In a method for the control of thermoacoustic instabilities or oscillations in a combustion system (15), pressure oscillations and/or heat release oscillations in the combustion system (15), which are linked to the thermoacoustic instabilities, are measured, the resulting measurement signal is filtered, time-delayed and amplified, and, according to the filtered, delayed and amplified measurement signal, the fuel stream to or the combustion air for the combustion system (15) is modulated. In such a method, the use of more cost-effective modulation devices is achieved in that modulation takes place at a subharmonic of a dominant instability frequency in the combustion system (15).
Subharmonic control

Fig. 2

Subharmonic control

Fig. 3
METHOD AND DEVICE FOR THE CONTROL OF THERMOACOUSTIC INSTABILITIES OR OSCILLATIONS IN A COMBUSTION SYSTEM

TECHNICAL FIELD

[0001] The present invention relates to the field of technology of combustion systems, in particular for gas turbines. It relates to a method for the control of thermoacoustic instabilities or oscillations in a combustion system, according to the preamble of claim 1, and to a device for carrying out the method.

PRIOR ART

[0002] Modern high-performance combustion systems for gas turbines require high-efficiency operation which is free of thermoacoustic oscillations, entails virtually no emissions and has a low blow-out limit in the lean mode. Thermoacoustic oscillations, in particular, may have an adverse effect on the proper operation of gas turbine plants. Even in the past, therefore, active control mechanisms have been used in order to suppress thermoacoustic instabilities which originate from coupling between heat release and acoustic modes in the combustion system. These control mechanisms have generally pulse the combustion air or modulated the fuel injection and at the same time brought about a phase shift in relation to the pressure or heat release oscillations, in such a way that the pressure rise and the heat release are uncoupled from one another. In particular, active control systems with open and closed control loops have been used in order to suppress the thermoacoustic pressure oscillations and to reduce the undesirable emissions of pollutants during premixing combustion. In this case, microphones or detectors for the superharmonic emission have been used in order to monitor the combustion process and deliver the necessary input signals for the control system. Thus, EP-A1-0 918 152 proposed a method and a device for the control of thermoacoustic oscillations in a combustion system, in which, in the combustion system, a signal correlated with the thermoacoustic fluctuations is measured and subsequently filtered and is phase-rotated, and, finally, is used for driving an acoustic source, by means of which the shear strata in the combustion system are excited acoustically.

[0003] EP-A1-1 050 713 discloses a method for suppressing or controlling thermoacoustic oscillations in a combustion system, in which the thermoacoustic oscillations are detected in a closed control loop and, as a function of the detected oscillations, acoustic oscillations of a defined amplitude and phase are generated by means of loudspeakers and are fed into the combustion system, within the control loop the amplitude of the acoustic oscillations generated being selected in proportion to the amplitude of the detected oscillations.

[0004] Finally, US-A1-20010027638 describes a method and a device for minimizing thermoacoustic oscillations in the combustion chamber of a gas turbine, in which, instead of acoustic oscillations being fed in, the injection of the premixing fuel into the premixing burner is used for exerting oscillation-suppressing influence on the combustion process.

[0005] The known control systems for suppressing the thermoacoustic oscillations require all the actuators with a higher working frequency in order to modulate the fuel stream or the combustion air. The modulations have to take place in real time in relation to the combustion pressure or to the heat release which are the starting point of the pressure or heat release fluctuation signals. When the unstable modes are at high frequencies, the obtainability and affordability of corresponding actuators present a practical problem because of the rarity of such components. By contrast, low-frequency actuators or valves can be obtained very much more simply.

PRESENTATION OF THE INVENTION

[0006] The object of the invention is, therefore, to specify a method for the control (attenuation or suppression) of thermoacoustic oscillations in combustion systems, which avoids the disadvantages of known methods and is suitable, in particular, for the use of actuators and/or valves with a low working frequency, and to specify a device for carrying out the method.

[0007] The object is achieved by means of the features of claims 1 and 4 taken as a whole. The essence of the invention is to use, instead of the dominant instability modes themselves, their subharmonic for the control device and modulation. The dominant instability modes can thereby be attenuated or suppressed, without correspondingly high-frequency actuators having to be used for modulation.

[0008] The filtering of the measurement signal in this case takes place preferably in a bandpass filter.

[0009] It has proved appropriate for modulation to take place at the 2nd subharmonic of a dominant instability frequency.

[0010] A preferred embodiment of the device according to the invention is characterized in that the bandpass filter is tuned to the second subharmonic of a dominant instability frequency in the combustion system.

[0011] The modulation device in this case comprises either a high-speed valve and the modulation channel is the fuel supply to the combustion system or the modulation device comprises an acoustic driver and the modulation channel is the combustion air supply to the combustion system.

BRIEF EXPLANATION OF THE FIGURES

[0012] The invention will be explained in more detail below with reference to exemplary embodiments, in conjunction with the drawing in which:

[0013] FIG. 1 shows a block diagram of a control device, such as is suitable for carrying out the method according to the invention;

[0014] FIG. 2 shows measurement results for the pressure fluctuations when the method according to the invention is used, in the case of various instability frequencies (dominant and subharmonic), as a function of the phase set in the control device according to FIG. 1; and

[0015] FIG. 3 shows measurement results for the pressure fluctuations when the method according to the invention is used, in the case of various instability frequencies (dominant and subharmonic), as a function of the amplification (amplitude) set in the control device according to FIG. 1.

EMBODIMENTS OF THE INVENTION

[0016] A block diagram of a control device used in the invention is illustrated in FIG. 1. The control device

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comprises a control loop 17, in which are arranged a bandpass filter 11, a delay and amplification unit 12, a modulation device 13, a modulation channel 14, the combustion system 15 (burner and combustion chamber) to be influenced and the control unit 16. The pressure oscillations (P in FIG. 1) or the heat release oscillations (OH in FIG. 1) in the combustion system 15 are measured by means of methods known from the prior art mentioned and the resulting measurement signal is fed back via the control unit 16 and the bandpass filter 11. The filtered signal is amplified and time-delayed in the delay and amplification unit 12, in order to obtain the desired phase change. The delay unit within the delay and amplification unit 12 is set to an optimized delay value by means of the control unit 16 and then delivers the amplified and phase-shifted signal to the modulation device 13 which acts on the combustion system 15 via a modulation channel 14.

When the modulation channel 14 is the fuel supply to the combustion system 15, a high-speed valve which modulates the fuel stream is used as the modulation device 13. When the modulation channel 14 is the combustion air supply to the combustion system 15, an acoustic driver, which excites acoustic oscillations in the combustion air, is used as the modulation device 13. According to the invention, then, the bandpass filter 11 is set to a subharmonic of a dominant instability frequency in the combustion system 15. The associated instability frequency itself is then influenced via the subharmonic of said dominant instability frequency.

Test measurements were conducted under standard conditions with a power output of 560 kW and with a lambda value of 2.1, the 2nd subharmonic frequency being used for modulation. Standardized frequencies (Strouhal number Si) were used. The Strouhal number is, as is known, the product of frequency and diameter, divided by the velocity. The results of the test measurements are illustrated in FIG. 2, where pressure fluctuations (p) in the combustion system for two standardized instability frequencies (Si=0.6 and Si=1.4) and for the subharmonic excitation signal (Si=0.25) are shown as a function of the time delay, expressed by the phase shift (phase in °). The subharmonic control leads to a suppression of the standardized dominant instability frequency (Si=0.6) by up to 31% in relation to the basic level (baseline). The second higher frequency (Si=1.4) and the impressed frequency (Si=0.25) lie at a much lower level.

According to FIG. 3, a change in amplification (amplitude) leads to a suppression of the dominant standardized frequency (Si=0.6) of up to 40% without the second unstable mode or the impressed signal being appreciably modified.

List of Reference Symbols

<table>
<thead>
<tr>
<th>Reference Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Control device</td>
</tr>
<tr>
<td>11</td>
<td>Bandpass filter</td>
</tr>
<tr>
<td>12</td>
<td>Delay and amplification unit</td>
</tr>
<tr>
<td>13</td>
<td>Modulation device</td>
</tr>
<tr>
<td>14</td>
<td>Modulation channel</td>
</tr>
<tr>
<td>15</td>
<td>Combustion system</td>
</tr>
<tr>
<td>16</td>
<td>Control unit</td>
</tr>
<tr>
<td>17</td>
<td>Control loop</td>
</tr>
</tbody>
</table>

1. A method for the control of thermoacoustic instabilities or oscillations in a combustion system (15), in which pressure oscillations and/or heat release oscillations in the combustion system (15), which are linked to the thermoacoustic instabilities, are measured, the resulting measurement signal is filtered, time-delayed and amplified, and, according to the filtered, delayed and amplified measurement signal, the fuel stream to or the combustion air for the combustion system (15) is modulated, characterized in that modulation takes place at a subharmonic of a dominant instability frequency in the combustion system (15).

2. The method as claimed in claim 1, characterized in that the filtering of the measurement signal takes place in a bandpass filter (11).

3. The method as claimed in either of claims 1 and 2, characterized in that modulation takes place at the 2nd subharmonic of a dominant instability frequency.

4. A device for carrying out the method as claimed in claim 1, comprising means for measuring the pressure oscillations and/or heat release oscillations in the combustion system which are linked to the thermoacoustic instabilities, a bandpass filter (11), a delay and amplification unit (12), a modulation device (13) and a modulation channel (14) leading to the combustion system (15), which are arranged in a closed control loop (17), characterized in that the bandpass filter (11) is tuned to a subharmonic of a dominant instability frequency in the combustion system (15).

5. The device as claimed in claim 4, characterized in that the bandpass filter (11) is tuned to the second subharmonic of a dominant instability frequency in the combustion system (15).

6. The device as claimed in either of claims 4 and 5, characterized in that the modulation device (13) comprises a high-speed valve and the modulation channel (14) is the fuel supply to the combustion system (15).

7. The device as claimed in either of claims 4 and 5, characterized in that the modulation device (13) comprises an acoustic driver and the modulation channel (14) is the combustion air supply to the combustion system (15).