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(54) **Serpentine microcircuit vortex turbulators for blade cooling**

(57) A cooling microcircuit (100) for use in a turbine engine component (90) is provided. The cooling microcircuit has at least one leg (132) through which a cooling

fluid flows. A plurality of cast vortex generators (180) are positioned within the at least one leg (132) to improve the cooling effectiveness of the cooling microcircuit (100).

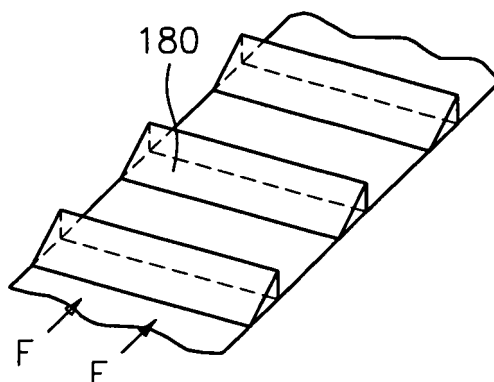


FIG. 4A

Description

BACKGROUND

(1) Field of the Invention

[0001] The present invention relates to a cooling microcircuit for use in turbine engine components, such as turbine blades, that has a plurality of vortex generators within the legs through which a cooling fluid flows to improve cooling effectiveness.

(2) Prior Art

[0002] A typical gas turbine engine arrangement includes a plurality of high pressure turbine blades. In general, cooling flow passes through these blades by means of internal cooling channels that are turbulated with trip strips for enhancing heat transfer inside the blade. The cooling effectiveness of these blades is around 0.50 with a convective efficiency of around 0.40. It should be noted that cooling effectiveness is a dimensionless ratio of metal temperature ranging from zero to unity as the minimum and maximum values. The convective efficiency is also a dimensionless ratio and denotes the ability for heat pick-up by the coolant, with zero and unity denoting no heat pick-up and maximum heat pick-up respectively. The higher these two dimensionless parameters become, the lower the parasitic coolant flow required to cool the high-pressure blade. In other words, if the relative gas peak temperature increases from 2500 degrees Fahrenheit (1371°C) to 2850 degrees Fahrenheit (1566°C), the blade cooling flow should not increase and if possible, even decrease for turbine efficiency improvements. That objective is extremely difficult to achieve with current cooling technology. In general, for such an increase in gas temperature, the cooling flow would have to increase more than 5% of the engine core flow.

SUMMARY OF THE INVENTION

[0003] Accordingly, the present invention relates to a turbine engine component, such as a turbine blade, which has one or more vortex generators within the cooling microcircuits used to cool the component.

[0004] In accordance with the present invention, a cooling microcircuit for use in a turbine engine component is provided. The cooling microcircuit broadly comprises at least one leg through which a cooling fluid flows and a plurality of cast vortex generators positioned within the at least one leg.

[0005] Further in accordance with the present invention, there is provided a process for forming a refractory metal core for use in forming a cooling microcircuit having vortex generators. The process broadly comprises the steps of providing a refractory metal core material and forming a refractory metal core having a plurality of indentations in the form of the vortex generators.

[0006] Other details of the serpentine microcircuits vortex turbulators for blade cooling of the present invention, as well as other advantages attendant thereto, are set forth in the following detailed description and the accompanying drawings wherein like reference numerals depict like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

FIG. 1 illustrates a turbine engine component having cooling microcircuits in the pressure and suction side walls;

FIG. 2 is a schematic representation of a cooling microcircuit for the suction side of the turbine engine component;

FIG. 3 is a schematic representation of a cooling microcircuit for the pressure side of the turbine engine component;

FIG. 4A illustrates a wedge shaped continuous rib type of vortex generator;

FIG. 4B illustrates a series of wedge shaped broken rib vortex generators;

FIG. 4C illustrates a delta-shaped backward aligned rib configuration of vortex generators;

FIG. 4D illustrates a series of wedge shaped backward offset rib vortex generators;

FIGS. 5 - 7 illustrate a process for forming a refractory metal core; and

FIG. 8 illustrates a plurality of vortex generators in a cooling microcircuit passage.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0008] Referring now to the drawings, FIGS. 1 - 3 illustrate a serpentine microcircuit cooling arrangement for a turbine engine component, such as a turbine blade. Referring now to the drawings, a turbine engine component 90, such as a high pressure turbine blade, may be cooled using the cooling design scheme shown in FIGS. 1 - 3. The cooling design scheme, as shown in FIG. 1, encompasses two serpentine microcircuits 100 and 102 located peripherally in the airfoil walls 104 and 106 respectively for cooling the main body 108 of the airfoil portion 110 of the turbine engine component. Separate cooling microcircuits 96 and 98 may be used to cool the leading and trailing edges 112 and 114 respectively of the airfoil main body 108. One of the benefits of the approach of the present invention is that the coolant inside the turbine engine component may be used to feed the leading and trailing edge regions 112 and 114. This is preferably done by isolating the microcircuits 96 and 98 from the external thermal load from either the suction side 116 or the pressure side 118 of the airfoil portion 110. In this way, both impingement jets before the leading and trailing edges become very effective. In the leading

and trailing edge cooling microcircuits 96 and 98 respectively, the coolant may be ejected out of the turbine engine component by means of film cooling.

[0009] Referring now to FIG. 2, there is shown a serpentine cooling microcircuit 102 that may be used on the suction side 118 of the turbine engine component. As can be seen from this figure, the microcircuit 102 has a fluid inlet 126 for supplying cooling fluid to a first leg 128. The inlet 126 receives the cooling fluid from one of the feed cavities 142 in the turbine engine component. Fluid flowing through the first leg 128 travels to an intermediate leg 130 and from there to an outlet leg 132. Fluid supplied by one of the feed cavities 142 may also be introduced into the cooling microcircuit 96 and used to cool the leading edge 112 of the airfoil portion 110. The cooling circuit 102 may include fluid passageway 131 having fluid outlets 133. Still further, as can be seen, the thermal load to the turbine engine component may not require film cooling from each of the legs that form the serpentine peripheral cooling microcircuit 102. In such an event, the flow of cooling fluid may be allowed to exit from the outlet leg 132 at the tip 134 by means of film blowing from the pressure side 116 to the suction side 118 of the turbine engine component. As shown in FIG. 2, the outlet leg 132 may communicate with a passageway 136 in the tip 134 having fluid outlets 138.

[0010] Referring now to FIG. 3, there is shown the serpentine cooling microcircuit 100 for the pressure side 116 of the airfoil portion 110. As can be seen from this figure, the microcircuit 100 has an inlet 141 which communicates with one of the feed cavities 142 and a first leg 144 which receives cooling fluid from the inlet 141. The cooling fluid in the first leg 144 flows through the intermediate leg 146 and through the outlet leg 148. As can be seen, from this figure, fluid from the feed cavity 142 may also be supplied to the trailing edge cooling microcircuit 98. The cooling microcircuit 98 may have a plurality of fluid passageways 150 which have outlets 152 for distributing cooling fluid over the trailing edge 114 of the airfoil portion 110. The outlet leg 148 may have one or more fluid outlets 153 for supplying a film of cooling fluid over the pressure side 116 of the airfoil portion 110 in the region of the trailing edge 114.

[0011] It is desirable to increase the convective efficiency of the cooling microcircuits 100 and 102 within the turbine engine component 90 so as to increase the corresponding overall blade effectiveness. To accomplish this increase in convective efficiency, internal features 180 may be placed inside the cooling passages. The existence of the features 180 enable the air inside the cooling microcircuits 100 and 102 to pick-up more heat from the walls of the turbine engine component 90 by increasing the turbulence inside the passages of the cooling microcircuits 100 and 102.

[0012] FIGS. 4A - 4D illustrate a series of vortex generator features 180 which could be placed in the legs 128, 130, 132, 144, 146, and 148 of the cooling microcircuits 100 and 102 within the turbine engine component

90. FIG. 4A illustrates a wedge shaped continuous rib type of vortex generator. FIG. 4B illustrates a series of wedge shaped broken rib vortex generators. FIG. 4C illustrates a delta-shaped backward aligned rib configuration of vortex generators. FIG. 4D illustrates a series of wedge shaped backward offset rib vortex generators. As the cooling flow F flowing in the respective legs 128, 130, 132, 144, 146, and/or 148 passes over these features, a series of vortices are generated.

[0013] If the legs 128, 130, 132, 144, 146, and 148 of the serpentine cooling microcircuits 100 and 102 are formed using refractory metal cores, a machining operation can be done to place these vortex generators in the core. FIGS. 5 - 7 illustrate a photo-lithography method of forming these features onto a refractory metal core material 200. The machining process may be done through a chemical etching process: Sufficient material may be taken out of the refractory metal core 200 to form the desired vortex generators/turbulators 180. During an investment casting process, these machined indentations are filled with superalloy material to form the vortex generators 180 within the legs of the cooling microcircuits. The overall process is referred to as a photo-etch process prior to investment casting. The process consists of using the refractory metal core as the core material in an investment casting technique to form the cooling passages with vortex generators in the blade cooling passage. The photo-etch process consists of two sub-processes: (1) the preparation of mask material through the process of photo-lithography; and (2) a subsequent process of chemically attacking the refractory metal core material by etching away as small surface indentations.

[0014] As shown in FIG. 5, a layer of polymer film mask material 202 is placed over the refractory metal core 200 and is subjected to UV light 204. The ultraviolet light 204 is programmed to impinge onto the polymer film mask material 202 for curing purposes. As certain designated parts of the polymer film mask material 202 are cured by light, the other surface areas of the polymer film mask material 202 are not affected by the light.

[0015] Referring now to FIG. 6, non-cured polymer film material is chemically removed from the area 210, while the cured polymer film material 202 is maintained so as to form a mask.

[0016] Referring now to FIG. 7, areas of the refractory metal core material 200 not protected by the mask are attacked by an etching chemical solution through acid dip or spray. The etching process leaves an indentation 212 in the refractory metal core 200 to form a turbulator, such as a trip strip or a vortex generator.

[0017] Alternatively, a laser beam can be used to outline the vortex generators in the refractory metal core material 200 with beams that penetrate the refractory metal core substrate 200 to form the desired features shown in FIGS. 4A - 4D.

[0018] FIG. 8 illustrates how the photo-etch process leads to the legs 128, 130, 132, 144, 146, and 148 in the turbine engine component 90 after the casting process.

In general, in an investment casting process, a wax pattern leads to the solidification of the superalloy, and the refractory metal core 200, as the core material, leads to the open spaces for the legs of the cooling microcircuits. The refractory metal core 200 is eventually removed through a leaching process. When alloy solidification takes place, the series of vortex generators 180 are placed on the walls of the legs 128, 130, 132, 144, 146, and/or 148 as shown in FIG. 8.

[0019] Extending the principle of creating turbulence, several vortex configurations can be designed to create areas of high heat transfer enhancements everywhere in a cooling passage. In terms of the design shown in FIGS. 1-3, both the pressure side and the suction side peripheral serpentine cooling microcircuits may not include film cooling with the exception of the last leg/passage of the serpentine arrangement for the pressure side circuit and for the tip of the suction side serpentine arrangement. Therefore, film cooling may not protect upstream sections of the serpentine cooling design. This is particularly important from a performance standpoint which allows for no mixing of the coolant from film with external hot gases. Since the cooling circuits 100 and 102 are embedded in the walls, their cross sectional area is small and internal features, such as the vortex generators 180 shown in FIGS. 4A - 4D, are needed to increase the convective efficiency of the circuits 100 and 102, leading to an overall cooling effectiveness for the turbine engine component 90. Naturally, the cooling flow may be reduced from typical values of 5% core engine flow to about 3.5%.

Claims

1. A cooling microcircuit (100,102) for use in a turbine engine component (90), said cooling microcircuit comprising:
 - at least one leg (128,130,132,144,146,148) through which a cooling fluid flows; and
 - a plurality of vortex generators (180) positioned within said at least one leg (128,130,132,144,146,148).
2. The cooling microcircuit of claim 1, wherein said vortex generators (180) are cast structures.
3. The cooling microcircuit of claim 1 or 2, wherein each said vortex generator (180) is wedge shaped.
4. The cooling microcircuit of claim 1 or 2, wherein said plurality of vortex generators comprises a plurality of wedge shaped continuous rib type of vortex generators (180).
5. The cooling microcircuit of claim 1 or 2, wherein said plurality of vortex generators comprises a series of wedge shaped broken rib vortex generators (180).
6. The cooling microcircuit of claim 1 or 2, wherein said plurality of vortex generators comprises a delta-shaped backward aligned rib configuration of vortex generators (180).
7. The cooling microcircuit of claim 1 or 2, wherein said plurality of vortex generators comprises a series of wedge shaped backward offset rib vortex generators (180).
8. The cooling microcircuit of any preceding claim, wherein said cooling microcircuit (100,102) has a serpentine arrangement with a plurality of legs (128,130,132,144,146,148) and wherein said vortex generators (180) are positioned in more than one of said legs (128,130,132,144,146,148).
9. The cooling microcircuit of any preceding claim, wherein said cooling microcircuit (100,102) is embedded within a wall (104,106) of said turbine engine component (90) and includes means for blowing cooling fluid over a tip (134) of said turbine engine component (90).
10. A turbine engine component (90) having an airfoil portion (110) with a pressure side (118) and a suction side (116) and a cooling microcircuit (100,102) embedded within at least one wall (104,106) of said pressure side (118) and said suction side (116), said cooling microcircuit comprising a cooling microcircuit of any preceding claim.
11. A process for forming a refractory metal core for use in forming a cooling microcircuit having vortex generators (180), said process comprising the steps of:
 - providing a refractory metal core material; and
 - forming a refractory metal core (200) having a plurality of indentations (212) in the form of said vortex generators (180).
12. The process of claim 11, wherein said forming step comprises depositing a polymer film material (202) on a surface of said refractory metal core material and applying UV light (204) to cure selected portions of said polymer film material (202).
13. The process of claim 12, wherein said forming step further comprises chemically removing non-cured portions of said polymer film material (202) while maintaining said cured portions.
14. The process of claim 13, wherein said forming step further comprises etching said refractory metal core material not protected by said cured polymer film material (202) to form said indentations (212).

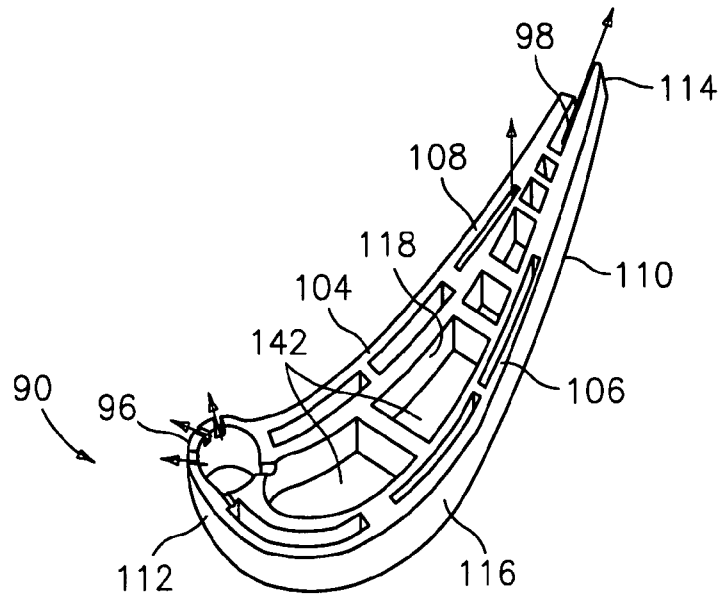


FIG. 1

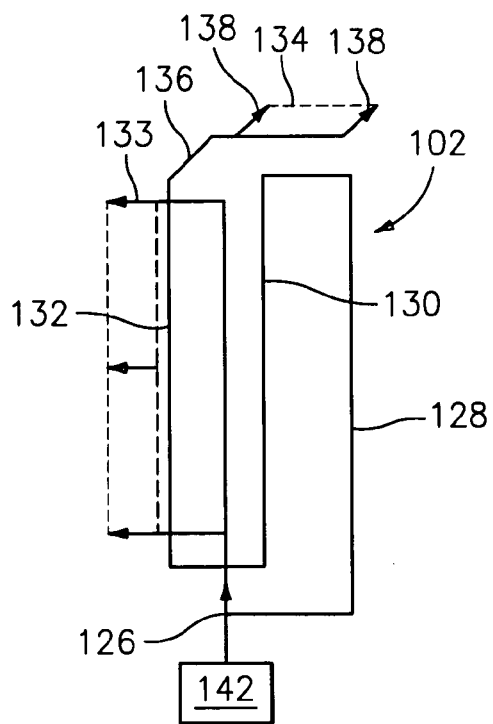


FIG. 2

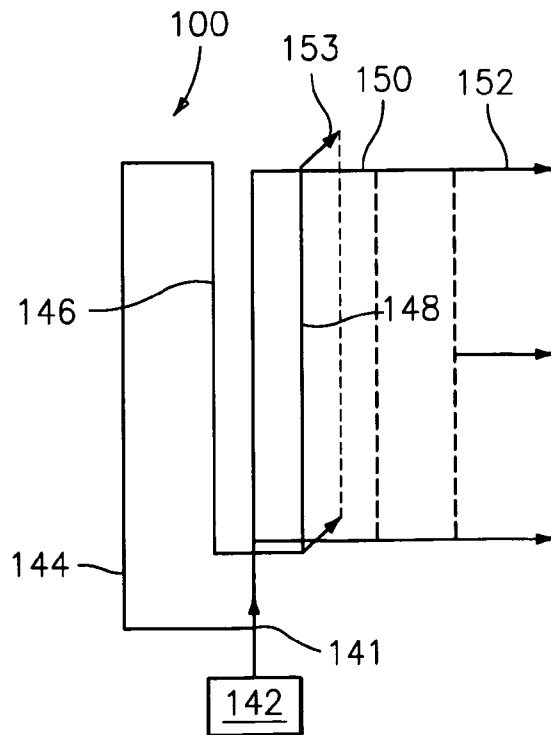


FIG. 3

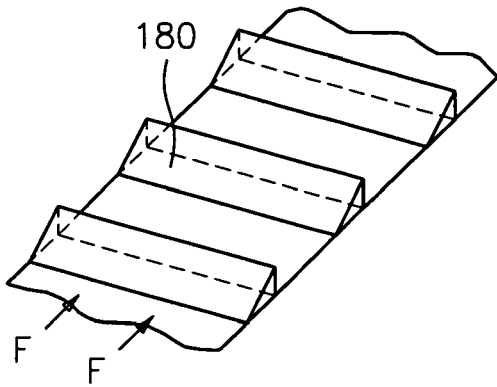


FIG. 4A

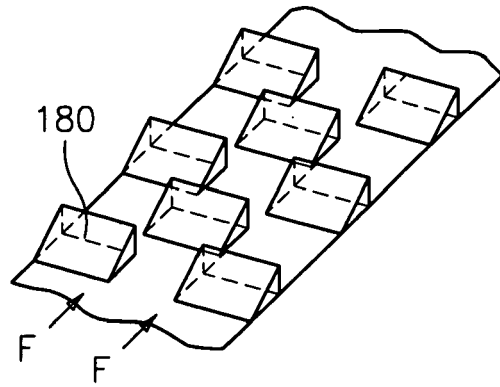


FIG. 4B

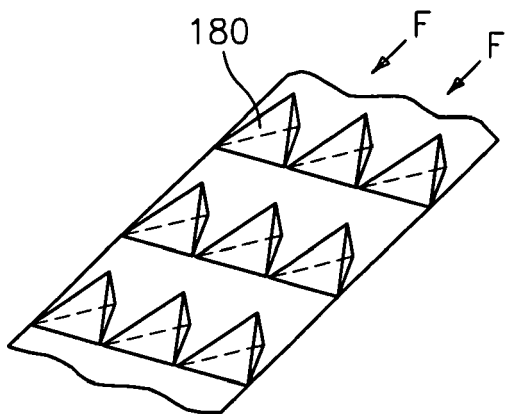


FIG. 4C

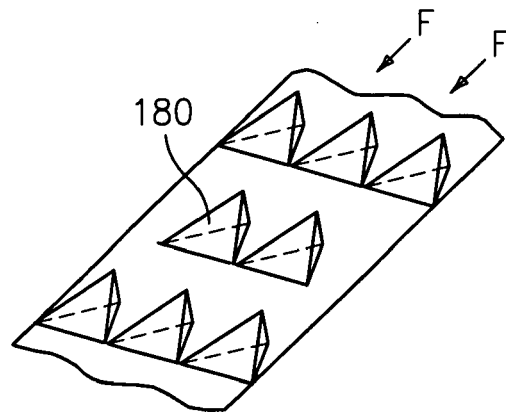


FIG. 4D

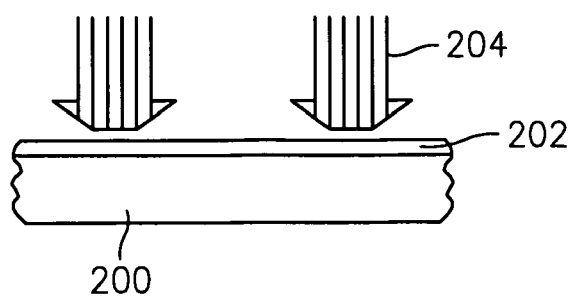


FIG. 5

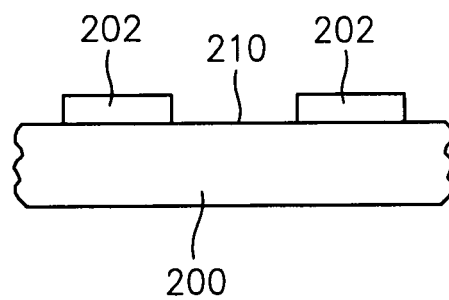


FIG. 6

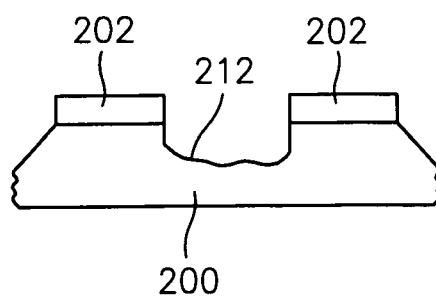


FIG. 7

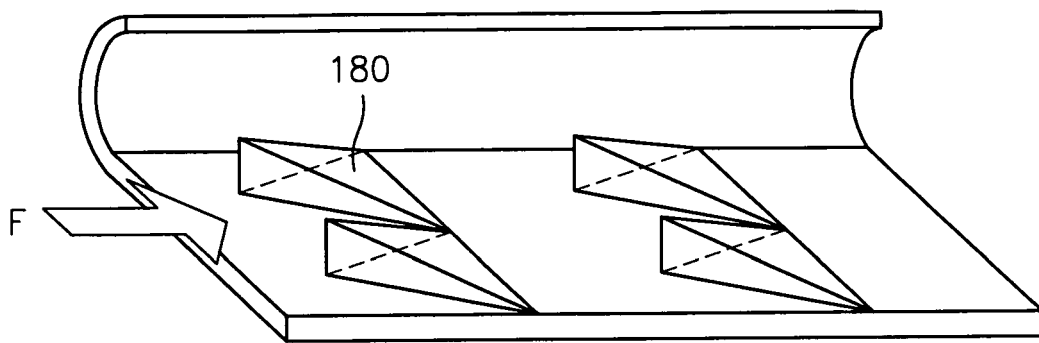


FIG. 8



EUROPEAN SEARCH REPORT

Application Number
EP 10 01 0854

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Place of search Munich		Date of completion of the search 20 December 2010	Examiner Rau, Guido
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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