sealing technology may have applications in other turbine locations, as well in other areas of application.

[0028] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

[0029] Various aspects and embodiments of the present invention are defined by the following numbered clauses:

1. A method of limiting cooling air from leaking into a gas turbine’s high temperature combustion gas passage, the method comprising the steps of:

   providing one or more blocks of material suitable for forming one or more corresponding turbine nozzle sealing flanges,
   providing a sinker electrical discharge machining device for machining features into the block(s) of material,
   providing an electrode for use with the sinker electrical discharge machining device to perform the machining of the features into the block(s) of material, the electrode having a series of crisscrossing negative grooves which form a positive honeycomb pattern that can be formed directly into the block(s) of material by the positive electrode burning the honeycomb pattern into each of the one or more blocks of material when the electrode is pressed into the block of material.

   using the electrode with the sinker electrical discharge machining device to form the honeycomb directly into each of the one or more blocks of material,
   optionally coating the resulting honeycomb formed directly into each of the one or more blocks of material with a coating suitable for oxidation and corrosion resistance and/or improved abradability, to thereby form one or more corresponding nozzle sealing flanges with the abradable honeycomb formed integrally in the nozzle sealing flanges, and
   providing one or more turbine sealing assemblies in which the one or more corresponding nozzle sealing flanges with integral abradable honeycombs are engaged by corresponding bucket angel wings, whereby the cooling air leaking into the gas turbine’s high temperature combustion gas passage is limited.

2. The method of clause 1, wherein at least one of the block(s) of material in which the honeycomb(s) is formed is separate from the turbine nozzle, and wherein the method further comprises the step of welding or brazing the block of material to the nozzle after the honeycomb has been formed in such block.

3. The method of clause 1 or 2, wherein at least one of the block(s) of material in which the honeycomb is formed is an integral part of the turbine nozzle.

4. The method of any of clauses 1 to 3, wherein the electrode has a series of crisscrossing negative grooves which form a positive diamond shaped honeycomb pattern that can be formed directly into the block of material by the positive electrode burning the diamond shaped honeycomb pattern in the block of material when the electrode is pressed into the block of material.

5. The method of clause 4, wherein the sinker electrical discharge machining device includes a press assembly on which the electrode is mounted to press the electrode into the block(s) of material to thereby burn the honeycomb directly into the block(s) of material.

6. The method of any of clauses 1 to 5, wherein the coating is an aluminide intermetallic coating.

7. A method of making a part with a predetermined integral abradable shape, the method comprising the steps of:

   providing a block of material suitable for making the part,
   providing a sinker electrical discharge machining device for machining features into the block of material,
   providing an electrode for use with the sinker electrical discharge machining device to perform the machining of the features in the block of material, the electrode being shaped to form the predetermined shape in the block of material,
   using the electrode with the sinker electrical discharge machining device to burn the predetermined integral abradable shape directly into the block of material, and
   optionally coating the resulting predetermined integral abradable shape directly into the block of material with a coating suitable for oxidation and corrosion resistance and/or improved abradability.
1. A method of making a turbine nozzle (11) sealing flange (16) with a plurality of abradable cavities (20) interconnected by a plurality of side walls formed in the sealing flange, the method comprising the steps of:

- providing a block of material suitable (18) for serving as a nozzle sealing flange (16),
- providing a sinker electrical discharge machining device (40) for machining features into the block of material (18),
- providing an electrode (42) for use with the sinker electrical discharge machining device (40) to perform the machining of the features in the block (18) of material, the electrode (42) being shaped to form in the block of material (18) the plurality of interconnected cavities, and
- using the electrode (42) with the sinker electrical discharge machining device (40) to plunge the electrode (42) directly into the block of material (18), to thereby form the nozzle sealing flange (16) with the plurality of interconnected cavities.

2. The method of claim 1 further comprising the step of coating the plurality of interconnected cavities (20) with a coating suitable (36) for oxidation and corrosion resistance and/or improved abradability.

3. The method of claim 1 or 2, wherein the block of material (18) in which the plurality of interconnected cavities (20) are formed is separate from the turbine nozzle (11), and wherein the method further comprises the step of welding or brazing the block of material (18) to the turbine nozzle (11) after the plurality of interconnected cavities (20) have been formed in such block (18).

4. The method of any of claims 1 to 3, wherein the block of material (18) in which the plurality of interconnected cavities (20) are formed is an integral part of the turbine nozzle (11).

5. The method of any of claims 1 to 4, wherein the plurality of interconnected cavities (20) form a honeycomb shape, and wherein each cell (20) of the honeycomb has a length and a width that results in the shape of the plurality of interconnected cavities (20) having a diamond shape.

6. The method of any preceding claim, wherein the block of material (18) is formed from an austentic nickel-chromium-based alloy.

7. The method of any preceding claim, wherein the electrode (42) is positive shaped so that the plurality of interconnected cavities (20) are sunk into the block of material (18), and wherein the plurality of interconnected cavities (20) are sunk into the block of material (18) by the positive electrode (42) burning the shape of the plurality of interconnected cavities (20) into the block of material (18).

8. The method of any preceding claim, wherein the plurality of cavities (20) form a honeycomb shape, and wherein each cell (20) of the honeycomb has a length of between 0.05 and 0.2 inches, a width of between 0.05 and 0.1 inches, a depth of about 0.1 to 0.6 inches, and a wall thickness of about 0.004 to 0.015 inches.

9. The method of any preceding claim, wherein the electrode (42) has a series of crisscrossing negative grooves (44) which form a positive diamond shaped honeycomb pattern that is burned into the block of material (18) when the electrode (42) is pressed into the block of material (18).

10. The method of claim 7, wherein the sinker electrical discharge machining device (40) includes a press assembly on which the electrode (42) is mounted to press the electrode (42) into the block of material (18) to thereby burn the plurality of interconnected cavities (20) directly into block of material (18).

11. The method of any preceding claim, wherein the plurality of interconnected cavities (20) are formed with a sidewall along the leading edge (19) and/or the trailing edge (21) of the plurality of interconnected cavities (20) to improve strength in the sealing flange (16).

12. The method of any preceding claim, wherein the plurality of interconnected cavities (20) are formed with walls thicker in a first direction than in a second direction, to thereby improve sealing between the nozzle sealing flange (16) and a turbine bucket angel wing (14) in the turbine's sealing assembly (10), when the nozzle sealing flange is in the sealing assembly.

13. The method of any preceding claim, wherein the plurality of interconnected cavities (20) are formed with thicker walls in the direction that cooling air flows into the turbine's high temperature combustion gas passage, rather than in the direction a turbine nozzle angel wing (14) in the turbine's sealing assembly (10) rubs the nozzle sealing flange (16), when the nozzle sealing flange (16) is in the sealing assembly (10), to thereby improve sealing between the nozzle sealing flange (16) and the bucket angel wing (14).

14. The method of any preceding claim, wherein the plurality of interconnected cavities (20) are formed in the sealing flange (16) so as to be angled.
in a predetermined direction, to thereby improve sealing between the nozzle sealing flange (16) and a bucket angel wing (14).

15. The method of any of claims 2 to 14 wherein the coating (30) is an aluminide intermetallic coating.
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Date of completion of the search: 22 March 2013
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