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Ohkita(10) **Pub. No.: US 2010/0040459 A1**(43) **Pub. Date: Feb. 18, 2010**(54) **FILM COOLING STRUCTURE****Publication Classification**(75) Inventor: **Yoji Ohkita, Tokyo (JP)**(51) **Int. Cl.**
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ARLINGTON, VA 22204 (US)(57) **ABSTRACT**(73) Assignee: **IHI CORPORATION, Tokyo (JP)**(21) Appl. No.: **12/514,511**(22) PCT Filed: **Mar. 13, 2007**(86) PCT No.: **PCT/JP2007/054910**§ 371 (c)(1),
(2), (4) Date: **May 12, 2009**(30) **Foreign Application Priority Data**

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A film cooling structure 10 includes a structural wall 11 that has an outer surface 12 exposed to combustion gas and an inner surface 13 positioned opposite to the outer surface 12, and film cooling holes 14 are formed at the structural wall 11 and introduce cooling air from the inner surface 13 toward the outer surface 12 in order to perform film cooling. The film cooling hole 14 includes an introducing portion 14a that extends to a middle position in the structural wall 11 from the inner surface 13 toward the outer surface 12, an enlarged portion 14b of which the cross-sectional area is gradually increased toward the outer surface 12 from an end of an outer surface side of the introducing portion 14a and which is opened at the outer surface 12, and a partition portion 16 that partitions the inside of the enlarged portion 14b into a plurality of spaces in a width direction of the hole perpendicular to a flow direction of the combustion gas.

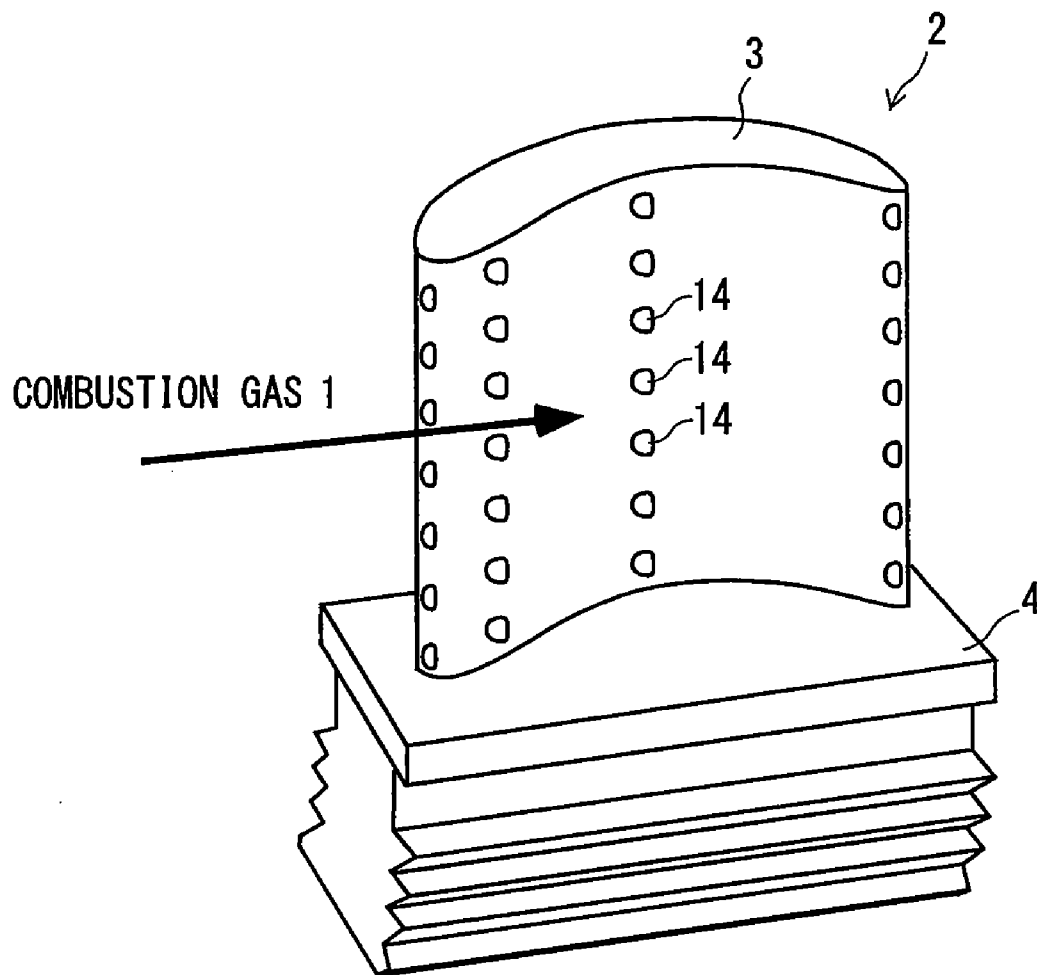


FIG. 1A

PRIOR ART

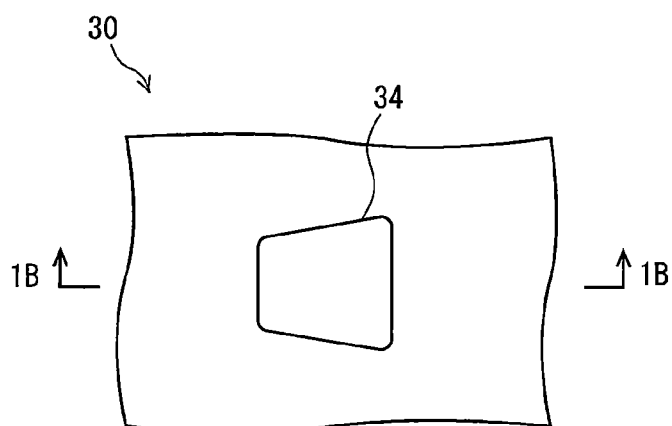


FIG. 1B

PRIOR ART

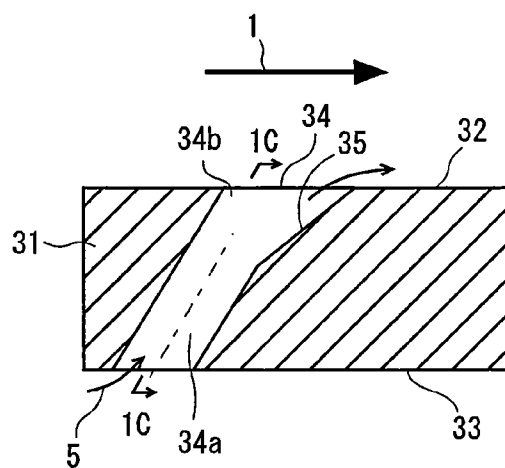


FIG. 1C

PRIOR ART

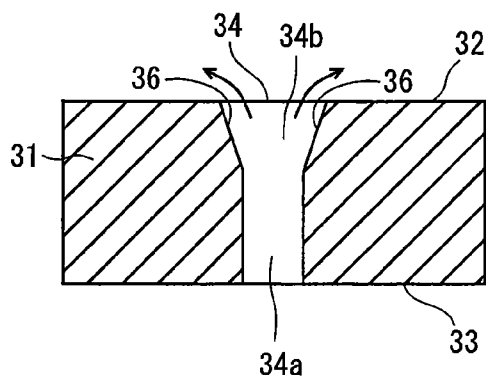


FIG. 2

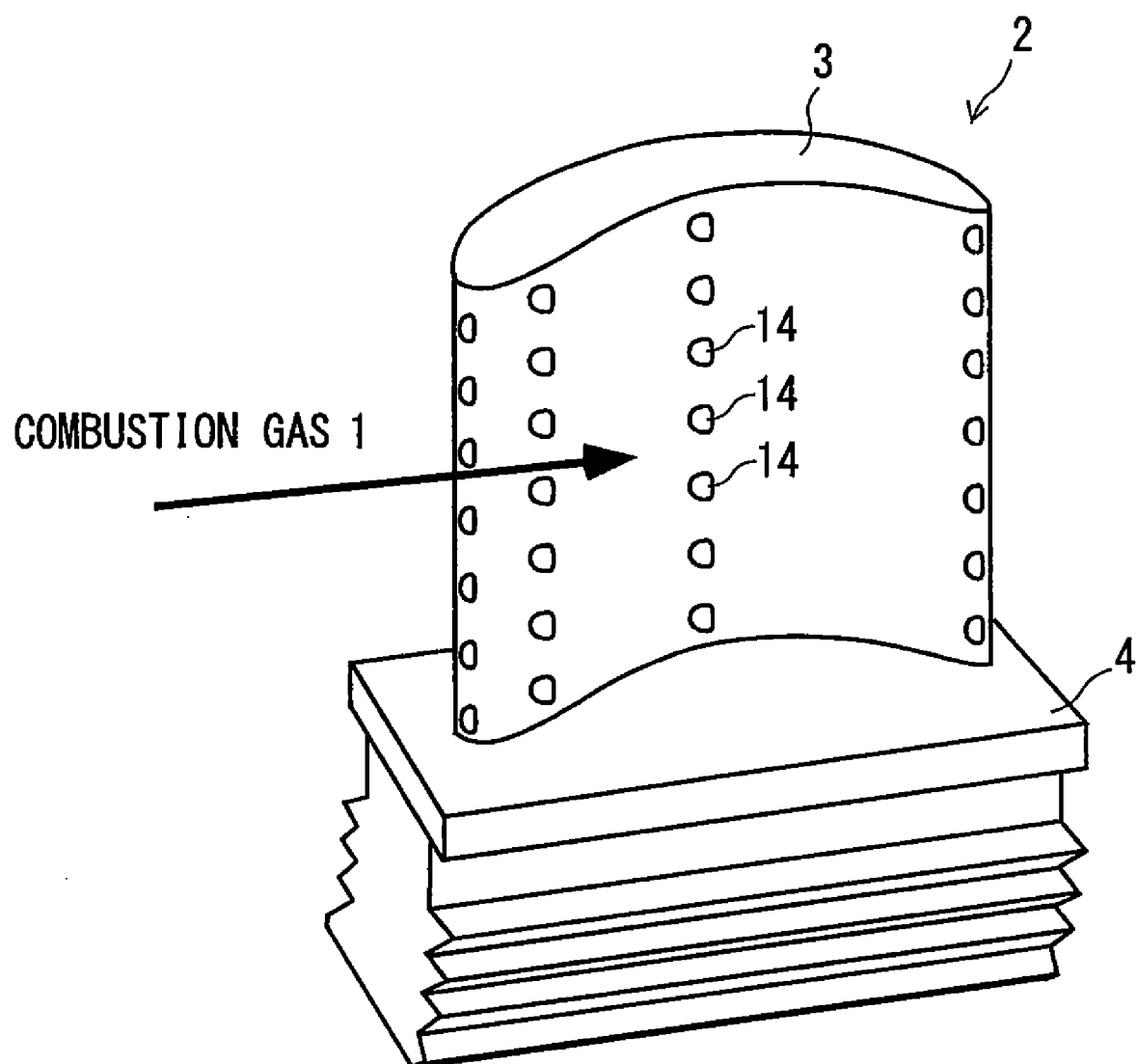


FIG. 3A

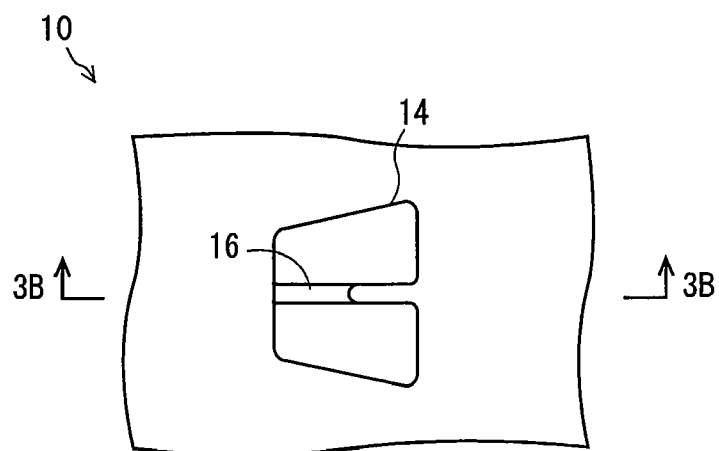


FIG. 3B

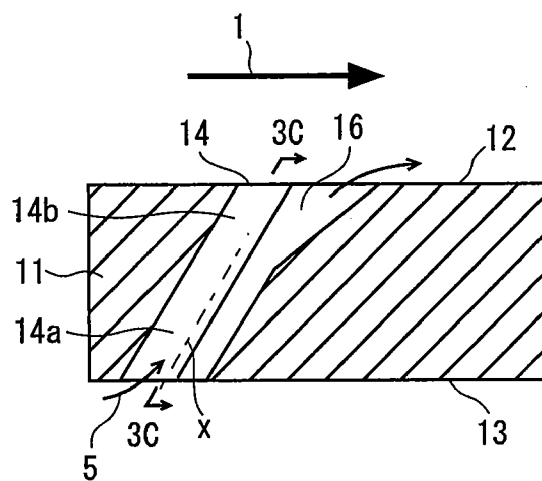


FIG. 3C

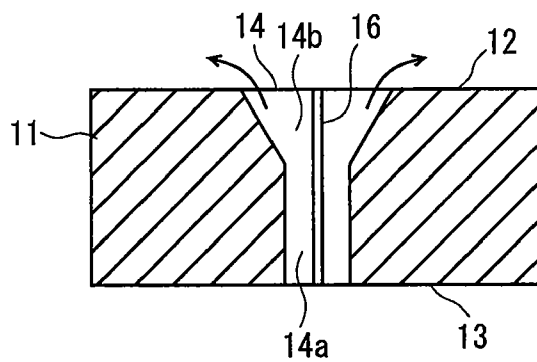


FIG. 4

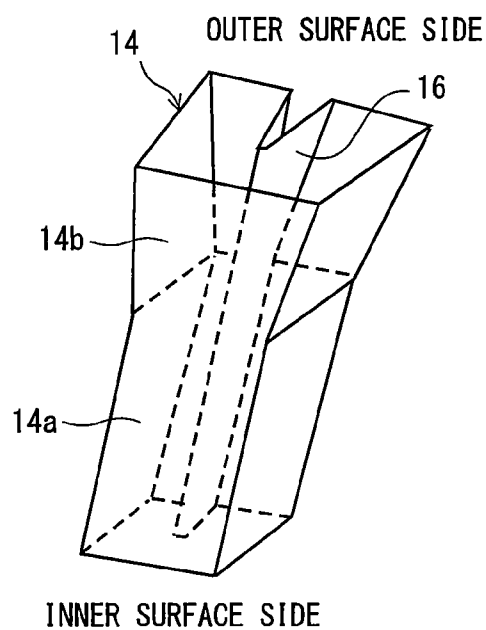
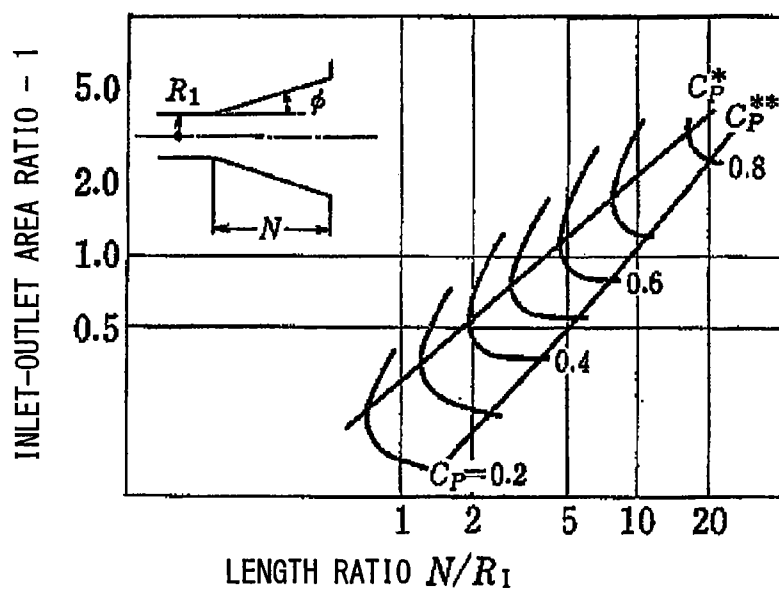


FIG. 5



FILM COOLING STRUCTURE

BACKGROUND OF THE INVENTION

[0001] 1. Technical Field of the Invention

[0002] The present invention relates to a film cooling structure that is suitable for film cooling of the surface of a component (turbine blade or the like) of a gas turbine engine.

[0003] 2. Description of the Related Art

[0004] The efficiency of a gas turbine engine is increased as combustion gas temperature rises. However, the combustion gas heats a structural wall of a component (a combustor liner, a turbine blade, a turbine shroud, or the like), that is disposed on a flow passage for combustion gas, to high temperature. Accordingly, in order to efficiently cool the structural wall of such the component, there is employed a film cooling structure. In the cooling structure, a cooling passage is formed therein, convection cooling is performed by making cooling air flow through the cooling passage, and film cooling is performed by making the cooling air be ejected from film cooling holes onto a surface, which is exposed to high-temperature combustion gas, in the shape of a film (for example, see the following Patent Documents 1 to 5).

[0005] FIGS. 1A to 1C show an example of a film cooling structure 30 of the related art. FIG. 1B is a cross-sectional view taken along a line 1B-1B of FIG. 1A, and FIG. 1C is a cross-sectional view taken along a line 1C-1C of FIG. 1B.

[0006] In FIGS. 1B and 1C, a structural wall 31 has an outer surface 32 that is exposed to combustion gas 1, and an inner surface 33 that is positioned opposite to the outer surface 32. Film cooling holes 34 are formed at the structural wall 31 so as to be inclined with respect to the outer surface 32 by a predetermined angle, and introduce cooling air 5 from the inner surface 33 toward the outer surface 32 in order to perform the film cooling of the outer surface 32. The film cooling hole 34 includes an introducing portion 34a that extends to a middle position in the structural wall 31 from the inner surface 33 toward the outer surface 32, and an enlarged portion 34b (diffuser) of which the cross-sectional area is gradually increased toward the outer surface 32 from an end of the introducing portion 34a facing the outer surface 32 and which is opened at the outer surface 32. As shown in FIG. 1B, a wall surface 35 of the enlarged portion 34b facing an upstream side in the flow direction of the combustion gas 1 is formed in a linear shape. Further, as shown in FIG. 1C, both wall surfaces 36 and 36 of the enlarged portion 34b in a direction perpendicular to the flow direction of the combustion gas 1 are formed in a linear shape.

[0007] [Patent Document 1]

[0008] Japanese Patent Application Laid-Open No. 2006-9785

[0009] [Patent Document 2]

[0010] Japanese Patent Application Laid-Open No. 2005-90511

[0011] [Patent Document 3]

[0012] Japanese Patent Application Laid-Open No. 2003-41902

[0013] [Patent Document 4]

[0014] Japanese Patent Application Laid-Open No. 2001-173405

[0015] [Patent Document 5]

[0016] Japanese Patent Application Laid-Open No. 10-89005

SUMMARY OF THE INVENTION

[0017] As for film cooling, it is preferable to spread the cooling air 5 on the outer surface 32, which is to be cooled, as thinly and broadly as possible, and to attach the cooling air to the outer surface 32 as close as possible. Accordingly, in order to spread the cooling air 5 thinly and broadly on the outer surface 32, it is effective to increase an enlarged angle of the enlarged portion 34b as much as possible.

[0018] However, the cross-sectional area of the hole is linearly increased at the enlarged portion 34b of the above-mentioned film cooling structure 30 in the related art. Accordingly, if an enlarged angle of the enlarged portion 34b is excessively large, the separation of the cooling air 5 occurs in the hole. For this reason, there have been problems that the cooling air 5 is not effectively diffused and it is difficult to improve average film cooling efficiency.

[0019] The invention has been made in consideration of the above-mentioned problems, and an object of the invention is to provide a film cooling structure that can increase an enlarged angle of an enlarged portion and improve average film cooling efficiency.

[0020] In order to solve the above-mentioned problems, the film cooling structure according to the invention includes the following means.

[0021] According to the invention, a film cooling structure includes a structural wall that has an outer surface exposed to combustion gas and an inner surface positioned opposite to the outer surface, and film cooling holes are formed at the structural wall and introduce cooling air from the inner surface toward the outer surface in order to perform film cooling of the outer surface. The film cooling hole includes an introducing portion that extends to a middle position in the structural wall from the inner surface toward the outer surface, an enlarged portion of which the cross-sectional area is gradually increased toward the outer surface from an end of an outer surface side of the introducing portion and which is opened at the outer surface, and a partition portion that partitions the inside of the enlarged portion into a plurality of spaces in a width direction of the hole perpendicular to a flow direction of the combustion gas.

[0022] Since the film cooling hole includes the partition portion that has been formed as described above, an effective area expansion ratio may be reduced. Accordingly, even though the enlarged angle of the enlarged portion in a transverse direction is large, the separation of the cooling air is suppressed. Therefore, since it is possible to effectively diffuse cooling air as compared to the related art, the enlarged angle of the enlarged portion in the transverse direction can be made large. As a result, it is possible to spread the cooling air thinly and broadly on the outer surface of the structural wall, and to improve average film cooling efficiency. Meanwhile, the definition of the average film cooling efficiency will be described below.

[0023] Further, since it is possible to spread the cooling air thinly and broadly as compared to the related art, the number of film cooling holes formed at the structural wall may be reduced. Accordingly, the number of processes for manufacturing the film cooling structure can be reduced. Furthermore, as the number of film cooling holes is reduced, the amount of

cooling air extracted from the compressor of the gas turbine engine can be decreased. Therefore, engine efficiency can be improved.

[0024] In addition, in the film cooling structure, the partition portion is formed at a middle position of the inside of the film cooling hole in the width direction of the hole perpendicular to the flow direction of the combustion gas, protrudes from one of the wall surfaces facing upstream and downstream sides in the flow direction of the combustion gas toward the other thereof, and extends over the entire inside of the hole from the inner surface of the structural wall toward the outer surface.

[0025] As described above, the partition portion does not completely partition the film cooling hole in the transverse direction, and extends over the entire structural wall in a thickness direction. Therefore, it is easy to form the film cooling hole.

[0026] From the above description, according to the invention, it is possible to obtain advantages of increasing an enlarged angle of an enlarged portion and improving average film cooling efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] FIG. 1A is a plan view of a film cooling structure in the related art.

[0028] FIG. 1B is a cross-sectional view taken along a line 1B-1B of FIG. 1A.

[0029] FIG. 1C is a cross-sectional view taken along a line 1C-1C of FIG. 1B.

[0030] FIG. 2 is a perspective view of a turbine rotating blade to which a film cooling structure according to the invention is applied.

[0031] FIG. 3A is a plan view of a film cooling structure according to an embodiment of the invention.

[0032] FIG. 3B is a cross-sectional view taken along a line 3B-3B of FIG. 3A.

[0033] FIG. 3C is a cross-sectional view taken along a line 3C-3C of FIG. 3B.

[0034] FIG. 4 is a perspective view showing the shape of a film cooling hole of the film cooling structure according to the embodiment of the invention.

[0035] FIG. 5 is a view illustrating the physical action of a partition portion.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0036] A preferred embodiment of the invention will be described in detail below with reference to accompanying drawings. Meanwhile, the same reference numerals are given to common portions in each drawing, and redundant description thereof will be omitted.

[0037] A film cooling structure according to the invention is applied to a component that is disposed on a flow passage for combustion gas in a gas turbine engine. Examples of this component include a combustor liner, a turbine nozzle vane, a turbine nozzle band, a turbine rotating blade, a turbine stator blade, a turbine shroud, and a turbine outlet liner.

[0038] FIG. 2 is a perspective view of a turbine rotating blade 2 to which the film cooling structure 10 according to the invention is applied. The turbine rotating blade 2 includes a blade portion 3 that serves as a structural wall having an outer surface 12 exposed to combustion gas 1, and a base portion 4 that is used to mount the blade portion 3 on a rotor of an

engine. A cooling circuit (not shown) through which cooling air flows is formed in the blade portion 3. This cooling air is extracted from a compressor of a gas turbine engine, and flows into the cooling circuit through a flow passage (not shown) that is formed in the base portion 4. The cooling air, which has flown into the cooling circuit, is ejected from a plurality of film cooling holes 14 that is formed on an outer surface 12 of the blade portion 3, and performs film cooling on the outer surface 12 of the blade portion 3. The film cooling structure 10 according to an embodiment of the invention will be described below.

[0039] FIGS. 3A to 3C show the film cooling structure 10 according to the invention. FIG. 3A is a plan view of the film cooling structure 10. FIG. 3B is a cross-sectional view taken along a line 3B-3B of FIG. 3A. FIG. 3C is a cross-sectional view taken along a line 3C-3C of FIG. 3B. Further, FIG. 4 is a perspective view showing the shape of the film cooling hole 14 of the film cooling structure 10 according to the embodiment of the invention.

[0040] As described above, the film cooling structure 10 is applied to a component such as a turbine rotating blade that is disposed on a flow passage for combustion gas 1 in a gas turbine engine. As shown in FIGS. 3B and 3C, the film cooling structure 10 includes a structural wall 11 that has the outer surface 12 exposed to the combustion gas 1 and an inner surface 13 positioned opposite to the outer surface 12. If the component of the gas turbine is, for example, a turbine rotating blade, a wall forming the blade portion of the turbine rotating blade is the structural wall 11. Cooling air 5 flows into the inner surface 13 of the structural wall 11.

[0041] The film cooling hole 14, which introduces the cooling air 5 from the inner surface 13 to the outer surface 12 in order to perform the film cooling of the outer surface 12, is formed in the structural wall 11. As shown in FIG. 3B, an axis of the film cooling hole 14 is inclined with respect to the outer surface 12 of the structural wall 11 by a predetermined angle so that the cooling air 5 is blown from the film cooling hole 14 in a direction corresponding to the flow of the combustion gas 1.

[0042] The film cooling hole 14 includes an introducing portion 14a that extends to a middle position in the structural wall 11 from the inner surface 13 toward the outer surface 12, and an enlarged portion 14b of which the cross-sectional area is gradually increased toward the outer surface 12 from an end of an outer surface side of the introducing portion 14a and which is opened at the outer surface 12.

[0043] The film cooling hole 14 further includes a partition portion 16 that partitions the inside of the enlarged portion 14b into a plurality of spaces in a width direction of the hole perpendicular to the flow direction of the combustion gas 1. In this case, the "width direction of the hole perpendicular to the flow direction of the combustion gas 1" is a direction perpendicular to the plane of FIG. 3B, and is a horizontal direction in FIG. 3C.

[0044] In the embodiment shown in FIGS. 3A to 3C and 4, the partition portion 16 is formed at a middle position of the inside of the film cooling hole 14 in the width direction of the hole perpendicular to the flow direction of the combustion gas 1, protrudes from the wall surface facing an upstream side in the flow direction of the combustion gas 1 toward the upstream side in the flow direction of the combustion gas 1, and extends over the entire inside of the hole from the inner surface 13 of the structural wall 11 toward the outer surface

12. A gap is formed between the partition portion **16** and a wall surface facing a downstream side in the flow direction of the combustion gas **1**.

[0045] One partition portion **16** has been formed in the embodiment shown in FIGS. **3A** to **3C** and **4**, but a plurality of partition portions may be formed at intervals in the width direction of the hole.

[0046] Further, in the embodiment shown in FIGS. **3A** to **3C** and **4**, the partition portion **16** has protruded from the wall surface facing the upstream side in the flow direction of the combustion gas **1** toward the upstream side in the flow direction of the combustion gas **1**. However, in contrast to this, the partition portion may protrude from the wall surface facing a downstream side in the flow direction of the combustion gas **1** toward the downstream side in the flow direction of the combustion gas **1**. In this case, a gap is formed between the partition portion **16** and a wall surface facing the upstream side in the flow direction of the combustion gas **1**.

[0047] According to this embodiment, it is possible to obtain the following effects.

[0048] FIG. **5** is a graph where a length ratio is represented on a horizontal axis in logarithmic scale, a value obtained by subtracting **1** from an inlet-outlet area ratio is represented on a vertical axis in logarithmic scale, and a pressure recovery rate (reduction rate) C_p is used as a parameter, as for a diffuser. In this case, if inlet-outlet area ratios are equal to each other, an enlarged angle is smaller when a length ratio is larger. Further, when a pressure recovery rate is high, separation hardly does occur. A straight line, which is represented by a pressure recovery rate C_p^{**} of the drawing, is obtained by connecting points where the maximum pressure recovery rate is obtained when an inlet-outlet area ratio of a diffuser is constant. Meanwhile, a straight line of C_p^* is a line where the maximum pressure recovery rate is obtained when a length ratio is constant. Accordingly, it is found out that if an inlet-outlet area ratio is constant, when an enlarged angle is small, a pressure recovery rate is high and separation hardly does occur. If a passage of the diffuser is divided into two or three equal parts, an enlarged angle of each of the small passages becomes a half or a third and becomes smaller than an enlarged angle determined by C_p^* . For this reason, a high pressure recovery rate is obtained over the entire passage.

[0049] Accordingly, according to this embodiment, if the film cooling hole **14** includes the partition portion **16** formed as described above, an effective area expansion ratio is suppressed. Therefore, even though an enlarged angle of the enlarged portion **14b** is increased in a transverse direction, the separation of the cooling air **5** is suppressed. For this reason, since it is possible to effectively diffuse the cooling air **5** as compared to the related art, the enlarged angle of the enlarged portion **14b** in the transverse direction can be increased. Accordingly, it is possible to spread the cooling air **5** thinly and broadly on the outer surface **12** of the structural wall **11**, and to improve average film cooling efficiency. In this case, the average film cooling efficiency is given by (fuel gas temperature-surface temperature of structural wall)/(combustion gas temperature-cooling air temperature).

[0050] Further, since it is possible to spread the cooling air **5** thinly and broadly on the outer surface **12** of the structural wall **11** as compared to the related art, the number of film cooling holes **14** formed at the structural wall **11** can be reduced. For this reason, the number of processes for manufacturing the film cooling structure **10** can be reduced. Further, as the number of film cooling holes **14** is reduced, the

amount of cooling air extracted from the compressor of the gas turbine engine can be decreased. Therefore, engine efficiency can be improved.

[0051] When the film cooling holes **14** are formed using a method such as electric discharge machining, an electric discharge machining electrode needs to be inserted into each of the divided holes in order to form holes if the partition portion **16** completely partitions the film cooling hole **14** in a transverse direction. Further, if the partition portion **16** is formed in a shape that is broken at a position in a thickness direction of the structural wall **11**, a plurality of processes is required to form one film cooling hole **14** (for example, electric discharge machining electrodes need to be inserted from the outer surface **12** and the inner surface **13** in order to form the hole.) Furthermore, even though other machining means is used, forming processes are complicated likewise.

[0052] In contrast, in this embodiment, the partition portion **16** does not completely partition the film cooling hole **14** in the transverse direction, and extends over the entire structural wall **11** in the thickness direction. Accordingly, if an electric discharge machining electrode, which is formed to form the film cooling hole **14** shown in FIGS. **3A** to **3C** and **4**, is inserted from the outer surface **12**, it is possible to form the film cooling hole **14** by a single process. Therefore, it is easy to form the film cooling hole **14**.

[0053] Meanwhile, the embodiment of the invention has been described above. However, the above-mentioned embodiment of the invention is only illustrative, and the scope of the invention is not limited to the embodiment of the invention. For example, the invention has been applied to the turbine rotating blade **2** in the above-mentioned embodiment, but may be applied to other components, such as a combustor liner, a turbine nozzle vane, a turbine nozzle band, a stationary turbine blade, a turbine shroud, and a turbine outlet liner, which are disposed on a flow passage for combustion gas in a gas turbine engine.

[0054] The scope of the invention is defined by the description of claims, and includes all modifications that are in a meaning and a scope equivalent to the description of claims.

1. A film cooling structure, comprising:

a structural wall that has an outer surface exposed to combustion gas and an inner surface positioned opposite to the outer surface,

wherein film cooling holes being formed at the structural wall and introducing cooling air from the inner surface toward the outer surface in order to perform film cooling of the outer surface,

the film cooling hole includes an introducing portion that extends to a middle position in the structural wall from the inner surface toward the outer surface, an enlarged portion of which the cross-sectional area is gradually increased toward the outer surface from an end of an outer surface side of the introducing portion and which is opened at the outer surface, and a partition portion that partitions the inside of the enlarged portion into a plurality of spaces in a width direction of the hole perpendicular to a flow direction of the combustion gas.

2. The film cooling structure according to claim **1**,

wherein the partition portion is formed at a middle position of the inside of the film cooling hole in the width direction of the hole perpendicular to the flow direction of the combustion gas,

and the partition portion protrudes from one of the wall surfaces facing upstream and downstream sides in the flow direction of the combustion gas toward the other thereof, and extends over the entire inside of the hole from the inner surface of the structural wall toward the outer surface.