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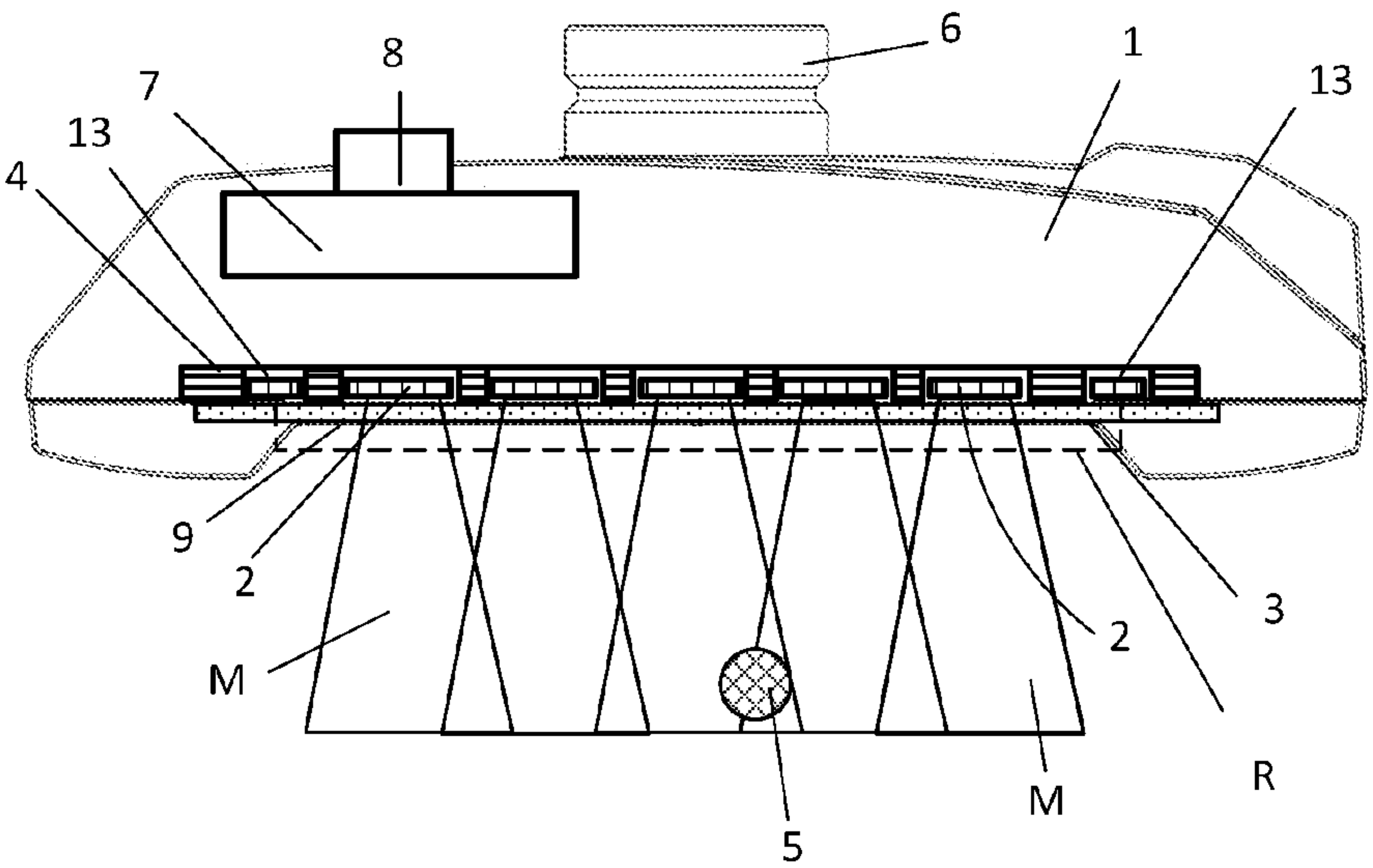
(54) Titre : CAPTEUR COMPRENANT UN ENSEMBLE ULTRASONIQUE MONOLITHIQUE
(54) Title: SENSOR WITH MONOLITHIC ULTRASONIC ARRAY

Fig. 1



(57) Abrégé/Abstract:
The invention relates to a sensor and a method for detecting the position of the sensor relative to a guide surface (5), comprising a housing (1) and an electronic analysis device (7) which outputs measurement values for the position of the guide surface (5) on the basis of the measurement signals. The sensor contains an ultrasonic transducer array, each of the two outer ends of which is additionally equipped with a respective reference ultrasonic transducer and a respective reflector surface (12) flush with the reference piezo disc (13) at a distance from the base side (9), said ultrasonic transducers and reflector surfaces being inclined by 45° relative to the base side (9) and pointing towards one another, thus forming a reference measurement path (R) with a known length between the two reference ultrasonic transducers. In the method for detecting the relative position, the measurement values are corrected with respect to environmental influences by measurements in a reference path.

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Abstract

The invention relates to a sensor and a method for detecting the position of the sensor relative to a guide surface (5), comprising a housing (1) and an electronic analysis device (7) which outputs measurement values for the position of the guide surface (5) on the basis of the measurement signals. The sensor contains an ultrasonic transducer array, each of the two outer ends of which is additionally equipped with a respective reference ultrasonic transducer and a respective reflector surface (12) flush with the reference piezo disc (13) at a distance from the base side (9), said ultrasonic transducers and reflector surfaces being inclined by 45° relative to the base side (9) and pointing towards one another, thus forming a reference measurement path (R) with a known length between the two reference ultrasonic transducers. In the method for detecting the relative position, the measurement values are corrected with respect to environmental influences by measurements in a reference path.

Sensor with Monolithic Ultrasonic Array

The invention relates to a sensor for detecting its position relative to a guide surface, having a housing on the bottom side of which is located a flat, elongated ultrasonic transducer array that consists of multiple measurement ultrasonic transducers, and having an electronic analysis device that provides measured values for the position of the guide surface as a function of measurement signals of the measurement ultrasonic transducers.

For guiding agricultural machinery and construction machinery, in particular for so-called asphalt pavers, guide wires are used that cause the machine to travel along a predetermined route. The guide wire is stretched parallel to the route at a precisely defined height. The position of the machine relative to the guide wire is detected by the sensor and transmitted to the machine's controller so that the controller guides the machine in such a way that the machine follows the guide wire at constant distances.

In order to meet modern requirements for precision in machine control, in particular z-axis control in road construction, it is necessary to use high-resolution sensors. It is preferable for ultrasonic sensors to be considered for this purpose, which are capable of generating precise positional information with respect to the guide wire or another guide surface.

“Ultrasonic sensor” or “sensor” is used here to refer to the entire sensor unit, consisting of ultrasonic transducers, electronics, and sensor housing, and “ultrasonic transducer” to refer to the physical sensor element that converts electrical energy into sound and, conversely, sound into electrical energy.

Today, ultrasonic transducers for use in air typically consist of a round matching layer and a round piezo plate, made, for example, of the material PZT. The back of the piezo plate is glued to the matching layer. Fine stranded wires, which are soldered to the piezo plate, produce the electrical connection. The matching layer has the task of matching the characteristic acoustic impedance of the piezo material to the characteristic impedance of the air. Acoustic matching layers can be made of hollow glass spheres that are stirred into an epoxy resin, for example. The thickness of the matching layer is lambda/4 of the desired ultrasonic frequency. Such ultrasonic transducers create a rotationally symmetric sound field. If a wider sound field is required in one direction, then several of these ultrasonic transducers are arranged in a tightly spaced row, thus forming an ultrasonic array. The ultrasound beams that are formed here overlap significantly.

A sensor called the "SONIC SKI plus," from the company MOBA Mobile Automation AG, is known in which four individual, circular ultrasonic transducers are arranged so as to be spaced apart in a row and are built into a housing. The four ultrasonic transducers are seated in recesses on the bottom of the housing. An additional reference measurement path to compensate for the temperature dependence of the speed of sound and any other environmental influences on the speed of sound is created by another ultrasonic transducer in an arm projecting from the housing at right angles and a second arm with a reflector surface opposite thereto. Located in the housing is a central analysis electronics unit, which controls and analyzes the four ultrasonic transducers and the ultrasonic transducer in the reference path after the echo transit time measurement. Since the four ultrasonic transducers are not located on a common matching layer, they do not form a monolithic ultrasonic array. This sensor is only intended for height measurement.

With its arms projecting at right angles to the left and right, the sensor is quite large in size and is unwieldy, and is high-maintenance in the daily operation of a road construction business. The individually recessed ultrasonic transducers built into the sensor housing become dirty quickly, and then distort the measurement result. Cleaning the recesses is relatively resource-intensive. The installation of individual ultrasonic transducers and the complex housing with its two projecting arms increase the sensor's manufacturing costs.

Described in German patent DE 38 16 198 C1 is a control sensor in which the positional information is determined by means of four ultrasonic sensors. The ultrasonic sensors are arranged singly on the bottom of the housing and are cast in a plastic block. No statements are made regarding the implementation of the requisite acoustic matching layer. Only a simple temperature sensor is provided for temperature compensation of the measurements.

Described in German patent DE 42 06 990 A1 is a method for detecting the lateral position of a construction machine with a sensor consisting of two ultrasonic transducers. The reference measurement is made by the same transducer with the aid of an echo that is reflected at two edges.

The object of the invention is to disclose a sensor for detecting its position relative to a guide surface that is capable of providing horizontal and vertical measurement results with high precision while simultaneously being easy to maintain and economical to manufacture.

This object is attained by a sensor the features of claim 1, and by the method claims 14 and 15. Advantageous embodiments of the invention are specified in the dependent claims.

The speed of sound is strongly dependent on temperature. With a reference measurement path of known length, the influence of the temperature can be compensated for through a simple ratio calculation. Another advantage of a reference measurement path is that other environmental factors on the speed of sound, and hence on the precision of the echo transit time measurement, can also be compensated for, as well.

The sensor for detecting its position relative to a guide surface has a housing, on the bottom side of which is located a flat, elongated ultrasonic transducer array that consists of multiple measurement ultrasonic transducers, and has an electronic analysis device that provides measured values for the position of the guide surface as a function of measurement signals of the measurement ultrasonic transducers. In the sensor according to the invention, a reference measurement path is realized by the means that one reference ultrasonic transducer apiece is additionally attached to each of the two outer ends of the ultrasonic transducer array, and one reflector surface apiece is attached at a distance from the bottom side and in alignment with the reference ultrasonic transducers, which reflector surfaces are each inclined at an angle of 45° to the bottom side and also face one another. Consequently, a reference measurement path with a known length between the two reference ultrasonic transducers is formed.

The reflector surfaces that are inclined at 45° are implemented as fixed brackets over the bottom side, and preferably are a direct component of the housing. This saves the additional installation of mechanical arms or booms.

This application speaks of a guide surface, relative to which the position of the sensor is determined. This can be the surface of a guide wire. However, it is equally possible to use a guide rod or the like, in which the upper edge constitutes the reference value for the positioning control. Provision is also made, however, that the sensor directly measures the distance to the ground below.

According to the invention, the two reference ultrasonic transducers and the measurement ultrasonic transducers are not of discrete construction, but instead are constructed with a single, elongated acoustic matching layer, with multiple measurement piezo plates that are spaced apart from one another applied to the back thereof, and one reference piezo plate apiece additionally applied to each of the two outer ends of this arrangement. The back of this matching layer with the piezo plates is surrounded by a foam. The opposite smooth, front side of the matching layer terminates flush with the bottom side of the sensor, and is the sound-radiating side of the ultrasonic transducer array. The ultrasonic transducer array is consequently implemented as a monolithic unit.

The reference measurement path can be constructed with discrete reference ultrasonic transducers in which the reference piezo plates are provided with an associated, separate matching layer. In a preferred variant embodiment, the reference and measurement ultrasonic transducers are integrated into the monolithic ultrasonic transducer array to form a unit.

Acoustic pulses are emitted and echo signals are received by the measurement ultrasonic transducers. An analysis device provides measured values for the position of the guide surface as a function of the measurement signals.

In this sensor, the monolithic ultrasonic transducer array, with its continuous, smooth acoustic matching layer, is built flush into the bottom of the sensor.

As a result of this flush arrangement of the sound-radiating side of the matching layer and the bottom of the sensor, a large, flat surface is produced that is easy to clean.

The matching layer of the ultrasonic transducer array, which has the thickness lambda/4 of the desired ultrasonic frequency, is elongated in design. At least two, and in one variant embodiment five, round measurement piezo plates are placed on the back thereof so as to be spaced apart in a row on the matching layer. They may be attached by soldering, gluing, or clamping, for example.

Experiments have shown that somewhat asymmetric ultrasound beams that are wider in one direction can be generated with rectangular piezo plates. If rectangular piezo plates are arranged on the back of the matching layer with the wide sides of the ultrasound beams spaced apart and next to one another, then the number of piezo plates required can be reduced as compared to the design with round piezo plates, because the rectangular piezo plates are then arranged somewhat farther apart.

Grooves that provide acoustic/mechanical decoupling between the individual piezo plates are placed on the back of the matching layer between the piezo plates. For good electromagnetic shielding, the back of the matching layer is first metallized, and the piezo plates are then placed on this metallization. The arrangement is embedded in a soft material made of polyurethane foam or silicone foam for mechanical decoupling from the sensor housing.

In another embodiment, the back of the matching layer of the ultrasonic transducer array is additionally provided with a surrounding edge so that the flat matching layer now forms a trough with the surrounding edge. The trough is metallized from the inside for electromagnetic shielding. The piezo plates are placed on the metallized floor of the trough, and are electrically contacted with thin stranded wires.

The method for determining environmental factors at the bottom side of the above-described sensor utilizes the reference measurement path by the means that one of the reference ultrasonic transducers emits a short acoustic pulse with a first sound frequency, which is deflected by the two reflector surfaces, travels over the reference measurement path to the other reference piezo plate, and is received there. The analysis device measures a first time between the emission of the acoustic pulse and its reception. The same measurement is then repeated in the opposite direction, and in so doing the analysis device measures a second time. The arithmetic mean is computed from the first and second measured times, and this reference transit time value Zr serves as a measure for the current values of the environmental factors at the bottom side of the sensor. The effect of wind on the reference measurement is eliminated by this dual measurement in opposite directions.

The method for determining a position of the above-described sensor relative to a guide surface is as follows:
First, the above-described reference measurement is carried out. Next, the sensor emits successive acoustic pulses with a second sound frequency through the measurement piezo plates, wherein the transmit pulse is always given to only one measurement piezo

plate. Next, the sensor receives echo signals at all measurement piezo plates. The transit time values thus determined are compensated using the reference value through a simple ratio calculation:

Distance L to wire in mm:

L=Lr * Z/Zr / 2,

where Z = transit time value in µs, Zr = reference transit time value in µs, Lr = reference length in mm.

The reference measurement path can operate with the same ultrasonic frequency as the measurement piezo plates. In a preferred embodiment, a higher ultrasonic frequency is chosen for the reference measurement path.

Optionally, the distance values thus determined can be sent to the control unit connected to the sensor with each measurement performed, or else the exact position of the wire below the sensor is determined first through trigonometric calculations and only the X and Y positions of the wire relative to the sensor are sent to the control unit.

The measured values are output through an electrical connection at the sensor. If only the distance between the sensor and the wire is to be output, this may take place by means of a standardized analog signal such as 0-10 V or 4-20 mA.

The CAN bus is very widely used in construction machinery. In one protocol, either the measured values from the individual piezo plates, or the X and Y positions of the wire relative to the sensor previously determined in the sensor, can be transmitted over the CAN bus.

In advantageous fashion, indicators are attached to the housing of the sensor that show whether the guide surface is located in a predefined horizontal and/or vertical position range of the sensor. These indicators give the operator of the machine the option to control the machine on its route manually as well.

The calculated position information of the guide surface in the measurement range of the sensor is advantageously displayed on the indicators on the housing as well. Thus, an operator of the machine can also control the machine on the correct route manually by observing the indicators. These indicators can be designed as a numeric display or as a +/- display for each of the two items of position information.

Embodiments of the invention are explained further on the basis of the figures. The drawings show:

Fig. 1 a cross-section through the sensor with measurement range;
Fig. 2 an oblique view of the sensor from below;
Fig. 3 a bottom view of the sensor;
Fig. 4 a side view of the sensor with connecting socket;
Fig. 5 a top view and a section through the monolithic ultrasonic transducer array;
Fig. 6 a top view of the monolithic ultrasonic transducer array with surrounding edge.

Shown in Figure 1 is a cross-section through a sensor with its ultrasound beams M that form, and the guide wire 5. The housing 1 is connected to the machine at a defined position by the mounting stud 6. The monolithic ultrasonic transducer array, consisting of the matching layer 3, the trough 4, the measurement piezo plates 2, and the reference piezo plates 13, is let flush into the bottom side 9 of the housing 1. The piezo plates 2 form the ultrasound beams M that detect the guide wire 5. Echoes reflected from there are received by the measurement piezo plates 2 again, and are analyzed in the analysis device 7. The values measured in the analysis device are forwarded to the machine through the connecting socket 8.

The two reference piezo plates 13 positioned at the each of the two ends of the matching layer 3 form the reference measurement path R, which is used for calculating the temperature influence of the air.

Bottom views of the sensor are shown in Fig. 2 and Fig. 3. The monolithic ultrasonic transducer array with its matching layer 3 is let flush into the bottom side 9 of the housing. A reflector bracket 11 is positioned over each of the ends of the matching layer 3; the reflector surfaces 12 of said brackets are rotated by 45° and form the reference measurement path over the matching layer 3. Attached to the housing 1 of the sensor is the mounting stud 6, which holds the sensor in a defined position. Indicators 10 that provide visual information about the position of the guide wire in the measurement range of the sensor are present on the sides of the housing 1.

Fig. 4 shows a side view of the sensor with the mounting stud 6 attached to the housing 1, and the connecting socket 8 for output of the measured values. A reflector bracket 11 can be seen above the bottom side 9.

Fig. 5 shows, in a top view and in an oblique view, the monolithic ultrasonic transducer array with the matching layer 3, four rectangular measurement piezo plates 2 for the distance measurements to the guide wire, and to the left and to the right thereof, one round reference piezo plate 13 apiece on the first and second ends of the matching layer for operating the reference path. The grooves 15 serve to decouple the measurement piezo plates 2 and the reference piezo plates 13.

Fig. 6 shows the ultrasonic transducer array as described in Fig. 5, but additionally with a surrounding edge so that a trough 4 is formed.

List of Reference Characters

1	housing
2	measurement piezo plates
3	matching layer
4	trough
5	guide surface, guide wire
6	mounting stud
7	analysis device
8	connecting socket
9	bottom side
10	indicators
11	reflector bracket
12	reflector surface
13	reference piezo plates
15	grooves
M	ultrasound beam
R	reference measurement path

Claims

1. Sensor for detecting its position relative to a guide surface (5), having a housing (1), on the bottom side (9) of which is located a flat, elongated ultrasonic transducer array that consists of multiple measurement ultrasonic transducers that are oriented with their sound-radiating transducer surfaces parallel to the ultrasonic transducer array, and having an electronic analysis device (7) that provides measured values for the position of the guide surface (5) as a function of measurement signals of the measurement ultrasonic transducers, characterized in that
one reference ultrasonic transducer apiece is additionally attached to each of the two outer ends of the ultrasonic transducer array, and they are likewise oriented with their sound-radiating transducer surfaces parallel to the ultrasonic transducer array, and one reflector surface (12) apiece is attached at a distance from the bottom side (9) and in alignment with the reference ultrasonic transducers, which reflector surfaces are each inclined at an angle of 45° to the applicable reference ultrasonic transducer and also face one another, and consequently a reference measurement path (R) with a known length between the two reference ultrasonic transducers is formed.

2. Sensor according to claim 1, characterized in that the two reflector surfaces (12) are each composed of one reflector bracket (11) connected to the housing (1).

3. Sensor according to claim 1, characterized in that the guide surface (5) is composed of the top edge of a guide wire.

4. Sensor according to claim 1, characterized in that the guide surface (5) is composed of the surface of the ground, of a curbstone, or of a roadway edge.

5. Sensor according to claim 1, characterized in that the reference ultrasonic transducers and the measurement ultrasonic transducers of the ultrasonic

transducer array are connected by a single, flat, elongated acoustic matching layer (3), to the back of which are applied multiple measurement piezo plates (2) that are spaced apart from one another, and one reference piezo plate (13) apiece is additionally applied to each of the two outer ends of this arrangement, and the back of the matching layer (3) with the piezo plates is surrounded by a foam, and its opposite smooth, front side terminates flush with the bottom side (9) of the sensor, and the ultrasonic transducer array is consequently implemented as a monolithic unit.

6. Sensor according to claim 5, characterized in that five round measurement piezo plates (2) are placed so as to be spaced apart in a row on the matching layer (3).

7. Sensor according to claim 5, characterized in that four rectangular measurement piezo plates (2) are placed so as to be spaced apart in a row on the matching layer (3).

8. Sensor according to claim 5, characterized in that grooves (15) in the matching layer (3) are located on the back in the spaces between the measurement piezo plates (2) for acoustic decoupling.

9. Sensor according to claim 5, characterized in that the foam consists of polyurethane foam or silicone foam.

10. Sensor according to claim 5, characterized in that the matching layer (3) additionally has a surrounding edge that forms a trough (4) with the matching layer (3), and the inside of this trough (4) is metallized.

11. Sensor according to claim 5, characterized in that the measured values are provided as an analog signal.

12. Sensor according to claim 5, characterized in that the measured values are provided as digital information at a CAN bus interface.

13. Sensor according to claim 5, characterized in that indicators (10) are attached to the housing (1) that show whether the guide surface (5) is located in a predefined horizontal and/or vertical position range of the sensor.

14. Method for determining environmental factors at the bottom side (9) of a sensor according to claim 1 or 2 by means of its reference measurement path (R), characterized in that one of the reference ultrasonic transducers emits a short acoustic pulse with a first ultrasonic frequency, which is deflected by the two reflector surfaces (12), travels over the reference measurement path (R) to the other reference ultrasonic transducer, and is received there, and the analysis device (7) measures a first time between the emission of the acoustic pulse and its reception, and the same measurement is then repeated in the opposite direction, and in so doing the analysis device (7) measures a second time, and the arithmetic mean is computed from the first and second measured times, and this mean value serves as a measure for the current values of the environmental factors at the bottom side (9) of the sensor.

15. Method for determining a position of a sensor according to one of claims 1 to 13 relative to a guide surface (5), in which transmit pulses with a second ultrasonic frequency are emitted by the measurement ultrasonic transducers, and their reflections at the guide surface (5) are received again as an echo, and the transit times of the echoes are measured, and positional information is produced therefrom in the analysis device (7) through trigonometric calculations and is output as measured values, characterized in that the current values of the environmental factors in the reference measurement path (R) calculated using the method according to claim 14 are used to compensate for environmental influences in the calculation of the positional information.

16. Method according to claims 14 and 15, characterized in that the first ultrasonic frequency in the reference measurement path is higher than the second ultrasonic frequency for determining the position of the guide surface.

17. Method according to claim 15, characterized in that only information about the vertical position of the guide surface (5) is output in a first operating mode, and horizontal and vertical information about the position of the guide surface (5) is output in a second operating mode.

18. Method according to claim 15, characterized in that the calculated positional information is displayed on the indicators (10) on the housing (1).

Fig. 1

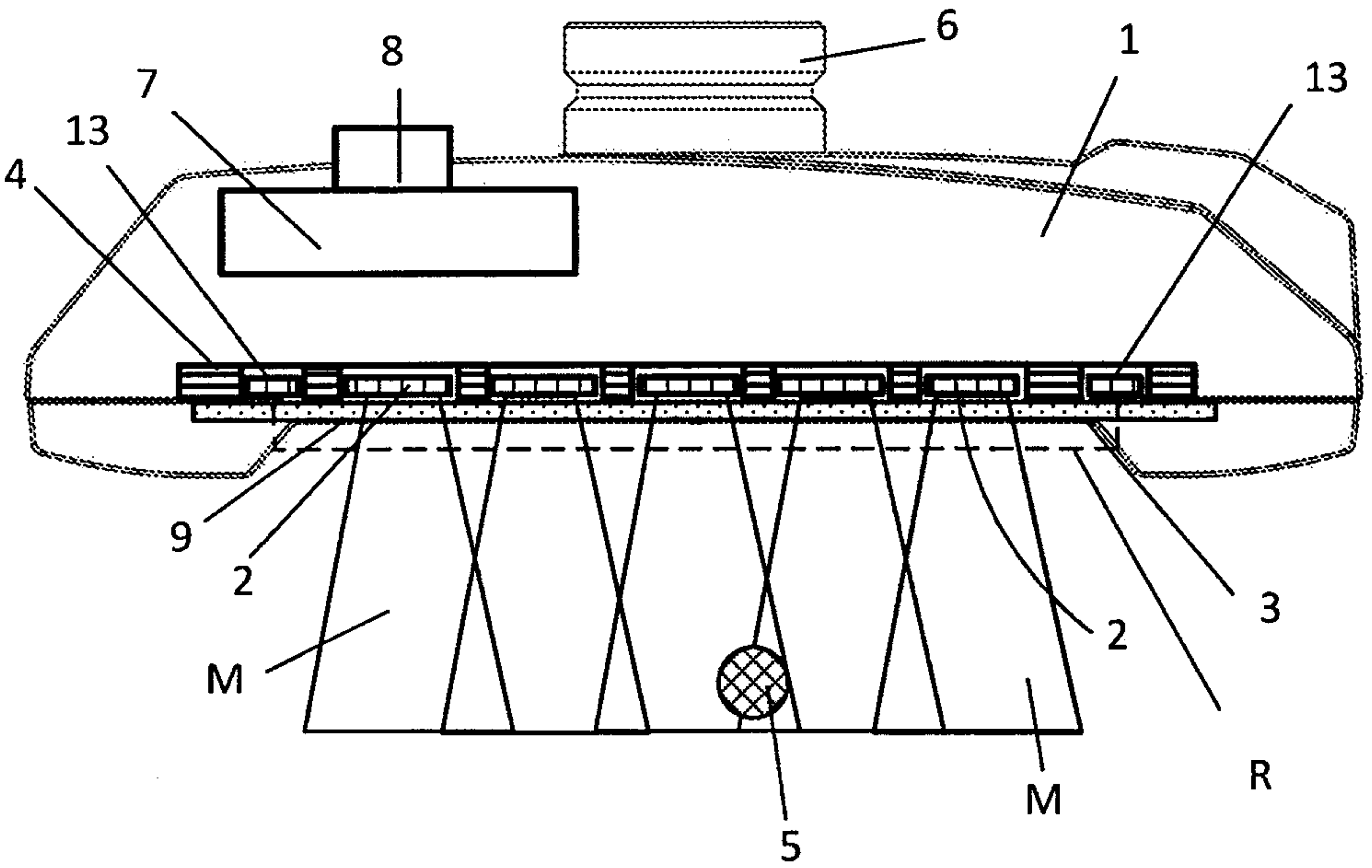

Fig. 4

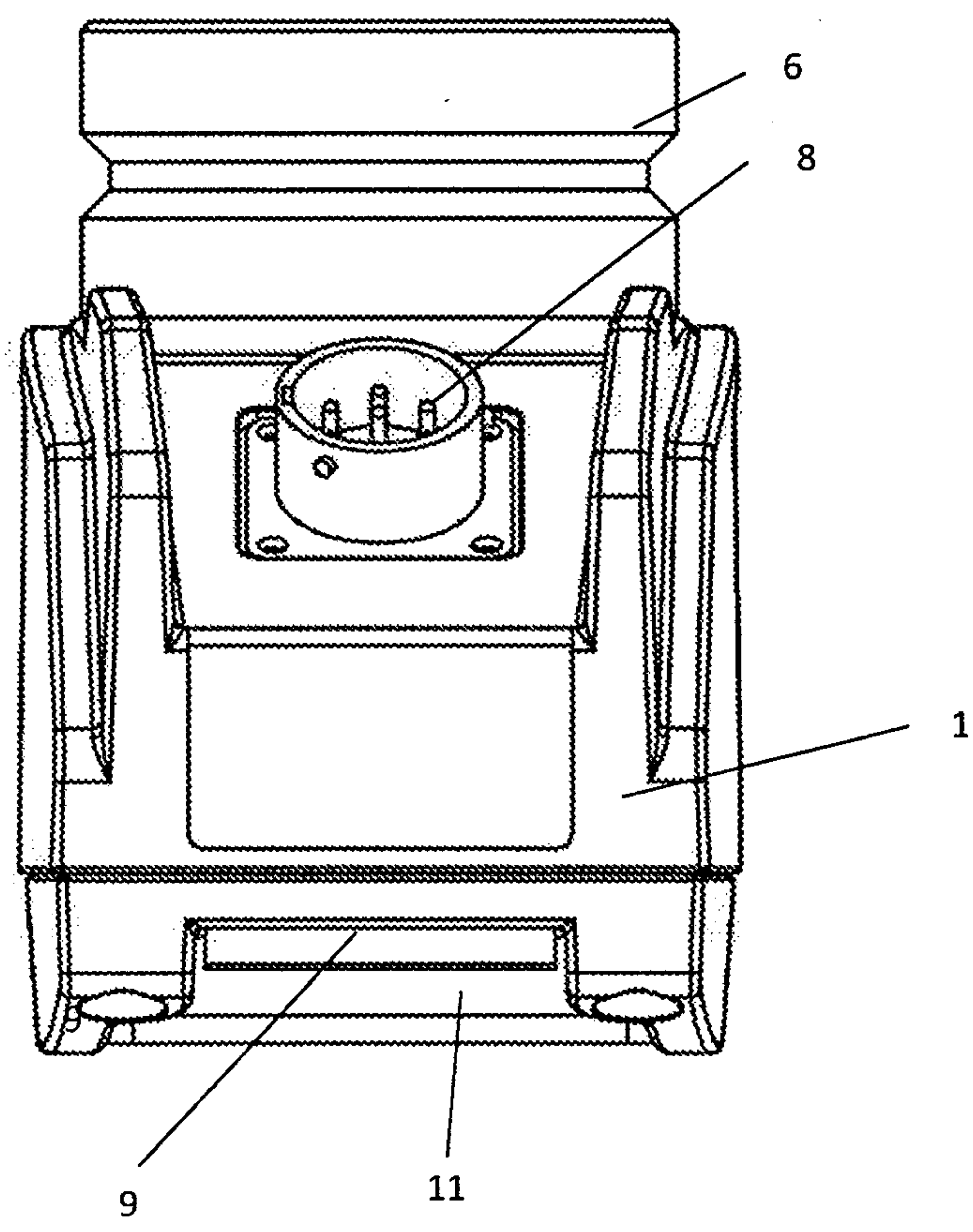

Fig. 2

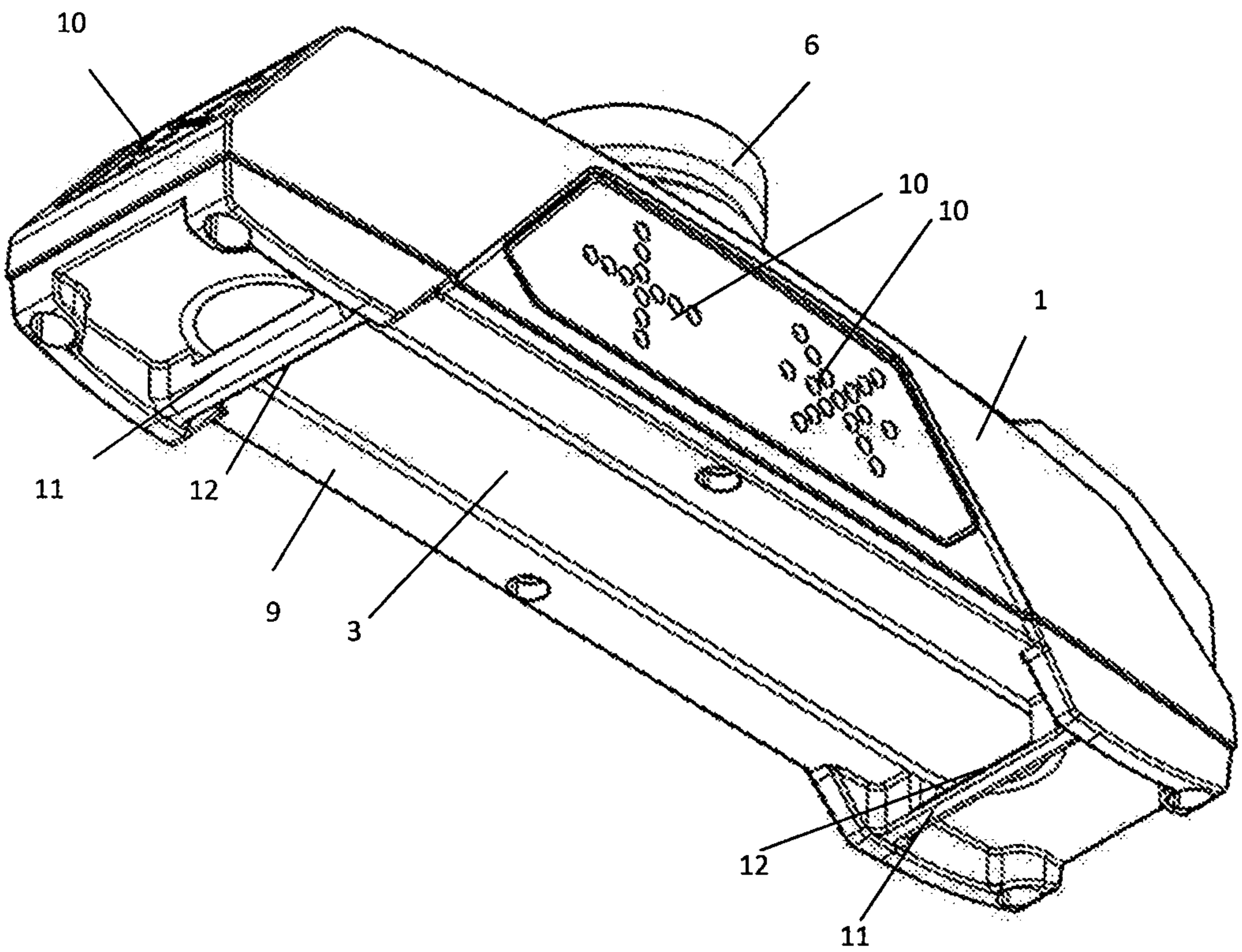

Fig. 3

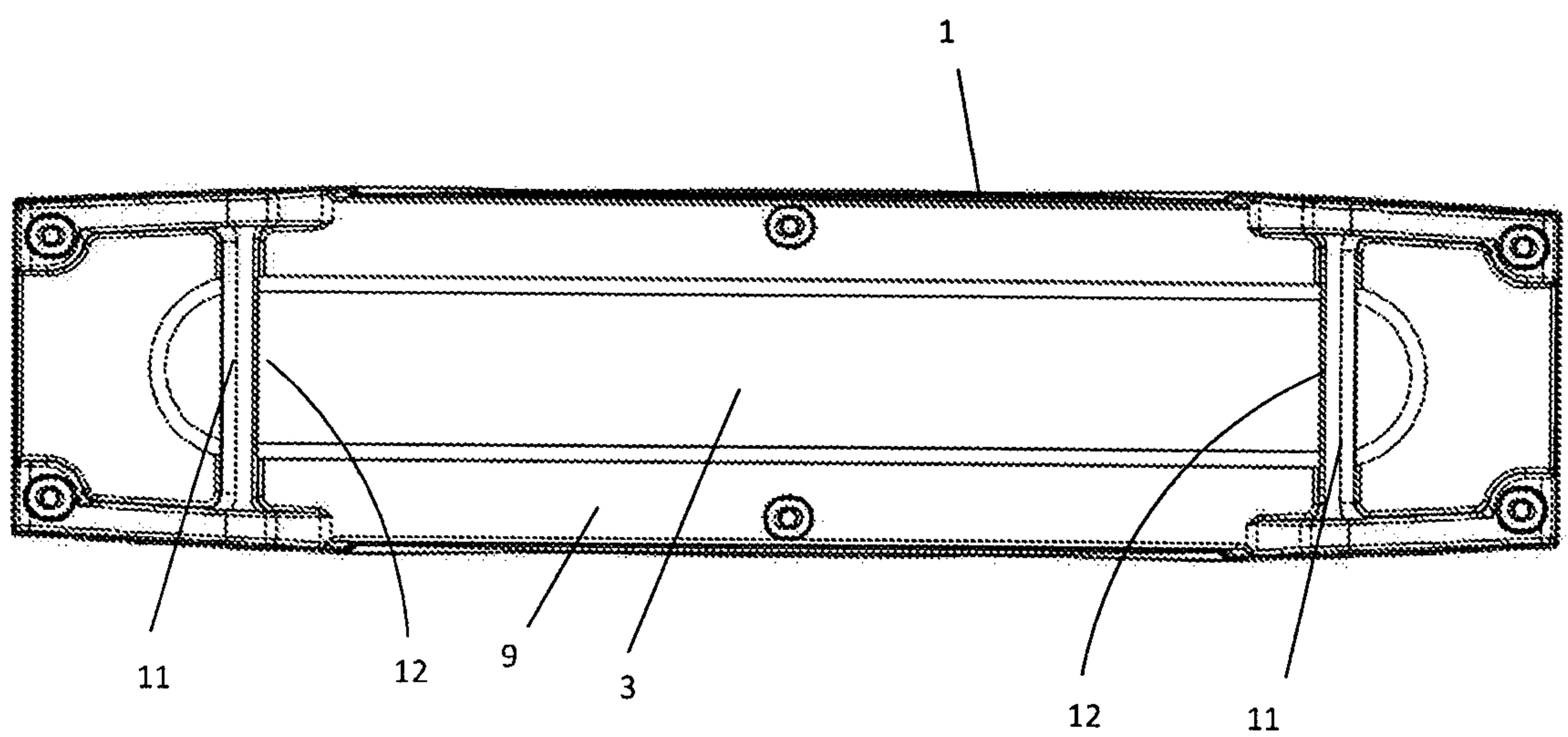

Fig. 5

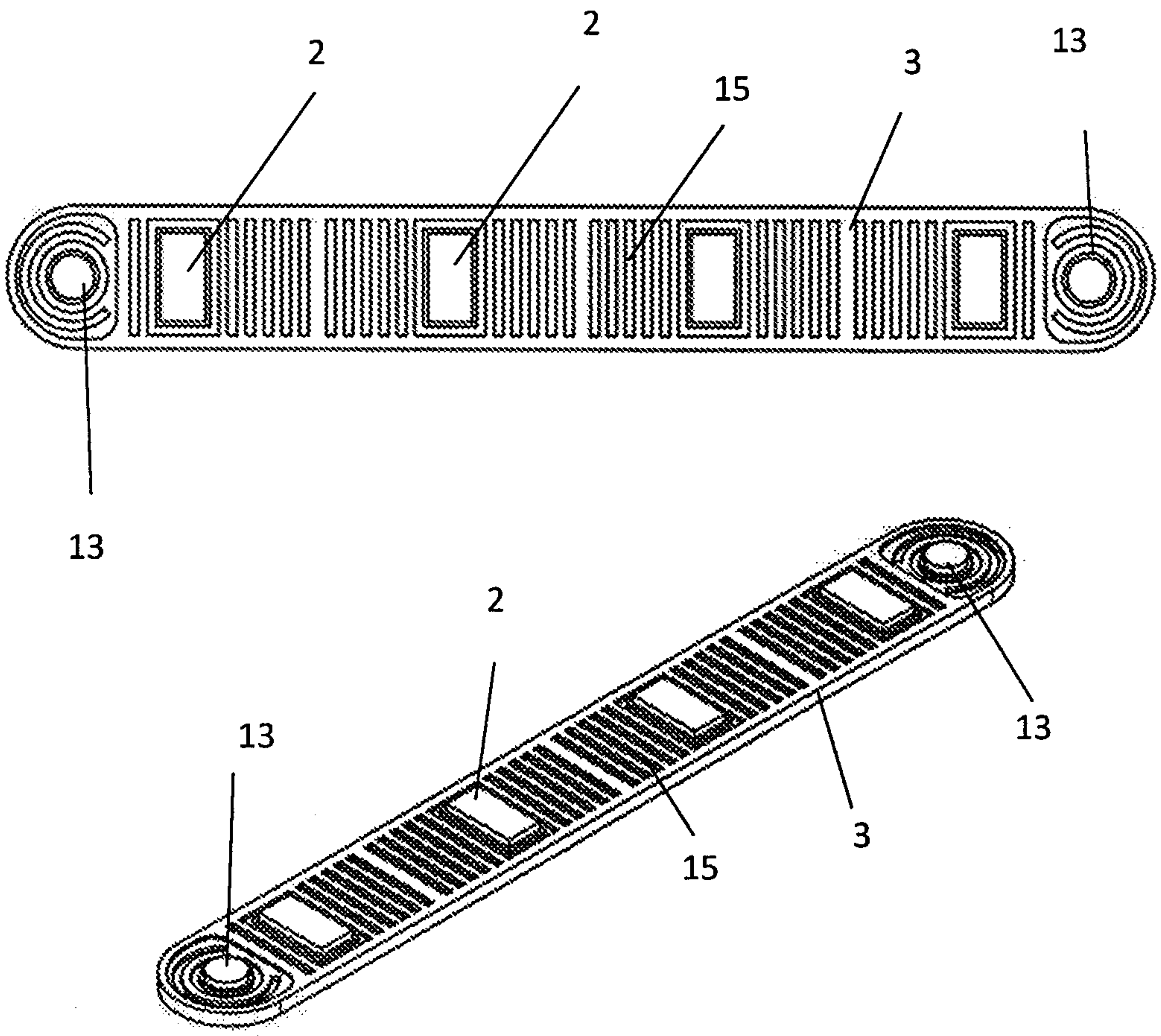

Fig. 6

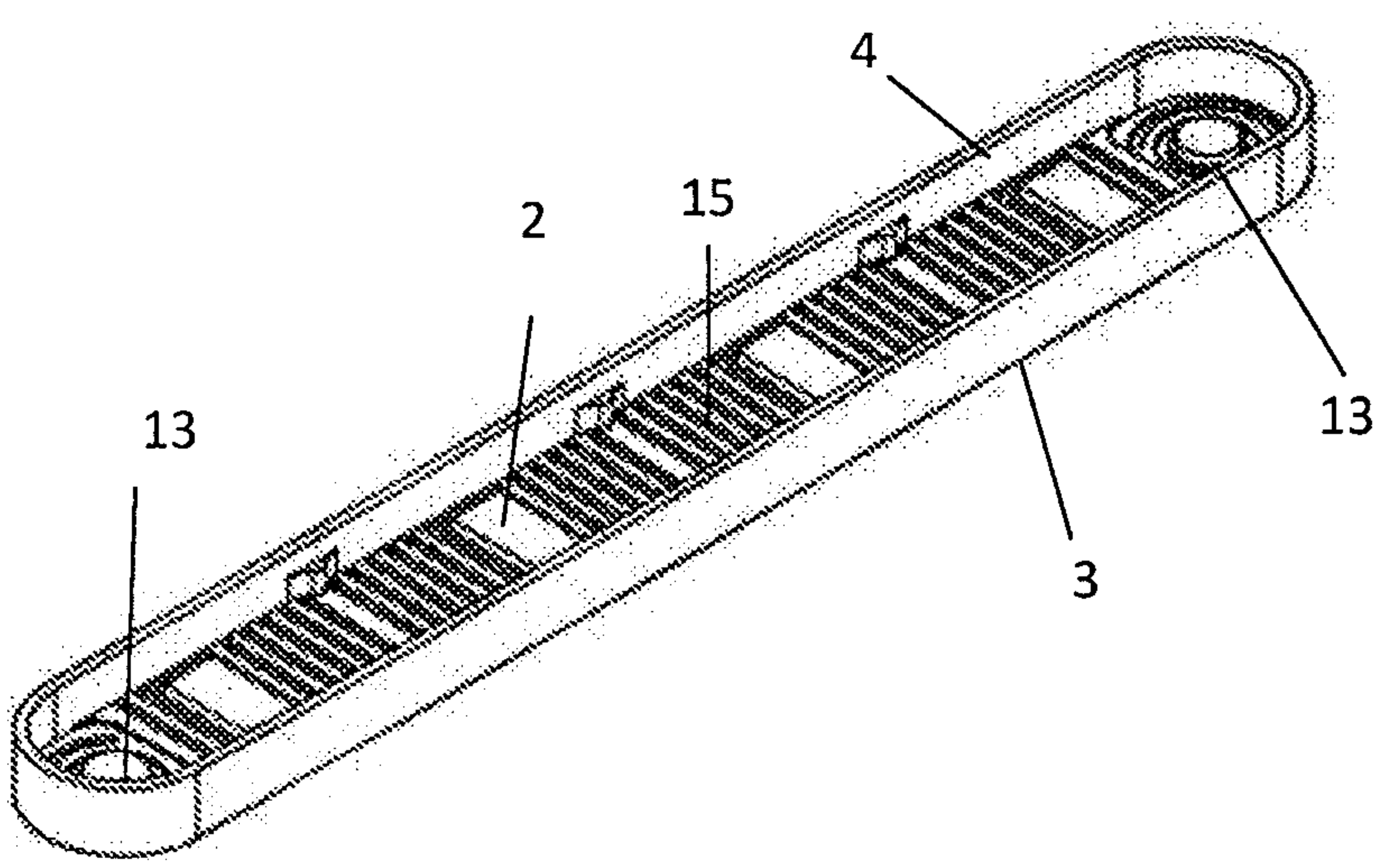

Fig. 1