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(54) A MIXER AND A METHOD FOR OPERATING THE SAME

(57) The mixer (7) comprises a housing (15), a duct (16) within the housing (15), at least a first injector (17a) and a second injector (17b) for injecting a fluid having a fluctuating mass flow into the duct (16). The first injector (17a) and the second injector (17b) are at a distance (D) such that the fluid mass flow injected through the first injector (17a) reaches the second injector (17b) in phase opposition with the fluid mass flow injected through the second injector (17b). The first and the second injectors (17a, 17b) are configured and arranged for injecting a mass flow having substantially the same fluctuation amplitude.

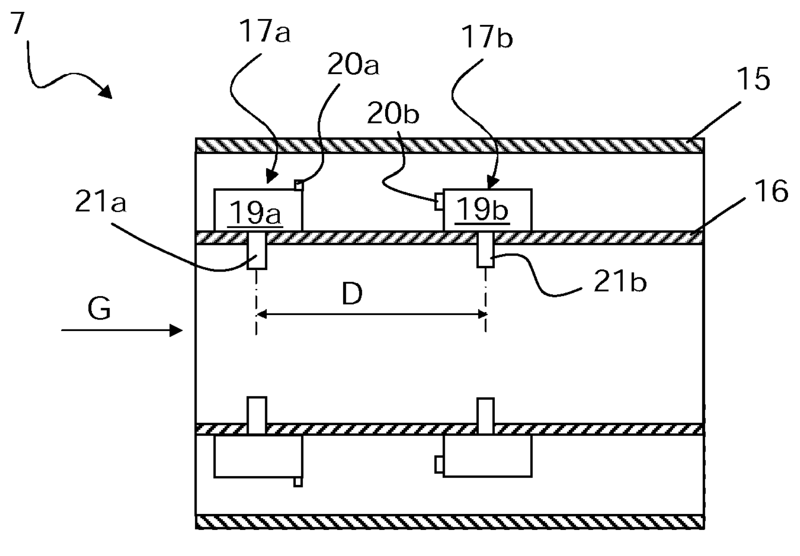

Fig. 4

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Description

TECHNICAL FIELD

[0001] The present invention relates to a mixer and a method for operating the same.

[0002] In particular the mixer is part of a gas turbine, e.g. a gas turbine of a power plant.

BACKGROUND

[0003] Figure 1 schematically shows an example of a gas turbine; the gas turbine 1 has a compressor 2, a first combustion chamber 3, a second combustion chamber 4 and a turbine 5. Possibly between the first combustion chamber 3 and the second combustion chamber 4 a high pressure turbine is provided. During operation air is compressed at the compressor 2 and is used to combust a fuel in the first combustion chamber 3; the hot gas (possibly partly expanded in the high pressure turbine) is then sent into the second combustion chamber 4 where further fuel is injected and combusted; the hot gas generated at the second combustion chamber 4 is then expanded in the turbine 5.

[0004] Between the first combustion chamber 3 and the second combustion chamber 4 a mixer 7 can be provided in order to dilute with air (or other gas) the hot gas coming from the first combustion chamber 3 and directed into the second combustion chamber 4. This allows a correct fuel injection and mixing with the hot gas at the second combustion chamber.

[0005] Figure 2 schematically shows the section of the gas turbine including the first and the second combustion chambers 3, 4. Figure 2 shows a first burner 3a of the first combustion chamber 3 where the compressed air coming from the compressor 2 is mixed with the fuel and a combustor 3b where the mixture is combusted generating hot gas (reference 20a indicates the flame). The hot gas is directed via a transition piece 3c into the mixer 7, where air is supplied into the hot gas to dilute it. The diluted (and cooled) hot gas is thus supplied into the burner 4a of the second combustion chamber 4 where further fuel is injected into the hot gas via a lance 8 and mixed to it. This mixture combusts in the combustor 4b by auto combustion (reference 20b indicates the flame), after a "delay time" from the injection into the second burner 4a.

[0006] The temperature at the inlet of the second burner 4a can fluctuate, typically because of mass flow fluctuation of the air coming from the mixer 7 and directed into the second burner 4a.

[0007] The delay time depends on, inter alia, the temperature within the second burner 4a, such that temperature fluctuations in the second burner 4a cause increase/decrease of the delay time and thus axial upstream/downstream oscillations of the flame in the combustor 4b.

[0008] In order to counteract these axial oscillations of the flame, the temperature in the second burner 4a has to be maintained constant and thus the temperature of the flow emerging from the mixer 7 has to be maintained constant.

[0009] The flow temperature at the exit of mixer 7 can vary because within the mixer 7 pressure fluctuations exist (e.g. due to the combustion in the combustor 3b and/or 4b); these pressure fluctuations cause diluting air fluctuating mass flow injection into the mixer.

[0010] In order to maintain the diluting air mass flow substantially constant, multiple injectors can be provided at different axial locations of the mixer 7, in such a way that fluctuating air mass flow supplied through upstream injectors compensate for fluctuating air mass flow supplied trough downstream injectors. In other words, air is injected in such a way that the dilution air mass flow injected from upstream injectors reaches the downstream injectors in phase opposition with respect to the dilution air injected through them (and vice versa); this way the upstream/downstream mass flows compensate for one another and air mass flow fluctuations are counteracted.

[0011] Nevertheless the mass flow fluctuations amplitude of air injected at different axial positions of the mixer can differ because of the acoustic mode within the mixer. The acoustic mode is the maximum fluctuation amplitude of the acoustic pressure over the axial axis of the mixer. The acoustic pressure derives by the relationship: $Pi=Pm+Pa$, wherein Pi is the pressure inside of the mixer, Pm is the average pressure in the mixer (i.e. the operating nominal pressure); Pa is the acoustic pressure, being the pressure fluctuations around the average pressure.

[0012] In this respect, figure 3A shows an example of an acoustic mode in connection with the axial position x along the mixer; references 17a and 17b indicate the injectors, which respectively inject the mass flow Ma and mass flow Mb. Aa and Ab identify the maximum amplitude of the acoustic pressure fluctuations at the injector axial locations 17a and 17b.

[0013] Figures 3B and 3C respectively show the mass flow Ma and Mb and their fluctuations; the mass flows Ma and Mb propagate along the mixer towards the mixer exit; the fluctuation course is defined with respect to the mean flow (which is in general different but could also be the same) and is shown as a wave that moves from the inlet to the outlet of the mixer.

[0014] Figure 3D shows the total mass flow Mtot and the fluctuations thereof, resulting from the overlapping of the mass flows Ma and Mb; as shown, since the fluctuation amplitude of the mass flow Mb is larger than the fluctuation amplitude of the mass flow Ma, the overlapping of the mass flows Ma and Mb does not result in fluctuation cancellation, but only in attenuated fluctuations.

SUMMARY

[0015] An aspect of the invention includes providing a mixer and a method by which the mass flow fluctuation cancellation for the fluid injected into the mixer can be improved.

[0016] Advantageously, by adjusting the pressure drop of the mass flow injected through different injectors, the fluctuations amplitude can be made comparable, such that overlapping of the mass flows injected through the different injectors can result in a large reduction or also cancellation of the mass flow fluctuations.

[0017] These and further aspects are attained by providing a mixer and a method in accordance with the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Further characteristics and advantages will be more apparent from the description of a preferred but non-exclusive embodiment of the mixer and method, illustrated by way of non-limiting example in the accompanying drawings, in which:

Figures 1 and 2 show a gas turbine and a part thereof;
Figures 3A through 3D show the acoustic mode in the mixer (figure 3A), the mass flow injected through the different injectors and the fluctuations thereof (figures 3B and 3C), the total mass flow injected into the mixer and the fluctuations thereof (figure 3D);
Figures 4 and 5 show different embodiments of the mixer;
Figures 6A through 6D show the acoustic mode in the mixer (figure 6A), the mass flow injected through the different injectors and the fluctuations thereof (figures 6B and 6C), the total mass flow injected into the mixer and the fluctuations thereof (figure 6D).

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0019] With reference to the figures, these show a mixer 7. The mixer 7 comprises a housing 15, a duct 16 within the housing 15, a first injector 17a and a second injector 17b for injecting a fluid (such as compressed air from the compressor, possibly cooled) into the duct 16; the fluid is injected by the first and second injector 17a, 17b with a fluctuating mass flow.

[0020] The first injectors 17a and 17b can be provided around the periphery of the duct 16 and can open in one or more points into the duct, as explained in the following.

[0021] The first injector 17a and the second injector 17b are at a distance D such that the fluid mass flow injected through the first injector 17a reaches the second injector 17b in phase opposition with the fluid mass flow injected through the second injector 17b. E.g. when the first injector 17a injects a large fluid mass flow, the large fluid mass flow axially travels through the duct 16 and reaches the second injector 17b when the second injector 17b is injecting fluid with a small fluid mass flow.

[0022] Advantageously, the first and the second injectors 17a, 17b are configured and arranged for injecting a mass flow (e.g. instantaneous mass flow) having substantially the same fluctuation amplitude. This allows a large reduction or also cancellation of the mass flow fluctuation for the mass flow resulting from the sum of the mass flow Ma from the first injector 17a and the mass flow Mb from the second injector 17b.

[0023] The first injector 17a can comprise a plenum 19a with at least an inlet 20a and at least a nozzle 21a for injecting the fluid into the duct 16. For example, the plenum 19a can be annular in shape and can embrace and be connected to the duct 16, the inlet 20a can be provided on any surface of the plenum 19a and the inlet 21a can protrude into the duct 16 or not.

[0024] Likewise, the second injector 17b can comprise a plenum 19b with at least an inlet 20b and at least a nozzle 21b for injecting the fluid into the duct 16. Also the plenum 19b can be annular in shape and can embrace and be connected to the duct 16, the inlet 20b can be provided on any surface of the plenum 19b and the inlet 21b can protrude into the duct 16 or not.

[0025] The injector can also be defined by a plurality of nozzles without the need of a plenum connected to it, as e.g. shown in figure 5.

[0026] In different embodiments, the first and/or the second injector can have any of the described structures. In the following reference to an embodiment with a plenum at both the first and the second injector 17a, 17b is made.

[0027] The inlet 20a of the first injector 17a and the inlet 20b of the second injector have different features in order to cause a different pressure drop for the fluid moving from the housing 15 into the plena 19a, 19b.

[0028] For example, these features of the inlets 20a, 20b include the inlet cross section and/or the inlet surface rugosity; other means are possible.

[0029] In addition, the nozzle 21a of the first injector 17a and the nozzle 21b of the second injector 17b can have different features in order to cause a different pressure drop for the fluid moving from the plena 19a, 19b into the duct 16. In case the injector 17a or 17b has no plenum, the nozzle 21a or 21b causes a pressure drop in the fluid moving from the housing 15 into the duct 16.

[0030] These features can include the nozzle cross section and/or the nozzle surface rugosity; other means are possible.

[0031] Naturally all combinations are possible, e.g. the following embodiments are possible:

- mixer with first injector 17a having the plenum 19a and second injector 17b having only nozzles (i.e. the second injector 17b does not have the plenum 19b) or vice versa; the nozzles 21a and 21b can have same or different features;
- mixer with both the first injector 17a and the second injector 17b having the plena 19a, 19b; the inlets into the plena have different features; the nozzles 21a and 21b can have same or different features;
- mixer with the first nozzle 21a and the second nozzle 21b having different features; the first injector 17a

and the second injector 17b can have the plena 19a, 19b or not or either only the first injector 17a or the second injector 17b can be provided with the plenum; the inlets 20a and 20b (if provided) can have same or different features.

[0032] The operation of the mixer is apparent from that described and illustrated and is substantially the following.

[0033] Hot gas G coming from the first combustion chamber 3 enters the duct 16 and passes through it, to be then discharged into the second combustion chamber 4.

[0034] The first injector 17a injects a fluid (compressed air e.g. from the compressor 2 possibly cooled) into the duct 16 to dilute and cool the hot gas; the fluid is injected into the duct 16 with a fluctuating mass flow Ma. After injection the mass flow (while mixing with the hot gas) travels through the duct 16 and reaches (completely or partly mixed to the hot gas) the second injector 17b (figure 6B).

[0035] Likewise, the second injector 17b injects a fluid (compressed air) into the duct 16 to dilute and cool the hot gas; the fluid is injected into the duct 16 with a fluctuating mass flow Mb (figure 6C).

[0036] The mass flow Ma reaches the second injector 17b in phase opposition with the mass flow Mb.

[0037] The fluid (compressed air) passes from the inside of the housing 15 into the plenum 19a of the first injector and 19b of the second injector. While passing through the inlets 20a and 20b the fluid undergoes a different pressure drop, such that the pressure inside the plena 19a and 19b is different and the flow injected through the injectors 17a and 17b and in particular the flow fluctuation amplitude thereof is different.

[0038] In addition, also the nozzles 21a and 21b can cause pressure drop for the fluid passing through them, to cause or contribute to cause injection of a different mass flow and thus different flow fluctuation amplitudes through the first and second injectors 17a, 17b.

[0039] As shown in figure 6D, the flow fluctuation amplitude for the mass flow Ma and Mb is made substantially equal; in addition, since the flow fluctuations are in phase opposition, their overlapping causes fluctuation cancellation.

[0040] The present invention also refers to a method for operating a mixer 7.

[0041] The method comprises injecting through the first and the second injectors 17a, 17b a mass flow (e.g. instantaneous mass flow) having substantially the same fluctuation amplitude.

[0042] According to the method:

- different pressure within the plenum 19a of the first injector 17a and plenum 19b of the second injector 17b can be provided. E.g., the fluid contained in the housing 15 can enter the plenum 19a of the first injector 17a and plenum 19b of the second injector 17b by passing through the inlet 20a of the first injector 17a and inlet 20b of the second injector 17b, and while passing through the inlet 20a of the first injector 17a and inlet 20b of the second injector 17b the fluid undergoes a different pressure drop, and/or
- the fluid contained in the plenum 19a of the first injector 17a and plenum 19b of the second injector 17b enters the duct 16 by passing through the nozzle 21a of the first injector 17a and nozzle 21b of the second injector 21b, and while passing through the nozzle 21a of the first injector 17a and nozzle 21b of the second injector 17b the fluid undergoes a different pressure drop.

[0043] The different pressure drop within the plena 19a, 19b and/or through the nozzles 21a, 21b causes injection of fluid with different fluctuation amplitude with respect to what would be imposed by the acoustic mode; therefore the fluctuations being in phase opposition and with substantially the same amplitude are cancelled following their overlapping.

[0044] Naturally the mixer can have more than two axially spaced injectors, which are at distances such as to reduce or cancel different frequencies. E.g. a mixer could have a first, a second and a third injectors, the first and the third injectors cooperating to cancel a fluctuation at a frequency and the second and third injectors cooperating to cancel fluctuations at another frequency. In a further example the mixer can have four injectors, with a first and a second injectors that cancel a frequency and a third and a fourth injectors that cancel another frequency. Naturally other examples with any number of injectors are possible.

[0045] Naturally the features described may be independently provided from one another. For example, the features of each of the attached claims can be applied independently of the features of the other claims.

[0046] In practice the materials used and the dimensions can be chosen at will according to requirements and to the state of the art.

REFERENCE NUMBERS

[0047]

1 gas turbine
2 compressor
3 first combustion chamber
3a first burner
3b combustor
3c transition piece
4 second combustion chamber
4a second burner
4b combustor
5 turbine
7 mixer
8 lance
9 turbine

15 housing
16 duct
17a, 17b injector
19a, 19b plenum
20a, 20b inlet
21a, 21b nozzle
Aa, Ab maximum amplitude for the mass flow fluctuations
D distance between the first and the second injectors
G hot gas
20a, 20b flame

Claims

1. A mixer (7) comprising a housing (15), a duct (16) within the housing (15), at least a first injector (17a) and a second injector (17b) for injecting a fluid having a fluctuating mass flow into the duct (16), wherein the first injector (17a) and the second injector (17b) are at a distance (D) such that the fluid mass flow injected through the first injector (17a) reaches the second injector (17b) in phase opposition with the fluid mass flow injected through the second injector (17b), **characterized in that** the first and the second injectors (17a, 17b) are configured and arranged for injecting a mass flow having substantially the same fluctuation amplitude.

2. The mixer (7) of claim 1, **characterized in that** the first injector (17a) comprises a plenum (19a) with at least an inlet (20a) and at least a nozzle (21a) for injecting the fluid into the duct (16).

3. The mixer (7) of claim 1 or 2, **characterized in that** the second injector (17b) comprises a plenum (19b) with at least an inlet (20b) and at least a nozzle (21b) for injecting the fluid into the duct (16).

4. The mixer (7) of claim 2 and 3, **characterized in that** the inlet (20a) of the first injector (17a) and the inlet (20b) of the second injector (17b) have different features in order to cause a different pressure drop for the fluid moving from the housing (15) into the plenum (19a) of the first injector (17a) and plenum (19b) of the second injector (17b).

5. The mixer (7) of claim 4, **characterized in that** the features of the inlet (20a) of the first injector (17a) and/or inlet (20b) of the second injector (17b) include the inlet cross section.

6. The mixer (7) of claim 4 or 5, **characterized in that** the features of the inlet (20a) of the first injector (17a) and/or inlet (20b) of the second injector (17b) include the inlet surface rugosity.

7. The mixer (7) of claim 1 or 2 or 3, **characterized in that** a nozzle (21a) of the first injector (17a) and a nozzle (21b) of the second injector (17b) have different features in order to cause different pressure drop for the fluid moving from the plena (19a, 19b) of the first and/or second injector (17a, 17b) into the duct (16).

8. The mixer (7) of claim 7, **characterized in that** the features of the nozzle (21a) of the first injector (17a) and/or nozzle (20b) of the second injector (17b) include the nozzle cross section.

9. The mixer (7) of claim 7 or 8, **characterized in that** the features of the nozzle (21a) of the first injector (17a) and/or nozzle (21b) of the second injector (17b) include the nozzle surface rugosity.

10. A method for operating a mixer (7) comprising a housing (15), a duct (16) within the housing (15), at least a first injector (17a) and a second injector (17b) for injecting a fluid having a fluctuating mass flow into the duct (16), wherein the first injector (17a) and the second injector (17b) are at a distance (D) such that the fluid mass flow injected through the first injector (10a) reaches the second injector (17b) in phase opposition with the fluid mass flow injected through the second injector (17b), **characterized by** injecting through the first and the second injectors (17a, 17b) a mass flow having substantially the same fluctuation amplitude.

11. The method of claim 10, **characterized in that** the first and second injectors (17a, 17b) each comprises: a plenum (19a, 19b) with at least an inlet (20a, 20b) and at least a nozzle (21a, 21b) for injecting the fluid into the duct (16), and by providing different pressure within the plenum (19a) of the first injector (17a, 17b) and plenum (19b) of the second injector (17b).

12. The method of claim 11, **characterized in that** fluid contained in the housing (15) enters the plenum (19a) of the first injector (17a) and plenum (19b) of the second injector (17b) by passing through the inlet (20a) of the first injector (17a) and inlet (20b) of the second injector (20b), and **in that** while passing through the inlet (20a) of the first injector (17a) and inlet (20b) of the second injector (17b) the fluid undergoes a different pressure drop.

13. The method of claim 11 or 12, **characterized in that** fluid contained in the plenum (19a) of the first injector (17a) and plenum (19b) of the second injector (17b) enters the duct (16) by passing through the nozzle (21a) of the first injector (17a) and nozzle (21b) of the second injector (17b), and **in that** while passing through the nozzle (21a) of the first injector (17a) and nozzle (21b) of the second injector (17b) the fluid undergoes a different pressure drop.

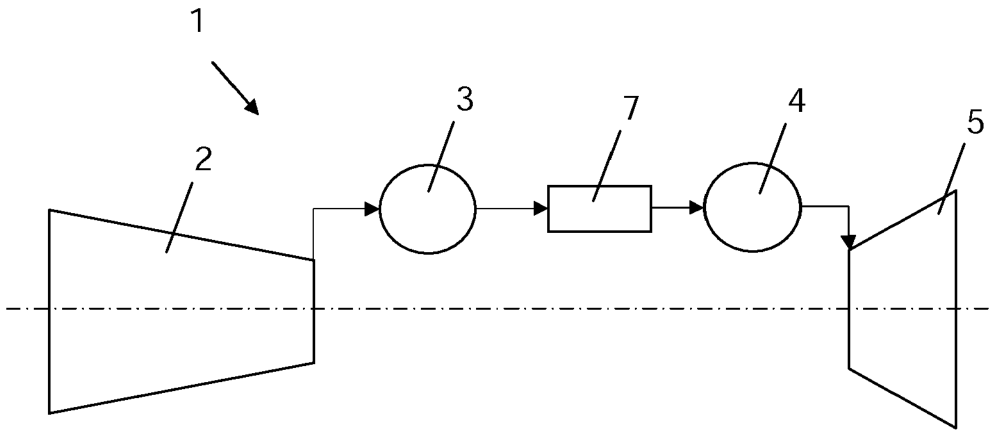

Fig. 1

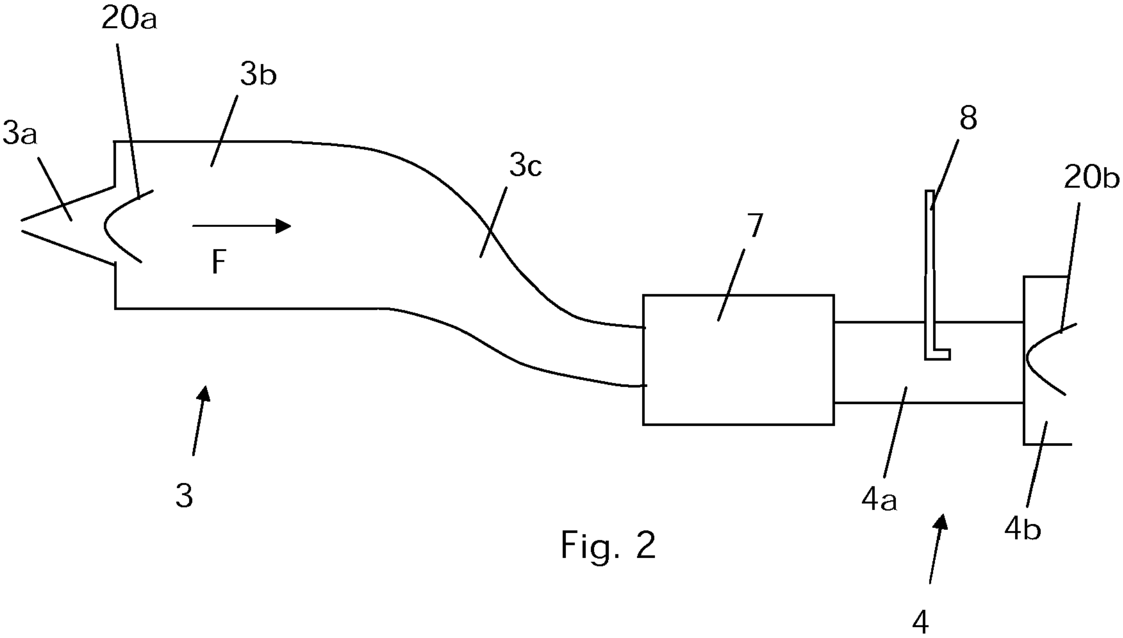

Fig. 2

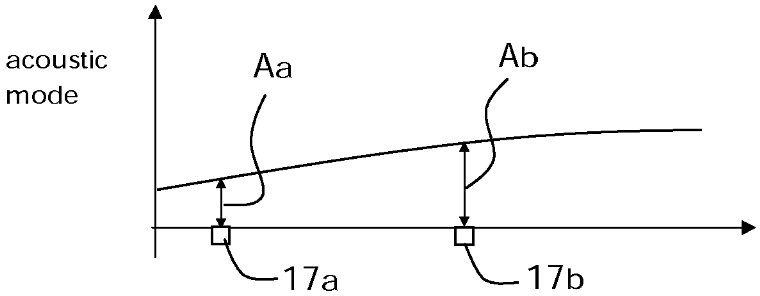

Fig. 3A

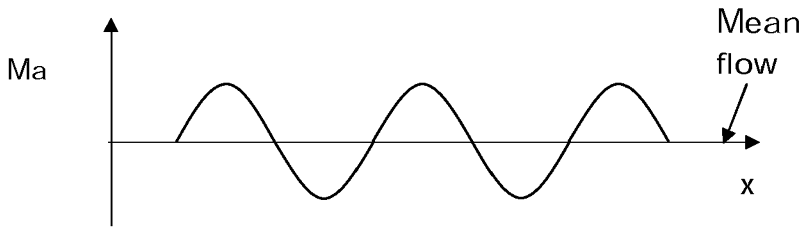

Fig. 3B

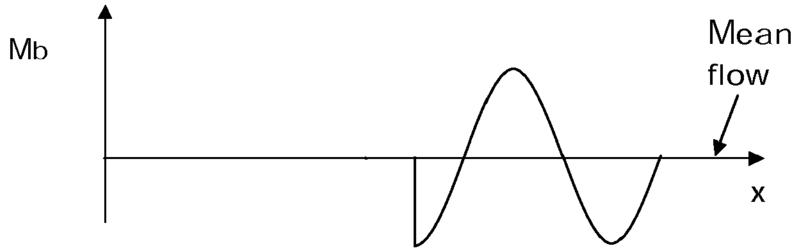

Fig. 3C

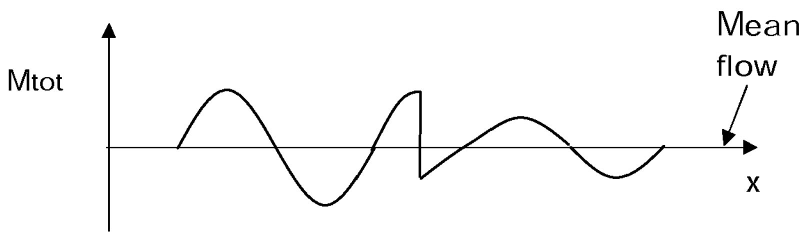

Fig. 3D

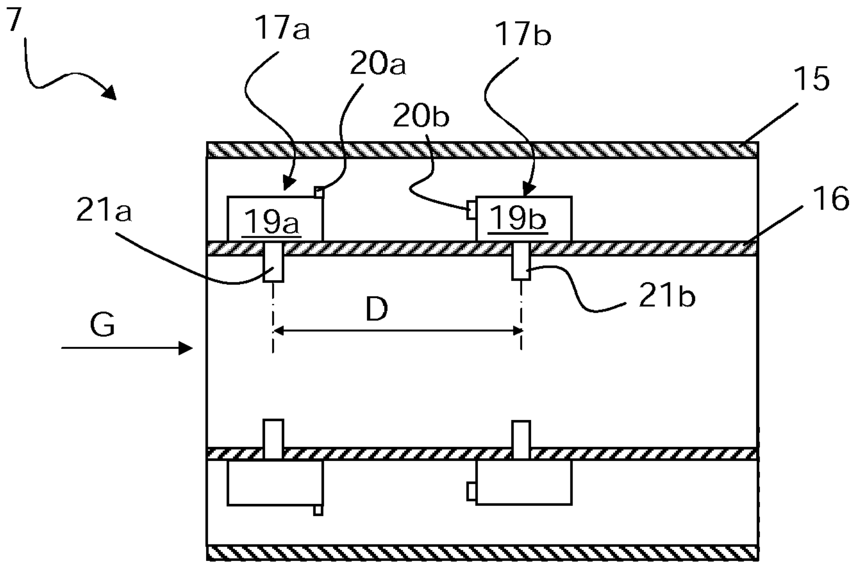
7
17a
20a
17b
20b
15
16
21a
19a
19b
21b
G
D

Fig. 4

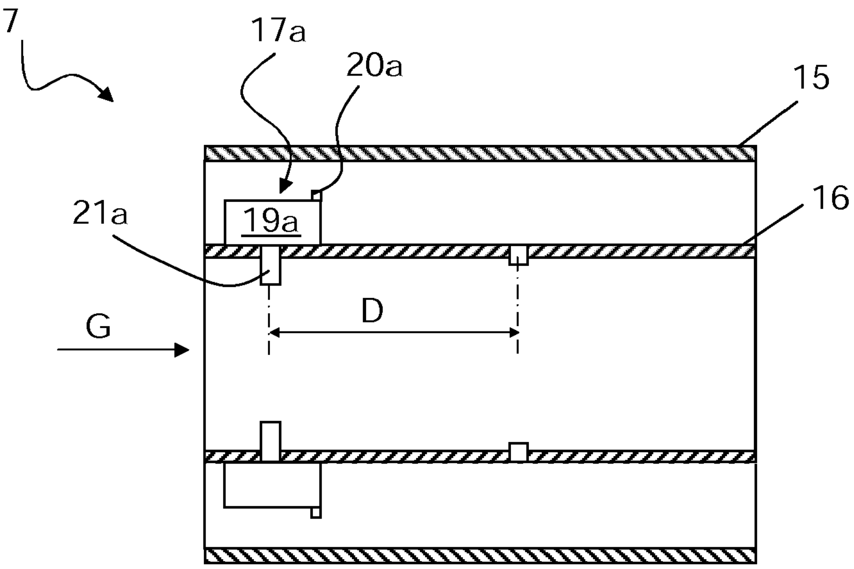
7
17a
20a
15
16
21a
19a
G
D

Fig. 5

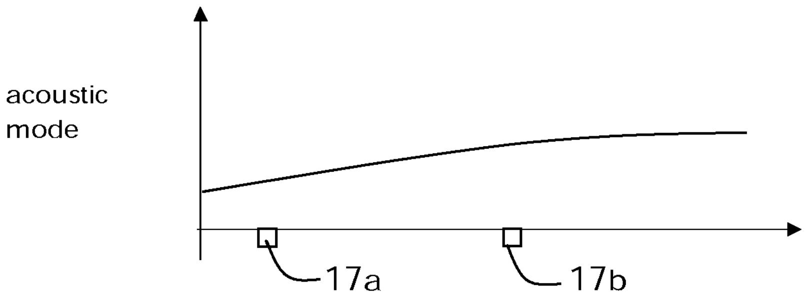

Fig. 6A

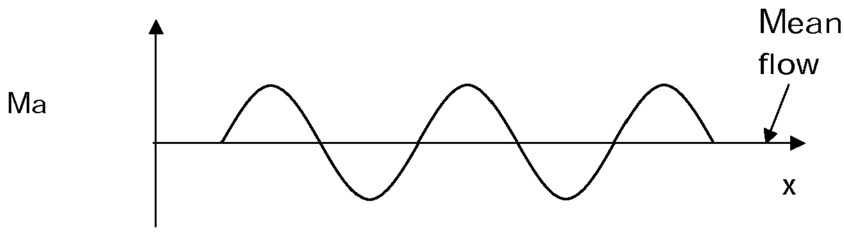

Fig. 6B

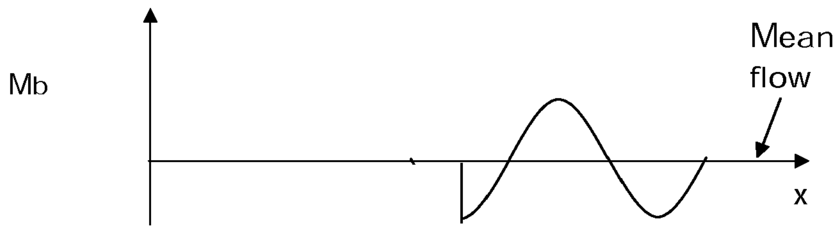

Fig. 6C

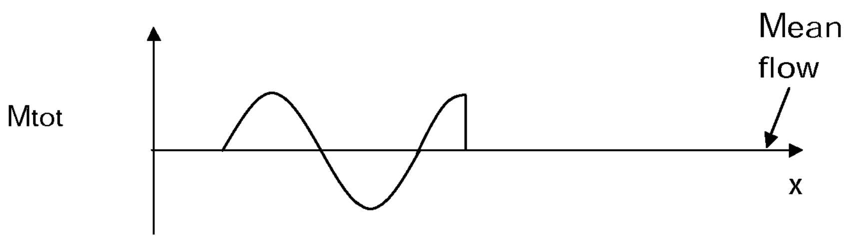

Fig. 6D

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EUROPEAN SEARCH REPORT

Application Number
EP 17 17 2854

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 A	US 5 943 866 A (LOVETT JEFFERY ALLAN [US] ET AL) 31 August 1999 (1999-08-31) * column 2, line 66 - column 11, line 36; figures 1-3 *	10 11-13	INV. F23R3/28
A	US 2015/226434 A1 (NAKAMURA SOSUKE [JP] ET AL) 13 August 2015 (2015-08-13) * paragraph [0022] - paragraph [0061]; figures 1-4 *	10-13	
A	US 2007/074518 A1 (ROGERS THOMAS J C [US] ET AL) 5 April 2007 (2007-04-05) * paragraph [0012] - paragraph [0034]; figures 1-3 *	10-13	
A	US 2016/177832 A1 (TONON DEVIS [CH] ET AL) 23 June 2016 (2016-06-23) * paragraph [0022] - paragraph [0090]; figures 1-7 *	10-13	

TECHNICAL FIELDS SEARCHED (IPC)

F23R

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	2 January 2018	Theis, Gilbert

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 17 2854

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02-01-2018

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