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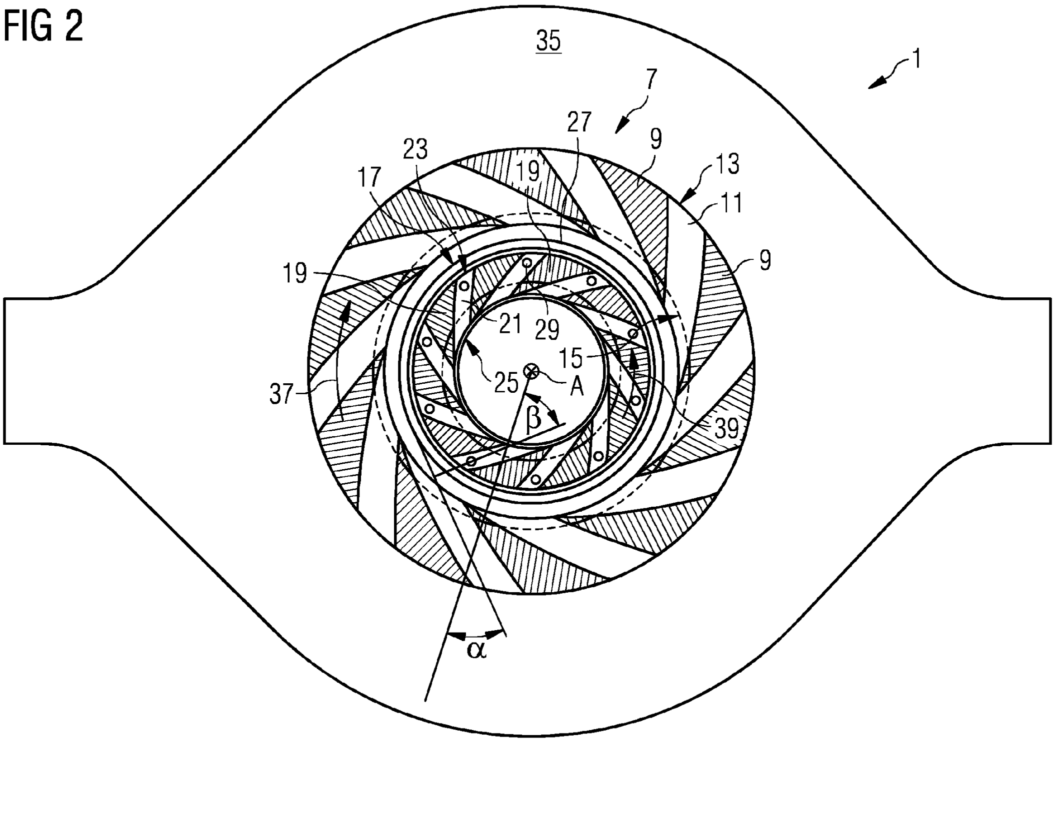
(54) **Gas Turbine Combustion System and Method of Flame Stabilization in such a System**

(57) A gas turbine combustion system (1) which comprises
- a first radial inflow swirler (7) having first radial outer intake openings (13) and first flow passages (11) extending from the first radial outer intake openings (13) to the first radial inner outlet openings (15), each first flow passage (11) including a first angle (α) with respect to the radial direction;
- a second radial inflow swirler (17) having second radial outer intake openings (23), second radial inner outlet openings (25) and second flow passages (21) extending from the second radial outer intake openings (23) to the second radial inner outlet openings (25), each second flow passage (21) including a second angle (β) with respect to the radial direction;
- where the radial outer circumference of the second radial inflow swirler (17) has a diameter that is smaller than the diameter of the radial inner circumference of the first radial inflow swirler (7) and the second radial inflow swirler (17) is located coaxially with and radially inside the first radial inflow swirler (7).

The first angle (α) has a different sign than the second angle (β) with respect to the radial direction.

FIG 2



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Description

[0001] The present invention relates to a gas turbine combustion system and to flame stabilisation in a gas turbine combustion system. In particular, the invention relates to flame stabilisation in swirl stabilized diffusion flames.

[0002] Although conventional diffusion flames that are swirl stabilised are not as prone to flame instabilities as are the flames in dry low emission burners (DLE- burners) , in which the air/ fuel ratio is at or near stoichiometric in order to reduce pollutants, the conventional burners still need a proper stable mixing to avoid any flameouts. In particular, if conventional burners are to be driven with a fuel containing H_2, which is for example present to a considerable amount in syngas or coke oven gas (COG) , flame stabilisation is still an issue because these gases will lead to higher flame speeds which might end up in more flameouts.

[0003] Multiple swirler concepts for manipulating mixing of fuel and air in gas turbine combustion systems are known from the state of the art. For example Bassam Mohammad and San-Mou Jeng "The Effect of Geometry on the Aerodynamics of a Prototype Gas Turbine Combustor", Proceedings of ASME Turbo Expo 2010: Power for Land, Sea and Air GT 2010, June 14 - 18, 2010, Glasgow, UK, EP 2 192 347 A1 and US 6,253,555 B1 describe combustion systems in which two radial inflow swirlers are arranged axially along a combustor central axis. In these combustion systems each radial swirler is used by different airstreams. While in the first two mentioned documents both swirlers produce a swirl with the same rotational direction the swirlers of US 6,253,555 B1 produce swirls of different rotational direction.

[0004] Yehida A. Eldrainy, et al. "A Multiple Inlet Swirler for Gas Turbine Combustors", World Academy of Science, Engineering and Technology, 53, 2009 describe a combustion system, in which a radial inflow swirler and an axial inflow swirler are combined.

[0005] US 6,311,496 B1 describes a gas turbine combustion system with two radial inflow swirlers that are successively used by the airstream.

[0006] However, in particular for combustion systems using fuel gas with hydrogen (H_2) like syngas or coke oven gas there is still need of improving flame stabilisation.

[0007] Hence, it is an objective of the present invention to provide a design for a gas turbine combustion system with increased stability of diffusion flames. It is a further objective of the present invention to provide a method of flame stabilisation in a gas turbine combustion system, in particular for diffusion flames.

[0008] The first objective is achieved by a gas turbine combustion system as claimed in claim 1. The second objective is achieved by a method of flame stabilisation in a gas turbine combustion system as claimed in claim 9. The depending claims contain further developments of the invention.

[0009] An inventive gas turbine combustion system comprises a central axis and a radial direction with respect to said central axis, a first radial inflow swirler and a second radial inflow swirler.

[0010] The first radial inflow swirler has radial outer intake openings located at a radial outer circumference of the first radial inflow swirler. The radial outer intake openings of the first radial inflow swirler are refered to as first radial outer intake openings in the following. Moreover, the first radial inflow swirler has outlet openings located at a radial inner circumference of the first radial inflow swirler. These outlet openings are referred to as first radial inner outlet openings in the following. Flow passages, named first flow passages in the following, extend from the first radial outer intake openings to the first radial inner outlet openings. Each first flow passage includes a first angle with respect to the radial direction.

[0011] The gas turbine combustion system further comprises a second radial inflow swirler having radial outer intake openings which are located at a radial outer circumference of the second radial inflow swirler and which are referred to as second radial outer intake openings in the following. In addition, the second radial inflow swirler has radial inner outlet openings, which are referred to as second radial inner outlet openings in the following and which are located at a radial inner circumference of the second radial inflow swirler. Flow passages, named second flow passages in the following, extend from the second radial outer intake openings to the second radial inner outlet openings. Each second flow passage includes an angle with respect to the radial direction. This angle is referred to as a second angle in the following. In a particular embodiment of the inventive gas turbine combustion system, the number of second flow passages may be identical to the number of first flow passages.

[0012] The radial outer circumference of the second radial inflow swirler has a diameter that is at least slightly smaller than the diameter of the radial inner circumference of the first radial inflow swirler, and the second radial inflow swirler is located coaxially with and radially inside the first radial inflow swirler.

[0013] According to the invention, the first angle has a different sign than the second angle with respect to the radial direction. In other words, the second radial inflow swirler produces a swirl counterrotating with respect to the swirl generated by the first radial inflow swirler. The counterrotation produced by the two swirlers leads to a more uniform mixing of an oxidant, like in particular the oxygen in the air, and fuel and to a stable flame which has the advantages of lesser flameouts, a more distributed mixing of fuel and the oxidant, a better control of the combustion burner, lesser hotspots and a lower heat load across the metal surfaces like, for example, the combustor walls. In a further development of the inventive gas turbine combustion system, the first angle and the second angle may have the same absolute value so that they only differ in their orientation with respect to the radial direction.

[0014] Preferably, fuel injection openings are located in the second radial inflow swirler and are open towards the second flow passages. More preferably, the fuel injection openings are located inside the second flow passages, in particular in the radial outer half of the second flow passages, preferably in the outer third of the second flow passages. By injecting fuel into the second flow passages a particular effective flame stabilisation can be achieved.

[0015] In an advantageous further development of the inventive combustion system, a radial gap may be present between the radial inner circumference of the first radial inflow swirler and the radial outer circumference of the second radial inflow swirler. In this case, the flow cross section of the second flow passages may be smaller than the flow cross section of the first flow passages since part of the fluid can be introduced into a combustion chamber through the radial gap while another part will be introduced into the combustion chamber through the second radial inflow swirler.

[0016] According to a second aspect of the present invention, a method of flame stabilisation in a gas turbine combustion system is provided. In the combustion system, a fluid flows along a flow path with a radial component from a fluid inlet to a fluid outlet. The fluid is a fluid that comprises an oxidant, and a fuel is mixed with the fluid that comprises an oxidant so as to transform the fluid into a mixture comprising fuel and the oxidant. When air is used as the fluid (that comprises oxygen as the oxidant) the fluid is transformed into a fuel/air mixture. A first swirl with a first rotational direction is introduced into the flowing fluid in a radial upstream section of the flow path. Moreover, a second swirl with a second rotational direction is introduced into at least a portion of the fluid in a radial downstream section of the flow path. According to the inventive method, the second rotational direction represents a counterrotation with respect to the first rotational direction. By introducing a counterrotation a better stability of the diffusion flame and a more uniform mixing of fuel and the oxidant can be achieved, as mentioned above with respect to the inventive combustion system. This is, in particular, true if the fuel contains hydrogen.

[0017] The inventive method is particularly effective in improving flame stability and uniform mixing of fuel and oxidant if fuel is introduced into the fluid where the second swirl is generated. In particular, the fuel is introduced into the fluid at a location where generation of the second swirl begins.

[0018] According to a further development of the invention, no second swirl is introduced into a portion of the fluid.

[0019] Further features, properties and advantages of the present invention will become clear from the following description of embodiments in conjunction with the accompanying drawings.

Figure 1 schematically shows a combustor arrangement for a gas turbine with an inventive combustion system and a combustion chamber.

Figure 2 shows the combustion system as seen from the combustion chamber.

[0020] An inventive combustion system will be described with respect to Figures 1 and 2 in the context of a combustor arrangement including an inventive combustion system. The inventive combustion system is adapted for performing the inventive method of flame stabilisation in a gas turbine combustion system which will also be described with respect to Figures 1 and 2.

[0021] Figure 1 shows part of a combustor arrangement in a sectional view. The combustor arrangement comprises a combustion chamber 3 and a combustion system 1 that is connected to a combustion chamber 3 via a small pre-chamber 5. The pre-chamber is sometimes also called transition section and may be part of the combustion system 1 like in the present embodiment. However, the pre-chamber 5 may as well be a part of the combustion chamber 3 or a distinct part that is neither part of the combustion system 1 nor of the combustion chamber 3.

[0022] The combustion system 1 comprises a first radial inflow swirler 7 that, shows rotational symmetry with respect to a central combustor axis A. The first radial inflow swirler is equipped with a number of vanes 9 that are distributed along the circumferential direction of the swirler 7 and are spaced apart from each other. Flow passages 11 are formed between neighbouring vanes 9. Each flow passage 11 extends from a first radial outer intake opening 13 located at a radial outer circumference of the swirler 7 to a first radial inner outlet opening 15 located at a radial inner circumference of the swirler 7. The flow passages 11 of the first swirler 7 are angled with respect to the radial direction of the swirler with a first angle α so that a swirl is imparted to a fluid flowing through the flow channel 11.

[0023] The combustion system 1 further comprises a second radial inflow swirler 17 that, like the first radial inflow swirler, shows radial symmetry. However, the second radial inflow swirler 17 has an outer circumference the diameter of which is smaller than the inner circumference of the first radial inflow swirler 11. The second radial inflow swirler 17 is located inside an opening formed by the inner circumference of the first radial inflow swirler 7 so that a fluid that exists the outlet openings 15 of the first radial inflow swirler 7 is directed towards the second radial inflow swirler 17.

[0024] Like the first radial inflow swirler 7, the second radial inflow swirler 17 comprises a number of vanes 19 that are distributed in circumferential direction of the swirler such that second flow passages 21 are formed between them. Each second flow passages 21, i.e. each flow passage of the second radial inflow swirler 17, extends from a second radial outer intake opening 23 located at the radial outer circumference of the second swirler to a second radial inner outlet opening 25, i.e. an outlet opening of the second swirler 17 that is located at the inner circumference of the second radial inflow swirler 17. The flow channels 21 of the second radial inflow swirler 17 include an angle with the radial direction (denominated β in Figure 2) which has, in the present embodiment, the same absolute value as the angle of the flow channels 11 of the first radial inflow swirler 7 but a different sign. Hence, the flow channels 11 of the first radial inflow swirler 7 impart a clockwise swirl to a flowing fluid and the flow channels 21 of the second radial inflow swirler 17 impart a counter-clockwise swirl to a fluid flowing therethrough, or vice versa.

[0025] Both swirlers 7, 17 are mounted to a base plate 31 such that they are arranged coaxially with each other and with respect to the combustor axis A. Moreover, in the present embodiment they are arranged such that a radial gap 27 is formed between the inner circumference of the first radial inflow swirler 7 and the outer circumference of the second radial inflow swirler 17.

[0026] Fuel channels 33 extend through the base plate 31 and lead to fuel opening 29 in the flow passages 21 of the second radial inflow swirler 7. The fuel openings 29 are located in the outer half of the second flow passages 21, preferably in the outer third of the second flow passages 21, and more preferably in the outer fourth of the second flow passages 21.

[0027] The first radial inflow swirler 7 is surrounded by a flow channel 35 which allows feeding a fluid, in particular air or any other suitable fluid that comprises an oxidant, to the intake openings 13 of the first radial inflow swirler.

[0028] During operation of a gas turbine air is fed to the intake openings 13 of the first radial inflow swirler 7 through the flow channel 35. The air then flows through the flow passages 11 of the first radial inflow swirler 7 whereby a first swirl (indicated by arrow 37) is imparted to the flowing air. Hence, in the present embodiment, the air swirls with a clockwise rotation after exciting the first swirler through the outlet openings 15. A part of the clockwise swirling air reaches the pre-chamber 5 through the radial gap 27. Another part of the clockwise swirling air enters the flow passages 21 of the second radial inflow swirler 17 through the intake openings 23. Thereby, the intake openings 23 of the second radial inflow swirler generate turbulences in the flow channel sections adjoining the intake openings 15. The turbulences are generated due to a reversal in rotation direction that is necessary for the air to enter the flow passages 21 of the second swirler 17. The turbulence are highest in a flow passage zone adjoining the intake openings 23 of the flow passages.

[0029] A fuel gas like, for example, syngas or coke oven gas (COG) is introduced into the turbulent airstreams in the second flow passages 21 through the fuel holes 29. The strong turbulence leads to a highly uniform mixing of fuel and air until the fuel/air mixture leaves the second flow channels 21 through the second outlet openings 25. Due to the angle β the second flow passages 21 include with the radial direction a second swirl (indicate by arrow 39) with a counter-clockwise rotation is imparted to the fuel/air mixture flowing through the second flow passages 21.

[0030] A further effect of giving the angle of the flow channels of the first and second swirlers a different sign with respect to the radial direction is that the fuel/air mixture has a different direction of rotation than the air entering the pre-chamber 5 through the gap 27 that is present between both swirlers 7, 17 in the described embodiment. As a consequence, the air rotating clockwise in the present embodiment can form an envelop around the fuel/air mixture rotating counter-clockwise in the present embodiment which makes it more difficult for fuel/air mixture to reach the wall of the pre-chamber 5 and the combustion chamber 3, thereby reducing heat load across the metal surface of the combustor wall. A further advantage is that turbulences are formed where the counter-clockwise swirling fuel/air mixture is in contact with the clockwise swirling air, which turbulences lead to a more distributed mixing of fuel and air. The mentioned effects contribute to leading to less flameouts and less hotspots, in particular with use of H_2 containing gases like syngas or COG. In the end, this leads to a better controllable combustion burner.

[0031] The present invention has been described with respect to a specific embodiment to describe a method of improve mixing of gas and air and to stabilise the flame by using the concepts of swirl strength in diffusion flames to anchor it in a stabile way. In particular, counterrotating swirls are used to improve mixing and stabilising of the flame. However, the invention shall not be restricted to the specific embodiment described with respect to the figures, since deviations thereform are possible. For example, while in the Figures both swirlers have the same number of flow passages the second wirler could have a higher or lower number of flow passages than the first swirler. Moreover, the flow passages of both swirlers are angled by the same absolute value with respect to the radial direction but with a different sign. In other embodiments it may be useful to also have different absolute values of the angles between the flow passages and the radial direction. A further possible deviation from the embodiment described with respect to the figures is the number of fuel opening that are present in each flow passage of the second swirler. While in the described embodiment only one fuel openings is present in each flow passage a higher number of fuel openings may be present as well. Moreover, the fuel openings do not need to be present in the base plate. Alternatively or additionally, fuel openings could be located in the sidewalls of the vanes. Since the location of the fuel openings is closely related to the geometry of the swirler and the fuel to be used the exact position of the fuel openings may depend on the concrete design of the first and second radial inflow swirler and/or on the intended use of the combustion system.

[0032] Since many deviations from the embodiment are possible, the present invention shall only be limited by the appended claims.

Claims

1. A gas turbine combustion system (1) comprising

   - a central axis (A) and a radial direction with respect to said central axis (A);
   - a first radial inflow swirler (7) having first radial outer intake openings (13) located at a radial outer circumference of the first radial inflow swirler (7), first radial inner outlet openings (15) located at a radial inner circumference of the first radial inflow swirler (7), and first flow passages (11) extending from the first radial outer intake openings (13) to the first radial inner outlet openings (15), each first flow passage (11) including a first angle (α) with respect to the radial direction;
   - a second radial inflow swirler (17) having second radial outer intake openings (23) located at a radial outer circumference of the second radial inflow swirler (17), second radial inner outlet openings (25) located at a radial inner circumference of the second radial inflow swirler (17), and second flow passages (21) extending from the second radial outer intake openings (23) to the second radial inner outlet openings (25), each second flow passage (21) including a second angle (β) with respect to the radial direction;
   - where the radial outer circumference of the second radial inflow swirler (17) has a diameter that is smaller than the diameter of the radial inner circumference of the first radial inflow swirler (7) and the second radial inflow swirler (17) is located coaxially with and radially inside the first radial inflow swirler (7),

   characterised in that
   the first angle (α) has a different sign than the second angle (β) with respect to the radial direction.

2. The gas turbine combustion system (1) as claimed in claim 1, **characterised in that** fuel injection openings (29) are located in the second radial inflow swirler (17) and are open towards the second flow passages (21).

3. The gas turbine combustion system (1) as claimed in claim 2, **characterised in that** the fuel injection openings (29) are located inside the second flow passages (21).

4. The gas turbine combustion system (1) as claimed in claim 3, **characterised in that** the fuel injection openings (29) are located in the radial outer half of the second flow passages (21) .

5. The gas turbine combustion system (1) as claimed in any of the claims 1 to 4, **characterised in that** the number of second flow passages (21) is identical to the number of first flow passages (11).

6. The gas turbine combustion system (1) as claimed in any of the claims 1 to 5, **characterised in that** a radial gap (27) is present between the radial inner circumference of the first radial inflow swirler (7) and the radial outer circumference of the second radial inflow swirler (17).

7. The gas turbine combustion system (1) as claimed in claim 6, **characterised in that** the flow cross section of the second flow passages (21) is smaller than the flow cross section of the first flow passages (11).

8. The gas turbine combustion system (1) as claimed in any of the claims 1 to 7, **characterised in that** the first angle (α) and the second angle (β) have the same absolute value.

9. A method of flame stabilisation in a gas turbine combustion system (1) in which a fluid flows along a flow path with a radial component, where

   - the fluid is a fluid that comprises an oxidant and a fuel is mixed with the fluid that comprises an oxidant so as to transform the fluid into a mixture comprising fuel and the oxidant;
   - a first swirl with a first rotational direction (37) is generated in the flowing fluid in a radial upstream section of the flow path; and
   - a second swirl with a second rotational direction (39) is generated in at least a portion of the fluid in a radial downstream section of the flow path, **characterised in that**

   the second rotational direction represents a counter rotation (39) with respect to the first rotational direction (37).

10. The method as claimed in claim 9, **characterised in that** fuel is introduced into the fluid where the second swirl is generated.

11. The method as claimed in claim 10, **characterised in that** the fuel is introduced into the fluid at a location where generation of the second swirl begins.

12. The method as claimed in any of the claims 9 to 11, **characterised in that** no second swirl is introduced into a portion of the fluid.

FIG 1

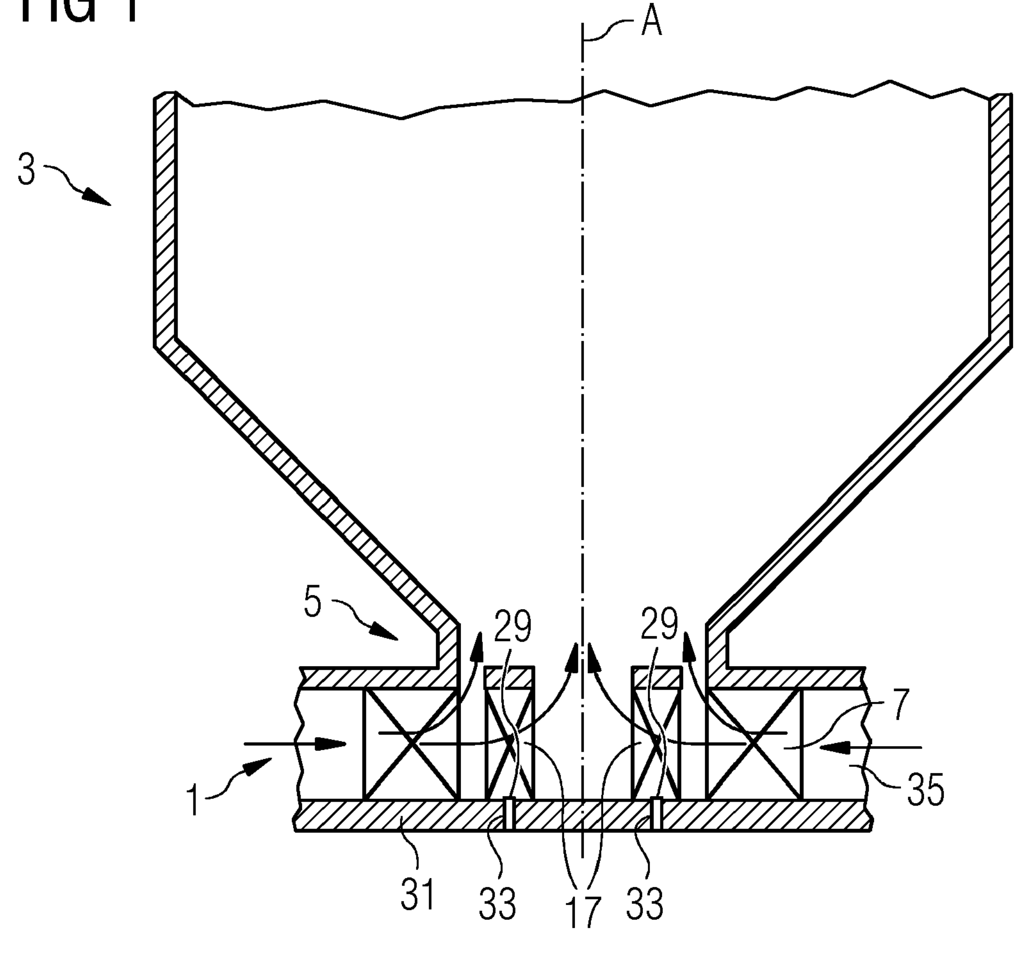
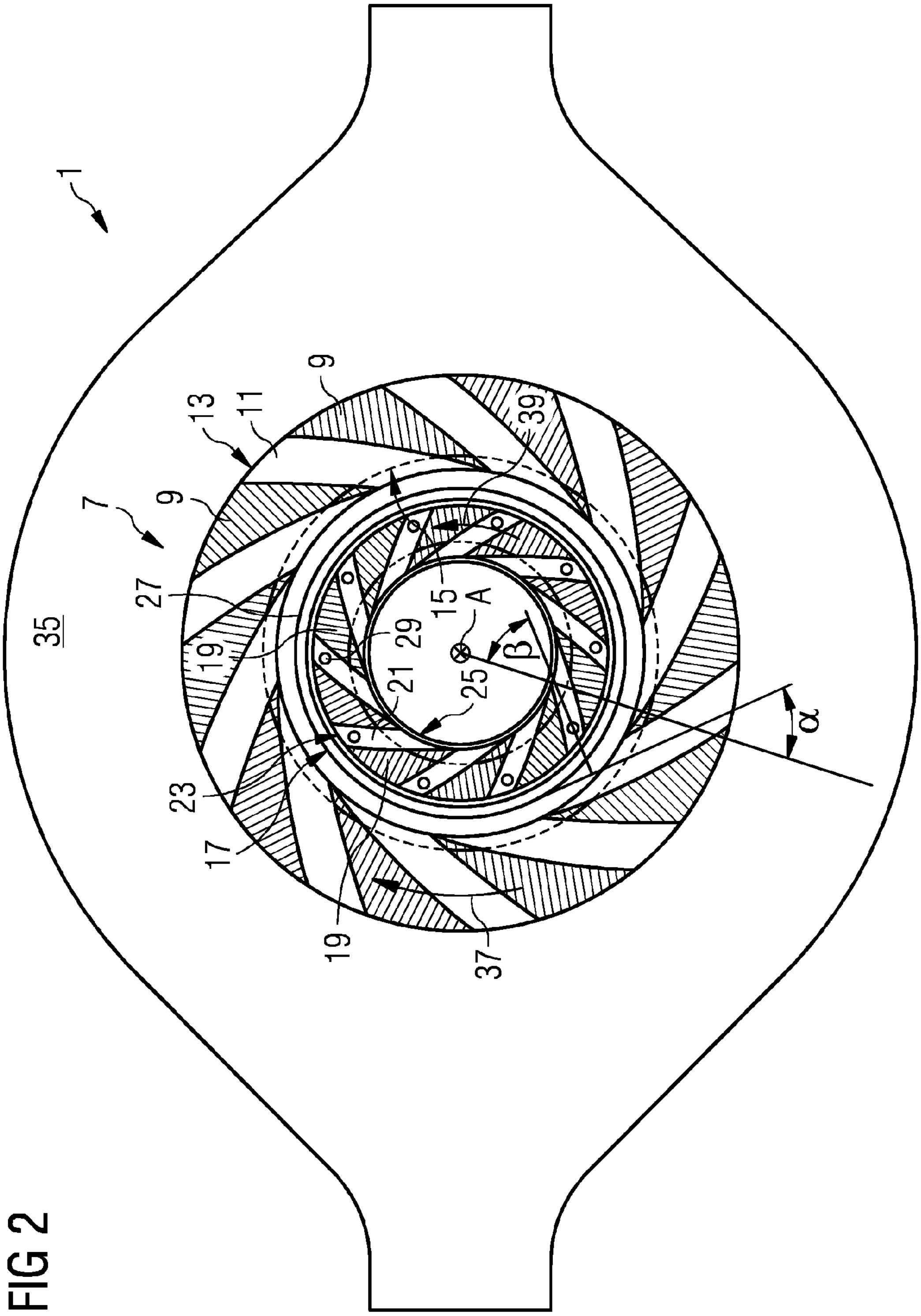


FIG 2



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EUROPEAN SEARCH REPORT

Application Number
EP 12 15 9203

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X Y	US 2005/257530 A1 (ZUPANC FRANK J [US] ET AL) 24 November 2005 (2005-11-24) * page 2, paragraph 20 - page 3, paragraph 25 * * page 3, paragraph 30 * * claims 1,6; figures 2-4 *	1,6-9 2-5,10, 11	INV. F23C7/00 F23R3/14 F23R3/28
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	18 July 2012	Gavriliu, Costin

CATEGORY OF CITED DOCUMENTS

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

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