COMBUSTOR AND HEAT SHIELD CONFIGURATIONS FOR A GAS TURBINE ENGINE

The present disclosure relates to combustor (105; 400) and heat shield (200) configurations for gas turbine engines (100). A heat shield for a gas turbine engine can include one or more effusion holes (226; 227; 235; 245; 330; 335; 340; 420) downstream of a dilution hole (220; 230; 255; 311; 316; 405) to restore a cooling film applied to the heat shield in the combustor. Effusion holes may be clustered in one or more configurations and rows following each dilution hole and/or on a trailing edge (211; 213) of each heat shield panel structure. One or more embodiments are directed to effusion holes positioned along a trailing edge of a heat shield panel.
The present disclosure relates to gas turbine engines, and in particular, combustor and heat shield configurations for gas turbine engines.

**BACKGROUND**

Gas turbine engines are required to operate efficiently during operation and flight. These engines create a tremendous amount of force and generate high levels of heat. As such, components of these engines are subjected to high levels of stress, temperature and pressure. It is necessary to provide combustor components that can withstand the demands of high levels of heat, stress, temperature, and pressure during operation of a gas turbine engine. It is also desirable to provide components with increased operating longevity.

Hot section components of a gas turbine engine are exposed to high temperature levels for prolonged periods of time. Thermal mechanical failure of a part can be detrimental to an engine operation and in some cases may result in catastrophic harm. In many cases, part failure to distress within the hot section requires replacement and in some cases overhaul of an entire part or assembly. Thus, there is a desire to improve tolerance of gas turbine engine parts and their ability to withstand operation in the hot section.

**BRIEF SUMMARY OF THE EMBODIMENTS**

Disclosed and claimed herein are combustor and heat shield configurations for a gas turbine engine. In one embodiment, a heat shield for a combustor of a gas turbine engine includes a panel structure having a surface configured to face a combustor cavity, the surface of the panel structure configured to receive cooling airflow, and a dilution hole in the surface of the panel structure, the dilution hole to provide airflow for the combustor cavity. The heat shield includes one or more effusion holes downstream of the dilution hole, wherein the one or more effusion holes are configured to restore cooling airflow to the surface of the panel structure downstream from dilution hole.

In one embodiment, the panel structure is configured to be mounted downstream from a second panel structure, the second panel structure arranged to provide a cooling air film to the surface.

In one embodiment, the one or more effusion holes are located in one or more rows, and wherein each row includes one or more effusion holes.

In one embodiment, the one or more effusion holes are located in one or more regions following the dilution hole.

In one embodiment, the one or more effusion holes are formed with at least one of a trumpet and cone shape.

In one embodiment, the one or more effusion holes include at least one pair of effusion holes angled towards one another.

In one embodiment, the one or more effusion holes are formed with openings smaller than an opening of the dilution hole.

In one embodiment, the heat shield includes one or more effusion holes along a trailing edge of the panel structure and downstream of the dilution hole.

One embodiment is directed to a combustor for a gas turbine engine. The combustor includes a combustor shell structure including a combustor cavity, and one or more panels lining the combustor shell structure. Each panel is configured to include a panel structure having a surface configured to face the combustor cavity, the surface of the panel structure configured to receive cooling airflow and a dilution hole in the surface of the panel structure, the dilution hole to provide airflow for the combustor cavity. Each panel includes one or more effusion holes downstream of the dilution hole, wherein the one or more effusion holes are configured to restore cooling airflow to the surface of the panel structure downstream from dilution hole.

In one embodiment, the one or more effusion holes are located in one or more rows, and wherein each row includes one or more effusion holes.

In one embodiment, the one or more effusion holes are located in one or more regions following the dilution hole.

In one embodiment, the one or more effusion holes are formed with at least one of a trumpet and cone shape.

In one embodiment, the one or more effusion holes include at least one pair of effusion holes angled towards one another.

In one embodiment, the one or more effusion holes are formed with openings smaller than an opening of the dilution hole.

In one embodiment, the heat shield includes one or more effusion holes along a trailing edge of the panel structure and downstream of the dilution hole.

According to an embodiment, the present disclosure provides a heat shield for a combustor of a gas turbine engine, the heat shield comprising: a panel structure having a surface configured to face a combustor cavity, the surface of the panel structure configured to receive cooling airflow; a dilution hole in the surface of
the panel structure, the dilution hole to provide airflow for the combustor cavity; and one or more effusion holes in the panel structure, wherein the one or more effusion holes are downstream of the dilution hole, wherein the one or more effusion holes are configured to restore cooling airflow to the surface of the panel structure downstream from dilution hole.

[0023] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the panel structure may be configured to be mounted downstream from a second panel structure, the second panel structure arranged to provide a cooling air film to the surface.

[0024] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the one or more effusion holes may be located in one or more rows, and wherein each row may include one or more effusion holes.

[0025] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the one or more effusion holes may be located in one or more regions following the dilution hole.

[0026] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the one or more effusion holes may be formed with at least one of a trumpet and cone shape.

[0027] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the one or more effusion holes may include at least one pair of effusion holes angled towards one another.

[0028] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the one or more effusion holes may be formed with openings smaller than an opening of the dilution hole.

[0029] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the heat shield may comprise one or more effusion holes along a trailing edge of the panel structure and downstream of the dilution hole.

[0030] According to another embodiment, the present disclosure provides a combustor of a gas turbine engine, the combustor comprising: a combustor structure including a combustor cavity; and one or more panels lining the combustor shell structure, wherein each panel is configured to include a panel structure having a surface configured to face the combustor cavity, the surface of the panel structure configured to receive cooling airflow, a dilution hole in the surface of the panel structure, the dilution hole to provide airflow for the combustor cavity; and one or more effusion holes downstream of the dilution hole, wherein the one or more effusion holes are configured to restore cooling airflow to the surface of the panel structure downstream from dilution hole.

[0031] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the combustor structure may be an annular structure including one or more heat shield panels mounted to an inner diameter structure and outer diameter structure of the annular structure.

[0032] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the panel structure may be configured to be mounted downstream from a second panel structure, the second panel structure arranged to provide a cooling air film to the surface.

[0033] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the one or more effusion holes may be located in one or more rows, and wherein each row may include one or more effusion holes.

[0034] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the one or more effusion holes may be formed with at least one of a trumpet and cone shape.

[0035] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the one or more effusion holes may include at least one pair of effusion holes angled towards one another.

[0036] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the one or more effusion holes may be formed with openings smaller than an opening of the dilution hole.

[0037] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the one or more effusion holes may be formed with openings smaller than an opening of the dilution hole.

[0038] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the combustor may comprise one or more effusion holes along a trailing edge of the panel structure and downstream of the dilution hole.

[0039] In addition to one or more of the features described above, or as an alternative to any of the foregoing embodiments, the one or more panels may line second and third rows of the combustor shell structure.

Brief Description of the Drawings

[0040] The features, objects, and advantages of the present disclosure will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 depicts a graphical representation of a gas turbine engine according to one or more embodiments;

FIGs. 2A-2B depict graphical representations a heat shield according to one or more embodiments;

FIG. 3 depicts a cross-sectional representation of a
heat shield configuration according to one or more embodiments; and

FIG. 4 depicts a graphical representation of a combustor configuration according to one or more embodiments.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

Overview and Terminology

[0041] One aspect of this disclosure relates to combustor and heat shield configurations for a gas turbine engine. In one embodiment, configurations are provided to restore air film cooling to one or more regions of a heat shield where air film cooling has been disrupted by dilution holes of the heat shield. According to one embodiment, a heat shield includes one or more effusion holes positioned down stream of a dilution hole in the heat shield. Effusion holes may be positioned following the dilution hole and/or along a trailing edge of a panel. Restoration of cooling may be provided by air flow exiting the effusion holes to provide cooling film to a hot side surface of the heat shield.

[0042] As used herein, the terms "a" or "an" shall mean one or more than one. The term "plurality" shall mean two or more than two. The term "another" as used herein is to be interpreted as inclusive or meaning any one or any combination. Therefore, "A, B or C" means "any of the following: A; B; C; A and B; A and C; B and C; A, B and C". An exception to this definition will occur herein is to be interpreted as inclusive or meaning any one or any combination. Therefore, "A, B or C" means "any of the following: A; B; C; A and B; A and C; B and C; A, B and C". An exception to this definition will occur when a combination of elements, functions, steps or acts are in some way inherently mutually exclusive.

[0043] Reference throughout this document to "one embodiment," "certain embodiments," "an embodiment," or similar term means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of such phrases in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner on one or more embodiments without limitation.

Exemplary Embodiments

[0044] Referring now to the figures, FIG. 1 depicts a graphical representation of a gas turbine engine according to one or more embodiments. In one embodiment, gas turbine engine 110 includes combustor 105 having an annular structure 110. According to another embodiment, annular structure 110 defines combustor cavity 120. According to another embodiment, annular structure 110 of combustor 105 can include one or more heat shield panels, shown as 115, lining the surfaces of annular structure 110.

[0045] Combustor 105 receives fuel from fuel nozzle 106 for combustion. The gas flow path is shown generally as 107 in combustor cavity 120 of annular structure 110. Gas flow path 107 flows downstream to turbine elements (not shown) of gas turbine engine 100.

[0046] Annular structure 110 includes outer diameter 125 and inner diameter 135. According to one or more embodiments, annular structure 110 includes one or more cooling holes in outer diameter 125 and inner diameter 135 to provide airflow into cavity 120 and which may be configured for cooling heat shield panels 115. Airflow received for combustor 105 is shown generally as 130. According to one embodiment, airflow received by combustor 105 and passing through annular structure 110 is shown as 140. Airflow 140 may be employed by heat shield panels 115 to provide cooling flow to a surface of the panels, shown as 136. According to one embodiment, dilution holes in heat shield panels 115 may disrupt cooling flow 136. As such, heat shield panels 115 may be configured with one or more effusion holes to restore disrupted cooling flow.

[0047] FIGs. 2A-2B depict graphical representations a heat shield according to one or more embodiments. FIG. 2A depicts a graphical representation of heat shield 200 including panels 2051-n. In one embodiment, heat shield 200 includes a plurality of rows of panels 2051-n, each panel relating to a panel structure having a surface 206 configured to face a combustor cavity (e.g., combustor cavity 120). The surface 206 of each panel structure may be configured to receive cooling airflow. According to one embodiment, the direction of the cooling airflow across the hot-side of panels 2051-n is shown generally as 207.

[0048] FIG. 2A shows four rows of panels 2051-n. Panel 2051 may be positioned nearest to a combustor bulkhead and may be associated with a first row of heat shield panels of a combustor. According to one embodiment, panels 2051-n may receive airflow to cool the surface of each panel. According to an exemplary embodiment, and as will be described in more detail below, cooling airflow for panels 2051-n may be provided by way of cooling openings in a combustor shell and from openings between one or more panels. By way of example, cooling air for panel 2052 may be emitted from an opening in heat shield 200 between trailing edge 208 of panel 2051 and leading edge 210 of panel 2052. Similarly, cooling air for panel 2053 may be emitted from an opening in heat shield 200 between trailing edge 211 of panel 2052 and leading edge 212 of panel 2053. In a similar fashion, cooling air for panel 2054 may be emitted from an opening in heat shield 200 between trailing edge 213 of panel 2053 and leading edge 214 of panel 2054. References to openings between leading and trailing edges of panels may related to one or more gaps, machined structures or pathways relative to panels of heat shield 200. Although referenced as heat shield 200, it should be appreciated that panels 2051-n may each be a heat shield.
[0049] Panel 205₂ includes dilution holes shown as 220 and panel 205₁ includes dilution holes shown as 230. Dilution holes 220 and 230 are openings in surface 206 of the panels 205₂ and 205₁, respectively. The dilution holes can provide airflow for combustor chamber. According to one embodiment, effusion holes are provided in heat shield 200 in one or more locations to restore disruption of cooling airflow across the surface of panels 205₁. The effusion holes may also provide cooling to hot spots or regions of the panels that can experience distress and wear to the hot gas environment.

[0050] According to one embodiment, panels 205₁,… include one or more effusion holes downstream of dilution holes, such as dilution holes 220 and 230. The one or more effusion holes are configured to restore cooling airflow to the surface of the panel structure downstream from dilution hole. According to another embodiment, effusion holes may be provided in other and/or additional rows of heat shield 200 for the second and third rows of panels 205₁.

[0051] FIG. 2A shows one or more configurations of effusion hole clusters according to an exemplary embodiment. Panel 205₂ includes cluster 225 of effusion holes 226 downstream of dilution holes 220. According to another embodiment, the trailing edge of each panel of panels 205₁,… can include effusion holes. Panel 205₂ includes effusion holes 227 along trailing edge 211. According to one embodiment, effusion holes 226 and effusion holes 227 can restore cooling airflow for surface 206 of panel 205₂ and/or downstream of panel 205₁, to restore cooling flow disrupted by dilution holes 220. Panel 205₃ includes clusters 240 of effusion holes 245 downstream of dilution holes 230. Panel 205₁ includes effusion holes 235 in cluster 222 along trailing edge 213. According to one embodiment, effusion holes 245 and effusion holes 246 can restore cooling flow for surface 206 of panel 205₃ that has been disrupted by dilution holes 230. The location, amount, and configuration of effusion holes 226, 227, 235 and 245 in FIG. 2A is exemplary. As will be discussed in FIG. 2B, effusion holes may be placed in a number of locations along panels 205₁,….

[0052] According to one embodiment, effusion holes 226, 227, 235 and 245 may be formed or shaped to direct airflow out of panels 205₁,… in a particular direction or directions. By way of example, effusion holes 226, 227, 235 and 245 of panels 205₁,… may be trumpet or cone shaped. Similarly, effusion holes 226, 227, 235 and 245 of panels 205₁,… may be arranged at similar or different penetration/exit angles to control the direction or airflow exiting effusion holes 226, 227, 235 and 245. In certain embodiments, heat shield 200 may include a panel, such as panel 205ₙ, that includes dilution holes 255 without effusion holes.

[0053] Referring now to FIG. 2B, a graphical representation is provided for a configuration of a heat shield panel according to one or more embodiments. Heat shield 260 includes one or more exemplary regions, such as regions 265 and 266, for placement of one or more effusion holes. Regions 265 and 266 are down stream of dilution holes 225 and 230, respectively. Effusion holes in regions 265 and 266 may be configured to receive cooling airflow from holes in a combustor shell and passages or space between a combustor shell and heat shield panels.

[0054] FIG. 3 depicts a cross-sectional representation of a heat shield configuration according to one or more embodiments. In one embodiment, a heat shield arrangement for a gas turbine engine includes a plurality of panels, or rows of panels that line a combustor. The panels may line inner and/or outer structures of the combustor. FIG. 3 depicts leading panel 301, second panel 302, and third panel 303. According to one embodiment, one or more of panels 301, 302, and 303 are configured to allow for cooling flow to be provided to hot-side of the panels and to allow for restoration of cooling flow to a hot-side of the panels when disrupted. Panels 301, 302, and 303 are shown relative to a combustor structure 305 (e.g., combustor shell, support structure, etc.).

[0055] According to one embodiment, combustor structure 305 includes one or more impingement holes to provide cooling to the back side of panels 301, 302, and 303. The impingement holes may also provide cooling airflow for the hot-side or panels 301, 302, and 303. In addition, the impingement holes may provide airflow for effusion holes of panels 301, 302, and 303. Airflow may be provided to the surface of a panel, such as hot side 304 of panel 302. By way of example, in certain embodiments, combustor structure 305 includes opening 306 to provide airflow 307. Airflow 307 may be emitted between panels 301 and 302 to cool the hot side 304. Airflow provided by the impingement holes may supply cooling air to gaps between panels and to effusion holes of panels 301, 302, and 303.

[0056] Combustor structure 305 may also include one or more structures 310 to provide dilution airflow 312 via dilution hole 311 in panel 302. Dilution airflow 312 can disrupt cooling airflow 307 from providing a cooling film downstream of dilution hole 311. According to one embodiment, panels, such as panel 302 may include one or more effusion holes, such as effusion holes 330. Effusion holes 330 are down stream of dilution hole 311 and provide cooling air 331 to regions of panel 302 on the hot side where the cooling has been disrupted. Cooling air 331 may provide an air film to hot side 304. In certain embodiments, cooling air 331 may be provided by openings in combustor structure, such as opening 306 and opening 325. Panel 302 may similarly include one or more effusion holes, shown as 335 at or near the trailing edge of panel 302 to provide a cooling film to the surface of panel 302 in areas that may not receive adequate cooling and/or regions that may be susceptible to distress.

[0057] According to another embodiment, effusion holes may be employed in a plurality of heat shield panels. Airflow may be provided to the surface of a panel, such as hot side 336 of panel 303. By way of example, in certain embodiments, combustor structure 305 includes opening 325 to provide airflow 326.
may be emitted between panels 302 and 303 to cool the hot side 336. Combustor structure 305 may also include structure 315 to provide dilution air 317 via dilution hole 316 in panel 303. Dilution air 317 can disrupt cooling air 326 from providing a cooling film downstream of dilution hole 316. According to one embodiment, panel 303 may include one or more effusion holes, such as effusion holes 340 to provide cooling air to regions of panel 303 cooling film provided by airflow 326 has been disrupted. [0058] In one embodiment, impingement holes of combustor structure 305 may be provided in one or more locations of the combustor structure shell. According to one embodiment, combustor structure 305 includes openings, such as openings 306 and 325. Openings 306 and 325 provide airflow for cooling the backside of panels 301, 302, and 303. In addition, openings in combustor structure 305, such as openings 306 and 325, provide airflow for one or more effusion holes of panels 301, 302, and 303. In certain embodiments, openings or impingement holes, such as openings 306 and 325, in combustor structure 305 provide airflow upstream and downstream of the impingement hole. By way of example, opening 325 may provide airflow 326 which provides upstream airflow 327a and downstream airflow 327b. At least a portion of upstream airflow 327a may merge with airflow 307 to provide cooling airflow for hot side 304. In certain embodiments, upstream airflow 327a may exit one or more effusion holes 330 of panel 302 as airflow 331. Downstream airflow 327b may provide cooling airflow for hot side of panel 303. Impingement holes in combustor structure 305 may be placed in one or more locations. An exemplary region of combustor structure 305 that may include impingement holes is shown as 328. Impingement holes in combustor structure 305 may collocated with effusion holes 330 and/or located downstream of dilution hole 311. [0059] FIG. 4 depicts a graphical representation of a combustor configuration according to one or more embodiments. Combustor 400 is shown as a partial representation of an annular structure. Combustor 400 includes outer diameter structure 401, inner diameter structure 402. According to one embodiment, a heat shield mounted to surface 402 may receive cooling airflow 410. According to one embodiment, inner diameter structure 402 includes dilution hole 405. Dilution hole 405 may provide airflow 411 to the combustor cavity. Airflow 411 may disrupt cooling airflow 410, as shown by 415. According to one embodiment, one or more effusion holes 420 may be positioned downstream of dilution hole 405, such as in areas 425. Effusion holes 420 may provide cooling airflow 426 to restore the film cooling downstream of dilution hole 405. According to one embodiment, effusion holes may be angled as shown as 430 to provide cooling airflow in one or more directions downstream of dilution hole 405. By way of example, at least one of the opening and or effusion hole structure itself of effusions holes 420 may be angled such that the resulting airflow 426 and 430 exit to one or more directions to provide a cooling film to surface 403. In addition the angle of airflow 426 and 430 may be associated with and/or based on cooling airflow 435 that continues past dilution hole 405. [0060] While this disclosure has been particularly shown and described with references to exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the claimed embodiments. The following clauses set out features of the present disclosure which may not presently be claimed but which may form basis for future amendments and/or a divisional application.

1. A heat shield for a combustor of a gas turbine engine, the heat shield comprising:

   a panel structure having a surface configured to face a combustor cavity, the surface of the panel structure configured to receive cooling airflow; a dilution hole in the surface of the panel structure, the dilution hole to provide airflow for the combustor cavity; and one or more effusion holes in the panel structure, wherein the one or more effusion holes are downstream of the dilution hole, wherein the one or more effusion holes are configured to restore cooling airflow to the surface of the panel structure downstream from dilution hole.

2. The heat shield of clause 1, wherein the panel structure is configured to be mounted downstream from a second panel structure, the second panel structure arranged to provide a cooling air film to the surface.

3. The heat shield of clause 1, wherein the one or more effusion holes are located in one or more rows, and wherein each row includes one or more effusion holes.

4. The heat shield of clause 1, wherein the one or more effusion holes are located in one or more regions following the dilution hole.

5. The heat shield of clause 1, wherein the one or more effusion holes are formed with at least one of a trumpet and cone shape.

6. The heat shield of clause 1, wherein the one or more effusion holes include at least one pair of effusions holes angled towards one another.

7. The heat shield of clause 1, wherein the one or more effusion holes are formed with openings smaller than an opening of the dilution hole.

8. The heat shield of clause 1, further comprising one or more effusion holes along a trailing edge of the panel structure and downstream of the dilution hole.

9. A combustor of a gas turbine engine, the combustor comprising:
a combustor structure including a combustor cavity; and
one or more panels lining the combustor shell structure, wherein each panel is configured to include
a panel structure having a surface configured to face the combustor cavity, the surface of the panel structure configured to receive cooling airflow,
a dilution hole in the surface of the panel structure, the dilution hole to provide airflow for the combustor cavity; and
one or more effusion holes downstream of the dilution hole, wherein the one or more effusion holes are configured to restore cooling airflow to the surface of the panel structure downstream from dilution hole.

10. The combustor of clause 9, wherein the combustor structure is an annular structure including one or more heat shield panels mounted to an inner diameter structure and outer diameter structure of the annular structure.

11. The combustor of clause 9, wherein the panel structure is configured to be mounted downstream from a second panel structure, the second panel structure arranged to provide a cooling air film to the surface.

12. The combustor of clause 9, wherein the one or more effusion holes are located in one or more rows, and wherein each row includes one or more effusion holes.

13. The combustor of clause 9, wherein the one or more effusion holes are located in one or more regions following the dilution hole.

14. The combustor of clause 9, wherein the one or more effusion holes are formed with at least one of a trumpet and cone shape.

15. The combustor of clause 9, wherein the one or more effusion holes include at least one pair of effusion holes angled towards one another.

16. The combustor of clause 9, wherein the one or more effusion holes are formed with openings smaller than an opening of the dilution hole.

17. The combustor of clause 9, further comprising one or more effusion holes along a trailing edge of the panel structure and downstream of the dilution hole.

18. The combustor of clause 9, wherein the one or more panels line second and third rows of the combustor shell structure.

Claims

1. A heat shield (200) for a combustor (105; 400) of a gas turbine engine (100), the heat shield comprising:
   a panel structure having a surface (206) configured to face a combustor cavity (120), the surface of the panel structure configured to receive cooling airflow;
a dilution hole (220; 230; 255; 311; 316; 405) in the surface of the panel structure, the dilution hole to provide airflow for the combustor cavity; and
one or more effusion holes (226; 227; 235; 245; 330; 335; 340; 420) in the panel structure, wherein the one or more effusion holes are downstream of the dilution hole, wherein the one or more effusion holes are configured to restore cooling airflow to the surface of the panel structure downstream from the dilution hole.

2. The heat shield (200) of claim 1, wherein the panel structure is configured to be mounted downstream from a second panel structure, the second panel structure arranged to provide a cooling air film to the surface.

3. The heat shield (200) of claim 1 or 2, wherein the one or more effusion holes (245) are located in one or more rows, and wherein each row includes one or more effusion holes.

4. The heat shield (200) of claim 1, 2 or 3, wherein the one or more effusion holes (226; 227; 235; 245; 330; 335; 340; 420) are located in one or more regions (265; 266) following the dilution hole (220; 230; 255; 311; 316; 405).

5. The heat shield (200) of any preceding claim, wherein the one or more effusion holes (226; 227; 235; 245; 330; 335; 340; 420) are formed with at least one of a trumpet and cone shape.

6. The heat shield (200) of any preceding claim, wherein the one or more effusion holes (226; 227; 235; 245; 330; 335; 340; 420) include at least one pair of effusion holes angled towards one another.

7. The heat shield (200) of any preceding claim, wherein the one or more effusion holes (226; 227; 235; 245; 330; 335; 340; 420) are formed with openings smaller than an opening of the dilution hole.

8. The heat shield (200) of any preceding claim, further comprising one or more effusion holes (227; 235; 330; 335; 340; 420) along a trailing edge (211, 213) of the panel structure and downstream of the dilution hole (220; 230; 255; 311; 316; 405).

9. A combustor (105; 400) of a gas turbine engine, the combustor comprising:
a combustor structure (305) including a combustor cavity (120); and
one or more panels lining the combustor shell structure, wherein each panel is a heat shield (200) according to any preceding claim.

10. The combustor (105; 400) of claim 9, wherein the combustor structure (305) is an annular structure (110) including one or more heat shield panels mounted to an inner diameter structure and outer diameter structure of the annular structure.

11. The combustor (105; 400) of claim 9 or 10, wherein the one or more panels line second and third rows of the combustor shell structure.
### DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
<th>Relevant to claim</th>
<th>CLASSIFICATION OF THE APPLICATION (IPC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>* page 2, paragraph 30 - page 3, paragraph 41 *</td>
<td>5,6</td>
<td>F23R3/06</td>
</tr>
<tr>
<td></td>
<td>* figures 2-4 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>* page 9, paragraph 46 - paragraph 48 *</td>
<td>5,6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* page 12, paragraph 55 - paragraph 59 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* page 15, paragraph 65 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* page 16, paragraph 68 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* figures 2-4,7,9 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* page 2, paragraph 21 - page 3, paragraph 32 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* figures 2-6 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* page 8, paragraph 44 - paragraph 46 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* page 11, paragraph 53 - page 13, paragraph 62 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* figures 22-4,8 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* page 2, paragraph 27 - page 4, paragraph 41 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* figures 1,3-5 *</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The present search report has been drawn up for all claims

---

**Place of search**: Munich  
**Date of completion of the search**: 30 June 2016  
**Examiner**: Gavriliiu, Costin

---

**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
- **B**: 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
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 30-06-2016. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 2005034399 A1</td>
<td>17-02-2005</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>WO 2014197045 A2</td>
<td>11-12-2014</td>
<td>EP 2971668 A2</td>
<td>20-01-2016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2016025342 A1</td>
<td>28-01-2016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 2014197045 A2</td>
<td>11-12-2014</td>
</tr>
<tr>
<td>US 2011023495 A1</td>
<td>03-02-2011</td>
<td>EP 2280225 A2</td>
<td>02-02-2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2011023495 A1</td>
<td>03-02-2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2016040879 A1</td>
<td>11-02-2016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 2014160299 A1</td>
<td>02-10-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2013340437 A1</td>
<td>26-12-2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 2013192540 A1</td>
<td>27-12-2013</td>
</tr>
</tbody>
</table>

For more details about this annex: see Official Journal of the European Patent Office, No. 12/82.