



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
26.07.2017 Bulletin 2017/30

(51) Int Cl.:
F23R 3/00 (2006.01) F23R 3/60 (2006.01)

(21) Application number: **16205818.4**

(22) Date of filing: **21.12.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(72) Inventors:
• **Tentorio, Luca**
Derby, Derbyshire DE24 8BJ (GB)
• **Huang, Hua Wei**
Derby, Derbyshire DE24 8BJ (GB)
• **Muldal, Carl**
Derby, Derbyshire DE24 8BJ (GB)

(30) Priority: **15.01.2016 GB 201600760**

(74) Representative: **Rolls-Royce plc**
Intellectual Property Dept SinA-48
PO Box 31
Derby DE24 8BJ (GB)

(71) Applicant: **Rolls-Royce plc**
London SW1E 6AT (GB)

(54) **GAS TURBINE COMBUSTION CHAMBER ARRANGEMENT**

(57) A combustion chamber arrangement comprising an outer annular wall (50) and an inner annular wall (52) spaced from the outer annular wall (50). The inner annular wall (52) comprising a plurality of tiles (48A, 52A). At least one of the tiles (48A, 52A) is secured to the outer annular wall (50) by at least one stud (66) and a cooperating nut (78). Each stud (66) comprises a head (68) and a threaded portion (70) extending from the head (68). The threaded portion (70) of each stud (66) extends through an aperture (64) in the tile (48A, 52A) and an

aperture (80) in the outer annular wall (50). The head (68) comprises a plurality of spacers (72) to space the head (68) from an inner surface (43) of the tile (48A, 52A). An associated washer (76) either has an aperture extending radially therethrough or a slot extending radially along one of the surfaces of the washer (76) to supply coolant over the stud (66) or the space between the inner annular wall (52) and the outer annular wall (50) is arranged to supply coolant over the stud (66).

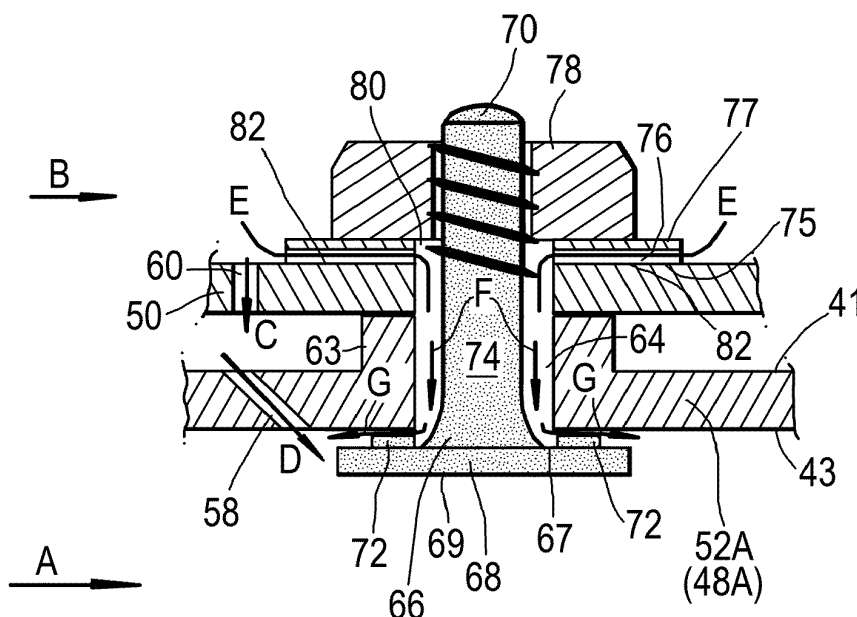


Fig.6

Description

[0001] The present disclosure concerns a combustion chamber arrangement and in particular to a dual wall combustion chamber arrangement including an inner wall comprising a plurality of tiles.

[0002] One known combustion chamber arrangement is a dual wall combustion chamber arrangement including an outer annular wall and an inner annular wall in which the inner annular wall comprises a plurality of combustion chamber tiles. The combustion chamber tiles have studs which are formed integrally with the combustion chamber tile during the manufacturing process, e.g. casting. Each stud has a threaded portion which extends through a corresponding aperture in the outer annular wall and a corresponding washer and nut are located on the stud to secure the tile to the outer annular wall. The combustion chamber tiles of the inner annular wall protect the outer annular wall from hot combustion gases.

[0003] The ends of the studs adjacent to each combustion chamber tile are exposed to the hot combustion gases due to thermal conduction from the inner surfaces of the combustion chamber tile.

[0004] The studs of the combustion chamber tiles may be cooled by directing coolant through impingement cooling apertures in the outer wall at the base of the studs. The studs of the combustion chamber tiles may also be cooled by providing effusion cooling apertures through the combustion chamber tiles to provide a film of coolant on the hot side of the combustion chamber tiles and on the hot side of the combustion chamber tile adjacent and over the ends of the studs.

[0005] If the combustion chamber tiles are manufactured by casting, it is difficult to control the position of the integral studs on the combustion chamber tiles. Furthermore, it is difficult to cool the hot side of the combustion chamber tiles in the vicinity of the studs due to the difficulty in laser drilling the effusion cooling apertures. Laser drilling the effusion cooling apertures involves drilling the apertures from the hot side of the combustion chamber tile and thus the laser beam will strike and damage any structure in the path of the laser beam at the cold side of the combustion chamber tile. If a stud is struck by the laser beam it will damage the stud and may cause the stud to fail in operation. Thus, this may result in the use of different patterns of effusion cooling apertures at different regions of the combustion chamber tiles, e.g. the effusion cooling apertures are angled at different angles in the different regions, rather than a single uniform pattern of effusion cooling apertures in the combustion chamber tiles. In order to avoid damage to the studs there is a zone around each stud where no cooling apertures are laser drilled. If the combustion chamber tiles are manufactured by additive layer manufacturing, e.g. laser powder bed, then either a large number of combustion chamber tiles may be built vertically in parallel at one time or a much smaller number of combustion chamber tiles may be built horizontally in parallel at one time. The former

method maximises the number of combustion chamber tiles produced at one time and hence minimises the cost per combustion chamber tile but the studs do not have acceptable quality. The latter method produces studs with acceptable quality but the cost per combustion chamber tile is much higher than the former method.

[0006] According to a first aspect of the present disclosure there is provided a combustion chamber arrangement comprising an outer annular wall and an inner annular wall spaced from the outer annular wall, the inner annular wall comprising a plurality of tiles, at least one of the tiles being secured to the outer annular wall by at least one stud and a cooperating nut, the at least one stud comprising a head and a threaded portion extending from the head, the threaded portion of the at least one stud extending through an aperture in the at least one tile and an aperture in the outer annular wall, wherein the head comprising a plurality of spacers to space the head from an inner surface of the at least one tile, the spacers being circumferentially spaced around the head of the stud, the head, the threaded portion and the spacers of the at least one stud being integral.

[0007] The at least one tile may have a plurality of studs, each stud having a cooperating nut, each stud comprising a head and a threaded portion extending from the head, the threaded portion of each stud extending through a respective aperture in the at least one tile and a respective aperture in the outer annular wall, wherein the head of each stud comprising a plurality of spacers to space the head from the inner surface of the at least one tile, the spacers being circumferentially spaced around the head of each stud, the head, the threaded portion and the spacers of each stud being integral.

[0008] Each tile may be secured to the outer annular wall by at least one stud and a cooperating nut, the at least one stud of each tile comprising a head and a threaded portion extending from the head, the threaded portion of the at least one stud extending through an aperture in the at least one tile and an aperture in the outer annular wall, wherein the head of the at least one stud of each tile comprising a plurality of spacers to space the head from the inner surface of the respective tile, the spacers being circumferentially spaced around the head of the stud of each tile, the head, the threaded portion and the spacers of the at least one stud of each tile being integral.

[0009] Each tile may have a plurality of studs, each stud having a cooperating nut, each stud comprising a head and a threaded portion extending from the head, the threaded portion of each stud extending through a respective aperture in the at least one tile and a respective aperture in the outer annular wall, wherein the head of each stud comprising a plurality of spacers to space the head from the inner surface of the at least one tile, the spacers being circumferentially spaced around the head of each stud, the head, the threaded portion and the spacers of each stud being integral.

[0010] The head of the at least one stud or the head

of each stud may locate in a corresponding recess in the tile and the plurality of spacers space the head from the inner surface of the recess of the tile.

[0011] The surface of the head of the stud remote from the threaded portion may be arranged flush with the inner surface of the tile.

[0012] The outer surface of the recess of the tile may abut the inner surface of the outer annular wall. The outer surface of the recess of the tile may be spaced from the inner surface of the outer annular wall.

[0013] The spacers may be cylindrical in cross-section or the spacers may be rectangular in cross-section.

[0014] Two of the sides of each rectangular cross-section spacers may be arranged parallel to corresponding sides of the other rectangular cross-section spacers.

[0015] Two of the sides of each spacer may extend radially with respect to the stud to define a plurality of radially extending passages. There may be five spacers.

[0016] A second spacer may be angularly spaced apart from a first spacer by a first angle, a third spacer may be angularly spaced apart from the second spacer by a second angle, a fourth spacer may be angularly spaced apart from the third spacer by a third angle, a fifth spacer may be angularly spaced apart from the fourth spacer by a fourth angle and the first spacer may be angularly spaced apart from the fifth spacer by a fifth angle. The first angle may be greater than the second angle, the second angle is less than the third angle, the third angle is equal to the fourth angle, the fifth angle is less than the fourth angle and the first angle is greater than the fifth angle. The middle of the fourth spacer and the middle of the first angle may be arranged diametrically opposite each other. The middle of the fourth spacer and the middle of the first angle may be arranged parallel to the axis of the annular outer wall. The middle of the first angle may be arranged axially upstream of the middle of the fourth spacer.

[0017] The spacers may be arcuate in cross-section and each spacer comprises a convex surface and a concave surface. There may be six spacers. A second spacer may be angularly spaced apart from a first spacer by a first angle, a third spacer may be angularly spaced apart from the second spacer by a second angle, a fourth spacer may be angularly spaced apart from the third spacer by a third angle, a fifth spacer may be angularly spaced apart from the fourth spacer by a fourth angle, a sixth spacer may be angularly spaced apart from the fifth spacer by a fifth angle and the first spacer may be angularly spaced apart from the sixth spacer by a sixth angle. The first angle may be greater than the second angle, the second angle is less than the third angle, the third angle is less than the fourth angle, the fifth angle is less than the fourth angle, the sixth angle is less than the fifth angle and the first angle is greater than the sixth angle. The middle of the first angle and the middle of the fourth angle may be arranged diametrically opposite each other. The middle of the first angle and the middle of the fourth angle may be arranged parallel to the axis of the annular outer

wall. The middle of the first angle may be arranged axially upstream of the middle of the fourth angle.

[0018] The concave surface of the first spacer may face the concave surface of the second spacer, the convex surface of the second spacer faces the concave surface of the third spacer, the convex surface of the third spacer faces the convex surface of the fourth spacer, the concave surface of the fourth spacer faces the concave surface of the fifth spacer, the convex surface of the fifth spacer faces the convex surface of the sixth spacer and the concave surface of the sixth spacer faces the convex surface of the first spacer.

[0019] There may be an even number of spacers and two adjacent spacers at a first radial side of the head may be arranged further circumferentially apart than two adjacent spacers at a second opposite radial side of the head

[0020] There may be an odd number of spacers and the middle of a spacer at a first radial side of the head and the middle of an angle between two adjacent spacers at a second opposite radial side of the head may be arranged diametrically opposite each other.

[0021] The spacers may be equi-circumferentially spaced around the head of the stud. The at least one stud may have a fillet between the head and threaded portion. The spacers do not overlap the fillet. The spacers may be radially spaced from the fillet.

[0022] Each stud may have a cooperating washer, the washer having at least one aperture extending radially there-through or the washer having at least one slot extending radially along one of the surfaces of the washer to supply coolant over the at least one stud.

[0023] The at least one washer may comprise a plurality of slots extending radially along an inner surface of the washer.

[0024] The at least one washer may comprise a plurality of slots extending radially along an outer surface of the washer.

[0025] The at least one washer may comprise a plurality of slots extending radially along an inner surface of the washer and a plurality of slots extending radially along an outer surface of the washer.

[0026] The tile may have at least one boss to space the tile from the annular outer annular wall, the at least one aperture in the tile extending through the at least one boss, and the boss having at least one cooling aperture extending there-through to supply coolant over the stud.

[0027] The at least one tile may have effusion cooling apertures extending there-through from the outer surface to the inner surface of the tile. The effusion cooling apertures may be arranged at an acute angle to the inner surface of the at least one tile.

[0028] The effusion cooling apertures may be arranged at an angle of 20° to 90° to the inner surface of the at least one tile. The effusion cooling apertures may be arranged at an angle of 20° to 30° to the inner surface of the at least one tile.

[0029] The at least one tile may be manufactured by

casting or additive layer manufacturing, e.g. powder bed laser deposition, direct laser deposition, selective laser sintering, selective laser melting etc. The at least one tile may comprise a nickel based superalloy, a cobalt based superalloy or an iron based superalloy.

[0030] The at least one stud may be manufactured by additive layer manufacturing, e.g. powder bed laser deposition, direct laser deposition, selective laser sintering, selective laser melting etc. The at least one stud may comprise a nickel based superalloy, a cobalt based superalloy or an iron based superalloy.

[0031] The at least one stud may comprise a different material to the at least one tile and the at least one stud comprises a material with higher temperature capability than the material of the tile. The at least one stud and the at least one tile may comprises different superalloys. The at least one stud and the at least one tile may comprises different nickel based superalloys.

[0032] The combustion chamber may be an annular combustion chamber or a tubular combustion chamber.

[0033] The combustion chamber may be a gas turbine engine combustion chamber.

[0034] The skilled person will appreciate that except where mutually exclusive, a feature described in relation to any one of the above aspects of the invention may be applied mutatis mutandis to any other aspect of the invention.

[0035] Embodiments of the invention will now be described by way of example only, with reference to the Figures, in which:

Figure 1 is partially cut away view of a turbofan gas turbine engine having a combustion chamber arrangement according to the present disclosure.

Figure 2 is an enlarged cross-sectional view of a combustion chamber arrangement according to the present disclosure.

Figure 3 is a perspective view of a combustion chamber tile of the combustion chamber arrangement shown in Figure 2.

Figure 4 is a cross-sectional view of a threaded stud of the combustion chamber arrangement shown in Figure 2.

Figure 5 is a perspective view of a threaded stud of the combustion chamber arrangement shown in Figure 2.

Figure 6 is an enlarged cross-sectional view through a threaded stud of the assembled combustion chamber arrangement according to the present disclosure.

Figure 7 is an enlarged cross-sectional view through an alternative threaded stud of the assembled com-

bustion chamber arrangement according to the present disclosure.

Figure 8 is an enlarged cross-sectional view through a further threaded stud of the assembled combustion chamber arrangement according to the present disclosure.

Figure 9 is a cross-sectional view in the direction of arrows AA-AA in figure 9.

Figure 10 is an enlarged cross-sectional view through another threaded stud of the assembled combustion chamber arrangement according to the present disclosure.

Figure 11 is an enlarged cross-sectional view through another threaded stud of the assembled combustion chamber arrangement according to the present disclosure.

Figure 12 is a cross-sectional view in the direction of arrows CC-CC in figure 11.

Figure 13 is a plan view of an arrangement of the spacers on a threaded stud used in Figure 6, Figure 7, Figure 10 or Figure 11.

Figure 14 is a plan view of an alternative arrangement of the spacers on a threaded stud used in Figure 6, Figure 7, Figure 10 or Figure 11.

Figure 15 is a plan view of an arrangement of the spacers on a threaded stud used in Figure 6, Figure 7, Figure 10 or Figure 11.

Figure 16 is a plan view of an alternative arrangement of the spacers on a threaded stud used in Figure 6, Figure 7, Figure 10 or Figure 11.

Figure 17 is a plan view of an alternative arrangement of the spacers on a threaded stud used in Figure 6, Figure 7, Figure 10 or Figure 11.

[0036] With reference to Figure 1, a gas turbine engine is generally indicated at 10, having a principal and rotational axis X-X. The engine 10 comprises, in axial flow series, an air intake 11, a propulsive fan 12, an intermediate pressure compressor 13, a high-pressure compressor 14, combustion equipment 15, a high-pressure turbine 16, an intermediate pressure turbine 17, a low-pressure turbine 18 and an exhaust nozzle 19. A fan nacelle 24 generally surrounds the fan 12 and defines the intake 11 and a fan duct 23. The fan nacelle 24 is secured to the core engine by fan outlet guide vanes 25.

[0037] The gas turbine engine 10 works in the conventional manner so that air entering the intake 11 is compressed by the fan 12 to produce two air flows: a first air

flow into the intermediate pressure compressor 13 and a second air flow which passes through the bypass duct 23 to provide propulsive thrust. The intermediate pressure compressor 13 compresses the air flow directed into it before delivering that air to the high pressure compressor 14 where further compression takes place.

[0038] The compressed air exhausted from the high-pressure compressor 14 is directed into the combustion equipment 15 where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through, and thereby drive the high, intermediate and low-pressure turbines 16, 17, 18 before being exhausted through the nozzle 19 to provide additional propulsive thrust. The high 16, intermediate 17 and low 18 pressure turbines drive respectively the high pressure compressor 14, the intermediate pressure compressor 13 and the fan 12, each by suitable interconnecting shaft 20, 21 and 22 respectively.

[0039] The combustion chamber 15, as shown more clearly in figure 2, is an annular combustion chamber and comprises a radially inner annular wall structure 40, a radially outer annular wall structure 42 and an upstream end wall structure 44. The radially inner annular wall structure 40 comprises a first annular wall 46 and a second annular wall 48. The radially outer annular wall structure 42 comprises a third annular wall 50 and a fourth annular wall 52. The second annular wall 48 is spaced radially from and is arranged radially around the first annular wall 46 and the first annular wall 46 supports the second annular wall 48. The fourth annular wall 52 is spaced radially from and is arranged radially within the third annular wall 50 and the third annular wall 50 supports the fourth annular wall 52. The upstream end of the first annular wall 46 is secured to the upstream end wall structure 44 and the upstream end of the third annular wall 50 is secured to the upstream end wall structure 44. The upstream end wall structure 44 has a plurality of circumferentially spaced apertures 54 and each aperture 54 has a respective one of a plurality of fuel injectors 56 located therein. The fuel injectors 56 are arranged to supply fuel into the annular combustion chamber 15 during operation of the gas turbine engine 10.

[0040] The second annular wall 48 comprises a plurality of rows of combustion chamber tiles 48A and 48B and the fourth annular wall 52 comprises a plurality of rows of combustion chamber tiles 52A and 52B. The combustion chamber tiles 48A and 48B are secured onto the first annular wall 46 by threaded studs, washers and nuts and the combustion chamber tiles 52A and 52B are secured onto the third annular wall 50 by threaded studs, washers and nuts.

[0041] Each of the combustion chamber tiles 48A, 48B, 52A and 52B has a first surface 41 and a second surface 43, as shown in figure 3. The first surface 41 of each combustion chamber tile 48A, 48B, 52A, 52B is an outer surface facing the respective outer annular wall 46 and 50 and the second surface 43 of each combustion chamber tile 48A, 48B, 52A, 52B is an inner surface facing

away from the respective outer annular wall 46 and 50.

[0042] The combustion chamber tiles 48A, 48B, 52A and 52B are for annular combustion chamber wall 40 and 42 and each combustion chamber tile 48A, 48B, 52A and 52B has effusion cooling apertures 58, as shown in figure 3. The effusion cooling apertures 58 extend through the combustion chamber tiles 48A, 48B, 52A, 52B from the first surface 41 to the second surface 43. The effusion cooling apertures 58 are arranged in axially spaced rows and the effusion cooling apertures 58 in each row are circumferentially spaced apart. The effusion cooling apertures 58 in each row are offset circumferentially from the effusion cooling apertures 58 in each adjacent row. The effusion cooling apertures 58 are arranged at an acute angle to the second surface 43 of the combustion chamber tiles 48A, 48B, 52A, 52B. The effusion cooling apertures 58 may be arranged at an angle of 20° to 90° to the second surface 43 of the combustion chamber tiles 48A, 48B, 52A, 52B. The effusion cooling apertures 58 are arranged for example at an angle of 20° to 30° to the second surface 43 of the combustion chamber tiles 48A, 48B, 52A, 52B.

[0043] In addition the first annular wall 46 and the third annular wall 50 are provided with a plurality of impingement cooling apertures 60 which are arranged to direct coolant, e.g. air, onto the first surface 41 of the tiles 48A, 48B, 52A and 52B, as shown in figure 6. The impingement cooling apertures 60 are generally arranged to extend perpendicularly through the first annular wall 46 and the third annular wall 50. The impingement cooling apertures 60 are generally arranged in rows in which the impingement cooling apertures 60 are circumferentially spaced and the impingement cooling apertures 60 in axially adjacent rows are circumferentially staggered.

[0044] Each combustion chamber tile 52A, 48A is shown more clearly in Figure 3, and comprises a rail 62 which extends around the periphery of the tile 52A, 48A and extends from the first surface 41 of the tile 52A, 48A towards the third annular wall 50 or first annular wall 46 respectively. The rail 62 spaces the tile 52A, 48A from the third annular wall 50 or first annular wall 46 respectively. The rail 62 comprises axially spaced circumferentially extending rail portions 62A and 62B and circumferentially spaced axially extending portions 62C and 62D which extend between and are secured to the rail portions 62A and 62B. Each combustion chamber tile 52A, 48A also has at least one mounting aperture 64 extending there-through from the first surface 41 to the second surface 43 of the combustion chamber tile 52A, 48A and in this arrangement there is a plurality of mounting apertures 64, for example four. Each combustion chamber tile 52A, 48A also has at least one boss 63 which extends from the first surface 41 of the tile 52A, 48A towards the third annular wall 50 or the first annular wall 46 respectively. Each mounting aperture 64 extends radially through a corresponding one of the bosses 63. The outer surface of each boss 63 of the combustion chamber tile 48A, 48B, 52A, 52B abuts the inner surface of the outer an-

nular wall 46 or 52 respectively.

[0045] In the combustion chamber arrangement according to the present disclosure as shown in figures 3 to 6 each of the combustion chamber tiles 52A, 52B is secured to the third annular wall 50, e.g. an outer annular wall, by at least one stud 66, a cooperating washer 76 and a cooperating nut 78 and in this arrangement there is a plurality of studs 66, a plurality of washers 76 and a plurality of nuts 78, e.g. four studs 66, four washers 76 and four nuts 78. Each stud 66 comprises a head 68 and a threaded portion 70 extending from the head 68, as shown in figures 4 and 5. The threaded portion 70 of each stud 66 extends through, e.g. radially through, a corresponding mounting aperture 64 in the respective combustion chamber tile 52A, 52B and an aligned mounting aperture 80 in the third annular wall 50. The head 68 of each stud 66 comprises a plurality of spacers 72 to space the head 68 from the second, inner, surface 43 of the associate combustion chamber tile 52A, 52B and each washer 76 has at least one aperture extending radially there-through or at least one slot extending radially along one of the surfaces 75, 77 of the washer 76, e.g. the surface 75 contacting the third annular wall 50 or the surface 77 contacting the nut 78. In this example each washer 76 has a plurality of slots 82 extending radially along the surface 75 of the washer 76 contacting the third annular wall 50. Each stud 66 has a corresponding washer 76 placed around the threaded portion 70 of the stud 66 and a corresponding nut 78 threaded onto the threaded portion 70 of the stud 66 and each stud 66 and respective nut 78 are tightened to secure the combustion chamber tile 48A, 48B, 52A, 52B onto the first wall 46 or third wall 50 respectively. Each stud 66 has a fillet 74 where the threaded portion 70 merges into the head 68.

[0046] Similarly, each of the combustion chamber tiles 48A, 48B is secured to the first annular wall 46, e.g. an outer annular wall, by at least one stud 66, a cooperating washer 76 and a cooperating nut 78 and in this arrangement there is a plurality of studs 66, a plurality of washers 76 and a plurality of nuts 78, e.g. four studs 66, four washers 76 and four nuts 78. Each stud 66 comprises a head 68 and a threaded portion 70 extending from the head 68. The threaded portion 70 of each stud 66 extends through, e.g. radially through, a corresponding mounting aperture 64 in the respective combustion chamber tile 48A, 48B and an aligned mounting aperture 80 in the third annular wall 50. The head 68 of each stud 66 comprises a plurality of spacers 72 to space the head 68 from the second, inner, surface 43 of the associated combustion chamber tile 48A, 48B and each washer 76 has at least one aperture extending radially there-through or at least one slot extending radially along one of the surfaces 75, 77 of the washer 76, e.g. the surface 75 contacting the third annular wall 50 or the surface 77 contacting the nut 78. In this example each washer 76 has a plurality of slots 82 extending radially along the surface 75 of the washer 76 contacting the third annular wall 50. Each stud 66 has a corresponding washer 76 placed around the

threaded portion 70 of the stud 66 and a corresponding nut 78 threaded onto the threaded portion of the stud 66.

[0047] It is to be noticed that in Figures 3 to 6 that the spacers 72 are circumferentially spaced around the head 68 of each stud 66 and in particular the spacers 72 are equi-circumferentially spaced around the head 68 of each stud 66. The spacers 72 are cylindrical and circular in cross-section. The spacers 72 do not overlap the fillet 74 of each stud 66 to avoid undesirable stress concentrations and damage to the stud and in this example the spacers 72 are radially spaced from the fillet 74 of each stud 66.

[0048] In operation hot combustion gases produced in the combustion chamber flow generally in the direction of arrow A within the annular combustion chamber 15. A coolant, for example air, flows in the direction of arrow B over the outer surfaces of the first annular wall 46 and the third annular wall 50. Some of the coolant, air, flows C through the impingement cooling apertures 60 to provide impingement cooling of the first surfaces 41 of the combustion chamber tiles 48A, 48B, 52A and 52B and then through the effusion cooling apertures 58 to provide a film of coolant on the second surfaces 43 of the combustion chamber tiles 48A, 48B, 52A and 52B. Further portions of the coolant flows E through the slots 82 along the surfaces 75 of the washers 76 and then turns to flow F radially through the mounting apertures 80 in the first and third annular walls 46 and 50 and then through the mounting apertures 64 in the bosses 63 and the main body of the combustion chamber tiles 48A, 48B, 52A and 52B. The coolant flows radially with respect to the annular combustion chamber 15 over the surface of the threaded portion 70 of each stud 66, then over the fillet 74 of each stud 66 and then is directed to flow over a cold surface 67 of the head 68 of each stud 66 and through the space between the head 68 of each stud 66 and the second, inner, surface 43 of the associated combustion chamber tile 48A, 48B, 52A and 52B and also between the spacers 72. Thus, the coolant cools the threaded portion 70, the spacers 72, the fillet 74 and the head 68 of each stud 66. The flow of coolant G may help form a cooling film of coolant on the second surface 43 of the combustion chamber tile 48A, 48B, 52A and 52B and over the surface of the head 68 of the stud 66. Some of the coolant flowing from effusion cooling apertures 58 over the second, inner, surface 43 of the combustion chamber tile 48A, 48B, 52A and 52B upstream of the stud 66 may flow over the cold surface 67 of the head 68 and in the space between the head 68 of each stud 66 and the second, inner, surface 43 of the associated combustion chamber tile 48A, 48B, 52A and 52B and also between the spacers 72 and around the fillet 74 and some of the coolant flowing from effusion cooling apertures 58 over the second, inner, surface 43 of the combustion chamber tile 48A, 48B, 52A and 52B upstream of the stud 66 may flow over the hot surface 69 of the head 68 of the stud 66. This provides additional cooling of the stud 66.

[0049] The boss, or each boss, 63 of the combustion

chamber tiles 52A, 48A may be replaced by a plurality of pillars arranged circumferentially around the respective mounting aperture 64 to transfer clamping loads rather than the boss 63. This would also allow coolant to flow between the pillars and then through the respective mounting aperture 64 to cool the stud 66. In this eventuality it may be possible to provide a conventional washer or a washer with the radial slots or radial apertures.

[0050] Another combustion chamber arrangement according to the present disclosure is shown in Figure 7 and it is substantially the same as that described with reference to Figures 3 to 6 and like parts are denoted by like numerals. The combustion chamber arrangement in Figure 7 differs in that each combustion chamber tile 48A, 48B, 52A, 52B has at least one boss 84 extending from the first surface 41 toward the first annular wall 46 or third annular wall 50 respectively and in this example and in this arrangement there is a plurality of bosses 84, for example four. Each combustion chamber tile 48A, 48B, 52A, 52B also has at least one recess 86 in the second surface 43 aligned with a boss 84 and in this arrangement there is a plurality of recesses 86, for example four, each one of which is aligned with a corresponding one of the bosses 84. Each boss 84 has an outer surface 88 parallel to and spaced from the first, outer, surface 41 and each recess 86 has an inner surface 90 parallel to and spaced from the second, inner, surface 43 of the combustion chamber tile 48A, 48B, 52A, 52B. Each combustion chamber tile 48A, 48B, 52A, 52B also has at least one mounting aperture 64 extending through the at least one boss 84 from the outer surface 88 of the boss 84 to the inner surface 90 of the recess 86 of the combustion chamber tile 48A, 48B, 52A, 52B and in this arrangement there is a plurality of mounting apertures 64, for example four, one extending through each boss 84 from the outer surface 88 of the boss 84 to the inner surface 90 of the corresponding recess 86 of the combustion chamber tile 48A, 48B, 52A, 52B. The outer surface 88 of each boss 84 of the combustion chamber tile 48A, 48B, 52A, 52B abuts the inner surface of the outer annular wall 46 or 52 respectively.

[0051] The head 68 of each stud 66 locates in a corresponding recess 86 in the combustion chamber tile 48A, 48B, 52A, 52B and the plurality of spacers 72 on the head 68 of each stud 66 space the head 68 from the inner surface 90 of the respective recess 86 of the combustion chamber tile 48A, 48B, 52A, 52B.

[0052] In this example the surface of the head 68 of each stud 66 remote from the threaded portion 70 is arranged flush with the inner surface 43 of the combustion chamber tile 48A, 48B, 52A, 52B. However, the surface of the head 68 of each stud 66 remote from the threaded portion 70 may be arranged so that it is not flush with the inner surface 43 of the combustion chamber tile 48A, 48B, 52A, 52B. The surface of the head 68 of each stud 66 remote from the threaded portion 70 may be arranged so that it is spaced back from the inner surface 43 of the combustion chamber tile 48A, 48B, 52A, 52B so that it

is positioned between the inner surface 90 of the recess 86 and the inner surface 43 of the combustion chamber tile 48A, 48B, 52A, 52B. The head 68 of each stud 66 and the corresponding recess 86 have matching shapes but the head 68 of the stud 66 has slightly smaller dimensions than the recess 86 so that there is a gap between the head 68 of the stud 66 and the recess 86. For example each head 68 may be circular in cross-section and the recess 86 is circular in cross-section. Each boss 84 may have a shape to match the shape of the corresponding recess 86. For example the recess 86 may be circular in cross-section and the boss 84 may be circular in cross-section. However, the boss 84 may have a different shape to the corresponding recess 86, for example the boss may be rectangular or square and the recess may be circular in cross-section.

[0053] In operation hot combustion gases produced in the combustion chamber flow generally in the direction of arrow A within the annular combustion chamber 15. A coolant, for example air, flows in the direction of arrow B over the outer surfaces of the first annular wall 46 and the third annular wall 50. Some of the coolant, air, flows C through the impingement cooling apertures 60 to provide impingement cooling of the first surfaces 41 of the combustion chamber tiles 48A, 48B, 52A and 52B and then through the effusion cooling apertures 58 to provide a film of coolant on the second surfaces 43 of the combustion chamber tiles 48A, 48B, 52A and 52B. Further portions of the coolant flows E through the slots 82 along the surfaces 75 of the washers 76 and then turns to flow F radially through the mounting apertures 80 in the first and third annular walls 46 and 50 and then through the mounting apertures 64 in the bosses 84 of the combustion chamber tiles 48A, 48B, 52A and 52B. The coolant flows radially with respect to the annular combustion chamber 15 over the surface of the threaded portion 70 of each stud 66, then over the fillet 74 of each stud 66 and then is directed to flow G over the head 68 of each stud 66 and through the space between the head 68 of each stud 66 and the inner surface 90 of the recess 86 of the associated combustion chamber tile 48A, 48B, 52A and 52B and also between the spacers 72. Thus, the coolant cools the threaded portion 70, the spacers 72, the fillet 74 and the head 68 of each stud 66. The coolant then turns to flow H radially with respect to the annular combustion chamber 15 through the gap between the periphery of the head 68 of the stud 66 and the side of the recess 86 and into the annular combustion chamber 15. The flow of coolant H may help form a cooling film of coolant on the second surface 43 of the combustion chamber tile 48A, 48B, 52A and 52B and over the surface of the head 68 of the stud 66.

[0054] A further combustion chamber arrangement according to the present disclosure is shown in Figures 8 and 9, but this does not show the stud. This arrangement is similar to that shown in Figure 7, but differs in that a plurality of cooling apertures 92 extend through an upstream sidewall 84A of the at least one boss 84, prefer-

ably each boss 84, to the corresponding recess 86. The cooling apertures 92 provide further coolant, air, into each recess 86 which supplements the coolant, air, flowing through the mounting apertures 80 in the first and third annular walls 46 and 50 and then through the mounting apertures 64 in the bosses 84 of the combustion chamber tiles 48A, 48B, 52A and 52B. These cooling apertures 92 may be formed by drilling, e.g. laser drilling, or during/by the additive layer manufacturing process. Alternatively, the washers 76 may be conventional washers and all the coolant, air, is supplied through the cooling apertures 92. Figure 9 also shows an arrangement of spacers 72 on the head 68 of a stud 66, which may be used in any of the embodiments of the present disclosure. The spacers 72 are circular in cross-section. The spacers 72 do not overlap the fillet 74 of the stud 66 and in this example the spacers 72 are spaced radially from the fillet 74 and the periphery of the stud 66. In this example there are four spacers 72. The head 68 of the stud 66D has a part circular peripheral edge portion 71A and a flat peripheral edge portion 71 B. The flat peripheral edge portion 71 B is arranged to cooperate with a similar flat sidewall of the recess 86 to prevent rotation of the stud 66 during tightening of the stud 66 and associated nut 78. In this example the flat sidewall is the upstream sidewall 84A of the recess 86.

[0055] Another combustion chamber arrangement according to the present disclosure is shown in Figure 10. This arrangement is similar to that shown in Figures 8 and 9, but differs in that the downstream sidewall 84B of the or each boss 84, recess 86, is angled to enable the coolant to flow onto the inner surface 43 of the combustion chamber tiles 48A, 48B, 52A and 52B. The upstream sidewall 84A is flat to prevent rotation of the bolt 66. Again the, or each, washer 76 may or may not have radial apertures or radial slots for the flow of coolant, air.

[0056] An additional combustion chamber arrangement according to the present disclosure is shown in Figures 11 and 12. This arrangement is similar to that shown in Figures 8 and 9, but differs in that the or each boss 84, recess 86, is cylindrical and the cooling apertures 92 are circumferentially spaced with respect to the axis of the mounting aperture 64 and the head 68 of the stud 66 is circular. Again the, or each, washer 76 may or may not have radial apertures or radial slots for the flow of coolant, air.

[0057] Figure 13 shows one arrangement of the spacers 72 on the head 68 of a stud 66A, which may be used in any of the embodiments of the present disclosure. In this type of stud 66A two of the sides of each spacer 72 extend radially with respect to the stud 66A to define a plurality radially extending passages 73A, 73B, 73C, 73D and 73E. In this arrangement there are five spacers 72A, 72B, 72C, 72D and 72E. A second spacer 72B is angularly spaced apart from a first spacer 72A by a first angle α_1 , a third spacer 72C is angularly spaced apart from the second spacer 72B by a second angle α_2 , a fourth spacer 72D is angularly spaced apart from the third spacer 72C

by a third angle α_3 , a fifth spacer 72E is angularly spaced apart from the fourth spacer 72D by a fourth angle α_4 and the first spacer 72A is angularly spaced apart from the fifth spacer 72E by a fifth angle α_5 . The first angle α_1 is greater than the second angle α_2 , the second angle α_2 is less than the third angle α_3 , the third angle α_3 is equal to the fourth angle α_4 , the fifth angle α_5 is less than the fourth angle α_4 and the first angle α_1 is greater than the fifth angle α_5 . The first angle α_1 is greater than the third angle α_3 . In this particular example the first angle is about 90° , the second angle is about 25° , the third angle is about 35° , the fourth angle is about 35° and the fifth angle is about 25° . It is also to be noted that the middle of the fourth spacer 72D and the middle of the first angle α_1 are arranged diametrically opposite each other. The middle of the fourth spacer 72D and the middle of the first angle α_1 are arranged parallel to the axis of the annular outer wall 46 or 50. The middle of the first angle α_1 is arranged axially upstream of the middle of the fourth spacer 72D.

[0058] Again it is to be noted that the spacers 72 are circumferentially spaced around the head 68 of the stud 66A and in particular the spacers 72 are not equi-circumferentially spaced around the head 68 of the stud 66A. The spacers 72 do not overlap the fillet 74 of the stud 66A and in this example the spacers 72 extend radially from the fillet 74 to the periphery of the stud 66A.

[0059] Figure 14 shows one arrangement of the spacers 72 on the head 68 of a stud 66B, which may be used in any of the embodiments of the present disclosure. In this type of stud 66B the spacers 72 are arcuate in cross-section and each spacer 72 comprises a concave surface and a concave surface. In this arrangement there are six spacers 72F, 72G, 72H, 72I, 72J and 72K. A second spacer 72G is angularly spaced apart from a first spacer 72F by a first angle α_6 , a third spacer 72H is angularly spaced apart from the second spacer 72G by a second angle α_7 , a fourth spacer 72I is angularly spaced apart from the third spacer 72H by a third angle α_8 , a fifth spacer 72J is angularly spaced apart from the fourth spacer 72I by a fourth angle α_9 , a sixth spacer 72K is angularly spaced apart from the fifth spacer 72J by a fifth angle α_{10} and the first spacer 72F is angularly spaced apart from the sixth spacer 72K by a sixth angle α_{11} . The first angle α_6 is greater than the second angle α_7 , the second angle α_7 is less than the third angle α_8 , the third angle α_8 is less than the fourth angle α_9 , the fifth angle α_{10} is less than the fourth angle α_9 , the sixth angle α_{11} is less than the fifth angle α_{10} and the first angle α_6 is greater than the sixth angle α_{11} . The first angle α_6 is about 50° , the second angle α_7 is about 20° , the third angle α_8 is about 45° , the fourth angle α_9 is about 55° , the fifth angle α_{10} is about 45° and the sixth angle α_{11} is about 20° . The middle of the first angle α_6 and the middle of the fourth angle α_9 are arranged diametrically opposite each other. The middle of the first angle α_6 and the middle of the fourth angle α_9 are arranged parallel to the axis of the annular outer wall 46 or 50. The middle

of the first angle α_6 is arranged axially upstream of the middle of the fourth angle α_9 .

[0060] The concave surface of the first spacer 72F faces the concave surface of the second spacer 72G, the convex surface of the second spacer 72G faces the concave surface of the third spacer 72H, the convex surface of the third spacer 72H faces the convex surface of the fourth spacer 72I, the concave surface of the fourth spacer 72I faces the concave surface of the fifth spacer 72J, the convex surface of the fifth spacer 72J faces the convex surface of the sixth spacer 72K and the concave surface of the sixth spacer 72K faces the convex surface of the first spacer 72F.

[0061] Again it is to be noted that the spacers 72 are circumferentially spaced around the head 68 of the stud 66B and in particular the spacers 72 are not equi-circumferentially spaced around the head 68 of the stud 66A. The spacers 72 do not overlap the fillet 74 of the stud 66A and in this example the spacers 72 extend radially from the fillet 74 to the periphery of the stud 66A.

[0062] Figure 15 shows the arrangement of the spacers 72 on the head 68 of a stud 66, which may be used in any of the embodiments of the present disclosure. The spacers 72 are circumferentially spaced around the head 68 of the stud 66 and in particular the spacers 72 are equi-circumferentially spaced around the head 68 of the stud 66. The spacers 72 do not overlap the fillet 74 of the stud 66 and in this example the spacers 72 are spaced radially from the fillet 74 and the periphery of the stud 66. The spacers 72 are cylindrical and circular in cross-section. In this example there are six spacers 72.

[0063] Figure 16 shows a further arrangement of spacers 72 on the head 68 of a stud 66C, which may be used in any of the embodiments of the present disclosure. The spacers 72 are rectangular, or square, in cross-section. The spacers 72 do not overlap the fillet 74 of the stud 66C and in this example the spacers 72 are spaced radially from the fillet 74 and the periphery of the stud 66C. Two of the sides of each rectangular cross-section spacer 72 are arranged parallel to corresponding sides of the other rectangular cross-section spacers 72. In this example there are four spacers 72.

[0064] Figure 17 shows a further arrangement of spacers 72 on the head 68 of a stud 66E, which may be used in any of the embodiments of the present disclosure. The spacers 72 are circular in cross-section. The spacers 72 do not overlap the fillet 74 of the stud 66 and in this example the spacers 72 are spaced radially from the fillet 74 and the periphery of the stud 66. In this example there are six spacers 72. The spacers 72 are equi-circumferentially spaced around the head 68 of the stud 66E. The head 68 of the stud 66E has a polygonal edge 71C and in this example is a hexagonal edge. The polygonal edge 71C is arranged to cooperate with a similar polygonal shaped recess 86 to prevent rotation of the stud 66E during tightening of the stud 66E and associated nut 78 or alternatively if the head 68 of the stud 66E does not locate in a recess 86 then a spanner may be used to

locate on the head 68. The studs 66A, 66B, 66 and 66C shown in Figures 11 to 13 respectively may also have a head 68 provided with a polygonal edge 71C and in this example is a hexagonal edge.

[0065] The head of the or each stud may be circular and have an Allen key socket to enable tightening of the stud and nut using an Allen Key and a spanner. Alternatively, the head of the stud may be polygonal, e.g. hexagonal, to enable tightening of the stud and nut using respective spanners or to enable the correspondingly shaped recess to prevent rotation of the stud and to enable tightening of the stud and nut using a spanner. In a further possibility, the head of the stud has one or more flat sides to cooperate with one or more flat sides of a correspondingly recess to enable tightening of the stud and nut using a spanner.

[0066] The head of the or each stud may have an even number of spacers and two adjacent spacers at a first radial side of the head may be arranged further circumferentially apart than two adjacent spacers at a second opposite radial side of the head.

[0067] The head of the or each stud may have an odd number of spacers and the middle of a spacer at a first radial side of the head and the middle of an angle between two adjacent spacers at a second opposite radial side of the head may be arranged diametrically opposite each other.

[0068] The spacers may be circumferentially spaced around the head of the, or each, stud. The spacers may be equi-circumferentially spaced around the head of the, or each, stud. The spacers are circumferentially spaced around the head of the, or each, stud with respect to the centre, or longitudinal axis, of the threaded portion of the, or each, stud, as clearly shown in the figures.

[0069] The spacers may not overlap the fillet. The spacers may be radially spaced from the fillet.

[0070] The at least one washer may comprise a plurality of slots extending radially along an inner surface of the washer. The at least one washer may comprise a plurality of slots extending radially along an outer surface of the washer. The at least one washer may comprise a plurality of slots extending radially along an inner surface of the washer and a plurality of slots extending radially along an outer surface of the washer.

[0071] The at least one tile may be manufactured by casting or additive layer manufacturing, e.g. powder bed laser deposition, direct laser deposition, selective laser sintering etc. The at least one tile may comprise a nickel based superalloy, a cobalt based superalloy or an iron based superalloy. The effusion cooling apertures are formed in the cast combustion chamber tiles by drilling, for example laser drilling. The effusion cooling apertures in the additive layer manufactured combustion chamber tiles may be formed during/by the additive layer manufacturing process or the effusion cooling aperture may be formed in the additive layer manufactured combustion chamber tiles by drilling, e.g. laser drilling.

[0072] The at least one stud may be manufactured by

additive layer manufacturing, e.g. powder bed laser deposition, direct laser deposition, selective laser sintering etc. or other suitable manufacturing technique. The at least one stud may comprise a nickel based superalloy, a cobalt based superalloy or an iron based superalloy. The head, the threaded portion and the spacers of each stud are integral, e.g. a single piece or a monolithic piece.

[0073] The at least one tile may have a plurality of studs, each stud having a cooperating washer and a cooperating nut, each stud comprising a head and a threaded portion extending from the head, the threaded portion of each stud extending through a respective aperture in the at least one tile and a respective aperture in the outer annular wall, wherein the head of each stud comprising a plurality of spacers to space the head from the inner surface of the at least one tile and each washer having at least one aperture extending radially there-through or at least one slot extending radially along one of the surfaces of the washer.

[0074] Each tile may be secured to the outer annular wall by at least one stud, a cooperating washer and a cooperating nut, the at least one stud of each tile comprising a head and a threaded portion extending from the head, the threaded portion of the at least one stud extending through an aperture in the at least one tile and an aperture in the outer annular wall, wherein the head of the at least one stud of each tile comprising a plurality of spacers to space the head from the inner surface of the respective tile and the associated washer for each tile having at least one aperture extending radially there-through or at least one slot extending radially along one of the surfaces of the washer.

[0075] Each tile may have a plurality of studs, each stud having a cooperating washer and a cooperating nut, each stud comprising a head and a threaded portion extending from the head, the threaded portion of each stud extending through a respective aperture in the at least one tile and a respective aperture in the outer annular wall, wherein the head of each stud comprising a plurality of spacers to space the head from the inner surface of the at least one tile and each washer having at least one aperture extending radially there-through or at least one slot extending radially along one of the surfaces of the washer.

[0076] The combustion chamber may be an annular combustion chamber or a tubular combustion chamber.

[0077] The combustion chamber may be a gas turbine engine combustion chamber.

[0078] An advantage of the present disclosure is that, because the studs are not integral with the combustion chamber tiles, it is possible to more easily provide a uniform pattern of effusion cooling apertures throughout the whole, or a major part of the combustion chamber tiles by drilling, e.g. laser drilling or EDM drilling, the cast combustion chamber tiles, e.g. the drilling machine does not have to be set to different drilling angles. It also reduced the cost of drilling the effusion cooling apertures. It also improves the cooling effectiveness of the effusion cooling

provided by the uniform pattern of effusion cooling apertures. Another advantage of the present disclosure is that, because the studs are not integral with the combustion chamber tiles, it enables the combustion chamber tiles to be built vertically by additive layer manufacturing in a laser powder bed at minimised cost. A further advantage is that if one or more studs are damaged on a combustion chamber tile it is easier and cheaper to replace a damaged stud, or replace damaged studs, compared to the conventional requirement to replace the entire combustion chamber tile. Additionally, the studs may be made from a different material to the combustion chamber tile, e.g. the studs may be made from a material, e.g. superalloy, which has a higher temperature capability than the combustion chamber tile, for example different superalloys, e.g. different nickel based superalloys.

[0079] It may also be possible to provide one or more conventional integral studs on one or more combustion chamber tiles.

[0080] It will be understood that the invention is not limited to the embodiments above-described and various modifications and improvements can be made without departing from the concepts described herein. Except where mutually exclusive, any of the features may be employed separately or in combination with any other features and the disclosure extends to and includes all combinations and subcombinations of one or more features described herein.

Claims

1. A combustion chamber arrangement (15) comprising an outer annular wall (46, 50) and an inner annular wall (48, 52) spaced from the outer annular wall (46, 50), the inner annular wall (48, 52) comprising a plurality of tiles (48A, 48B, 52A, 52B), at least one of the tiles (48A, 48B, 52A, 52B) being secured to the outer annular wall (46, 50) by at least one stud (66) and a cooperating nut (78), the at least one stud (66) comprising a head (68) and a threaded portion (70) extending from the head (68), the threaded portion (70) of the at least one stud (66) extending through an aperture (64) in the at least one tile (48A, 48B, 52A, 52B) and an aperture (80) in the outer annular wall (46, 50), wherein the head (68) comprising a plurality of spacers (72) to space the head (68) from an inner surface (43) of the at least one tile (48A, 48B, 52A, 52B), the spacers (72) being circumferentially spaced around the head (68) of the stud (66), the head (68), the threaded portion (70) and the spacers (72) of the at least one stud (66) being integral.
2. A combustion chamber as claimed in claim 1 wherein each tile (48A, 48B, 52A, 52B) is secured to the outer annular wall (46, 50) by at least one stud (66) and a cooperating nut (78), the at least one stud (66) of

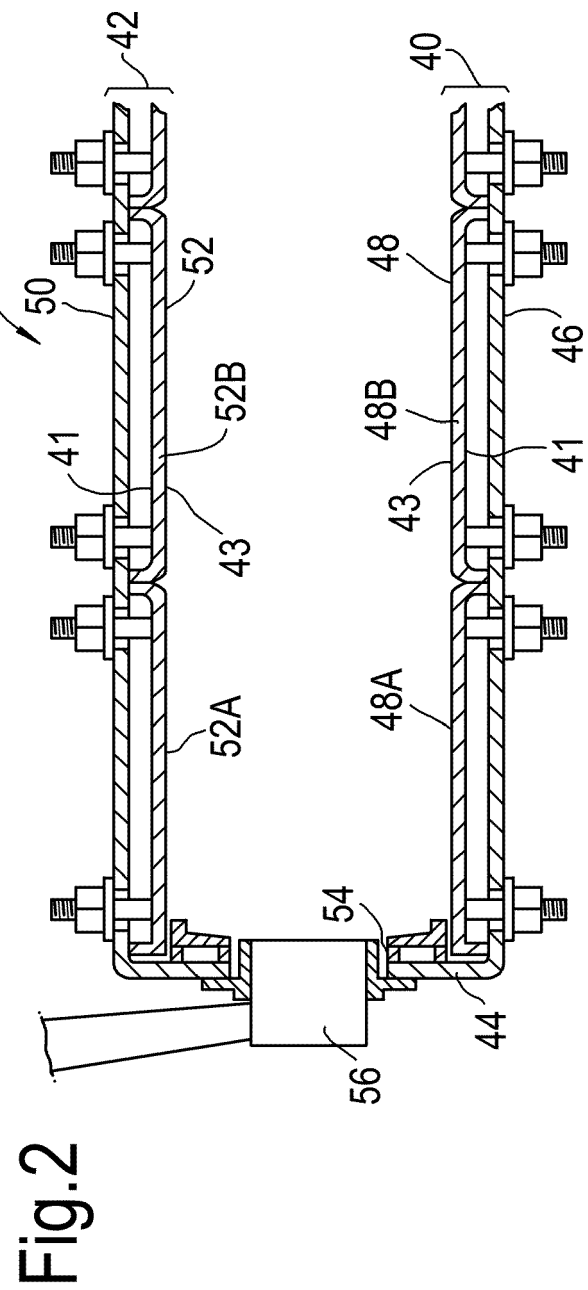
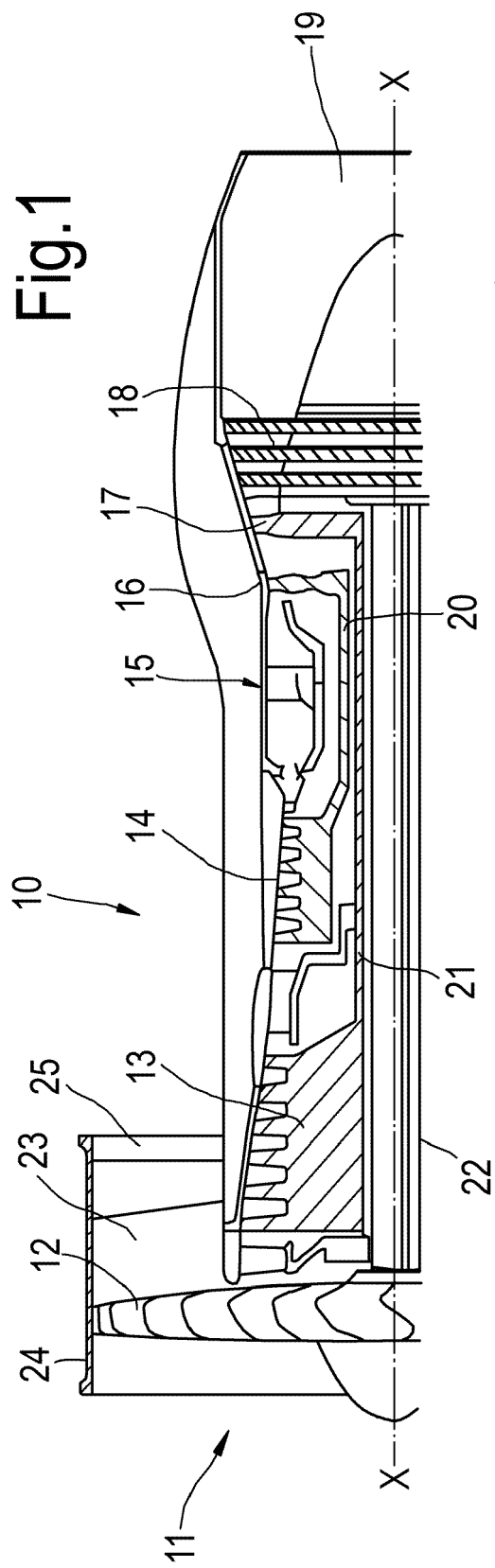
- each tile (48A, 48B, 52A, 52B) comprising a head (68) and a threaded portion (70) extending from the head (68), the threaded portion (70) of the at least one stud (66) extending through an aperture (64) in the at least one tile (48A, 48B, 52A, 52B) and an aperture (80) in the outer annular wall (46, 50), wherein the head (68) of the at least one stud (66) of each tile (48A, 48B, 52A, 52B) comprising a plurality of spacers (72) to space the head (68) from the inner surface (43) of the respective tile (48A, 48B, 52A, 52B), the spacers (72) being circumferentially spaced around the head (68) of the stud (66) of each tile (48A, 48B, 52A, 52B), the head (68), the threaded portion (70) and the spacers (72) of the at least one stud (66) of each tile (48A, 48B, 52A, 52B) being integral.
3. A combustion chamber as claimed in claim 2 wherein each tile (48A, 48B, 52A, 52B) has a plurality of studs (66), each stud (66) having a cooperating nut (78), each stud (66) comprising a head (68) and a threaded portion (70) extending from the head (68), the threaded portion (70) of each stud (66) extending through a respective aperture (64) in the at least one tile (48A, 48B, 52A, 52B) and a respective aperture (80) in the outer annular wall (46, 50), wherein the head (68) of each stud (66) comprising a plurality of spacers (72) to space the head (68) from the inner surface (43) of the at least one tile (48A, 48B, 52A, 52B), the spacers (72) being circumferentially spaced around the head (68) of each stud (66), the head (68), the threaded portion (70) and the spacers (72) of each stud (66) being integral.
 4. A combustion chamber as claimed in any of claims 1 to 3 wherein the head (68) of the at least one stud (66) or the head (68) of each stud (66) locates in a corresponding recess (86) in the tile (48A, 48B, 52A, 52B) and the plurality of spacers (72) space the head (68) from the inner surface (90) of the recess (86) of the tile (48A, 48B, 52A, 52B).
 5. A combustion chamber as claimed in claim 4 wherein the surface of the head (68) of the stud (66) remote from the threaded portion (70) is arranged flush with the inner surface (43) of the tile (48A, 48B, 52A, 52B).
 6. A combustion chamber as claimed in claim 4 or claim 5 wherein an outer surface (88) of the recess (86) of the tile (48A, 48B, 52A, 52B) abuts an inner surface of the outer annular wall (46, 50).
 7. A combustion chamber as claimed in any of claims 1 to 6 wherein the spacers (72) are cylindrical in cross-section or the spacers (72) are rectangular in cross-section.
 8. A combustion chamber as claimed in any of claims 1 to 6 wherein two of the sides of each spacer (72A, 72B, 72C, 72D, 72E) extend radially with respect to the stud (66A) to define a plurality of radially extending passages (73A, 73B, 73C, 73D, 73E).
 9. A combustion chamber as claimed in any of claims 1 to 8 wherein there are five spacers (72A, 72B, 72C, 72D, 72E), a second spacer (72B) is angularly spaced apart from a first spacer (72A) by a first angle (α_1), a third spacer (72C) is angularly spaced apart from the second spacer (72B) by a second angle (α_2), a fourth spacer (72D) is angularly spaced apart from the third spacer (72C) by a third angle (α_3), a fifth spacer (72E) is angularly spaced apart from the fourth spacer (72D) by a fourth angle (α_4), and the first spacer (72A) is angularly spaced apart from the fifth spacer (72E) by a fifth angle (α_5).
 10. A combustion chamber as claimed in claim 9 wherein the first angle (α_1) is greater than the second angle (α_2), the second angle (α_2) is less than the third angle (α_3), the third angle (α_3) is equal to the fourth angle (α_4), the fifth angle (α_5) is less than the fourth angle (α_4) and the first angle (α_1) is greater than the fifth angle (α_5).
 11. A combustion chamber as claimed in claim 9 or claim 10 wherein a middle of the fourth spacer (72D) and a middle of the first angle (α_1) are arranged diametrically opposite each other.
 12. A combustion chamber as claimed in claim 11 wherein the middle of the fourth spacer (72D) and the middle of the first angle (α_1) are arranged parallel to the axis of the annular outer wall (46, 50).
 13. A combustion chamber as claimed in any of claims 1 to 6 wherein the spacers (72F, 72G, 72H, 72I, 72J, 72K) are arcuate in cross-section and each spacer (72F, 72G, 72H, 72I, 72J, 72K) comprises a convex surface and a concave surface.
 14. A combustion chamber as claimed in claim 13 wherein there are six spacers (72F, 72G, 72H, 72I, 72J, 72K), a second spacer (72G) is angularly spaced apart from a first spacer (72F) by a first angle (α_6), a third spacer (72H) is angularly spaced apart from the second spacer (72G) by a second angle (α_7), a fourth spacer (72I) is angularly spaced apart from the third spacer (72H) by a third angle (α_8), a fifth spacer (72J) is angularly spaced apart from the fourth spacer (72I) by a fourth angle (α_9), a sixth spacer (72K) is angularly spaced apart from the fifth spacer (72J) by a fifth angle (α_{10}) and the first spacer (72F) is angularly spaced apart from the sixth spacer (72K) by a sixth angle (α_{11}).
 15. A combustion chamber as claimed in claim 14

wherein the first angle (α_6) is greater than the second angle (α_7), the second angle (α_7) is less than the third angle (α_8), the third angle (α_8) is less than the fourth angle (α_9), the fifth angle (α_{10}) is less than the fourth angle (α_9), the sixth angle (α_{11}) is less than the fifth angle (α_{10}) and the first angle (α_6) is greater than the sixth angle (α_{11}). 5

16. A combustion chamber as claimed in claim 14 or claim 15 wherein a middle of the first angle (α_6) and a middle of the fourth angle (α_9) are arranged diametrically opposite each other. 10
17. A combustion chamber as claimed in any of claims 14 to 16 wherein the concave surface of the first spacer (72F) faces the concave surface of the second spacer (72G), the convex surface of the second spacer (72G) faces the concave surface of the third spacer (72H), the convex surface of the third spacer (72H) faces the convex surface of the fourth spacer (72I), the concave surface of the fourth spacer (72I) faces the concave surface of the fifth spacer (72J), the convex surface of the fifth spacer (72J) faces the convex surface of the sixth spacer (72K) and the concave surface of the sixth spacer (72K) faces the convex surface of the first spacer (72F). 15 20 25
18. A combustion chamber as claimed in any of claims 1 to 17 wherein the at least one tile (48A, 48B, 52A, 52B) is manufactured by casting or additive layer manufacturing and the at least one tile (48A, 48B, 52A, 52B) comprises a nickel based superalloy, a cobalt based superalloy or an iron based superalloy. 30
19. A combustion chamber as claimed in any of claims 1 to 18 wherein the at least one stud (66) is manufactured by additive layer manufacturing and the at least one stud (66) comprises a nickel based superalloy, a cobalt based superalloy or an iron based superalloy. 35 40
20. A combustion chamber as claimed in any of claims 1 to 19 wherein the at least one stud (66) comprises a different material to the at least one tile (48A, 48B, 52A, 52B) and the at least one stud (66) comprises a material with higher temperature capability than the material of the tile (48A, 48B, 52A, 52B). 45

50

55



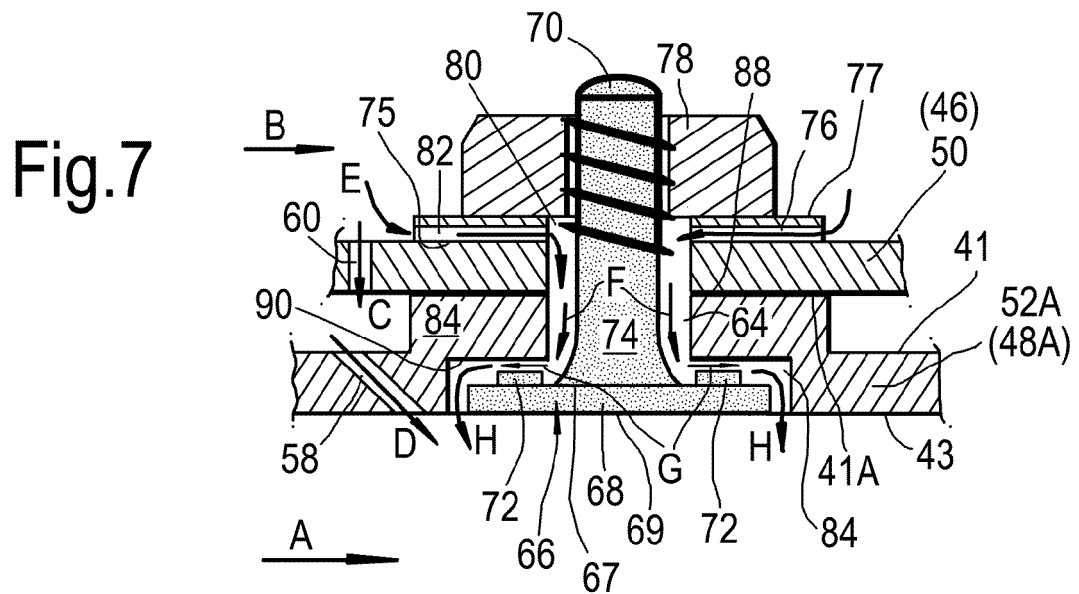
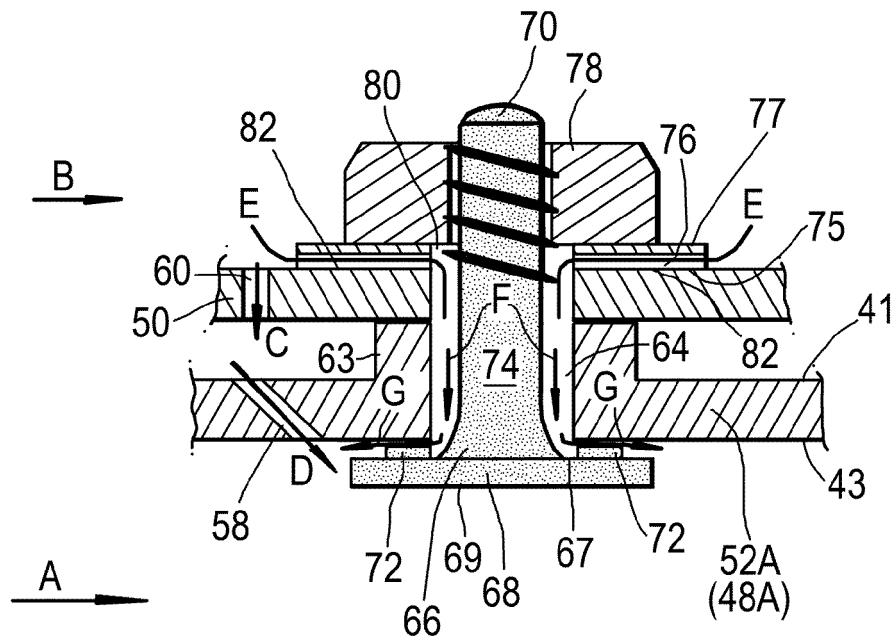
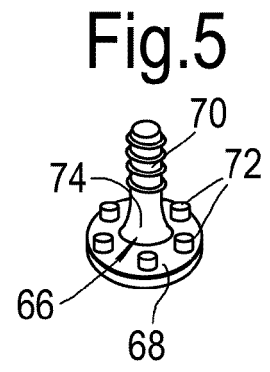
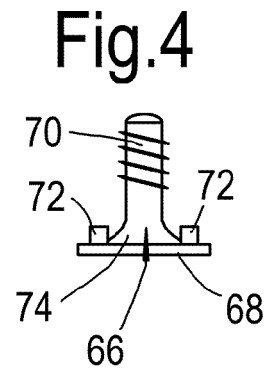
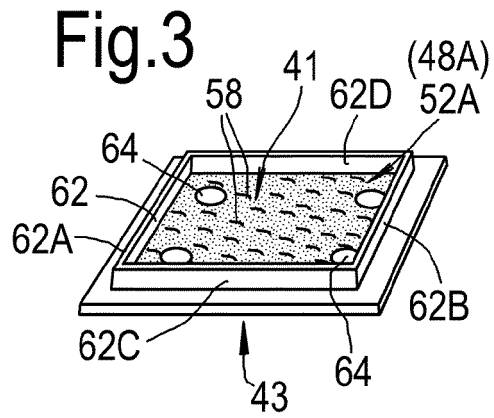


Fig.8

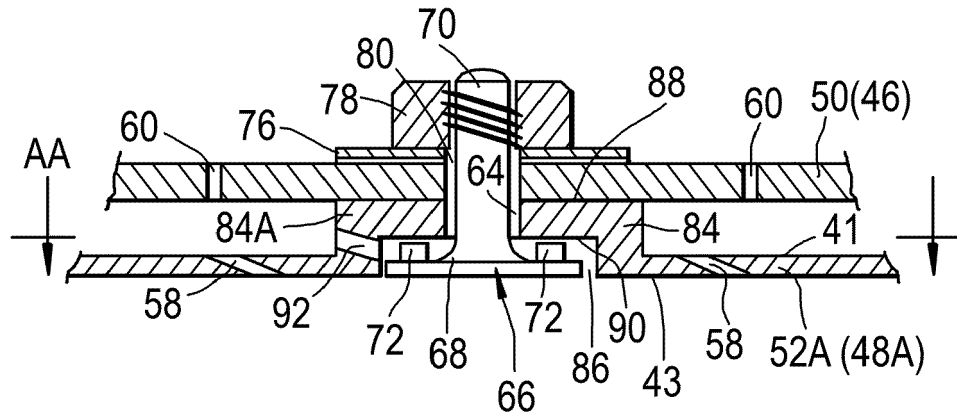


Fig.9

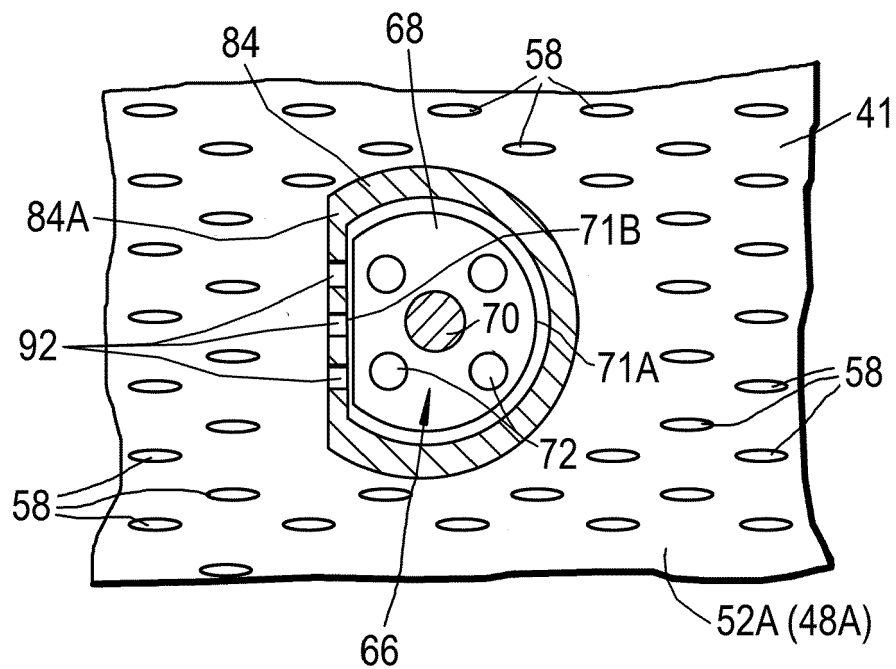


Fig.10

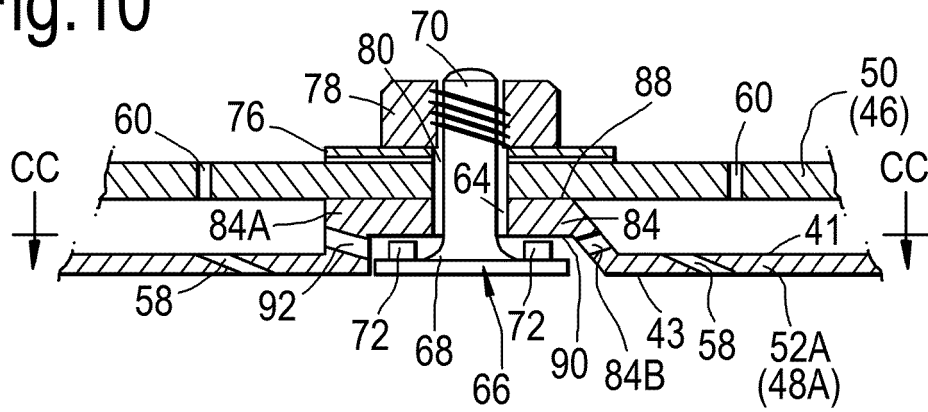


Fig.11

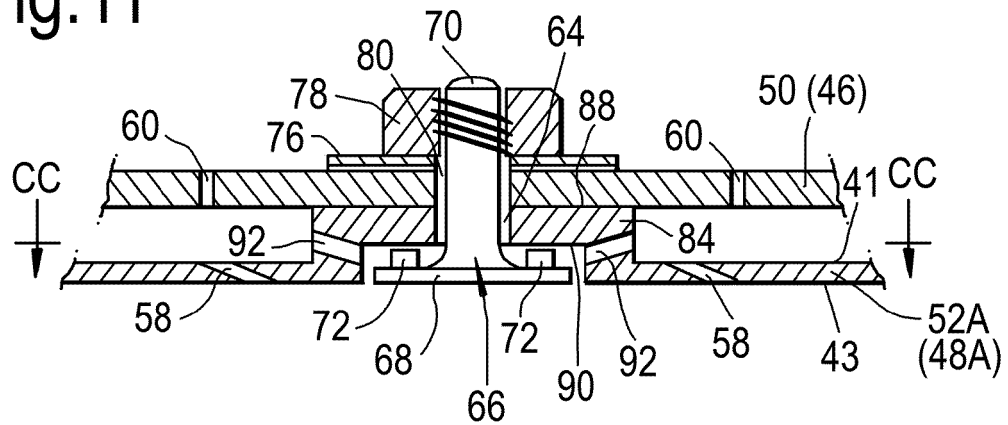


Fig.12

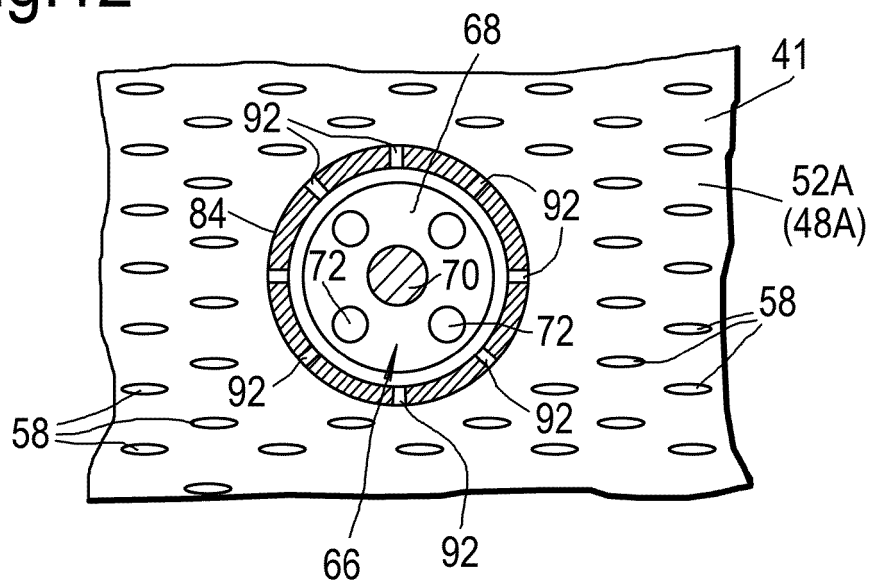


Fig.13

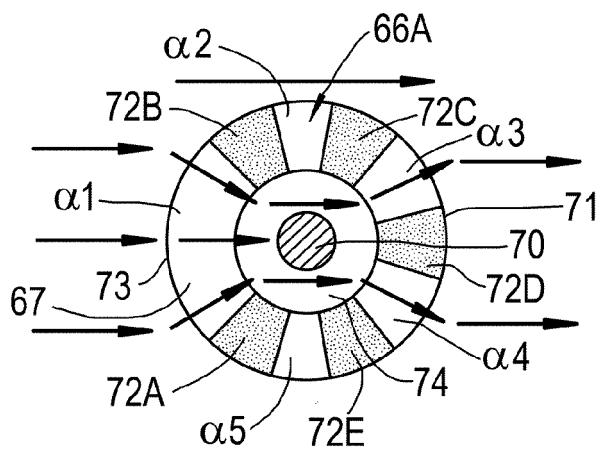


Fig.14

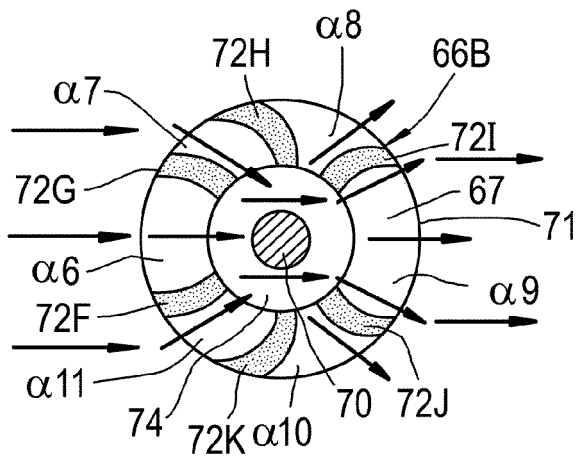


Fig.15

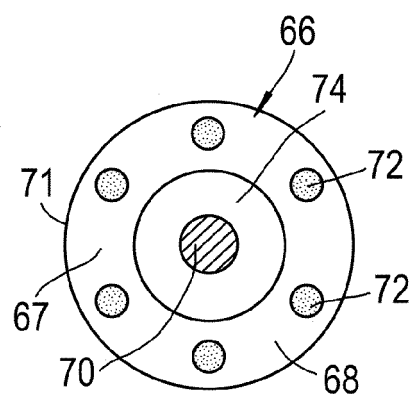


Fig.16

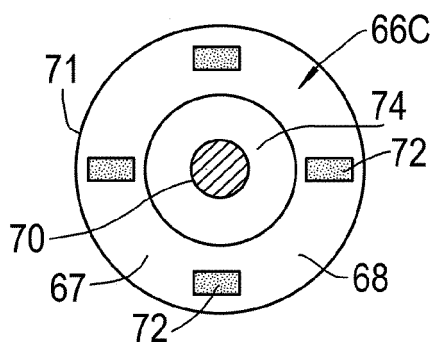
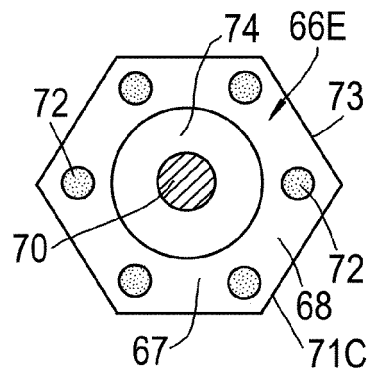


Fig.17





EUROPEAN SEARCH REPORT

Application Number
EP 16 20 5818

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	DE 100 36 211 A1 (ROLLS ROYCE DEUTSCHLAND [DE]) 7 February 2002 (2002-02-07) * paragraphs [0028] - [0031] * * figures 1, 2 *	1-6	INV. F23R3/00 F23R3/60
Y	JP S59 162323 A (HITACHI LTD; HITACHI ENG CO LTD) 13 September 1984 (1984-09-13) * figures 1, 5, 6 *	1-6	
			TECHNICAL FIELDS SEARCHED (IPC)
			F23R
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 14 June 2017	Examiner Vogl, Paul
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			

 1
EPO FORM 1503 03/82 (P04C01)

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

EP 16 20 5818

5

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

14-06-2017

10

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 10036211 A1	07-02-2002	NONE	
JP S59162323 A	13-09-1984	JP H0517384 B2 JP S59162323 A	09-03-1993 13-09-1984

15

20

25

30

35

40

45

50

55

EPO FORM P0459

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