

Description

This invention relates to gas turbine engines for powering aircraft, and more particularly to the fuel nozzle arrangement for the combustor in the engine.

To power higher and higher performance aircraft, the aircraft gas turbine industry is expending significant effort in attempting to increase the thrust-to-weight ratio of its engines. Greater thrust can be achieved in part by increasing the burner temperature rise, and weight reduction is obtained in part by shortening the combustor. One vehicle for attaining increased temperature rise without sacrificing flame stability is a double annular burner, exemplified in US-A-4,194,358. However, while double annular burners are capable of increased temperature rise, they have the disadvantage of increasing dome height and combustor surface area, which increases engine weight.

In both double annular and conventional single annular burners, a major factor limiting the combustor volumetric heat release rate is the rate of mixing between fuel and air.

Fuel-injectors/air-swirlers in the combustor dome are quite effective mixing devices, but regions of relatively low mixing, and therefore low volumetric heat release, exist in areas adjacent to the swirlers. Because the combustor interior is not uniformly occupied by high intensity burning, a longer combustor is needed to ensure combustion is complete before the product gases enter the turbine.

Swirl orientation could be used to improve the uniformity of high intensity combustion in single and double annular burners, but normally it is not so used, for combustor durability reasons. If adjacent swirlers had alternating swirl orientations, e.g., first swirler: clockwise, second swirler: counterclockwise, third swirler: clockwise, etc., the fuel-air mixture near the periphery of one swirler would always be flowing in the same direction as the peripheral flow from the adjacent swirler. Thus, the two swirlers would reinforce one another, increasing the mixing and burning rate between swirlers. However, combustors with all swirlers at a constant radius, or double annular combustors with two rows of swirlers separated by an intervening wall, usually have the same swirl orientation for all swirlers because of the need to avoid thermal distress of the burner liner. With all swirl orientations the same, flow at the periphery of one swirler opposes the direction of flow near the edge of the adjacent swirlers, thereby preventing hot gases from any swirler from impinging on the combustor walls. The deleterious side effect of a common swirl orientation is the creation of low intensity combustion regions between swirlers.

It is also already known, see US-A-3 000 183 (on which the two-part form of the claim is based) to provide two tiers of fuel injectors in a single annular com-

bustor. This known combustor has each of the fuel injectors of one tier radially aligned with a fuel injector of the other tier and in one embodiment the direction of swirl of the fuel injectors in one tier is the same but is opposite to the direction of swirl of the fuel injectors in the other tier. This causes interference of the swirl of adjacent fuel injectors in one of the tiers and reinforcement of the swirl between a pair of radially aligned fuel injectors.

Reference is also made to DE-A-2 223 093 which discloses a combustor having a plurality of tiers of fuel injectors shaped in the form of a half-spherical cup having a plate-shaped member at the downstream end thereof. The plate-shaped members are spaced from one another defining nozzles therebetween to accelerate compressor air flowing therethrough into the combustion zone. This air forms a vortex around the circumference of each plate-shaped member. In one embodiment of plate-shaped members of adjacent tiers are circumferentially off-set to reduce to a minimum the boundary layer between vortices around adjacent plate-shaped members.

The object of this invention is to provide an improved annular combustor for a gas turbine engine, which increases the intensity of combustion so as to enable a reduction in combustor size and weight while increasing the burner temperature rise and the overall thrust-to-weight ratio of the engine,

To achieve this, there is provided in accordance with the invention an annular combustor for a gas turbine engine having an outer annular axially extending wall and an inner annular axially extending wall concentrically disposed relative to said outer wall and defining a combustion chamber, a dome interconnecting said inner wall to said outer wall at the forward end for enclosing the forward end of said combustion chamber, a plurality of fuel injectors having air swirl means disposed in said dome, said fuel injectors each being arranged in a smaller radii and a larger radii tier, said air swirl means being disposed such that the rotation of the swirl of air in each air swirl means of each tier is in the same direction and the swirl rotation of each air swirl means in the larger radii tier is opposite to the swirl rotation of each air swirl means in the smaller radii tier, three adjacent fuel injectors of said plurality of fuel injectors including two of said adjacent fuel injectors being from one of said larger radii tier or said smaller radii tier and one of said adjacent fuel injectors being from the other of said larger radii tier or said smaller radii tier being together arranged such that imaginary lines passing through the center of each of said three adjacent fuel injectors define a triangle, characterized in that each of the fuel injectors in one of said tiers is located circumferentially between and equally spaced from two adjacent fuel injectors of the other tier so that the fuel/air emitted from each of said fuel injectors in one tier interacts with the discharge from two adjacent fuel injectors in the other tier for es-

establishing a reinforced fuel/air swirl pattern in the front end of said annular combustor for stabilizing the burning.

The swirl component of the air issuing from each of said fuel injectors reinforces the swirl introduced by the two adjacent swirlers defining the triangle without directing the reinforced-swirl, hot combustion products against the walls of the burner liner.

The foregoing and other features and advantages of the present invention will become more apparent from the following description and accompanying drawings.

Figure 1a is a schematic illustration of the dome and fuel injector locations of a typical prior art combustor.

Figure 1b is a schematic illustration of the combustor of Figure 1a, showing the regions of higher and lower combustion intensity.

Figure 1c is an enlarged schematic view of Figure 1a, showing two adjacent fuel nozzles.

Figure 2a is a schematic illustration of the dome and triangular arrangement of fuel injectors in a combustor utilizing the present invention.

Figure 2b is a schematic of the combustor of Figure 2a, showing the regions of high and low intensity combustion.

Figure 2c is an enlarged schematic view of Figure 2a, showing several fuel injectors.

Figure 3 is a graphical illustration comparing the pattern factor of the prior art fuel injector arrangements with that for the present invention.

While the invention herein is described using schematic illustrations of combustors, it is to be understood that the fabrication of the combustors, the fuel injectors, and the supporting structures are well known in the art and examples of typical installations can be found in such aircraft engines as the PW 4000, PW 2000 and F 100 series of engines manufactured by Pratt and Whitney of United Technologies Corporation.

Suffice it to say that the combustor is of the annular type having an outer annular shaped liner and an inner annular shaped liner defining a combustion chamber that consists of a combustion zone and a dilution zone. The liner may conform to a suitable louver or Floatwall liner construction made from materials capable of withstanding the high temperatures associated with high speed aircraft. In a typical embodiment, the annular combustor carries a dome interconnecting the inner and outer liners at the forward end that serves to close the forward end of the combustion chamber and support a plurality of fuel injectors that deliver the fuel and air into the combustion zone. The air is ingested into the engine and its pressure and temperature are raised by suitable compressors before being supplied to the combustor. For the sake of understanding this invention, a portion of the air is supplied into the combustion zone through the air

swirlers around the fuel nozzles, which may be of the pressure atomizing type or the airblast type, a portion of air is supplied through the combustor air holes, formed in the combustor liner downstream of the fuel injectors, and a portion of the air is used to cool the liner by inserting the cooling air along the combustor walls.

To better appreciate this invention, reference should be made to Figures 1a, 1b, and 1c, showing a typical prior art arrangement of fuel injectors mounted in the dome of a combustor. As mentioned earlier, it is customary to locate each of the equally spaced fuel injectors at a constant radius around the dome of the combustor. It is also typical of these prior art installations to have the same air swirl orientation in each of the fuel injectors, i.e., all swirlers impart a clockwise swirl or else all swirlers impart a counterclockwise swirl to the air they admit to the combustor.

As noted Figure 1a, the dome of the combustor represented by reference numeral 10 contains equally spaced fuel injectors represented by the circles 12, it being understood that the fuel injectors contain an orifice for issuing fuel to the combustion zone and an air swirler for issuing air into the combustion zone. As the name implies, the swirler imparts a swirl to the air prior to being ingested in the combustion zone and the orientation or direction of the swirl is controlled by the design of the swirler. The arrows A in this example shows that the swirl direction is clockwise and all swirls have the same orientation. While it is possible to alternate the orientation of adjacent swirlers, to do so would adversely affect the life of the liner because hot gases would be directed against the liner wall. Hence, the mutual swirl reinforcement resulting from adjacent swirlers having opposite swirl orientations would be obtained at the expense of combustor durability, and hence alternating swirl orientation is not acceptable in modern conventional combustors of the single annular or double annular type.

As noted in Figure 1b, the high intensity combustion in the primary zone 14 indicated by the shaded region B of the combustor does not fully occupy the combustor volume. Thus, the combustor is larger than might otherwise be required.

As depicted in Figures 2a, 2b, and 2c, the fuel injectors 12a are arranged in the dome generally illustrated by reference numeral 10a to define a triangle configuration as noted by the dashed lines identified by reference letter G. The inner radius fuel injector 12 is located circumferentially between and is equally spaced from two adjacent outer radius fuel injectors 12 of the triangle configuration. Additionally, the direction of the swirl, from adjacent fuel injectors, alternates, as viewed from Figure 2a where adjacent swirlers are at different radii. As noted, the inner radius swirler 12a rotates clockwise and the outer radius swirler 12a rotates counter-clockwise, a design which permits the fuel injectors to reinforce one another's

swirl without directing the combustion gases against the liner.

Also, as noted by viewing Figure 2b, because of the mutual reinforcement, fuel tends to be distributed more uniformly and fuel-air mixing tends to be more intense, hence, intense combustion begins closer to the combustor dome as depicted by reference letter C1, and the high intensity burning extends over a shorter expanse as indicated by reference letter D1. Also of significance, because of the arrangement of the fuel injectors, intense burning occupies a larger fraction of the annulus as depicted by the shaded area indicated by reference letter E1. With less combustion length needed for high efficiency burning, the combustor's length can be reduced, which in turn reduces engine length and weight. It will be appreciated from the foregoing that the diameter of the dome of the combustor using this invention is not increased over the diameter of the dome of the prior art combustor depicted in Figures 1a, 1b, and 1c.

As is obvious from the foregoing discussion, the present invention places more fuel injectors in a dome area no larger than that of the prior art combustor, a design which increases the influence of fuel injectors and their high mixing rates on the combustor flow-field. As noted in Figure 2c, the zone of low intensity burning depicted by reference letter F1 occupies a smaller region when compared with the prior art combustor.

As shown in Figure 3, the arrangement of the fuel injectors as taught by the present invention results in a combustor that is shorter than the prior art combustor without incurring the pattern factor penalty normally associated with combustor length reduction. Moreover, for a fixed length combustor, the pattern factor for the present invention (TRINAR combustor) is less than that for a conventional combustor (Figures 1a, 1b, and 1c).

What has been disclosed by this invention is an improved burning concept that allows for a shorter combustor without incurring a pattern factor penalty. Also, fuel-air mixing enhanced to achieve higher intensity combustion in a shorter length. As does the double annular combustor, the present invention permits the use of more fuel injectors, but without increasing dome height or liner surface areas as would be necessary with the double annular combustor.

Claims

1. Annular combustor for a gas turbine engine having an outer annular axially extending wall and an inner annular axially extending wall concentrically disposed relative to said outer wall and defining a combustion chamber, a dome (10a) interconnecting said inner wall to said outer wall at the forward end for enclosing the forward end of said

combustion chamber, a plurality of fuel injectors (12a) having air swirl means disposed in said dome (10a), said fuel injectors (12a) each being arranged in a smaller radii and a larger radii tier, said air swirl means being disposed such that the rotation of the swirl of air in each air swirl means of each tier is in the same direction and the swirl rotation of each air swirl means in the larger radii tier is opposite to the swirl rotation of each air swirl means in the smaller radii tier, three adjacent fuel injectors (12a) of said plurality of fuel injectors (12a) including two of said adjacent fuel injectors (12a) being from one of said larger radii tier or said smaller radii tier and one of said adjacent fuel injectors (12a) being from the other of said larger radii tier or said smaller radii tier being together arranged such that imaginary lines (G) passing through the center of each of said three adjacent fuel injectors (12a) define a triangle, characterized in that each of the fuel injectors (12a) in one of said tiers is located circumferentially between and equally spaced from two adjacent fuel injectors (12a) of the other tier so that the fuel/air emitted from each of said fuel injectors (12a) in one tier interacts with the discharge from two adjacent fuel injectors (12a) in the other tier for establishing a reinforced fuel/air swirl pattern in the front end of said annular combustor for stabilizing the burning.

Patentansprüche

1. Ringbrenner für ein Gasturbinentriebwerk, der eine äußere, ringförmige, sich axial erstreckende Wand und eine innere, ringförmige, sich axial erstreckende Wand hat, welche relativ zu der äußeren Wand konzentrisch angeordnet ist und mit dieser eine Brennkammer bildet, eine Kuppel (10a), welche die innere Wand mit der äußeren Wand an dem vorderen Ende verbindet, um das vordere Ende der Brennkammer zu verschließen, eine Vielzahl von Brennstoffeinspritzvorrichtungen (12a), die eine Luftdralleinrichtung haben, welche in der Kuppel (10a) angeordnet ist, wobei die Brennstoffeinspritzvorrichtungen (12a) jeweils in einer Reihe mit kleinerem Radius und einer Reihe mit größerem Radius angeordnet sind, wobei die Luftdralleinrichtung so angeordnet ist, daß die Drehung des Luftdralls in jeder Luftdralleinrichtung jeder Reihe in derselben Richtung erfolgt und die Dralldrehung von jeder Luftdralleinrichtung in der Reihe mit größerem Radius entgegengesetzt ist zu der Dralldrehung jeder Luftdralleinrichtung in der Reihe mit kleinerem Radius, wobei drei benachbarte Brennstoffeinspritzvorrichtungen (12a) der Vielzahl von Brennstoffeinspritzvorrichtungen (12a) zwei der benach-



swirl without directing the combustion gases against the liner.

Also, as noted by viewing Figure 2b, because of the mutual reinforcement, fuel tends to be distributed more uniformly and fuel-air mixing tends to be more intense, hence, intense combustion begins closer to the combustor dome as depicted by reference letter C1, and the high intensity burning extends over a shorter expanse as indicated by reference letter D1. Also of significance, because of the arrangement of the fuel injectors, intense burning occupies a larger fraction of the annulus as depicted by the shaded area indicated by reference letter E1. With less combustion length needed for high efficiency burning, the combustor's length can be reduced, which in turn reduces engine length and weight. It will be appreciated from the foregoing that the diameter of the dome of the combustor using this invention is not increased over the diameter of the dome of the prior art combustor depicted in Figures 1a, 1b, and 1c.

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barten Brennstoffeinspritzvorrichtungen (12a) umfassen, die aus der Reihe mit größerem Radius oder aus der Reihe mit kleinerem Radius stammen, wobei eine der benachbarten Brennstoffeinspritzvorrichtungen (12a) aus der anderen Reihe, also aus der Reihe mit größerem Radius oder aus der Reihe mit kleinerem Radius stammt, die gemeinsam so angeordnet sind, daß imaginäre Linien (G), welche durch die Mitte von jeder der drei benachbarten Brennstoffeinspritzvorrichtungen (12a) hindurchgehen, ein Dreieck bilden, dadurch gekennzeichnet, daß jede der Brennstoffeinspritzvorrichtungen (12a) in einer der Reihen umfangsmäßig zwischen und gleichabständig von zwei benachbarten Brennstoffeinspritzvorrichtungen (12a) der anderen Reihe angeordnet ist, so daß das Brennstoff/Luft-Gemisch, das von jeder der Brennstoffeinspritzvorrichtungen (12a) in einer Reihe emittiert wird, mit der Abgabe aus zwei benachbarten Brennstoffeinspritzvorrichtungen (12a) in der anderen Reihe zusammenwirkt, um ein verstärktes Brennstoff/Luft-Drallmuster in dem vorderen Ende des Ringbrenners zum Stabilisieren der Verbrennung zu schaffen.

tes rangées à plus grand rayon ou à plus petit rayon étant disposés ensemble de façon que les lignes imaginaires (G) passant par le centre de chacun desdits trois injecteurs de carburant voisins (12a) définissent un triangle, caractérisé en ce que chacun des injecteurs de carburant (12a) dans l'une desdites rangées est situé périphériquement entre deux injecteurs de carburant voisins (12a) de l'autre rangée et à distance égale de ceux-ci de façon que le mélange air/carburant provenant de chacun desdits injecteurs de carburant (12a) dans une rangée entre en interaction avec celui provenant des deux injecteurs de carburant (12a) dans l'autre rangée pour créer un motif de turbulence renforcé air/carburant à l'extrémité avant dudit dispositif de combustion annulaire afin de stabiliser la combustion.

Revendications

1. Dispositif de combustion annulaire pour moteur à turbine à gaz ayant une paroi extérieure annulaire disposée axialement et une paroi intérieure annulaire disposée axialement, placées concentriquement par rapport à ladite paroi extérieure et définissant une chambre de combustion, un dôme (10a) interconnectant ladite paroi intérieure à ladite paroi extérieure à l'extrémité avant pour fermer l'extrémité avant de ladite chambre de combustion, plusieurs injecteurs de carburant 12a ayant des moyens de turbulence d'air disposés dans ledit dôme (10a), lesdits injecteurs de carburant (12a) étant disposés chacun sur une rangée de plus petit rayon et une rangée de plus grand rayon, lesdits moyens de turbulence d'air étant disposés de façon que la rotation de la turbulence de l'air dans chacun des moyens de turbulence d'air de chaque rangée soit dans le même sens et que la rotation de la turbulence de chaque moyen de turbulence d'air dans la rangée de plus grand rayon soit opposée à la rotation de la turbulence de chaque moyen de turbulence d'air dans la rangée de plus petit rayon, trois injecteurs de carburant voisins (12a) desdits divers injecteurs de carburant (12a) comprenant deux desdits injecteurs de carburant voisins (12a) appartenant à l'une desdites rangées à plus grand rayon ou à plus petit rayon et un desdits injecteurs de carburant (12a) faisant partie de l'autre desdites

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