(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 722 164 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
15.11.2006 Bulletin 2006/46

(51) Int Cl.:
F23D 11/10 *(2006.01)* ***F23C 7/00*** *(2006.01)*
F23R 3/28 *(2006.01)* ***F23R 3/14*** *(2006.01)*

(21) Application number: **06009563.5**

(22) Date of filing: **09.05.2006**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

(30) Priority: **12.05.2005 DE 102005022772**

(71) Applicant: **UNIVERSITÄT KARLSRUHE
76131 Karlsruhe (DE)**

(72) Inventors:
- **Zarzalis, Nikolaos, Prof. Dr.
76189 Karlsruhe (DE)**
- **Fokaides, Paris
76137 Karlsruhe (DE)**
- **Merkle, Klaus
71701 Schwieberdingen (DE)**

(74) Representative: **Gagel, Roland
Patentanwaltskanzlei
Dr. Roland Gagel
Landsberger Strasse 480 a
D-81241 München (DE)**

(54) **Fuel injection apparatus**

(57) The present invention relates to a fuel injection apparatus with fuel injection means (10) adapted to spray liquid fuel (17) across a primary flow (3) of gaseous oxidation medium onto the radially inner surface (7) of an annular member (16) downstream of said fuel injection means (10) to form a fuel film flow in a generally downstream direction over said surface (7), a downstream end of said annular member (16) terminating in an annular lip (8). Swirl generation means apply a swirl to the primary flow (3) of gaseous oxidation medium. The apparatus also comprises means (1) for directing a secondary flow (2) of gaseous oxidation medium, a mass flow of which is equal or higher than a mass flow of the primary flow (3), over the radially outer surface of said annular member (16) to cooperate with said primary flow (3) to provide atomization of said fuel film downstream of said annular lip (8). The apparatus is characterized in that a diffuser (5) at an injection opening (14) to the combustion chamber (15) has a diffuser angle of ≤ 15° and that said means (1) for directing the secondary flow (2) is designed to apply a swirl with a swirl number of < 0.2 or to apply no swirl to the secondary flow (2). With the proposed fuel injection apparatus a homogeneous distribution of liquid fuel and air in the combustion region is achieved.

EP 1 722 164 A1

Printed by Jouve, 75001 PARIS (FR)

Description

Technical field of the invention

[0001] The present invention relates to a fuel injection apparatus, in particular for aircraft gas turbine engines, comprising a central channel which extends at least between a fuel injection means and an injection opening to a combustion chamber and forms a diffuser at said injection opening, wherein said fuel injection means is adapted to spray liquid fuel across a primary flow of gaseous oxidation medium onto the radially inner surface of a generally annular member downstream of said fuel injection means to form a fuel film flow in a generally downstream direction over said surface, a downstream end of said annular member terminating in an annular lip. The fuel injection apparatus further comprises swirl generation means applying a swirl to the primary flow of gaseous oxidation medium and means for directing a secondary flow of gaseous oxidation medium, a mass flow of which is equal or higher than a mass flow of the primary flow, over the radially outer surface of said annular member to cooperate with said primary flow to provide atomization of said fuel film downstream of said annular lip.

Background of the invention

[0002] A gas turbine engine includes a compressor that provides pressurized air to a combustor wherein the air is mixed with fuel and ignited for generating hot combustion gases. This gases flow downstream to one ore more turbines said extract energy therefrom to power the compressor and provide useful work such as powering an aircraft in flight. The air is supplied through surrounding assemblies, known as swirl generators, which impart a swirling motion to the air so as to cause the air and fuel to be thoroughly mixed.

[0003] A main object of the continuing development of fuel injection systems for gas turbines is the improvement of the efficiency which requires an increased pressure and temperature level within the combustion chamber. These increased levels, however, also result in an increased emission of undesired oxides of nitrogen. Such oxides are considered as harmful emissions which should be reduced.

[0004] One known way to reduce the emission of oxides of nitrogen is the optimization of the mixing of the liquid fuel with the air which is fed into the combustion chamber for combustion purposes. If the fuel is poorly atomized and evaporated so said liquid fuel droplets remain or if local areas of high fuel concentration occur, the combustion temperature increases locally. This in turn results in a correspondingly increased rate in the production of the oxides of nitrogen.

[0005] In order to improve the mixing of the liquid fuel with the gaseous oxidation medium like air it is known to use air atomizer nozzles in the burner stages of gas turbines. An example of such a fuel injection apparatus according to the introductory portion of present claim 1 is disclosed in DE 196 27 760 A1. In this fuel injection apparatus a swirl of the same direction is applied to the primary and to the secondary flow of gaseous oxidation medium. The annular lip is arranged at a position of the central channel which provides the smallest flow cross section of the primary and secondary flow of gaseous oxidation medium within the apparatus, resulting in an optimized atomization of the fuel. A similar fuel injection apparatus is shown in EP 1 158 246 A2, which discloses the generation of counter rotating swirls of the two flows of oxidation medium.

[0006] When using such known injection apparatuses in gas turbine engines, the mixing of liquid fuel and oxidation medium is not yet satisfactory resulting in a locally and temporally inhomogeneous distribution of liquid fuel and oxidation medium in the combustion chamber. This gives rise to an undesired inhomogeneous temperature distribution. In other words, locally confined stoichiometric regions can not be avoided even during combustion with an excess of oxygen, which due to their high temperatures cause a high production rate of harmful oxides of nitrogen.

[0007] It is an object of the present invention to provide a fuel injection apparatus which achieves a more homogeneous distribution of liquid fuel and oxidation medium in the combustion region.

Description of the invention

[0008] The object is achieved with the fuel injection apparatus according to claim 1. Advantageous embodiments of the fuel injection apparatus are subject matter of the dependent claims or are described in the subsequent part of the description and preferred embodiments.

[0009] The proposed fuel injection apparatus comprises a central channel extending at least between a fuel injection means and an injection opening to a combustion chamber, said central channel forming a diffuser at said injection opening. The fuel injection means is adapted to spray liquid fuel across a primary flow of gaseous oxidation medium, in particular air, onto the radially inner surface of a generally annular member downstream of the fuel injection means to form a fuel film flow in a generally downstream direction over said surface. The downstream end of said annular member terminates in an annular lip, also called atomizer lip. The apparatus further comprises a swirl generation means which applies a swirl to the primary flow of gaseous oxidation medium, and means for directing a secondary flow of gaseous oxidation medium, a mass flow of which is equal or higher than a mass flow of the primary flow, over the radially outer surface of the annular member to cooperate with said primary flow to provide atomization of said fuel film downstream of said annular lip. The annular lip preferably is arranged at a position of the central channel at which a smallest flow cross section of the primary and secondary flow of gaseous oxidation medium is achieved within the apparatus. The proposed fuel injection apparatus is characterized in that said diffuser formed of said central channel has a diffuser angle of s 15° and that said means for directing the secondary flow of gaseous oxidation medium to the radially outer surface of the annular member is designed to apply a swirl with a swirl number of lower than 0.2 to the secondary flow or to apply no swirl to the secondary flow.

[0010] The present invention is based on the finding that with the generation of a lifted flame within the combustion chamber a better mixing between the liquid fuel and the oxidation medium is achieved. The lifted flame allows the mixing process to completely or partly take place within the combustion chamber prior to combustion. In order to allow the generation of such a lifted flame - in contrast to the normally arising attached flame - at a distance from the injection opening which is sufficient to achieve a more homogeneous mixing, the two measures of the characterizing portion of claim 1 have to be taken. A further improvement in the generation of a lifted flame having a sufficiently high distance from the injection opening is achieved when the edges of the injection opening are designed as sharp edges. The further components of the fuel injection apparatus can be designed in the manner known in the art, for example as known from DE 196 27 760 A1, which is included in the present patent application by reference.

[0011] In the present fuel injection apparatus the primary flow of gaseous oxidation medium is supplied to the central channel preferably via a primary flow duct through a first discharge opening downstream of the fuel injection means, for example one or several spray nozzles. The discharge opening surrounds the central channel at this position. In the same manner the secondary flow is preferably supplied via a secondary flow duct through a second discharge opening downstream of the first discharge opening, said second discharge opening also surrounding the central channel. The two discharge openings are separated by the annular member forming the annular lip. The swirl generation means for applying a swirl to the primary flow and, if applicable, to the secondary flow are arranged within the primary and the secondary flow duct.

[0012] The diffuser is formed at the downstream end of the central channel by increasing the cross section of the central channel towards the combustion chamber. This can be a linear as well as a nonlinear increase resulting in a straight-line or, for example, a convex inner shape of the diffuser section. In case of a convex shape it is the tangent to this shape at the downstream end of the diffuser which must have an angle against the central axis of equal or less than 15° in order to fulfill the requirement of the present fuel injection apparatus.

[0013] In a further improved embodiment the central member terminating in the annular lip extends to a length in a flow direction of said primary flow, i.e. in a downstream direction of the central channel, which length is higher than the inner diameter of the opening formed by the angular lips. Such an elongated annular member allows evaporation of a higher portion of the liquid fuel applied to the annular member and results in a more homogeneous distribution of the liquid fuel in the oxidation medium already within the fuel injection apparatus. The length of the annular member in the downstream direction preferably is ≥ 1.5 times of the inner diameter of the opening formed by the angular lip.

[0014] A further improvement of the mixing of the liquid fuel and the oxidation medium is achieved with an elongation of the distance between the annular lip and the injection opening to the combustion chamber. A longer distance allows a longer time for mixing between the atomized liquid fuel and the oxidation medium which also results in a more homogeneous distribution of the fuel at the combustion region. If the distance is too large, the inner wall is wetted with liquid fuel, which again deteriorates the fuel distribution at the combustion region. In a preferred embodiment of the proposed fuel injection apparatus, the distance is selected as large as possible without wetting the inner wall of the central channel at the injection opening with liquid fuel.

[0015] In a further advantageous embodiment of the present fuel injection apparatus one or several fuel supply channels for liquid fuel are arranged, preferably symmetrically around the central channel, within the annular member. These additional fuel supply channels have discharge openings at the radially inner surface of this annular member upstream of the annular lip. The liquid fuel can be supplied through this additional fuel supply channels to the radially inner surface of the annular member in addition to the supply of fuel via the central fuel injection means or alternatively to this central injection. Preferably the liquid fuel is supplied through the central injection means during low load conditions of the gas turbine, whereas the liquid fuel is supplied through the additional fuel supply channel(s) during high load conditions of the turbine engine. This also leads to an improvement in the homogeneity of the fuel distribution in the combustion region. At high load conditions it could occur that not all of the liquid fuel supplied through the central injection means reach the inner surface of the annular member resulting in a poorer atomization. At this high load conditions, however, the fuel can be reliably supplied to this surface through the additional fuel supply channels arranged inside of the annular member.

Brief description of the drawings

[0016] The following exemplary embodiment,shows an example of the proposed fuel injection apparatus with reference to the accompanying figure without limiting the scope of the invention as defined in the claims. The figure shows an example of the fuel injection apparatus in a schematic view.

Description of preferred embodiments

[0017] The fuel injection apparatus shown in figure 1 can be used in a gas turbine engine, a section of which is shown for example in figure 1 of DE 196 27 760 A1.

[0018] The exemplary fuel injection apparatus comprises a central channel 13 which extends between a fuel spray nozzle 10 and an injection opening 14 to the combustion chamber 15 not explicitly shown in this figure. The fuel injection apparatus further comprises a primary flow duct 6 and a secondary flow duct 1 downstream of said primary flow duct 6. The two flow ducts 6, 1 are separated by a generally annular member 16 terminating in an annular lip 8 in the downstream direction. The flow ducts 1, 6 are formed concentrically to the central axis A of the central channel 13, which is the central axis of the radially symmetric fuel injection apparatus of the present example.

[0019] Upstream of the annular lip 8 a diffuser 5 is formed at the injection opening 14. The diffuser 5 is formed with a linear increasing cross section of the central channel 13. Between the diffuser 5 and the annular lip 8 a intermediate section 12 having a constant diameter is provided. The length of this intermediate section 12 together with the length of the diffuser 5 in the flow direction is selected such that it is as long as possible without wetting of the inner wall of the diffuser 5 with liquid fuel droplets. This maximum length improves the mixing between the liquid fuel atomized at the annular lip 8 and the air flow due to a longer flight time of the fuel prior to combustion.

[0020] Annular member 16 also comprises additional fuel channels 11 for supplying liquid fuel to the radially inner surface of the annular member 16. Although these fuel channels 11 are shown in the figure to be arranged vertically with respect to the central axis A, this is only exemplary. They can also be arranged at another angle with respect to the central axis A or can follow a curved line, preferably in order to enter the central channel 13 in flow direction nearly tangentially to the radially inner surface 7 of the annular member 16.

[0021] In the primary 6 and secondary duct 1 swirl generators (not shown) are arranged to apply a swirl to the primary flow 3 of air and to the secondary flow 2 of air which is supplied from the compressor stage of the gas turbine. The swirl generator in the secondary flow duct 1 is designed such that the swirl of the secondary flow 2 has a swirl rate of less than 0.2. The swirl directions of the primary flow 3 and secondary flow 2 can be co-rotating or counter-rotating. It is also possible to provide the secondary flow duct 1 without any swirl generator. In this case the secondary flow 2 is without any swirl. The cross sections of the primary duct 6 and the secondary duct 1 are such that the mass flow of the air through the secondary duct 1 is equal or greater than the mass flow of the air through the primary duct 6.

[0022] During operation of the fuel injection apparatus liquid fuel 17 is sprayed by the fuel spray nozzle 10 to the radially inner surface 7 of the annular member 16 as indicated in the figure. At the same time the primary air flow 3 and secondary air flow 2 are supplied through the primary 6 and secondary duct 1 to the central channel 13. This is indicated by corresponding arrows in the figure. The liquid fuel 17 sprayed onto the inner surface 7 of the annular member 16 forms a thin film of liquid fuel on the surface 7 which moves downstream towards annular lip 8. Due to the shearing stream of the secondary flow 2 and the primary flow 3 at the edge of this annular lip 8 the fuel film tears off and at the same time is atomized and/or evaporated due to the shearing forces of the air flows. Annular lip 8 is arranged at the narrowest flow cross section or immediately before this narrowest flow cross section of the primary and secondary flow, i.e. at the position of highest flow velocities. This results in a maximum atomizing effect and leads to an optimum atomizing of the liquid fuel.

[0023] Due to the low swirl of the secondary flow 2 compared with the swirl of the primary flow 3 and to the small diffuser angle α of $\leq 15°$ the combustion flame forms not immediately at the injection opening 14 in the combustion chamber 15, but at a downstream distance from this injection opening. Such a flame which is not attached to the injection opening is called a lifted flame. The sharp edges 4 of the injection opening furthermore improve the formation of such a lifted flame. In the present embodiment the distance between the lifted flame and the injection opening 14 is large enough to enable a significant further mixing of the atomized fuel with the air prior to combustion, which results in a more homogeneous distribution of the fuel at the combustion region.

[0024] In the proposed injection apparatus the liquid fuel 17 is sprayed by the fuel spray nozzle 10 onto the radially inner surface 7 of the annular member 16 during low load operation of the gas turbine. During high load operation the fuel is not supplied via the central fuel spray nozzle 10 but through the additional fuel supply channels 11 in order to achieve a more reliable wetting of the inner surface 7 of the annular member 16 at this load. The preferably concentrically arranged fuel supply channels 11 can nevertheless also be operated at the same time as the fuel spray nozzle 10 and vice versa.

[0025] In the present example the length L of the annular member 16 in flow direction is larger than the diameter D of annular lip 8 at the downstream end of the annular member 16. This results in a longer distance available for the evaporation of the liquid fuel sprayed onto the inner surface 7 of the annular member 16. Therefore, the mixing of air and liquid fuel is further improved by this measure.

List of reference signs

[0026]

1 secondary flow duct
2 secondary flow of air

3 primary flow of air
4 sharp edges
5 diffuser
6 primary flow duct
7 inner surface of annular member
8 annular lip
9 flow cross section
10 fuel spray nozzle
11 additional fuel supply channels
12 intermediate section
13 central channel
14 injection opening
15 combustion chamber
16 annular member
17 liquid fuel

Claims

1. Fuel injection apparatus, in particular for aircraft gas turbine engines, comprising

- a central channel (13) which extends at least between a fuel injection means (10) and an injection opening (14) to a combustion chamber (15) and forms a diffuser (5) at said injection opening (14),

wherein said fuel injection means (10) is adapted to spray liquid fuel (17) across a primary flow (3) of gaseous oxidation medium onto the radially inner surface (7) of a generally annular member (16) downstream of said fuel injection means (10) to form a fuel film flow in a generally downstream direction over said surface (7), a downstream end of said annular member (16) terminating in an annular lip (8),

- swirl generation means applying a swirl to the primary flow (3) of gaseous oxidation medium and
- means (1) for directing a secondary flow (2) of gaseous oxidation medium, a mass flow of which is equal or higher than a mass flow of the primary flow (3), over the radially outer surface of said annular member (16) to cooperate with said primary flow (3) to provide atomization of said fuel film downstream of said annular lip (8),

characterized in that said diffuser (5) has a diffuser angle of equal or less than 15° and said means (1) for directing the secondary flow (2) of gaseous oxidation medium over the radially outer surface of said annular member (16) is designed to apply a swirl with a swirl number of < 0.2 or to apply no swirl to the secondary flow (2).

2. Fuel injection apparatus according to claim 1, **characterized in that** said annular lip (8) is arranged at a position of said central channel (13) providing a smallest flow cross section of the primary (3) and secondary flow (2) of gaseous oxidation medium within the apparatus.

3. Fuel injection apparatus according to claim 1 or 2, **characterized in that** said injection opening (14) has sharp edges (4).

4. Fuel injection apparatus according to any of claims 1 to 3, **characterized in that** said annular lip (8) extends to a length in a flow direction of said primary flow (3) in the central channel (13) which is larger than an inner diameter of an opening formed by said annular lip (8).

5. Fuel injection apparatus according to any of claims 1 to 4, **characterized in that** a distance between the annular lip (8) and the injection opening (14) is as large as possible without wetting an inner wall of the diffuser (5) with liquid fuel during operation.

6. Fuel injection apparatus according to any of claims 1 to 5, **characterized in that** said annular member (16) at least one supply channel (11) for liquid fuel to the radially inner surface (7) of the generally annular member (16).

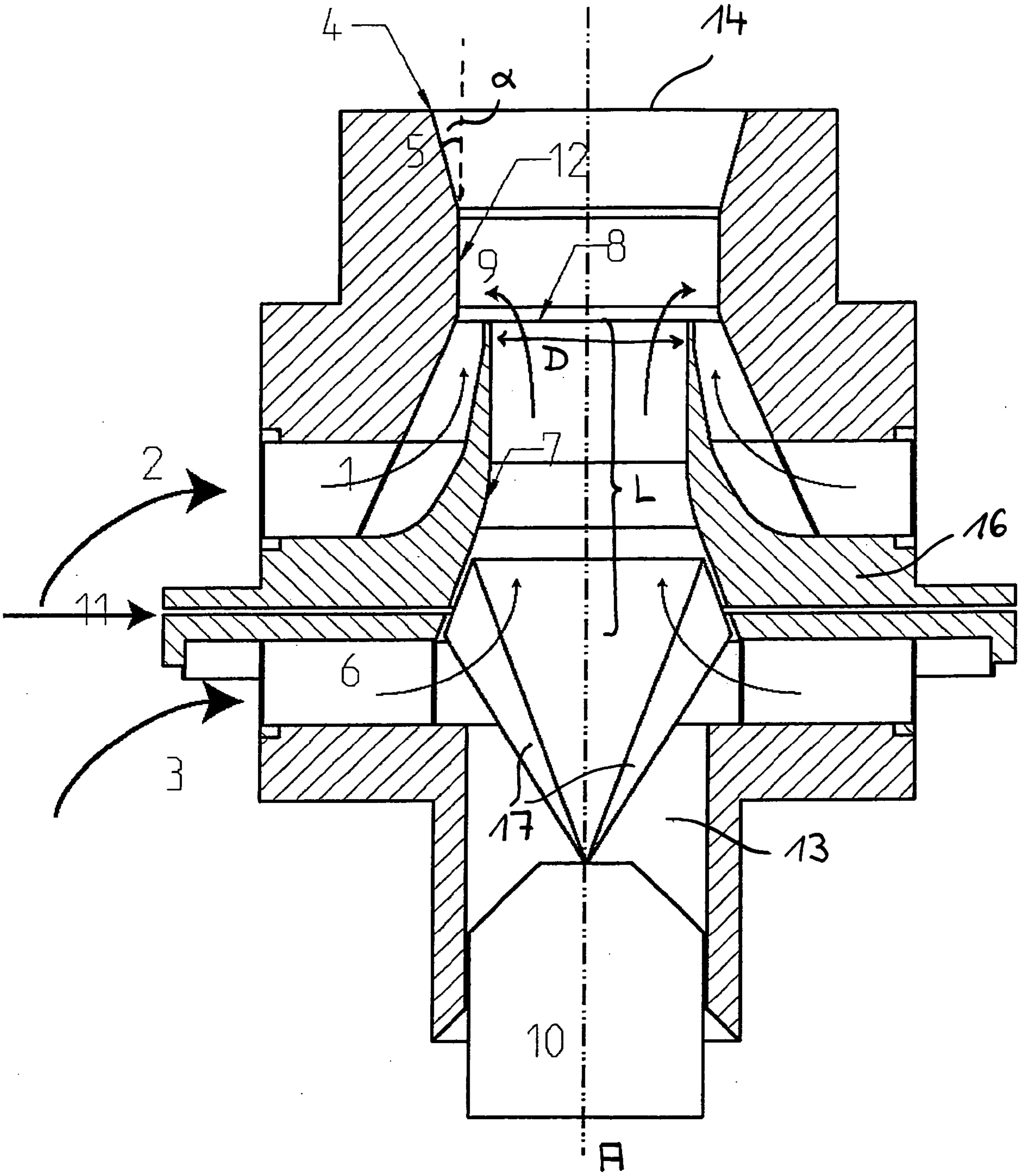

Fig. 1

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 00 9563

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 4 842 197 A (SIMON ET AL) 27 June 1989 (1989-06-27) * column 3, line 11 - line 49 * * column 4, line 3 - line 25 * * figure 1 * -----	1-5	INV. F23D11/10 F23C7/00 F23R3/28 F23R3/14
A	US 2004/219466 A1 (MARINO JOHN A ET AL) 4 November 2004 (2004-11-04) * page 3, paragraph 29 * * page 4, paragraph 40 * * figure 3A * -----	1	
A	US 5 490 378 A (BERGER ET AL) 13 February 1996 (1996-02-13) * column 5, line 61 - column 6, line 32; figure 6 * -----	1	
A	US 5 966 937 A (GRAVES ET AL) 19 October 1999 (1999-10-19) * column 3, line 41 - line 61 * * figure 1 * -----	1	TECHNICAL FIELDS SEARCHED (IPC)
A	US 5 373 693 A (ZARZALIS ET AL) 20 December 1994 (1994-12-20) * column 5, line 43 - column 6, line 20 * * figure 6 * -----	1	F23D F23C F23R
A	US 6 543 235 B1 (CROCKER DAVID S ET AL) 8 April 2003 (2003-04-08) * column 4, line 57 - column 6, line 18; figures 3,4 * -----	1	
A	US 5 417 070 A (RICHARDSON ET AL) 23 May 1995 (1995-05-23) * column 2, line 10 - column 4, line 11; figure 1 * -----	1	
	-/--		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	10 July 2006	Gavriliu, C

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)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 00 9563

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
D,A	DE 196 27 760 A1 (MTU MOTOREN- UND TURBINEN-UNION MUENCHEN GMBH, 80995 MUENCHEN, DE; MTU) 15 January 1998 (1998-01-15) * column 2, line 29 - column 3, line 17; figure 1 * -----	1	
			TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	10 July 2006	Gavriliu, C

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

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 06 00 9563

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.

10-07-2006

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4842197 A	27-06-1989	DE 3642122 C1	09-06-1988
		FR 2608214 A1	17-06-1988
		GB 2198521 A	15-06-1988
US 2004219466 A1	04-11-2004	CN 1550713 A	01-12-2004
US 5490378 A	13-02-1996	DE 4110507 A1	01-10-1992
		WO 9217736 A1	15-10-1992
		EP 0577618 A1	12-01-1994
		JP 3150971 B2	26-03-2001
		JP 6507231 T	11-08-1994
US 5966937 A	19-10-1999	NONE	
US 5373693 A	20-12-1994	DE 4228816 A1	03-03-1994
		FR 2695191 A1	04-03-1994
		GB 2270974 A	30-03-1994
US 6543235 B1	08-04-2003	NONE	
US 5417070 A	23-05-1995	NONE	
DE 19627760 A1	15-01-1998	WO 9801706 A1	15-01-1998
		EP 0910776 A1	28-04-1999
		ES 2162683 T3	01-01-2002
		US 6244051 B1	12-06-2001

EPO FORM P0459

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

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- DE 19627760 A1 **[0005] [0010] [0017]**
- EP 1158246 A2 **[0005]**