The present invention relates to a damping device for a combustor of a gas turbine for suppressing combustion instabilities. More specifically, the invention relates to a design of a broadband damping device for a low emission combustor having at least one resonator for damping pressure fluctuations in the combustion chamber. It is an object of the invention to provide a damping device with a quarter wave damper having broadband characteristics. The damping device for a combustor of a gas turbine according to the invention comprises a casing defining a resonator volume, a hole at a front face of the casing for allowing fluid communication between the resonator volume and the combustion chamber, the casing having parameters such that it acts as a quarter wave damper, is characterized in that the resonator volume is limited by a rear face and at least one lateral surface of the casing, whereby at least one lateral surface is equipped with one or more cavities inside and the rear face is equipped with at least one feed hole for feeding a purging fluid into the resonator volume. The preferably groove-shaped side cavities initiate energy dissipating vertical flows.
The present invention relates to a damping device for a combustor of a gas turbine. More specifically, the invention relates to a design of a broadband damping device for a low emission combustor having at least one resonator for damping pressure fluctuations in the combustion chamber.

Gas turbines are known to comprise at least one combustor, wherein a fuel and air are combusted to generate high pressure hot combustion gases that are expanded in a turbine performing work. In general, the combustion may occur either in a number of combustors circumferentially positioned around a longitudinal axis of the gas turbine or in an annular combustion chamber with a number of burners at its upstream end. During operation of the combustor significant pressure oscillations at various frequencies may occur. If one of these frequencies corresponds to an eigenfrequency of a component or a system structural damages to the components of the gas turbine plant may result limiting its operating regime.

For the attenuation of combustion dynamics, gas turbine combustors are usually provided with damping devices, in particular Helmholtz resonators, to damp pressure oscillations. Helmholtz resonators are widely used in this technical field. Their use is disclosed in many prior art publications. Usually a plurality of resonators is coupled to the combustor at its upstream end and/or downstream at its liner in flow communication with the interior of the combustor. A drawback of conventional Helmholtz resonators is the required space. Helmholtz dampers require a relatively high volume, but the available space in the region surrounding the combustor is often limited. A consequence are design constraints to install such damping devices. Another significant design consideration is the component weight, Helmholtz resonators are relatively heavy.

EP 2402658 discloses a combustor with lean combustion and low emissions for a gas turbine that requires a small mounting space for an acoustic damper that can achieve size reduction. In order to achieve this aim, according to a first aspect the combustor comprises an acoustic damper that includes an acoustic damper resonance space communicating with the inner combustion chamber. The acoustic damper is provided along a combustor housing extending in a direction intersecting an axial direction of the combustor. Because the damper is provided along the housing so as to extend in a direction intersecting the axial direction of the combustor, the acoustic damping device is disposed widely in the circumferential direction, without concentrating in a particular section of the combustor in its circumferential direction. As a result, the damping device is prevented from protruding toward the outer circumference of the housing, and the space needed outside the combustor can be reduced.

A different approach for damping pressure oscillations caused by combustion dynamics is the application of quarter wave dampers. A quarter wave damper includes a resonator tube of a defined length $L$. A quarter wave damper is tuned to a quarter of the wavelength of an acoustical oscillation. The resonant frequency of a quarter wave damper is

$$f = \frac{c_0}{4L},$$

wherein $c_0$ is the speed of sound in the resonator tube and $L$ is the length of the resonator tube.

Consequently a quarter wavelength damper may absorb a frequency corresponding to a wavelength four times the tube length $L$.

Fig. 1 shows in a rough schematic manner the main features of a quarter wave damper 2 connected to a combustor or a supply line for fuel or air to a combustion chamber. The damper 2 includes a casing 3, usually designed as a tube, fixed to the combustor liner 4 or the fuel or air supply line, the tube 3 having a length 5 and defining a resonator volume 6. Via an opening 7 at its front face the resonator volume 6 is in flow communication with the combustion chamber 8 in which the pressure oscillations, to be damped, may occur. The damper parameter that mainly defines the damped frequency is the tube length 5. Consequently, these geometrical features have to be determined in accordance with the combustion dynamics of the combustor.

An essential feature of the quarter wave dampers according to the state of the art is that they provide high damping performances, but only in a narrow frequency band that lies around the resonance frequency of the damper. This behavior is a fundamental disadvantage for a use in gas turbine combustors.

The frequency of pressure oscillations may slightly change from gas turbine to gas turbine and, in addition, also for the same gas turbine it may slightly change as a function of variations of the operating conditions (for example
part load, base load, transition). If narrow band dampers are adopted, each of these frequency shifts will result in a rise of pulsations.

SUMMARY

Therefore, it is the technical aim of the present invention to avoid the above-mentioned disadvantages by providing a damping device with a quarter wave damper having broadband characteristics and by providing a combustor equipped with such a damping device.

According to a first aspect of this invention this aim is achieved by a damping device according to claim 1.

According to a second aspect of this invention this aim is achieved by a combustor according to claim 15.

Preferred embodiments of these inventive aspects are subject of the respective dependent claims.

More specifically, it is the basic idea of this invention to provide a damping device, particularly a quarter wave damper with a modified new design, the damping device comprising a casing, particularly a tubular casing, defining a resonator volume, a hole at a front face of this casing for allowing fluid communication between the resonator volume and the combustion chamber, a rear face with at least one feed hole for feeding a purging fluid into the resonator volume and at least one lateral surface, whereby this lateral surface is equipped with one or more side cavities inside.

The feeding hole at the rear face and the hole at the front face define a flow path across the resonator volume inside the quarter wave damper.

According to a preferred embodiment the at least one side cavity is groove-shaped and runs circumferentially around the lateral surface of the casing.

In particular, the lateral surface of the damper casing is equipped with two or more circumferential cavities, arranged in a number of rows along the casing between its rear end and its front end.

This design is preferably applicable for quarter wave dampers with a circular cross section.

According to an alternative embodiment, preferably applicable to quarter wave dampers with a polygonal, especially rectangular cross section, the provision of side cavities is limited to one side. A first lateral surface of the e.g. rectangular damper is equipped with a number of consecutively arranged side cavities, whereas a second lateral surface, e.g. the opposite surface, is even. Preferably the side cavities extend over the whole width of the said first lateral surface.

During operation of the combustor a mass flow of a purging fluid, preferably purging air, passes the resonator volume from the feed opening at the rear face towards the front face and exits the resonator volume through the opening there into the combustion chamber. The side cavities in the lateral surface, arranged orthogonally or at least essentially orthogonally to the mass flow of the purging fluid, cause flow disturbances. Vortical flows are initiated at each cavity. The formed shear layers roll up, thereby interacting with existing and new shear layers and vortices in a complex interaction. These energy dissipating processes absorb acoustic power.

One parameter for controlling the damping quality of a certain damper configuration is the flow velocity of the mass flow of purging fluid through the resonator volume. The damping quality of the damper during operation can be changed by varying the flow velocity.

BRIEF DESCRIPTION OF THE DRAWINGS

Further characteristics and advantages of the invention will be more apparent from the description of preferred embodiments of the invention, illustrated by way of nonlimiting examples in the accompanying drawings, in which:

Figure 1 is a rough schematic view showing the principle features of a damping device, comprising a quarter wave damper coupled to a combustor;

Figure 2 shows in a similar view a damping device with a quarter wave damper, modified according to the invention;

Figure 2a shows a detail of Fig. 2;

Figures 3a and 3b show, in addition to Fig. 2, alternative designs of a quarter wave damper according to the invention;

Figure 4a and 4b show two alternative embodiments of arranging quarter wave dampers around a combustor.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Fig. 1 shows in a rough schematic manner the main features of a quarter wave damper 2 coupled to the liner 4 of a combustor 1 or a supply line of the fluid injection system according to the state of the art. The quarter wave damper 2 includes a casing 3, usually designed as a tube, fixed to the combustor liner 4. The tubular casing 3, having a longitudinal axis 15, a front face with an opening 7, a rear end face 11 and a lateral surface 14, defines a resonator volume 6. Via an opening 7 at its front face the resonator volume 6 is in flow communication with the combustion chamber 8 in which the pressure oscillations, to be damped, occur. The distance between the front face with opening 7 and the rear end
face 11 defines the length 5 of the quarter wave damper 2. The damper parameter that mainly defines the damped frequency is its length 5. Consequently, these geometrical features have to be determined in accordance with the combustion dynamics of the combustor. As the name implies, the quarter wave damper 2 is tuned to a quarter of the wavelength of the relevant acoustical oscillations in the combustion chamber 8. The resonant frequency is \( f = \frac{c_0}{4L} \), wherein \( c_0 \) is the speed of sound in the resonator volume 6 and L is the length 5 of its tubular casing 3.

**[0027]** It is known per se to couple a number of quarter wave dampers 2 with different lengths 5 to a combustor 1, e.g. two different lengths, to damp oscillations of different frequencies, particularly to damp two dominant frequencies.

**[0028]** Fig. 2 shows in a similar view a damping device with a modified quarter wave damper 2 in accordance with the invention. The combustion chamber 8 is enclosed by the liner 4 of the combustor 1. The modified quarter wave damper 2 is coupled to said liner 4 in a manner, known per se. The quarter wave damper 2 comprises an essentially cylindrical casing 3 with an opening 7 at its front face, a lateral surface 14 and a rear end 11. The opening 7 at the front face enables flow communication between the combustion chamber 8 and the resonator volume 6 inside the casing 3. The lateral surface 14 of the casing 3 is equipped with at least one cavity 9. This cavity 9 may run circumferentially around the inner lateral surface 14. As shown in Fig. 2, a number of rows of circumferentially running cavities 9 may be arranged along the lateral surface between the front end and the rear end of the casing 3.

**[0029]** In addition, the rear end 11 of the damper 2 is equipped with an opening 10 for feeding a purging fluid, usually air, into the resonator volume 6. During operation of the combustor 1 a mass flow 12 of purging air is flowing through the resonator volume 6 from the opening 10 at the rear face 11 towards the front face and exits the resonator volume 6 through the opening 7 into the combustion chamber 8.

**[0030]** The groove-shaped cavities 9 in the lateral surface 14 cause flow disturbances, as shown in Fig. 2a. When passing the edges of the side cavities 9 vortical flows 13 are initiated at each cavity 9. The shear layers, formed in the velocity-gradient region, roll up into a spiral, thereby interacting with existing and new shear layers and vortices in a complex interaction. As a consequence these energy dissipating processes absorb acoustic power.

**[0031]** The structural parameters of the damper and the flow velocity are defined in order to damp at the desired frequency. It applies the equation

\[
U = \frac{f_0 W_{\text{eff}}}{0.39},
\]

wherein \( U \) is the flow velocity through the damper, \( f_0 \) is the frequency to damp, \( W_{\text{eff}} \) stands for the effective width of the cavity 9 and the divisor 0.39 represents the optimal Strouhal number.

**[0032]** Figures 3a and 3b show in an exemplary manner different geometrical options of a modified quarter wave damper 2 according to the invention.

**[0033]** Fig. 3a depicts a corrugated damper 2. At least one lateral surface 14 of the casing 3 is provided with a corrugated design. Preferably the cross section of a quarter wave damper 2 according to this design is circular. In this case the casing 3 is made of a corrugated tube from a suitable material.

**[0034]** Alternatively a rectangular cross section can be provided. In that case two opposite lateral surfaces 14 are provided with a corrugated design.

**[0035]** The corrugation is disposed orthogonally to the direction of the mass flow 12 of purging air. When passing the individual corrugations, a respective vortice flow is formed at each cavity 9.

**[0036]** Fig. 3b depicts an alternative embodiment, a side branched quarter wave damper. The provision of side cavities 9 is limited to one of the longitudinal sides. This design may preferably be used for dampers 2 with a rectangular cross section. One lateral surface 14 of the rectangular damper is equipped with a number of consecutively arranged side cavities 9, whereas the opposite surface 14 is even. Preferably, the side cavities 9 extend over the whole width of the surface 14.

**[0037]** The figures 4a and 4b show in a rough schematic manner two basic options regarding the application of a damping device according to the invention to a can combustor of a gas turbine.

**[0038]** For the purpose of reducing the required space outside the combustor 1 the quarter wave dampers 2 have to be prevented from protruding toward the outer circumference of the combustor 1.

**[0039]** This is achieved by arranging the individual quarter wave dampers 2 around the combustor in such a way that the longitudinal axes 15 of the quarter wave dampers 3 are inclined or parallel to the surface of the liner 4.

**[0040]** The two basic options comprise an arrangement around the combustion chamber in circumferential direction or in longitudinal direction. A number of quarter wave dampers 2 is folded around the combustor 1 of the gas turbine. This means, the longitudinal axis 15 of the applied dampers 2 is arranged parallel or essentially parallel to the outer surface of the liner 4.
According to the first option (Fig. 4a) the longitudinal axis 15 of the dampers 2 is in line with the circumferential direction of the combustor 1. A number of dampers 2 is coupled to the liner 4 in different axial positions of the combustor 1.

According to the second option (Fig. 4b) the longitudinal axis of the dampers 2 is in line with the longitudinal axis of the combustor 1. A number of dampers 2 is coupled to the liner around the circumference of the combustor at essentially the same axial position.

As indicated by the figures, both options offer the possibility of applying quarter wave dampers 2 of different lengths to damp more than one dominant frequency.

**REFERENCE NUMBERS**

1. combustor
2. quarter wave damper
3. casing of the quarter wave damper
4. combustor liner
5. length of the quarter wave damper
6. resonator volume
7. hole for fluid communication
8. combustion chamber
9. side cavity
10. opening at rear end
11. rear end of the quarter wave damper
12. air flow
13. vortice flow
14, 14', 14" lateral surface of the quarter wave damper
15. longitudinal axis of the quarter wave damper
16. \( W_{eff} \) effective width of the cavity 9

**Claims**

1. Damping device for a combustor (1) of a gas turbine for suppressing combustion instabilities in a combustion chamber (8), comprising a liner (4) extending from an upstream end downwardly around the combustion chamber (8), at least one acoustic damper (2) provided along the liner (4) and/or a supply line for fuel or air to the combustion chamber (8), the acoustic damper (2) comprising a casing (3) defining a resonator volume (6), a hole (7) at a front face of the casing (3) for allowing fluid communication between the resonator volume (6) and the combustor chamber (8), characterized in that the resonator volume (6) is limited by a rear face (11) and at least one lateral surface (14) of the casing (3), whereby at least one lateral surface (14) is equipped with one or more cavities (9) and the rear face (11) is equipped with at least one feed hole (10) for feeding a purging fluid into the resonator volume (6).

2. Damping device according to claim 1, characterised in that at least one of the cavities (9) is groove-shaped.

3. Damping device according to claim 2, characterised in that at least one cavity (9) runs circumferentially around the lateral surface (14).

4. Damping device according to claim 3, characterised in that two or more rows of circumferentially running cavities (9) are arranged consecutively in a longitudinal direction of the casing (3).

5. Damping device according to one of claims 1 to 4, characterised in that the casing (3) is equipped with at least one corrugated lateral surface (14).

6. Damping device according to claim 1, characterised in that casing (3) is a tube.

7. Damping device according to claim 6, characterised in that the casing (3) has a circular or elliptic cross section.

8. Damping device according to claim 6, characterized in that the casing (3) has a polygonal, particularly rectangular cross section.
9. Damping device according to claim 8, characterised in that at least a first lateral surface (14') is equipped with one or more side cavities (9), whereas at least a second lateral surface (14") is even.

10. Damping device according to claim 1 or 9, characterised in that a longitudinal axis (15) of the damper casing (3) possesses an orientation orthogonally or essentially orthogonally to the outer surface of the combustor liner (4).

11. Damping device according to claim 1 or 9, characterised in that the longitudinal axis (15) of the damper casing (3) possesses an inclined orientation to the outer surface of the combustor liner (4).

12. Damping device according to claim 1 or 9, characterised in that the longitudinal axis (15) of the damper casing (3) is arranged parallel to the outer surface of the liner (4).

13. Damping device according to any of claims 1 to 12, characterised in that the damping device is a quarter wave damper (2).

14. Damping device according to any of claims 1 to 13, characterised in that the quarter wave damper (2) is coupled to a can combustor or to an annular combustion chamber.

15. Combustor for a gas turbine, disposed downstream from a compressor and upstream from a turbine, said combustor (1) comprising at least one burner at an upstream end, configured to inject a fuel or a fuel/air mixture into a combustion chamber (8), a liner (4) extending from the upstream end downwardly around the combustion chamber (8), wherein the combustor (1) additionally comprises at least one quarter wave damper (2) according to claim 13 for suppressing combustion instabilities in the combustion chamber (8).

16. Combustor according to claim 15, characterized in that at least two quarter wave dampers (2) are disposed circumferentially around the combustor liner (4).

17. Combustor according to claim 15, characterized in that at least two quarter wave dampers (2) are disposed in different longitudinal positions of the combustor (1).

18. Combustor according to any of claims 15 to 17, characterised in that at least two quarter wave dampers (2) of different geometry, particularly of different length, are coupled to the liner (4).

19. Combustor according to any of claims 15 to 18, characterised in that the combustor (1) is a can combustor or an annular combustion chamber of a stationary gas turbine.
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