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(54) **METHOD FOR MEASURING SOUND IN A WAVEGUIDE, ESPECIALLY IN A VENTILATION SYSTEM, AND A DEVICE FOR IMPLEMENTING THE METHOD**

(57) The object of the invention is a method for measuring sound in a waveguide (1), especially in a ventilation system, characterised in that a plate (2) from a material transferring vibrations is used, preferably a metal one, on which at least one accelerometer (3) is mounted, wherein the plate is mounted in the waveguide (1) so that the entire plate (2) is located within the waveguide (1), and then the sound in the waveguide (1) is estimated based on a signal from the said at least one accelerometer (3).

The object of the invention is also a device for measuring sound in a waveguide (1), especially in a ventilation system, characterised in that it comprises a plate (2) from a material transferring vibrations, preferably from metal, on which at least one accelerometer (3) is mounted, wherein the plate is adapted to be mounted in the waveguide (1) so that the entire plate is located within the waveguide.

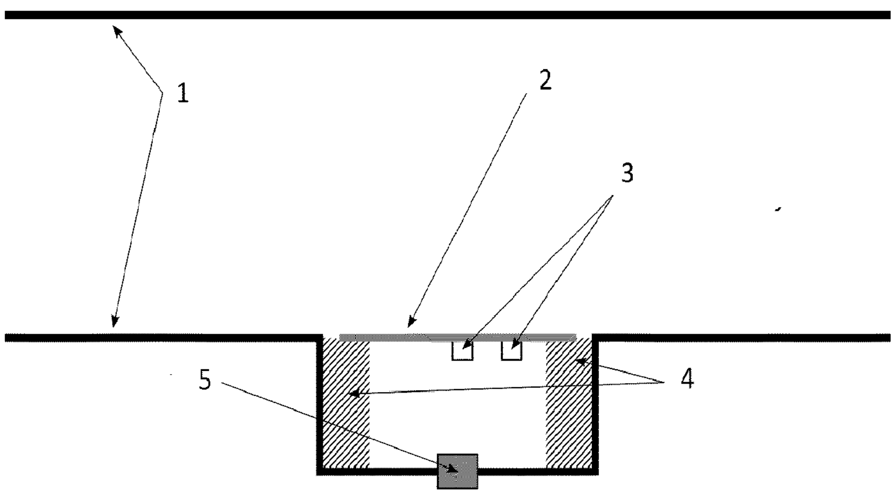

Fig. 1

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Description

[0001] The object of the invention is a method for measuring sound in a waveguide, especially in a ventilation system, and a device for implementing the method.

[0002] To reduce noise in ducts in which a flow of air or gas takes place (ventilation systems, air-conditioning inlet and outlet systems of flow machines, e.g. compressors, blowers, turbines, combustion engines), systems for active attenuation of noise are used more and more often. Such a system consists of an electroacoustic device which removes an undesirable sound by generating an anti-sound (anti-noise) with the same amplitude and an opposite phase. The original noise is superimposed on the generated noise, which results in attenuation of both sounds. The effectiveness of such a system depends on the accuracy in measuring a sound in a waveguide.

[0003] However, an accurate measurement of sound in a waveguide causes a lot of problems. In the case of using microphones, the air flowing around the microphone generates local noises which are superimposed on sounds actually audible in the waveguide and cause corruptions in the measurement. This may lead to malfunctioning of the system for active reduction of noise when it attempts to attenuate, throughout the waveguide, the sound which is actually audible only within a few centimetres from the microphone.

[0004] The existing solutions have disadvantages that make them difficult to use in practice: microphone windscreens cease to fulfil their function at a greater air flow, mounting of the microphone in a specially soundproofed box is not always possible due to their dimensions, and flow microphones (the only ones currently on the market, provided by Gras) are characterised by high price and worse properties than microphones mounted in the said box.

[0005] An alternative to the measurement by means of microphones is a measurement of vibrations by means of accelerometers and estimation of sound on the basis of these measurements, but direct connection to the waveguide causes severe corruptions resulting from low resonant frequencies of the waveguide as a whole. Furthermore, accelerometers are usually characterised by a low range of measured frequencies, the said range typically including only a fraction of audible frequencies. There are accelerometers having a sufficiently large measuring range but their price makes solution of this type not economically justified when used in the systems for active reduction of noise. For this reason, in this field, measurement by means of accelerometers is generally not taken into consideration.

[0006] The aim of the invention is therefore to provide a device and a method for measuring sound in a waveguide, free from the above-described disadvantages.

[0007] The above-mentioned problems were solved by mounting an accelerometer (or accelerometers) not directly to the waveguide but to a vibration transfer plate placed inside the waveguide. Thereby, problems normally encountered during measurements by means of accelerometers (measurement inaccuracies resulting from resonant frequencies of the waveguide) are avoided and dimensions of the measuring device are significantly reduced in relation to the use of the box for microphone. It is also a considerably cheaper solution than dedicated measuring microphones for flows.

[0008] The object of the invention is a method for measuring sound in a waveguide, especially in a ventilation system, characterised in thata plate from a material transferring vibrations is used, preferably a metal one, on which at least one accelerometer is mounted, wherein the plate is mounted in the waveguide so that the entire plate is located within the waveguide, and then the sound in the waveguide is estimated based on a signal from the said at least one accelerometer.

[0009] Preferably, a plate which is not part of the waveguide is used.

[0010] Preferably, the plate is mounted to the waveguide by means of a material attenuating vibrations.

[0011] Preferably, the plate is adapted to be mounted in the waveguide in parallel to the walls of the waveguide in such a way that the plate is substantially beyond the light of the waveguide. Preferably, the plate is mounted in a broadening of the waveguide or in a recess of passive attenuation of the waveguide.

[0012] Preferably, the accelerometer or accelerometers are mounted onto the surface of the plate on the side opposite to the light of the waveguide.

[0013] Preferably, frequency response of the plate is modelled or measured, and then it is taken into consideration in the estimation of sound in the waveguide.

[0014] The object of the invention is also a device for measuring sound in a waveguide, especially in a ventilation system, characterised in that it comprises a plate from a material transferring vibrations, preferably from metal, on which at least one accelerometer is mounted, wherein the plate is adapted to be mounted in the waveguide so that the entire plate is located within the waveguide.

[0015] Preferably, the plate is adapted to be mounted to the waveguide by means of a material attenuating vibrations.

[0016] Preferably, the device further comprises an element or elements from a material attenuating vibrations, intended for mounting the plate to the waveguide.

[0017] Preferably, the plate is adapted to be mounted in the wavewguide in parallel to the walls of the waveguide in such a way that the plate is substantially beyond the light of the waveguide. Preferably, the plate is adapted to be mounted in a broadening of the waveguide or in a recess of passive attenuation of the waveguide.

[0018] The use of the metal plate mounted to the waveguide structure, especially by means of a material attenuating vibrations, as a source of vibrations measured by accelerometers, allows for more accurate measurement of sound in the waveguide thanks to making its properties independent of physical characteristics of the waveguide (dimensions and materials affect the position of resonant frequencies on which measurement is very inaccurate). The plate, due to its dimensions, has resonant frequencies higher than those for attenuation of which active methods of noise reduction are used, therefore measurement in the most important range is not affected by vibrations of the waveguide as a whole. Furthermore, frequency response of the plate can be measured or modelled, and then be taken into consideration in the estimation of sound in the waveguide.

[0019] Now, the invention will be presented in greater detail in embodiments, with reference to the accompanying drawings in which:

Fig. 1 schematically shows a system mounted in a waveguide,

Fig. 2 schematically shows the system mounted in the waveguide inside a passive attenuator,

Fig. 3 and Fig. 4 schematically show different variants of mounting of the system,

Fig. 5 shows a picture of a test plate with accelerometers mounted thereon,

Fig. 6 shows a picture of the test plate placed inside a waveguide segment,

Figs. 7 - 9 show a comparison of sound levels for different frequencies for measurement made with a microphone (gray, dashed line) and for sound estimation using measurements from accelerometers (black line).

[0020] Fig. 1 shows a system mounted in a standard waveguide (1) so that it does not limit the flow. For this purpose, the whole is mounted in a specially prepared broadening of the waveguide (1). The edges of the cavity are lined with a material attenuating vibrations (4), on which a metal plate (2) is mounted. Again, in order not to interfere with the air flow in the waveguide (1), one or more accelerometers (3) are mounted to the underside of the plate (2) (i.e. to the surface oriented towards the cavity walls, and not to the light of the waveguide). Cables (not shown in the drawing) are brought to the accelerometers (3) through a passage (5) in the the wall of the waveguide (1). Direction of the air flow in the waveguide (1) does not matter.

[0021] Fig. 2 shows the same system, yet mounted inside a passive attenuator (6). In this case, it may not be necessary to broaden the waveguide (1) but only to replace a part of the existing attenuation with the system, with the addition of a passage for cables (5).

[0022] The material attenuating vibrations (4) does not have to cover the entire recess in the passive attenuator (6), but only a part to which the plate (2) is mounted, as shown in Fig. 3. The plate may also be mounted directly to the material of the passive attenuator, as illustrated in Fig. 4.

[0023] In order to test the operation of the system according to the invention, it was prepared and tested in a test waveguide located in PLUM's laboratory.

[0024] All measurements of vibrations were performed by means of accelerometers provided by Brüel & Kjær, model 4533-B. All measurements of sound were performed by means of microphones provided by Brüel & Kjær, model 4189-A-021. The system used to perform analogue-to-digital conversion was Brüel & Kjær LAN-XI, model 3050. The sampling frequency used was 51.2 kHz.

[0025] Accelerometers with different settings were mounted to steel plates with different dimensions. Fig. 5 shows a plate with dimensions of 30x30x1 [mm] with five accelerometers mounted thereon. The plate was placed in a waveguide comprising a passive attenuator (a picture of the plate placed inside a waveguide segment is shown in Fig. 6). In a wall of the same waveguide segment, opposite to the plate, a microphone was mounted, having been placed in a special box reducing the impact of the air flow on the measurement.

[0026] This segment was attached to the complete test waveguide behind the system for active reduction of noise. During all the tests, the system for active reduction of noise stayed turned off. A loudspeaker constituting an element of the system for active reduction of noise was used as a source of known noise used for tuning the system of filters processing data from the accelerometers.

[0027] The results obtained, Figs. 7 - 9, show a comparison of sound levels (power [dB]) for different frequencies [Hz] for measurement made with a microphone (gray, dashed line) and for sound estimation using measurements from the accelerometers (black line).

[0028] These results correspond to the following conditions of measurement:

Fig. 7 - lack of air flow, lack of artificially generated noise.
Fig. 8 - lack of air flow, artificially generated noise.
Fig. 9 - air flow forced by a fan rotating at a speed of 2880 [RPM], lack of artificially generated noise.

[0029] Frequencies above 1 [kHz] are not presented because they are not relevant due to the properties of the passive attenuator - the attenuator operates at a frequency of as low as 500 [Hz], whereby, frequencies higher than this are not attenuated in the active system, and so their measurement is not necessary (important because of the limited measurement bandwidth of accelerometers).

Claims

1. A method for measuring sound in a waveguide (1), especially in a ventilation system, **characterised in that** a plate (2) from a material transferring vibrations is used, preferably a metal one, on which at least one accelerometer (3) is mounted, wherein the plate is mounted in the waveguide (1) so that the entire plate (2) is located within the waveguide (1), and then the sound in the waveguide (1) is estimated based on a signal from the said at least one accelerometer (3).

2. The method according to claim 1, **characterised in that** a plate (2) which is not part of the waveguide (1) is used.

3. The method according to claim 1 or 2, **characterised in that** the plate (2) is mounted to the waveguide (1) by means of a material attenuating vibrations (4).

4. The method according to claim 1, 2 or 3, **characterised in that** the plate (2) is adapted to be mounted in the waveguide (1) in parallel to the walls of the waveguide (1) in such a way that the plate (2) is located substantially beyond the light of the waveguide (1).

5. The method according to any one of claims 1 to 4, **characterised in that** the plate (2) is mounted in a broadening of the waveguide (1).

6. The method according to any one of claims 1 to 4, **characterised in that** the plate (2) is mounted in a recess of passive attenuation (6) of the waveguide (1).

7. The method according to any one of claims 1 to 6, **characterised in that** the accelerometer or accelerometers (3) are mounted onto the surface of the plate (2) on the side opposite to the light of the waveguide (1).

8. The method according to any one of claims 1 to 7, **characterised in that** frequency response of the plate (2) is modelled or measured, and then it is taken into consideration in the estimation of sound in the waveguide.

9. A device for measuring sound in a waveguide (1), especially in a ventilation system, **characterised in that** it comprises a plate (2) from a material transferring vibrations, preferably from metal, on which at least one accelerometer (3) is mounted, wherein the plate is adapted to be mounted in the waveguide (1) so that the entire plate is located within the waveguide.

10. The device according to claim 9, **characterised in that** the plate (2) is adapted to be mounted to the waveguide (1) by means of a material attenuating vibrations (4).

11. The device according to claim 9, **characterised in that** it further comprises an element or elements from a material attenuating vibrations (4), intended for mounting the plate (2) to the waveguide (1).

12. The device according to claim 9 or 10, or 11, **characterised in that** the plate (2) is adapted to be mounted in the wavewguide (1) in parallel to the walls of the waveguide (1) in such a way that the plate (2) is located substantially beyond the light of the waveguide (1).

13. The device according to any one of claims 9 to 12, **characterised in that** the plate (2) is adapted to be mounted in a broadening of the waveguide (1).

14. The device according to any one of claims 9 to 12, **characterised in that** the plate (2) is adapted to be mounted in a recess of passive attenuation (6) of the waveguide (1).

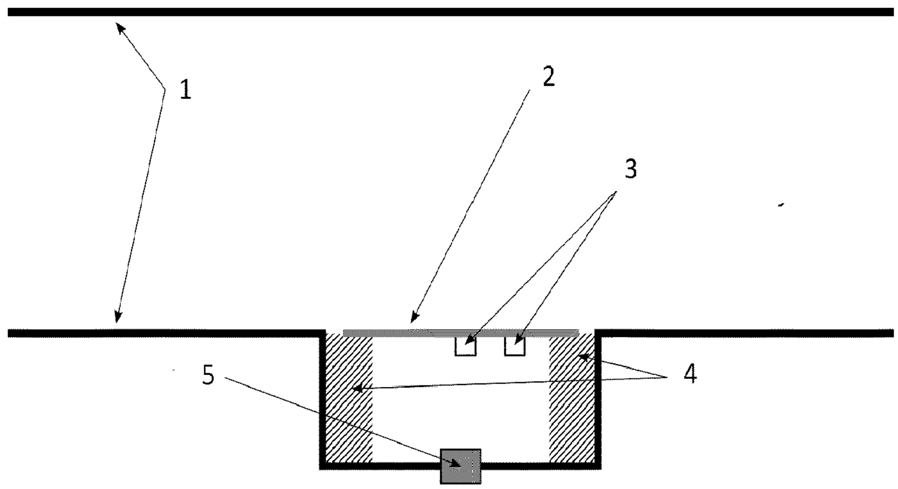


Fig. 1

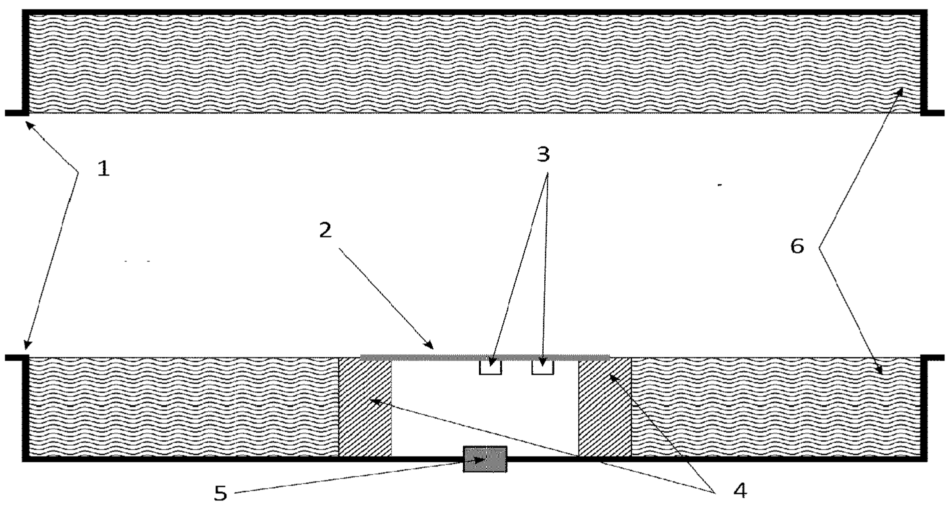


Fig. 2

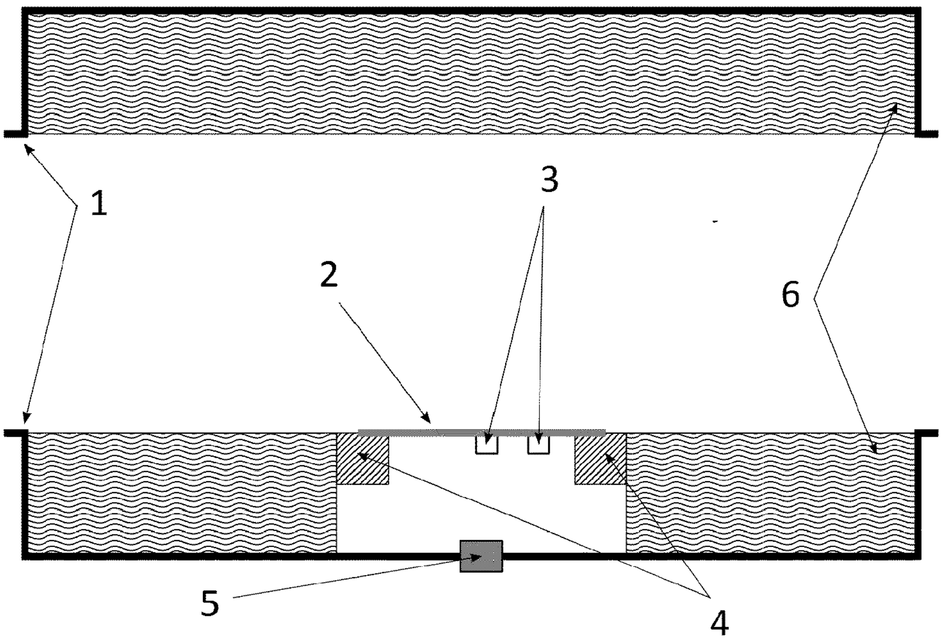


Fig. 3

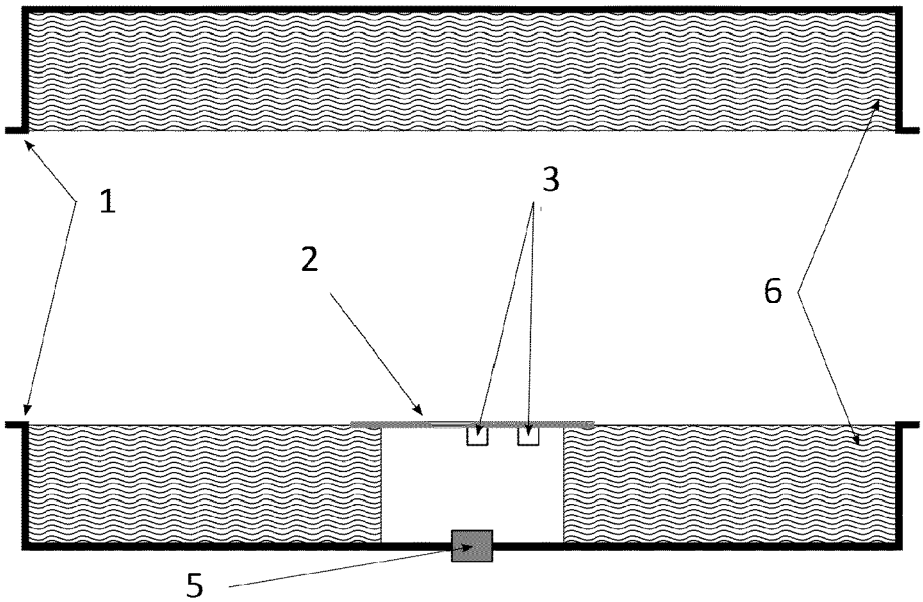


Fig. 4

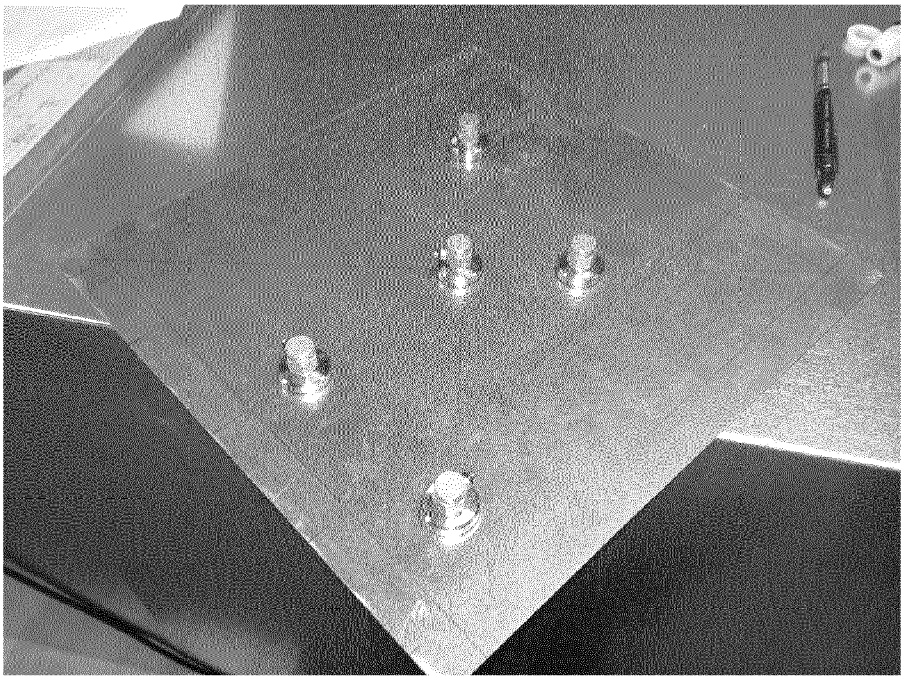


Fig. 5

Fig. 6

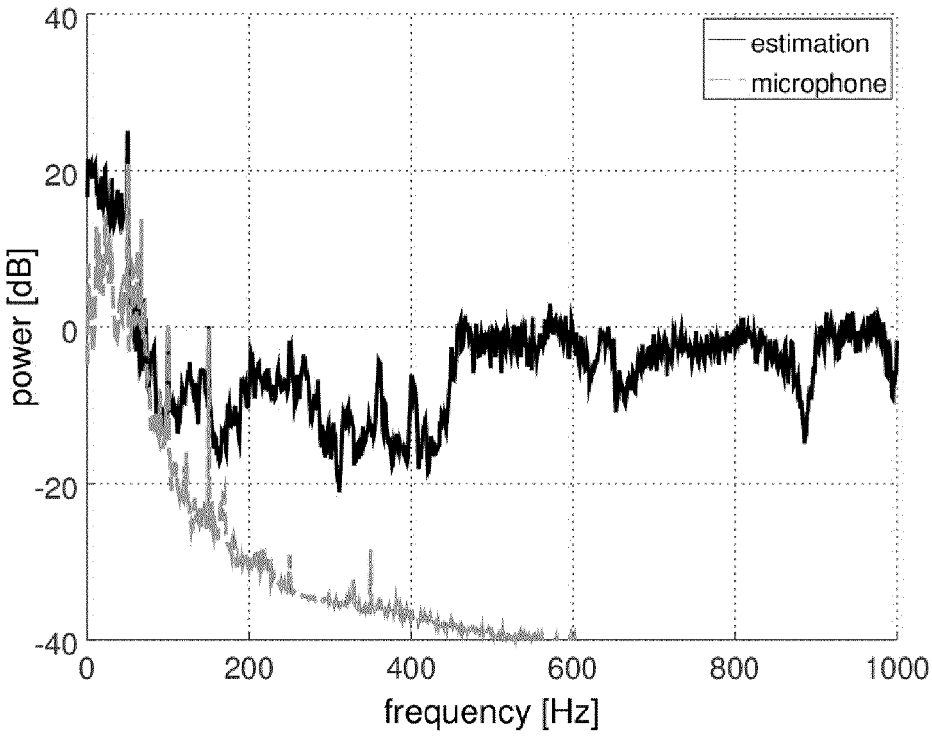

40
20
0
-20
-40
power [dB]
0
200
400
600
800
1000
frequency [Hz]
estimation
microphone

Fig. 7

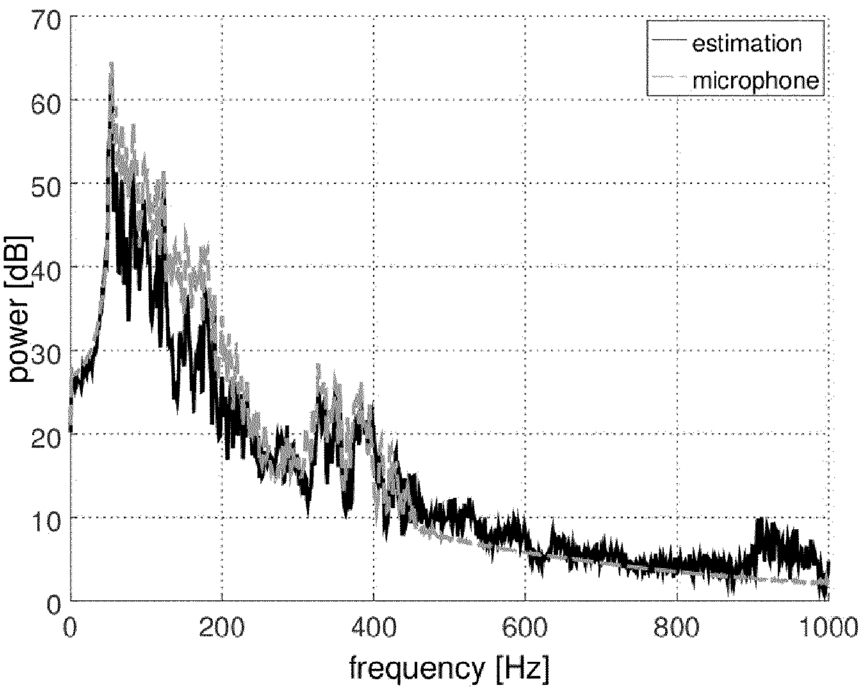
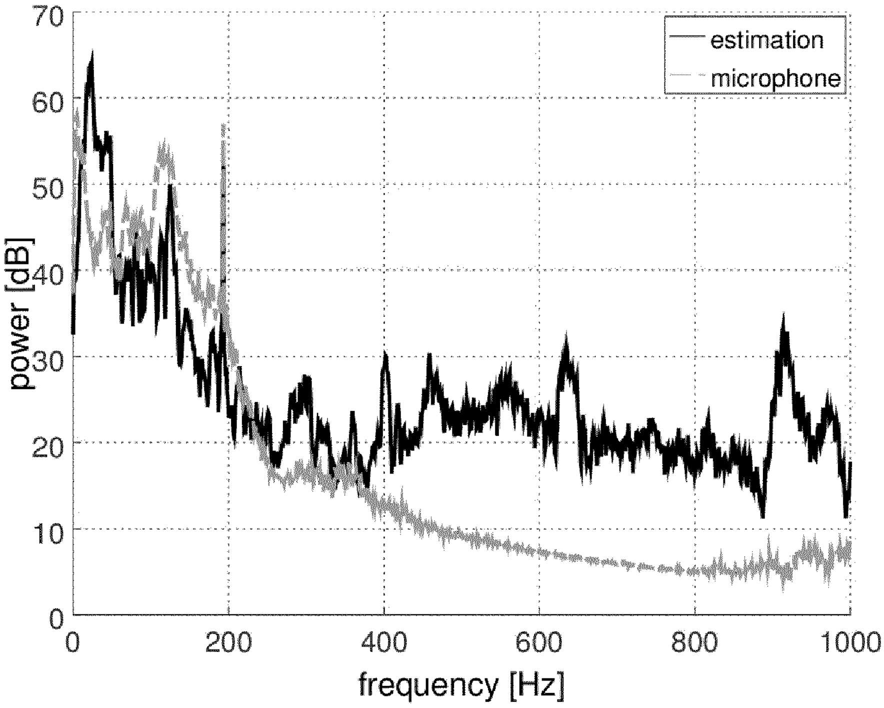

70
60
50
40
30
20
10
0
power [dB]
0
200
400
600
800
1000
frequency [Hz]
estimation
microphone

Fig. 8


70
60
50
40
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20
10
0
power [dB]
0
200
400
600
800
1000
frequency [Hz]
estimation
microphone

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 15 17 9735

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	FINEFIELD J K ET AL: "COMBINED FEEDBACK AND ADAPTIVE DIGITAL CONTROL OF CYLINDER VIBRATIONS USING SMART MATERIALS", PROCEEDINGS OF THE CONFERENCE ON DECISION AND CONTROL. TUCSON, DEC. 16 - 18, 1992; [PROCEEDINGS OF THE CONFERENCE ON DECISION AND CONTROL], NEW YORK, IEEE, US, vol. 2 OF 04, 16 December 1992 (1992-12-16), pages 1809-1814, XP000370326, ISBN: 978-0-7803-0872-5 * page 1809 - page 1810 * -----	1,9	TECHNICAL FIELDS SEARCHED (IPC) G10K F24F F02M F16L

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	15 July 2016	Lorne, Benoît

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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