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(54) SENSORIZED ELASTOMERIC EXPANSION JOINT

(57) A sensorized elastomeric expansion joint (1), comprising: at least one elastomeric body (2), elongated along its longitudinal axis (14), having an upper face (21) that comprises two upper grooves (3) and a lower face (22), that comprises a lower groove (4) that extends parallel to the longitudinal axis (14); two L-shape parts (5), embedded in the elastomeric body (2), made of two plates which form a 90° angle, extending along the long-

itudinal axis (14); a plate (6), embedded in the elastomeric body (2) between the upper grooves (3) and disposed in a plane parallel to the upper and lower faces (21, 22) and extending along the longitudinal axis (14); and one or more buckypaper strip sensors (8), completely embedded in the elastomeric body (2) in a plane parallel to the upper and lower faces (21, 22).

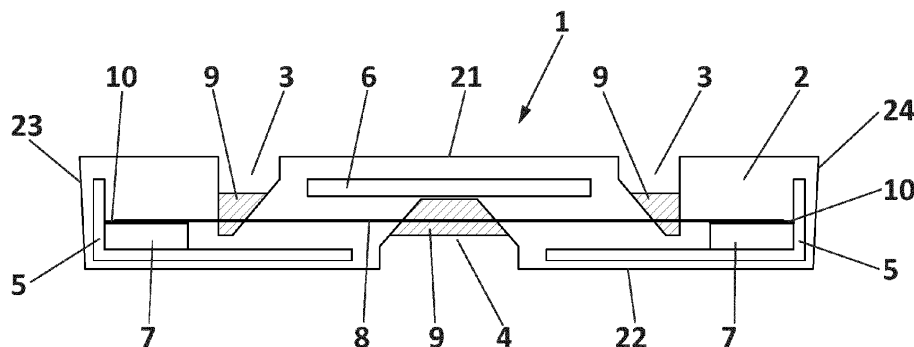


FIG. 3B

Description

TECHNICAL FIELD

[0001] The present invention belongs to the field of construction, more particularly to the detection of deformation in elastomeric expansion joints or movement joints used in constructions, such as bridges.

STATE OF THE ART

[0002] An expansion joint, or a movement joint, is an assembly designed to hold parts together while safely absorbing temperature-induced expansion and contraction of building materials. They are commonly found between sections of buildings, bridges, sidewalks, railway tracks, piping systems, ships and other structures.

[0003] Particularly, bridge expansion joints are designed to allow for continuous traffic between structures while accommodating movement, shrinkage and temperature variations on reinforced and prestressed concrete, composite, and steel structures. They prevent the bridge from bending out of place in extreme conditions, and also allow enough vertical movement to permit bearing replacement without the need to dismantle the bridge expansion joint.

[0004] Expansion joints are essential for roads and their maintenance, since a joint in poor condition represents a risk for users, as well as an incorrect transmission of the loads acting on the infrastructures where they are located. The constant alterations they suffer due to traffic, temperature, rain, earth movements and the bridge itself, make their maintenance very costly, and these elements absorb a significant percentage of the budget allocated to the maintenance of the infrastructures.

[0005] There are various types of expansion joints, which can accommodate different levels of movement. One type of expansion joints are the elastomeric expansion joints, as shown in Fig. 1, which comprise an elastomeric body 2 having an upper face 21 and a lower face 22. Two steel angle parts 5 and a steel plate 6 are embedded in the elastomeric body.

[0006] Each angle part 5 is made of two plates which form a 90° angle with respect to each other. The apex of each angle 5 is located at the lower left and right edge, respectively, of the elastomeric body 2. The two angle parts 5 are arranged symmetrically with respect to a longitudinal axis 14 of the elastomeric body 2. The angle parts 5 extend longitudinally along the elastomeric body 2, parallel to its longitudinal axis 14. The plate 6 is embedded in a middle region of the elastomeric body 2, parallel to the upper face 21 of the elastomeric body 2 and extending longitudinally along it, parallel to the longitudinal axis 14.

[0007] Two upper exposed grooves 3 are provided on the upper face 21 of the elastomeric body 2, extending parallel to their longitudinal axis 14, on both sides of the plate 6, and one exposed lower groove 4 is provided on

the lower face, extending parallel to the longitudinal axis 14, arranged between the two angles 5. These grooves 3, 4 are symmetrical about the longitudinal axis 14 of the elastomeric body 2, allowing it to flex when the joint is subjected to stress.

[0008] There is a growing trend of interest in developing structural monitoring systems that allow to determine the level of movements of the elastomeric expansion joints.

[0009] The general practice for monitoring expansion joints, i.e. the movements of the structure where they are installed, is to use sensors external to the joint, which are difficult to install, at the time they are needed, and to maintain, separately from the joint. For example, the ROBO-SMART for expansion joints (https://www.magebagroup.com/latam/data/docs/es_BR/4000/BROCHURE-ROBO-SMART-expansion-joints-latam-es.pdf?v=1.0, last visited on September 19, 2023) is a self-powered and integrated acquisition unit. However, as shown in Fig. 2, it has the disadvantage that it needs a sensor 11 external to the expansion joint itself, so it can be affected by atmospheric conditions, or even easily stolen or damaged. In addition, it is expensive to be installed as the procedure must be executed without affecting the service of the structure and usually the installation point is difficult to access requiring auxiliary means and difficult to maintain.

[0010] A joint disclosed in document CN110849237 has the same problems as the previous one, as it discloses a monitoring and connecting device for an expansion joint of a highway bridge, which comprises a connecting rod which is anchored on the side wall of the expansion joint, where the sensor is positioned.

[0011] Also, document CN 111256924 describes a monitoring method for expansion joints on largespan high-speed railway bridges, used for long-term monitoring. As all the previous documents, this invention is also external to the joint, and presents the same problems.

[0012] Documents CN106767664 and KR101693759, which use a load cell, also present the same difficulties.

[0013] In order to solve said problems, alternative investigation lines work with sensors embedded within the elastomeric matrix itself. This field presents many challenges, as construction materials often have complex curing or setting processes that can damage the sensors.

[0014] Regarding this kind of sensor, document EP3929357B1 describes a method for manufacturing a sensorized elastomeric support, which comprises a buckypaper strip deformation sensor for measuring deformations of the support, both in a vertical and a horizontal direction, but facing much smaller unit deformations, in particularly tensile strains, than those occurring during the opening and closing movement in the operational function of the expansion joint. Manufacturing methods of buckypaper strips are for example disclosed in US7459121B2. EP3524339A1 discloses a method for increasing the thickness of a buckypaper sheet.

DESCRIPTION OF THE INVENTION

[0015] The present invention overcomes the drawbacks of conventional elastomeric expansion joints in relation to their instrumentation for controlled maintenance. It provides a sensorized elastomeric expansion joint with an embedded sensor based on buckypaper, which allows the remote management of the state of conservation of the expansion joints of structures, such as bridges and viaducts, in real time. It increases the useful life of the sensing devices by the protection provided: protection against the action of the weather, acts of vandalism and presence of living beings (vegetation, birds, rodents, etc.). Moreover, it reduces the cost of the required expansion joint maintenance operations and increases road safety.

[0016] Buckypaper is a thin sheet made from an aggregate of carbon nanotubes or carbon nanotube grid paper. The production of buckypaper sheets typically includes making a suspension of carbon nanotubes dispersed in a liquid medium and filtering the suspension by a filter membrane, such that the carbon nanotubes are deposited directly on the filter membrane as the fluid medium flows through the filter membrane. The buckypaper sheet is typically dried and thereafter separated from the filter membrane. Document US7459121 B2 discloses and exemplary method for producing buckypaper. Document EP3524339A1 discloses a method for increasing the thickness of a buckypaper sheet.

[0017] The electrical resistance of a buckypaper strip changes in response to deformation. The inventors advantageously use this property of buckypaper for employing buckypaper strips as deformation sensor, thus providing a sensorized elastomeric expansion joint that overcomes the drawbacks disclosed above. Therefore, in this description, the buckypaper strip is referred to as buckypaper strip sensor or buckypaper strip deformation sensor.

[0018] In the present document, the terms "horizontal" and "vertical" are interpreted with reference to the orientation of the elastomeric joint when in use. More specifically, when the elastomeric joint is in use, the vertical direction corresponds to the direction of the weight supported by the elastomeric joint, while the horizontal direction (perpendicular to the vertical direction and to the longitudinal axis of the elastomeric body of which the elastomeric joint is made) corresponds to the expansion direction of the joint. Similarly, the terms "upper", "lower" and the like are interpreted according to said vertical direction.

[0019] In the present document, the term "face" refers to each distinct side of the elastomeric joint. An elastomeric joint, when in use, generally comprises a horizontal lower face or base resting on a surface (such as on the ground or on another construction part, such as buttress), a horizontal upper face supporting the loads (i. e. traffic) and one or more lateral faces. The faces are substantially planar and usually include one or more grooves which

interrupt the continuity of the faces, allowing the joint to bent, if necessary.

[0020] A first aspect of the present invention is directed to a sensorized elastomeric expansion joint. It comprises an elastomeric body, intended to be placed between two parts of a structure, such as a bridge, and fixed for example with fixing bolts. The elastomeric body is elongated along a longitudinal axis. The elastomeric body defines an upper face, which comprises two upper grooves, which are exposed and extend longitudinally parallel to the longitudinal axis of the elastomeric body. The elastomeric body also defines a lower face, which comprises a lower groove, which is also exposed and extends longitudinally along the elastomeric body parallel to its longitudinal axis.

[0021] The sensorized elastomeric expansion joint also comprises two parts embedded into the elastomeric body. Each part defines an angle. In other words, each part is made of two portions (plates) which form a 90° angle with respect to each other, in an "L" shape. The apex of each angle is located at the lower left and right edge, respectively, of the elastomeric body. The two L-shape parts are arranged symmetrically with respect to the longitudinal axis of the elastomeric body. The L-shape parts extend longitudinally along the elastomeric body, parallel to its longitudinal axis. The lower groove is centered between both L-shape parts.

[0022] The expansion joint also comprises a plate, embedded in a middle region of the elastomeric body, parallel to its upper face and extending longitudinally along it, parallel to the longitudinal axis. The plate is placed between both upper grooves. The plate and the L-shape parts are usually made of metal, preferably steel. They reinforce the elastomeric body, providing greater structural strength to the joint.

[0023] As previously explained, the elastomeric expansion joint object of the present invention is sensorized and to this end, it comprises an elongated buckypaper strip, which is embedded in the elastomeric body, in a plane parallel to its upper and lower faces. In the plane in which it is embedded, the buckypaper strip sensor extends from a location disposed at one side of the longitudinal axis of the elastomeric body (for example in the vicinity of one of the two longitudinal side faces of the joint) to a location disposed at the other side of the longitudinal axis of the elastomeric body (for example in the vicinity of the other (the opposite) longitudinal side face of the joint). The buckypaper strip sensor can take any orientation within this plane, except parallel to the longitudinal axis of the joint. The buckypaper strip sensor can be perpendicular to the longitudinal axis of the elastomeric body. Alternatively, it can extend diagonally with respect to the longitudinal axis of the elastomeric body. In this second case, when the buckypaper strip sensor extends diagonally, a preferred angle between the buckypaper strip sensor and the longitudinal axis of the joint is an angle between 30° and 60°, more preferably between 40° and 50°.

[0024] In use of the joint, the buckypaper strip sensor suffers a deformation once the elastomeric joints move in any direction, and therefore it can determine the tension which the elastomeric joint suffers, and therefore the movement of the structure (i.e., bridge) where it is placed. Particularly, the buckypaper strip sensor provides an ohm's measurement of the electric resistance, depending on the deformation it suffers. Electrical resistance data is preferably provided to a processor, to transform it into a distance measurement, which represents the structural movement, i.e., the opening or closing of the joint.

[0025] During the fabrication process of the elastomeric joint, the elastomeric body requires vulcanization for rubber curing, reaching temperatures of about 140°C. As previously indicated, this is the reason why a buckypaper strip sensor is chosen to sensorized the joint, together with the high strength of the buckypaper strip compared to its thickness, which makes it minimally invasive to the elastomeric body. And not only to sensorized it but doing so in such a way that the sensor is embedded in the elastomeric body, in order to avoid all the problems previously described regarding wear and tear due to the environment, maintenance, etc. As this kind of sensor resists these high vulcanization temperatures without affecting its sensing capabilities or integrity, it is suitable to be embedded in the elastomeric body.

[0026] The buckypaper strip sensor, which is placed in a plane parallel to the upper and lower faces of the elastomeric body, is preferably placed in, approximately, a middle region between the L-shape parts and the plate, and parallel to the upper and lower faces of the elastomeric body. This is so because, if it were placed too close to the L-shape parts or too close to the plate, it would not suffer enough deformation or it would suffer too much deformation, even breaking, and the measurement obtained would not be precise. In view of the above, the middle region is defined as a region substantially situated in a middle point (in the vertical direction) between the horizontal plates of the L-shape parts and the plate..

[0027] The buckypaper strip sensor must be completely embedded in the elastomeric body, without it being exposed to the outside anywhere. Since the most critical areas of possible exposure are the three grooves, the elastomeric body has been manufactured to ensure that there is elastomeric material covering the sensor, so that it is completely embedded in the elastomeric body. This is why the grooves are shallower than the ones in conventional joints-

[0028] In order to maintain the buckypaper strip sensor in said middle region, the elastomeric body preferably comprises two lifting parts, placed on the L-shape parts, each lifting part resting on the horizontal plate of a corresponding L-shape part, and parallel to the lower face of the elastomeric body. In this way, the buckypaper strip sensor leans on the lifting parts, and it is elevated so it is approximately placed in the middle region. Preferably, the lifting parts are placed at selected locations along the

longitudinal axis of the elastomeric body. The lifting parts are preferably made of metal.

[0029] A wire, preferably a standard copper wire, with a commercial high temperature coating, can be attached to each end of the buckypaper strip sensor (which is typically manufactured leaving a conductive fragment (for example a 10 mm conductive fragment) at both ends), to allow the buckypaper strip sensor's measurements to be read outside the joint. In embodiments of the invention, the high temperature coating resists temperatures above 180°C, which is vulcanization temperature. These wires are fixed by combining a silver resin and then instant glue or other resin acting as a high temperature resistant fixative. The adhesives that fix the cables to the buckypaper will require mechanical resistance properties (once the resin or adhesive is cured) of at least 30 N/mm² tensile stress, a compressive stress resistance of at least 80 N/mm² and a shear strength of at least 20 N/mm². Then, to fix the wired buckypaper to the lifting parts, a non-conductive adhesive material can be used. First, covering the lifting part and then on the buckypaper strip sensor supported on the lifting part, to fix it properly avoiding any possible current shunt by insulating the metallic parts (lifting parts and L-shaped parts). The non-conductive adhesive material used can be, for example, Kapton, which is a polyimide film used in flexible printed circuit boards (flexible electronics) and various space instruments, and is chosen as a simple, tough and minimally invasive insulation option. It is adequate for the vulcanization process, as it remains stable over a temperature range from - 269 to +400 °C. Coating the lifting parts with Kapton tape film has been identified as the simplest option to avoid current shunts, etc.

[0030] In an embodiment of the invention, the lifting parts are placed symmetrically with respect to the longitudinal axis of the elastomeric body. In this way, the buckypaper strip sensor is placed parallel to the upper and lower faces of the elastomeric body and perpendicular to its longitudinal axis (it forms a 90° angle with the longitudinal axis).

[0031] In an alternative embodiment of the invention, the lifting parts are placed not symmetrically with respect to the longitudinal axis of the elastomeric body. In this way, the buckypaper strip sensor is parallel to the upper and lower faces of the elastomeric body but it is not perpendicular to its longitudinal axis.

[0032] The embodiment where the buckypaper strip sensor forms a 90° angle with the longitudinal axis provides a more directly interpretable result, since it is a measurement of deformations in the same direction of opening and closing of the expansion joint. However, it only allows to measure deformations perpendicular to the longitudinal axis of the elastomeric body. On the other hand, the embodiment where the buckypaper strip sensor is not perpendicular to its longitudinal axis allows to measure both deformations, perpendicular and parallel to said longitudinal axis. This last embodiment also has the advantage that the buckypaper strip sensor is usually

longer, so it is more unlikely to break due to the tensions that the joint suffers.

[0033] A sensorized elastomeric expansion joint can comprise more than one buckypaper strip sensor. In this case, both embodiments (buckypaper strip sensor perpendicular or not perpendicular to the longitudinal axis), can be combined.

[0034] Elastomeric expansion joints are known from the state of the art which can comprise a bigger elastomeric body than the ones previously described. As an exemplary embodiment, the section of the joint appears like two elastomeric bodies combined on one of their side faces. The bigger elastomeric body is manufactured using a bigger cast. In this case, the complete elastomeric body comprises four upper grooves and two lower grooves. Moreover, the joint comprises two L-shape parts, on both sides of the complete elastomeric body, two plates, placed between the upper grooves, and an additional lower plate, embedded between the lower grooves.

[0035] When this kind of joint is a sensorized elastomeric joint, the lifting parts are preferably also placed on the L-shape parts and the buckypaper strip sensor is placed on the lifting parts, being completely embedded in the elastomeric body too, to avoid contact of the buckypaper strip sensor with the outside.

[0036] In the manufacturing method of a conventional elastomeric expansion joint, a lower and upper mold that form a standard formwork are introduced into a press for the vulcanization process, after the usual elastomeric material and metal reinforcement (angles and plate) are placed inside and the mold is closed.

[0037] For the manufacturing of the sensorized elastomeric expansion joint, the molds need to be previously modified with respect to conventional ones, as they need to provide enough space for the additional elastomeric regions employed to cover the buckypaper strip when crossing the original grooves of the joint. Additionally, the lifting parts need to be fixed to the L-shape parts and covered with the adhesive and insulating material. Finally, the buckypaper strip sensors are placed. All of these elements are situated between the elastomeric material and introduced in the mold, in order to be vulcanized.

[0038] The sensorized elastomeric expansion joint of the invention can be implemented with any kind of conventional elastomeric expansion joint having a profile like the one described in Fig. 1 of the state of the art. For example, the expansion joints from the COMPOSAN's catalogue JNA-42 - 52 - 70 - 80 / JNA - 100 - 160 - 230 - 330 - 130 (see <https://composanindustrial.com>).

[0039] Additional advantages and features of the invention will become apparent from the detailed description that follows and will be particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] To complete the description and in order to

provide for a better understanding of the invention, a set of drawings is provided. Said drawings form an integral part of the description and illustrate embodiments of the invention, which should not be interpreted as restricting the scope of the invention, but just as an example of how the invention can be carried out. The drawings comprise the following figures:

Fig. 1 illustrates a cross section of an elastomeric expansion joint of the state of the art.

Fig. 2 illustrates a view of an externally sensorized expansion joint of the state of the art.

Figs. 3A and 3B respectively illustrate a plan view and an elevation section view of a sensorized elastomeric expansion joint according to an embodiment of the invention.

Figs. 4A and 4B respectively illustrate a plan view and an elevation section view of a sensorized elastomeric expansion joint according to an embodiment of the invention.

Fig. 5 illustrates a view of a middle section of an expansion joint according to the invention, during its manufacturing process, including buckypaper strip sensors placed in different locations within a same plane of the elastomeric body.

Fig. 6 illustrates an elevation section view of an expansion joint according to an embodiment of the invention, having a bigger elastomeric body.

Fig. 7A illustrates an elevation section view of an expansion joint according to another embodiment of the invention. In this case, the buckypaper strip sensor is placed directly on the L-shape parts.

Fig. 7B illustrates an elevation section view of an expansion joint according to another embodiment of the invention. In this case, the buckypaper strip sensor is placed on lifting parts disposed on the L-shape parts.

Fig. 8 illustrates the expansion joint of the invention installed on a structure.

Fig. 9A illustrates, on the top, a graphic of the measurement (Ohms) obtained by a sensor integrated in an expansion joint according to Fig. 7A, and on the bottom, a graphic of the real deformation (mm) of the joint.

Fig. 9B illustrates, on the top, a graphic of the measurement (Ohms) obtained by a sensor integrated in an expansion joint according to Fig. 7B, and on the bottom, a graphic of the real deformation (mm) of the

joint.

Fig. 9C illustrates, on the top, a graphic of the measurement (Ohms) obtained by a sensor integrated in an expansion joint according to the present invention, and on the bottom, a graphic of the real deformation (mm) of the joint.

DESCRIPTION OF A WAY OF CARRYING OUT THE INVENTION

[0041] The following description is not to be taken in a limiting sense but is given solely for the purpose of describing the broad principles of the invention. Next embodiments of the invention will be described by way of example, with reference to the above-mentioned drawings, showing apparatuses and results according to the invention.

[0042] Figs. 3A-3B and 4A-4B show views of a sensorized elastomeric expansion joint 1 according to embodiments of the invention. The joint 1 comprises an elastomeric body 2, intended to be placed between two parts 12 of a structure, such as a bridge, and fixed with fixing bolts. The elastomeric body 2 is elongated in a direction perpendicular to the union between the two parts 12 of the structure, following a longitudinal axis 14 (shown in Figure 5). Figure 8 shows the joint 1 placed on a structure 12, particularly between two parts of a bridge.

[0043] The elastomeric body 2 defines an upper face 21, a lower face 22, opposite to the upper face 21 and two lateral faces 23, 24. The lower face 22 is intended to be placed in an area between two parts 12 of the structure and intended to be fixed to both. Each of the lateral faces 23, 24 of the joint 1 contacts one of the parts 12 of the structure. The upper face 21, opposed to the lower face 22, remains exposed.

[0044] The upper face 21 comprises two upper grooves 3, which are exposed and extend longitudinally parallel to the longitudinal axis 14 of the elastomeric body 2. The upper grooves 3 are symmetrically positioned with respect to the longitudinal axis 14. The lower face 22 also comprises a lower groove 4, which is also exposed and extends longitudinally parallel to the longitudinal axis of the elastomeric body 2. The lower groove 4 is centered in the lower face 22. The presence of the grooves 3 and 4 mean that the respective faces are not completely flat surfaces but are so with the exception of the dip or depression created by the grooves 3 and 4. A skilled person in the art understands that the grooves 3 and 4 do not prevent the upper face 21 and the lower face 22 from playing their role in the use of the joint, serving as a flexible link between the two parts 12 of the structure.

[0045] The sensorized elastomeric expansion joint 1 also comprises two L-shape parts 5, embedded in the elastomeric body 2 and extending longitudinally, parallel to the longitudinal axis 14 of the elastomeric body 2. Each L-shape part 5 is made of two plates which form a 90° angle with respect to each other, in a "L" shape. The apex

of each L-shape part 5 is located at the lower left and right edge, respectively, of the elastomeric body 2. One of the plates of each part 5 is parallel to the lower face 22 of the elastomeric body 2 and the other plate of each part 5 is parallel to a lateral 23, 24 face of the elastomeric body 2. The horizontal plate may end in the proximity of the lower groove 4 and vertical plate may end in the proximity of the upper face 21. The two L-shape parts 5 are arranged symmetrically with respect to the longitudinal axis 14 of the elastomeric body 2. The lower groove 4 is centered between both L-shape parts 5, as shown in Fig. 3.

[0046] The elastomeric expansion joint 1 also comprises a plate 6, embedded in the elastomeric body 2, parallel to the upper face 21 of the elastomeric body 2, centered in the elastomeric body 2 with respect to the longitudinal axis 14 and aligned with it. The plate 6 is disposed between the two upper grooves 3.

[0047] The sensorized elastomeric expansion joint additionally comprises, as shown in Figs. 3 and 4, a buckypaper strip sensor 8, which is embedded in a middle region of the elastomeric body 2. Particularly, as shown in Fig. 3, the buckypaper strip sensor 8 is positioned in a plane parallel to the upper and lower faces 21 and 22 of the elastomeric body 2. The sensor 8 is in a middle region defined in a middle point in the vertical direction between the plane which contains the plate 6 and the plane which contains the plates of the L-shape parts 5, which are parallel to the lower face 22 of the elastomeric body 2.

[0048] Consequently, the buckypaper strip sensor 8 is contained in a plane parallel to the upper and lower faces 21 and 22 of the elastomeric body 2. In this plane, the buckypaper strip sensor 8 can be either perpendicular to the longitudinal axis 14 of the elastomeric body 2 (forming an angle A of 90°), or diagonal (forming an angle A to the longitudinal axis 14, but not parallel thereto). When the buckypaper strip sensor 8 is disposed diagonally, angle A is preferably comprised in a range between 30° and 60°, more preferably between 40° and 50°. In an example, Fig. 3A, shows an embodiment where angle A is 90°, being the buckypaper strip sensor 8 perpendicular to the longitudinal axis 14 of the elastomeric body 2. In another example, Fig. 4B shows an embodiment where angle A is greater than 0° and smaller than 90° (the sensor is disposed diagonal to the longitudinal axis 14).

[0049] In order to maintain the buckypaper strip sensor 8 in the middle region of the elastomeric body, the joint 1 also comprises two lifting parts 7, identical and placed on the horizontal plate of the L-shape parts 5. In the embodiment shown in Figure 4B the lifting parts 7 are in contact with the apexes of the respective L-shape part 5. The lifting parts 7 are thick enough so they can cover the space between the plane of the plates of the L-shape parts 5 parallel to the lower face 22 of the elastomeric body 2 and the middle region of the body 2 where the buckypaper strip sensor 8 needs to be situated. In this way, the buckypaper strip sensor 8 leans on the lifting parts 7 of both plates, and it is elevated so it is placed in the middle region, parallel to the upper and lower faces

21, 22 of the elastomeric body 2.

[0050] When the elastomeric expansion joint 1 suffers a deformation, the deformation is transferred to the buckypaper strip sensor 8, which obtains an electric resistance measurement. This measurement can be translated into a length measurement, which represents the deformation that the elastomeric expansion joint 1 suffers. This measurement can be sent to a processor, computer or the like for further processing and/or supervision of the structure on which the joint is located.

[0051] As shown in Fig. 3B and 4B, the buckypaper strip sensor 8 is completely embedded in the elastomeric body 2, without it being exposed to the outside through any of the grooves 3 and 4. This is why the grooves 3 and 4 are less deep than the grooves of a conventional expansion joint. The additional elastomeric material (with respect to conventional joints) that is incorporated to the elastomeric body 2 is represented in Fig. 3B and 4B as three additional elastomeric regions 9, placed inside the upper and lower grooves 3, 4, covering the buckypaper strip sensor 8. The elastomeric regions 9 can have any thickness, provided it is ensured that the buckypaper strip is embedded in the elastomeric body. For example, the elastomeric regions 9 can have a thickness of approximately 15mm. They prevent the buckypaper strip sensor 8 from suffering wear and tear.

[0052] To fix the buckypaper strip sensor 8 to the lifting parts 7, an adhesive material 10 is used, with mechanical resistance properties (once the resin or adhesive is cured) of at least 30 N/mm² tensile stress, a compressive stress resistance of at least 80 N/mm² and a shear strength of at least 20 N/mm².

[0053] Wires can also be connected to the buckypaper strip sensor 8, in order to retrieve the measurement obtained. A wire connected to a sensor 8 is within the elastomeric body 2 and the free end of the wire extends outwards the joint 1, so that reading of measurements is enabled from the outside. Where the wires connect to the buckypaper strip sensor 8, they are also covered with the same adhesive non-conductive material 10.

[0054] Fig. 5 shows a view of the joint, during its manufacturing process. It shows a lower part of the elastomeric body 2 where several lifting parts 7 have been placed. Buckypaper strip sensors 8 have been fixed to them using the adhesive material 10. They are placed in both configurations along the elastomeric body 2, forming an angle A greater than 0° and smaller than 90°, and forming a 90° angle with the longitudinal axis 14 of the elastomeric body 2. All these elements will be later covered with an upper part of the elastomeric body 2, completely embedding the buckypaper strip sensors 8.

[0055] Fig. 7A and 7B show an elevation section view of two alternative embodiments of an elastomeric expansion joint having an embedded buckypaper strip sensor 8. Fig. 7A shows an embodiment in which the elastomeric expansion joint 1 does not have lifting parts 7. The buckypaper strip sensor 8 is placed directly on the L-shape parts 5. The buckypaper strip sensor 8 only ex-

tends between the outer ends of the horizontal plates of the L-shape parts 5. The joint shown in Fig. 7B has lifting parts 7, but the sensor 8 is of shorter length than, for example, the joint in Fig. 3A-3B. Both in Fig. 7A and 7B the working length of the buckypaper strip sensor 8 is reduced, being the working length the part of the buckypaper strip sensor 8 which does not lay on the horizontal plate of the L-shape parts 5, making it less accurate, meaning that the results obtained in terms of sensor response are of lower quality, as can be seen in the upper graphs of Figs. 9A and 9B that correspond to embodiments shown in Figs. 7A and 7B, compared to the top graph in Fig. 9C, regarding signal stability, etc. In fact, being the buckypaper strip sensor 8 shorter in length in these embodiments, it assumes higher levels of deformation due to the shorter sensors, what can cause its breaking.

[0056] For these reasons, the joint in Fig. 7A and 7B is less recommended. The lower groove 4 also needs to be completely filled with elastomeric material, to avoid the buckypaper strip sensor to be exposed. Fig. 7B shows a second embodiment, where the lifting parts 7 are lay on the horizontal plates of the L-shape parts 5, but not contacting their vertical plates thereof nor their apexes. In this embodiment the buckypaper strip sensor 8 is approximately placed in a middle region. Like in the previous embodiment, the working length of the buckypaper strip sensor 8 is reduced, so it is less accurate and more prone to breaking. Experimental results obtained with the joints shown in Fig. 7A and 7B are shown later.

[0057] Fig. 6 shows a different elastomeric expansion joint 1 according to the invention, which comprises a bigger elastomeric body 2. The section of this expansion joint looks as if two elastomeric bodies as the previously defined have been merged on one of their sides forming one complete elastomeric body. However, these bigger elastomeric bodies 1 are manufactured using a bigger cast, and not by merging. In this way, the complete body comprises four upper grooves 3 and two lower grooves 4, all of them placed symmetrically with respect to the union between both elastomeric bodies 2. In this case, the joint comprises two L-shape parts 5, embedded in both sides of the complete elastomeric body, with horizontal plates parallel to the lower face 22 of the elastomeric bodies 22 and vertical plates parallel to the lateral faces 23, 24 of the elastomeric bodies, respectively. It also comprises two plates 6, embedded between the upper grooves 3, and an additional lower plate 13, embedded between the lower grooves 4. The L-shape parts 5, the plates 6 and the additional lower plate all extend parallel to the longitudinal axis 14. In this case, as shown in Fig. 6, the lifting parts 7 lay on the horizontal plate of the L-shape parts 5 and contact their vertical plates. The buckypaper strip sensor 8 leans on the lifting parts 7 and is completely embedded in the elastomeric body.

[0058] Fig. 9A depicts two graphics which, on the top, show the data (Ohms) obtained with the sensorized elastomeric expansion joint 1 of the embodiment shown

in Fig. 7A and, on the bottom, the real deformation (mm) of the joint. As it can be appreciated, the measurement obtained is non-stable, and therefore, this embodiment is not accurate enough.

[0059] Fig. 9B depicts two graphics which, on the top, show the data (Ohms) obtained with the sensorized elastomeric expansion joint 1 shown in Fig. 7B and, on the bottom, the real deformation (mm) of the joint. As it can be appreciated, the results obtained show a high relaxation and therefore, this embodiment is not accurate enough.

[0060] Fig. 9C depicts two graphics which, on the top, show the data (Ohms) obtained with the sensorized elastomeric expansion joint 1 of the present invention and, on the bottom, the real deformation (mm) of the joint. As it can be appreciated, the measurement obtained is very accurate.

[0061] The numerical signs and corresponding components indicated in Fig. 1 to 8 are further listed below:

Sensorized elastomeric expansion joint 1	
Elastomeric body 2	
Upper face 21	
Lower face 22	
Upper grooves 3	25
Lower groove 4	
L-shape part 5	
Plate 6	
Lifting parts 7	
Buckypaper strip sensor 8	30
Additional elastomeric region 9	
Adhesive non-conductive material 10	
External sensor 11	
Bridge sides 12	
Additional plate 13	35
Longitudinal axis 14	

[0062] In this text, the term "comprises" and its derivations (such as "comprising", etc.) should not be understood in an excluding sense, that is, these terms should not be interpreted as excluding the possibility that what is described and defined may include further elements, steps, etc.

[0063] In the context of the present disclosure, a deviation within reasonable limits from any exact value or values indicated in the present disclosure, should be accepted, because a skilled person in the art will understand that such a deviation from the values indicated is inevitable due to measurement inaccuracies, etc. Unless something else is explicitly stated, all ranges mentioned in this document include the end points of the respective range. Thus, for example, a range indicated using an expression such as "between X and Y" includes X and Y.

[0064] The invention is obviously not limited to the specific embodiment(s) described herein, but also encompasses any variations that may be considered by any person skilled in the art (for example, as regards the choice of materials, dimensions, components, configura-

tion, etc.), within the general scope of the invention as defined in the claims.

5 Claims

1. Sensorized elastomeric expansion joint (1), that comprises:

- at least one elastomeric body (2) elongated along a longitudinal axis (14), having an upper face (21) that comprises two upper grooves (3) that extend parallel to the longitudinal axis (14) and a lower face (22), opposite to the upper face (21), that comprises a lower groove (4) that extends parallel to the longitudinal axis (14),
- two L-shape parts (5), embedded in the elastomeric body (2), wherein each L-shape part (5) is made of a horizontal plate and a vertical plate which form a 90° angle with respect to each other, the L-shape parts (5) extending along the longitudinal axis (14) and each of them forming an apex which is positioned at the lower left and right edge, respectively, of the elastomeric body (2),
- a plate (6), embedded in the elastomeric body (2) between the upper grooves (3) and disposed in a plane parallel to the upper and lower faces (21, 22) of the elastomeric body (2) and extending along the longitudinal axis (14), and
- one or more buckypaper strip sensors (8), completely embedded in the elastomeric body (2) in a plane parallel to the upper and lower faces (21, 22).

2. The sensorized elastomeric expansion joint (1) of claim 1, wherein the two L-shape parts (5) are symmetrical with respect to the longitudinal axis (14) of the elastomeric body (2).

3. The sensorized elastomeric expansion joint (1) of claim 1, that additionally comprises two lifting parts (7) placed on the L-shape parts (5) to lift the one or more buckypaper strip sensors (8).

4. The sensorized elastomeric expansion joint (1) of claim 3, wherein the lifting parts (7) lay on the horizontal plate of the L-shaped parts (5) and contact the vertical plate.

5. The sensorized elastomeric expansion joint (1) of claims 3 or 4, wherein the one or more buckypaper strip sensors (8) are fixed to the lifting parts (7) by means of an adhesive non-conductive material (10).

5. The sensorized elastomeric expansion joint (1) of claim 5, wherein the adhesive non-conductive material (10) is a resin having thermal resistance greater

than 180°C, tensile stress resistance of at least 30 N/mm², compressive stress resistance of at least 80 N/mm² and shear strength of at least 20 N/mm².

6. The sensorized elastomeric expansion joint (1) of any of the previous claims, that additionally comprises wires connected to the buckypaper strip sensor (8), the wires coming out of the elastomeric body (2).

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7. The sensorized elastomeric expansion joint (1) of any of the previous claims, wherein at least one of the one or more buckypaper strip sensors (8) is disposed diagonally with respect to the longitudinal axis (14) of the elastomeric body (2).

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8. The sensorized elastomeric expansion joint (1) of claim 7, wherein an angle (A) formed between the buckypaper strip sensor (8) and the longitudinal axis (14) of the elastomeric body (2) is comprised between 30° and 60°, preferably between 40° and 50°.

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9. The sensorized elastomeric expansion joint (1) of any of claims 1 to 6, wherein at least one of the one or more buckypaper strip sensors (8) is perpendicular to the longitudinal axis (14) of the elastomeric body (2).

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10. A structure having at least two parts, wherein a sensorized elastomeric expansion joint (1) of any of claims 1 to 9 is placed between the at least two parts of the structure.

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11. The structure of claim 10, wherein the structure is a bridge or a viaduct.

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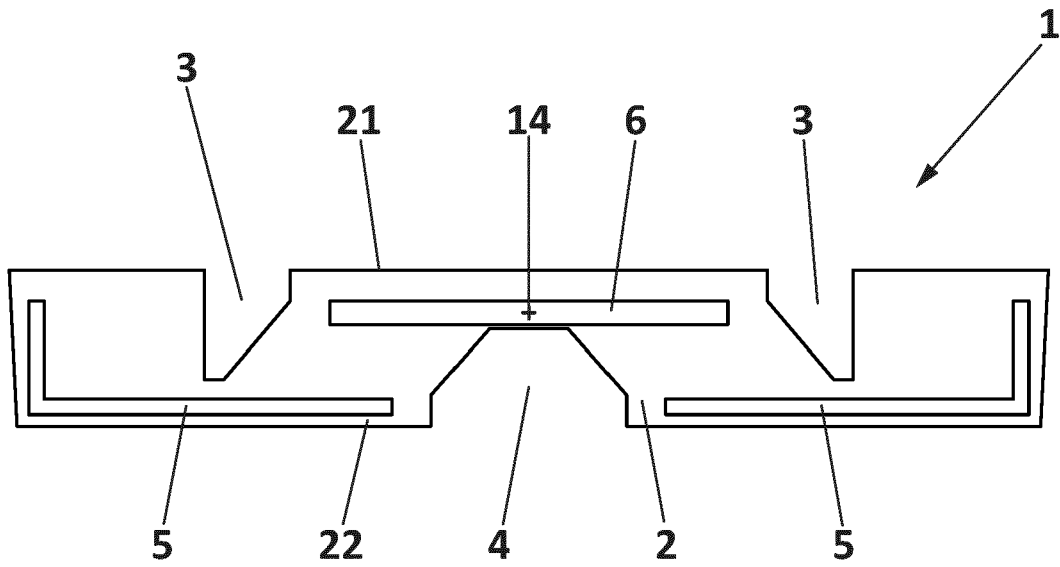


FIG. 1
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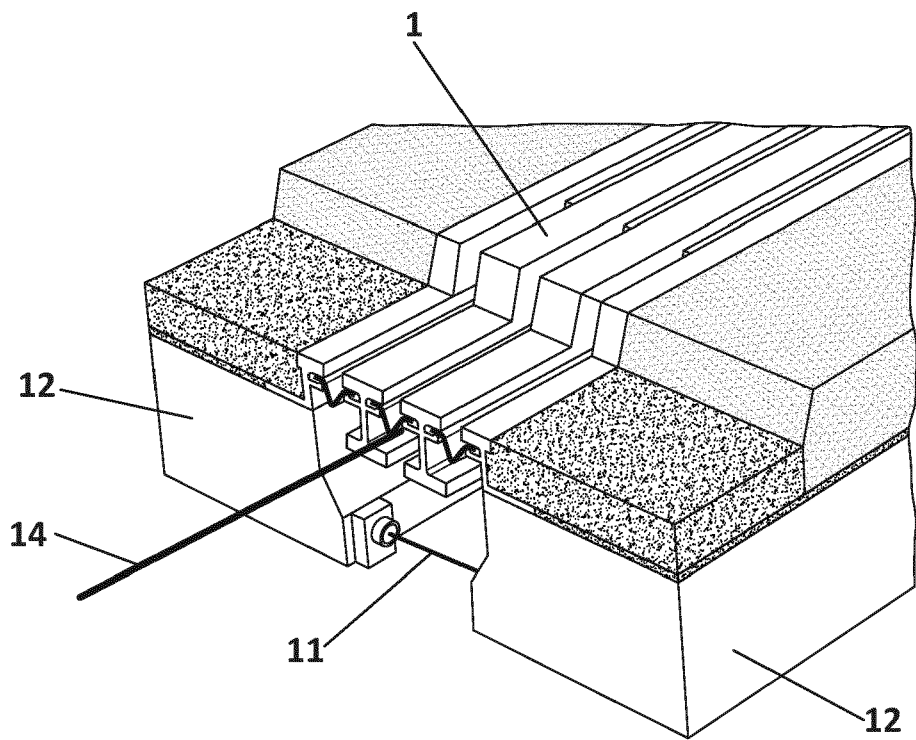


FIG. 2
(STATE OF THE ART)

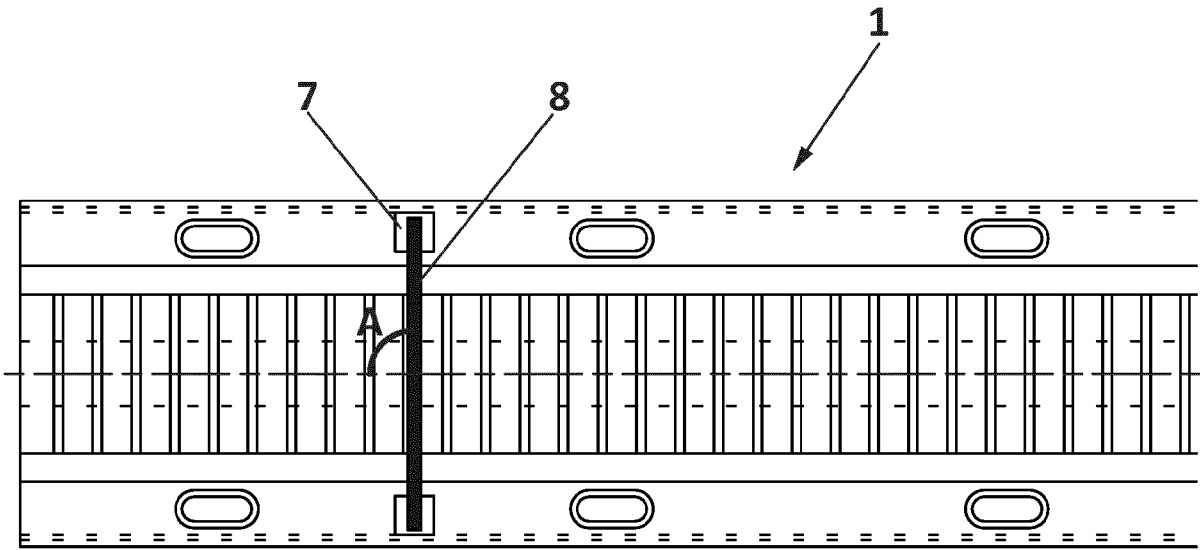


FIG. 3A

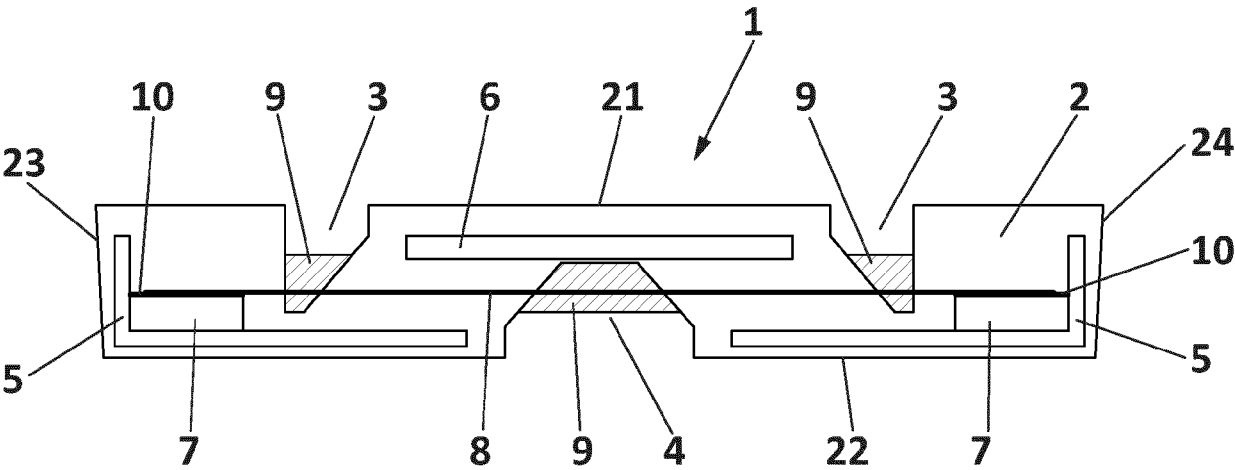


FIG. 3B

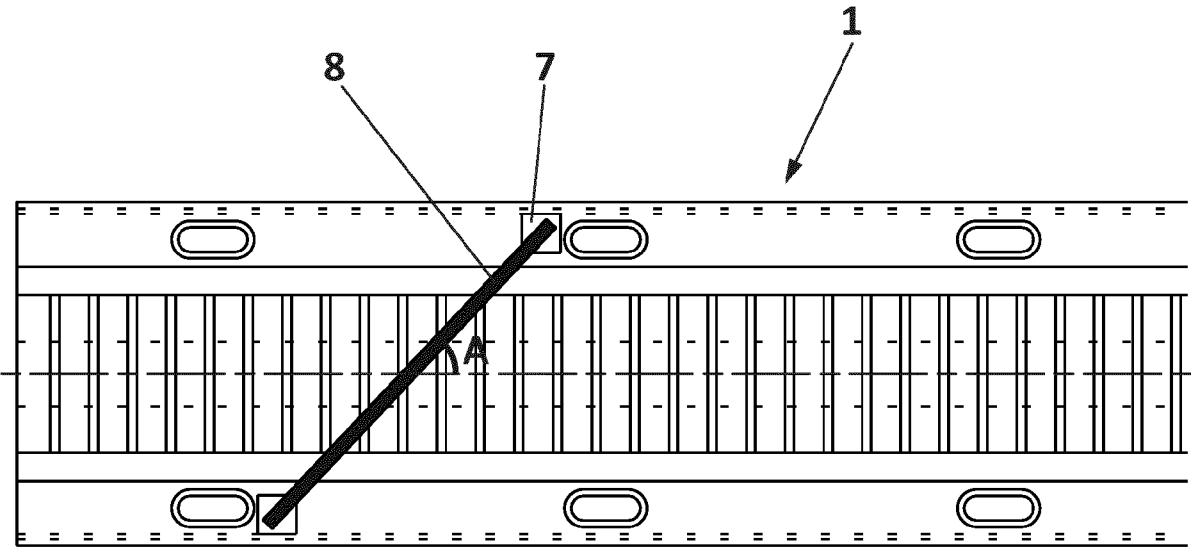


FIG. 4A

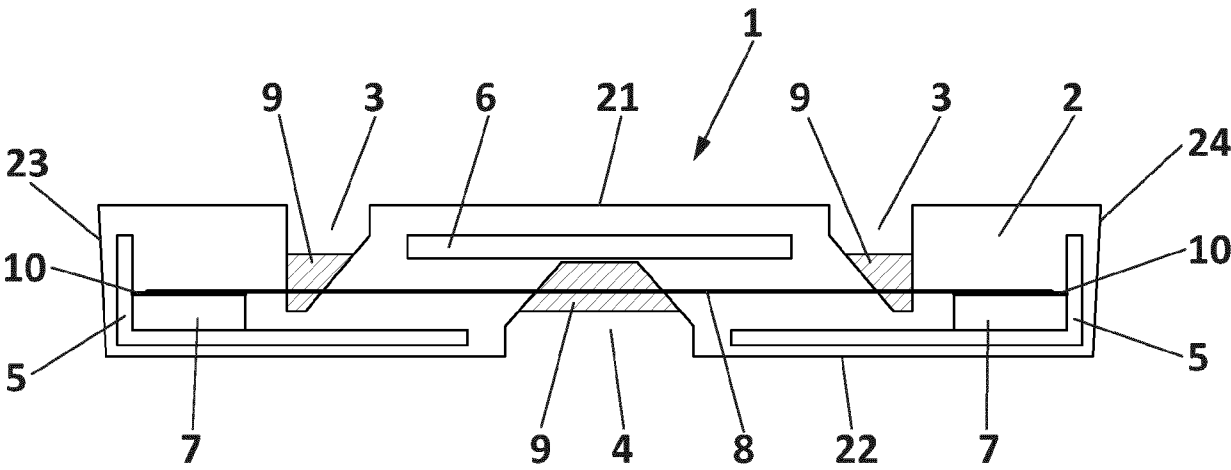


FIG. 4B

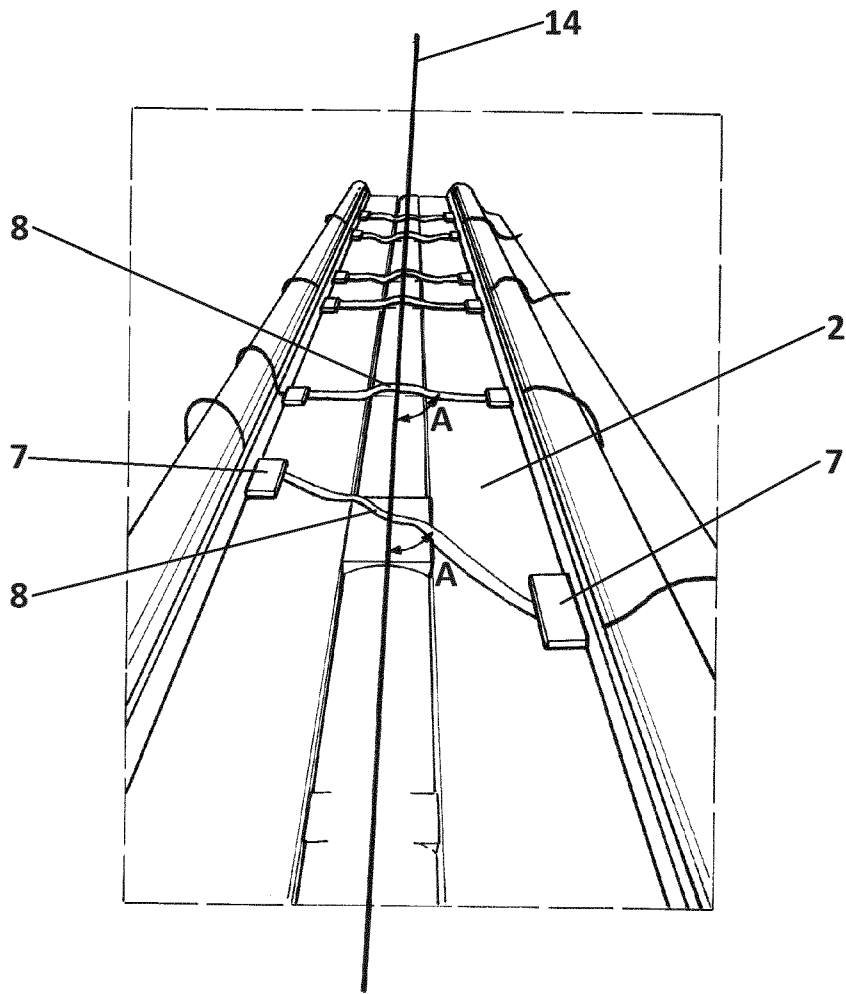


FIG. 5

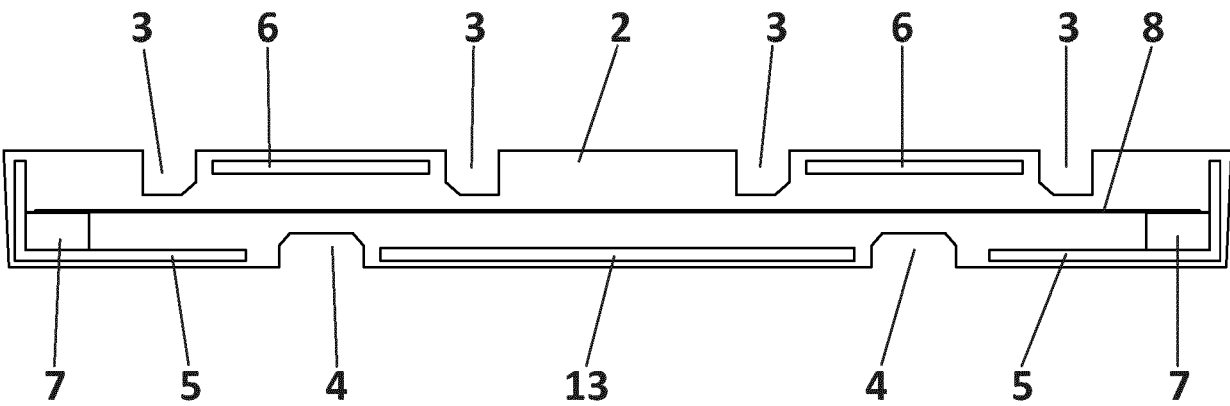


FIG. 6

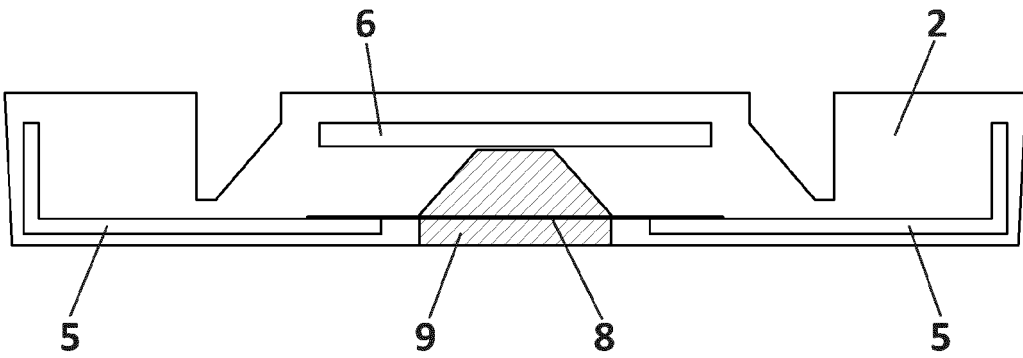


FIG. 7A

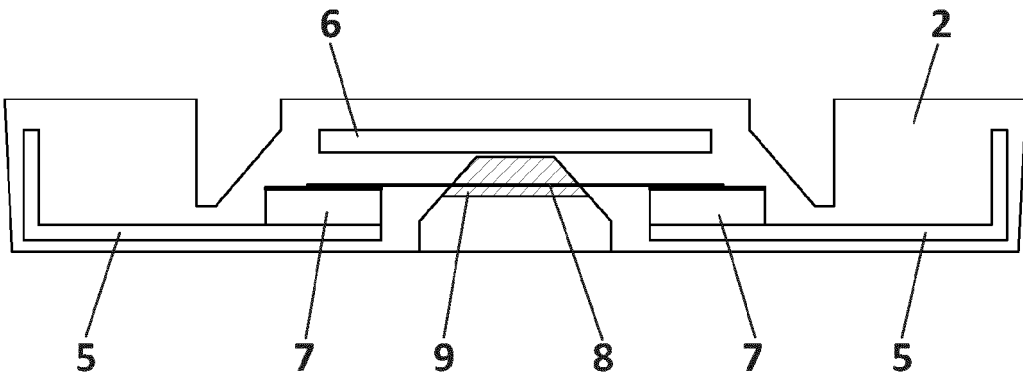


FIG. 7B

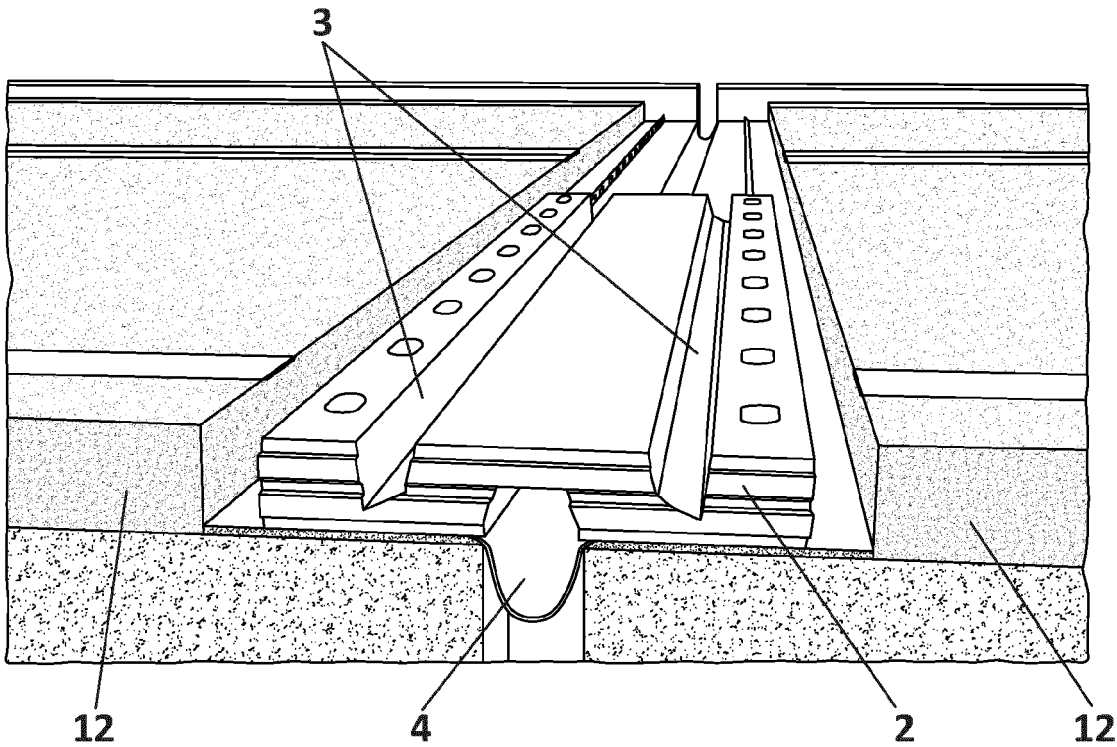


FIG. 8

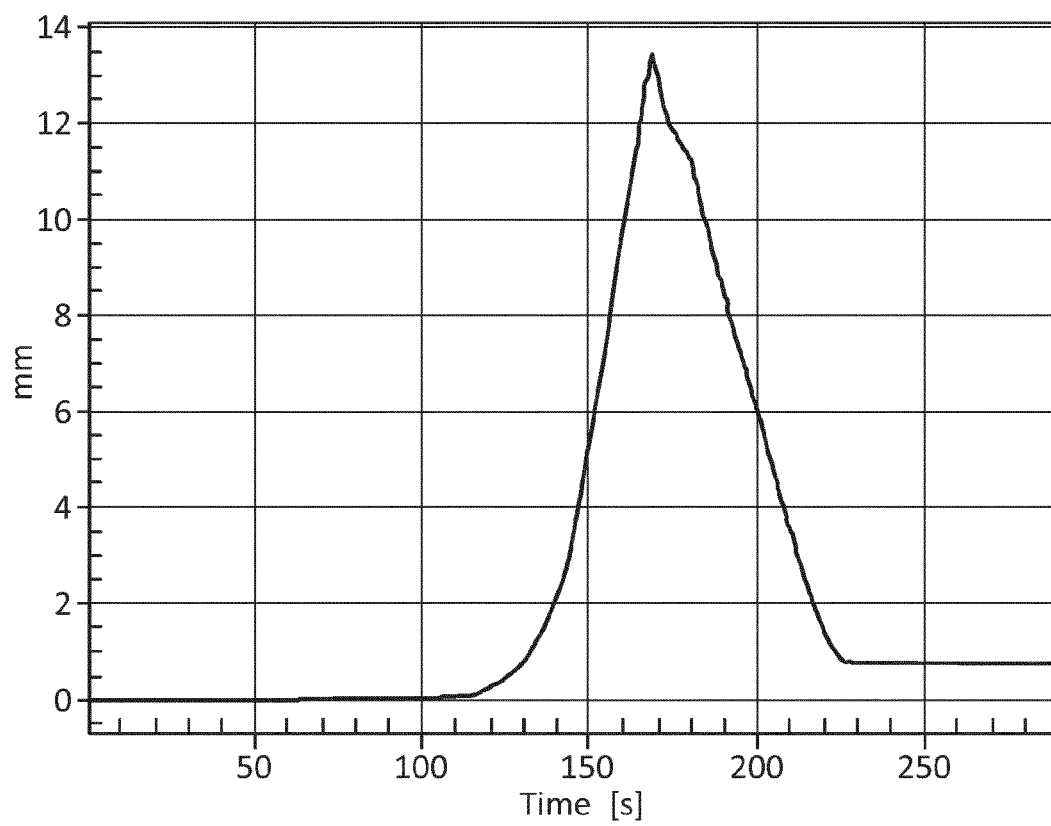
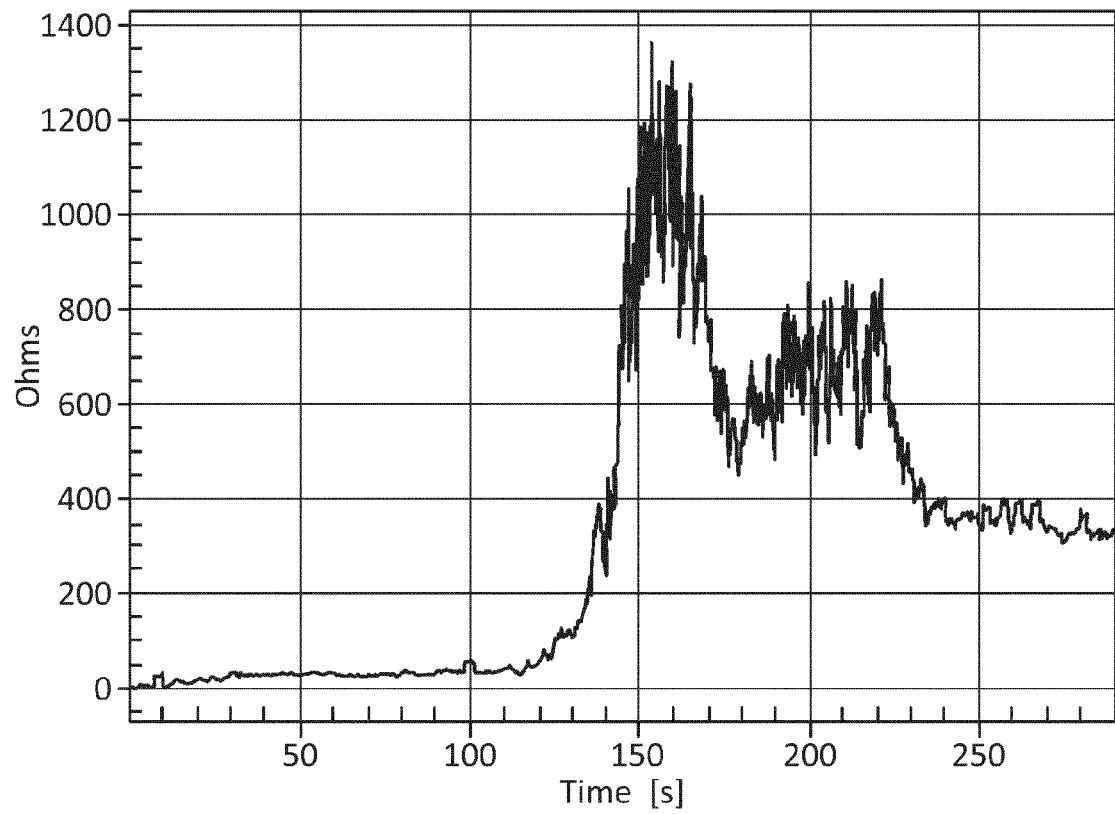


FIG. 9A

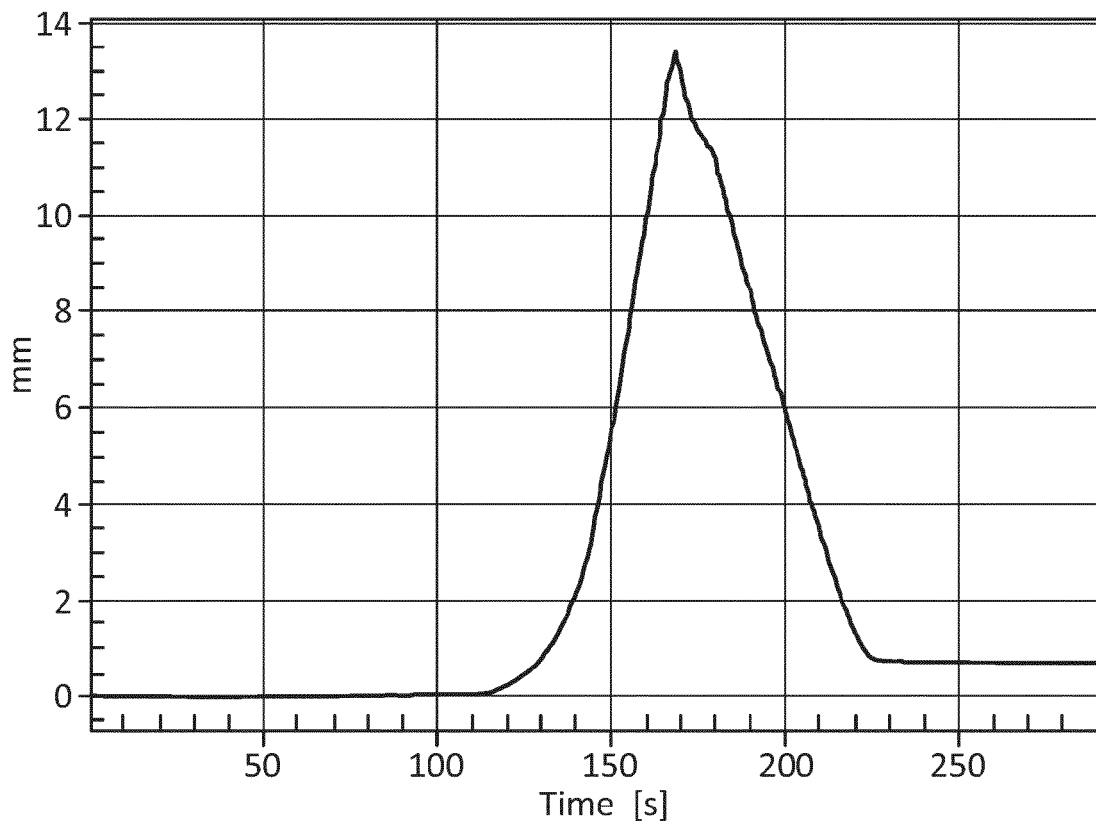
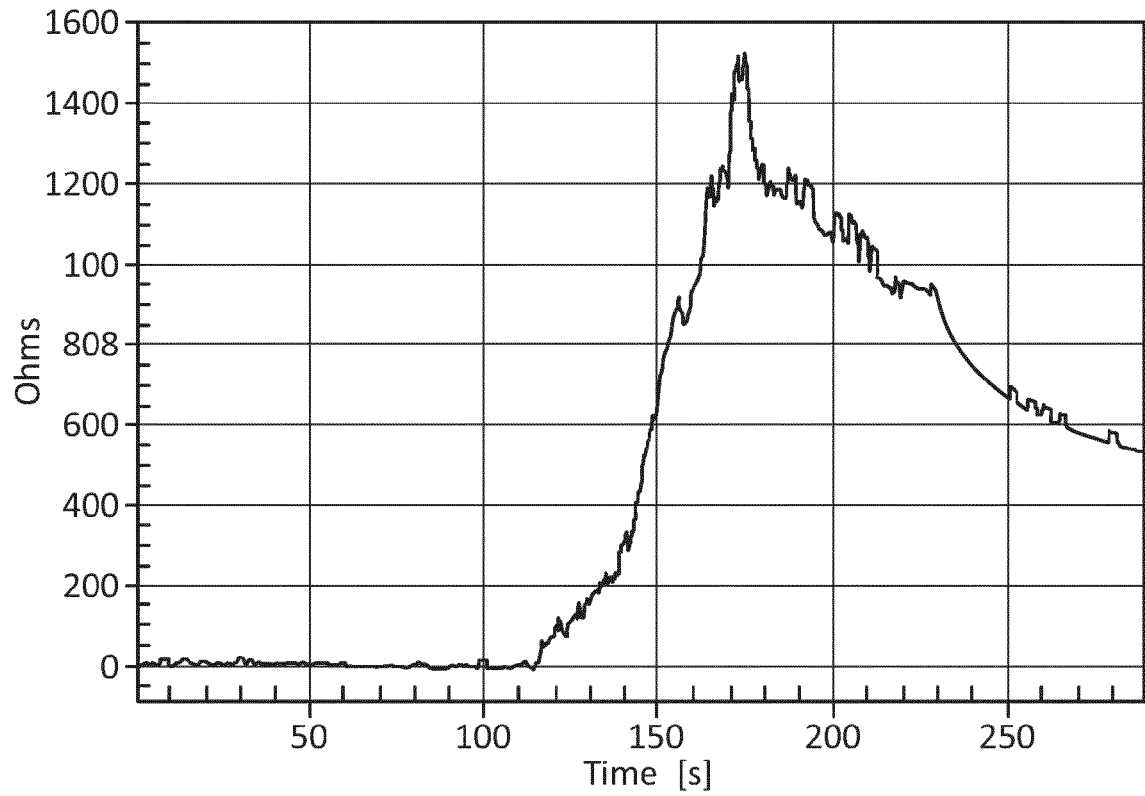
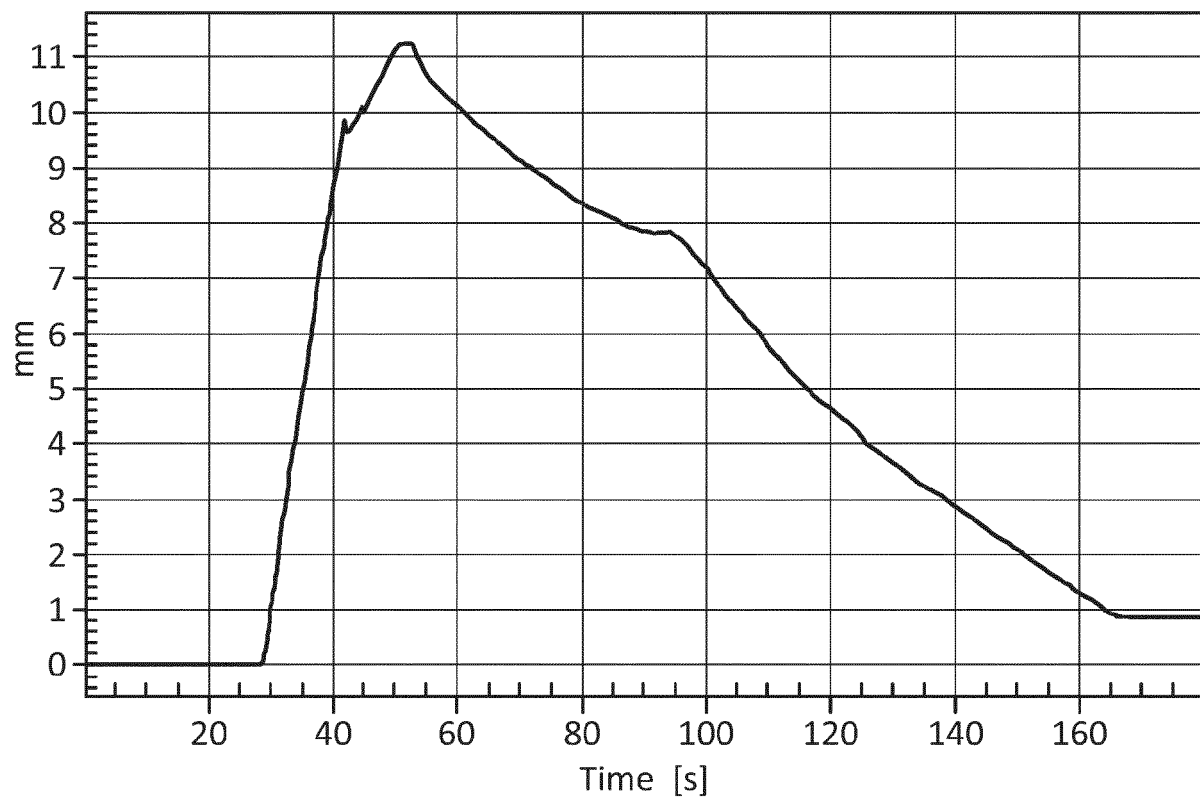
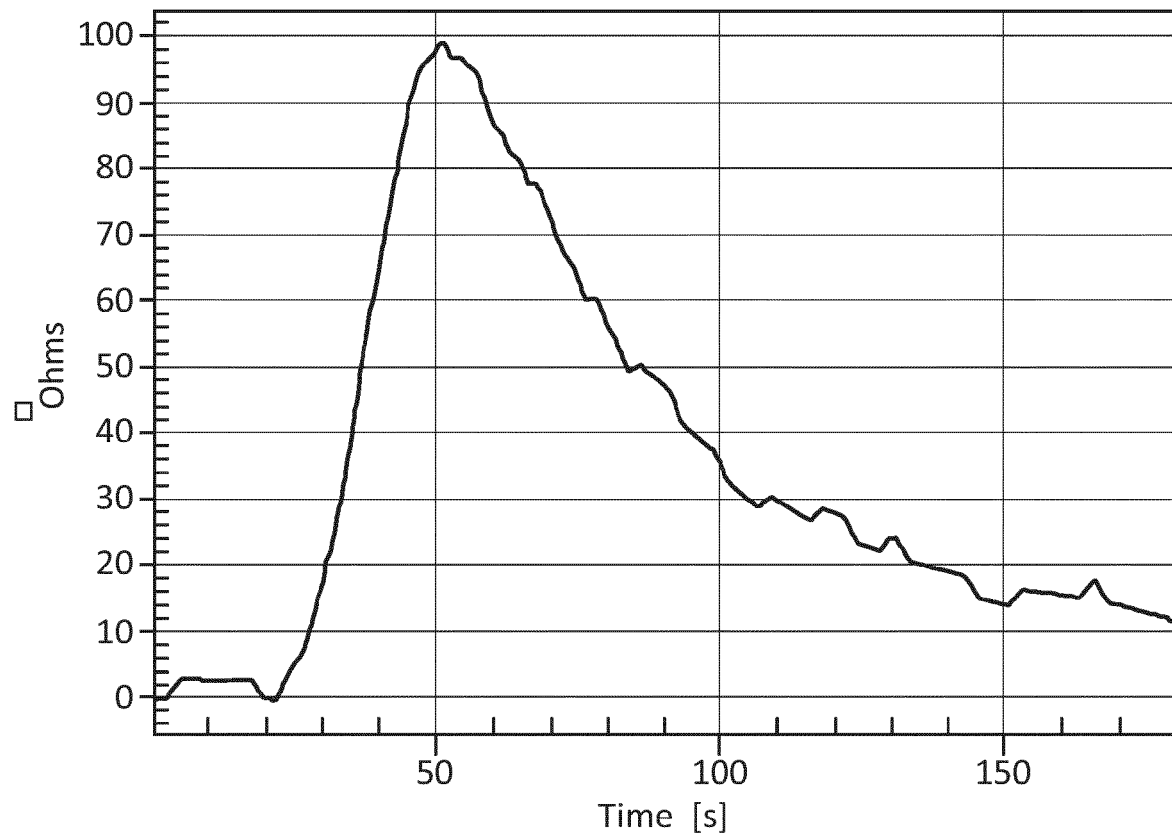


FIG. 9B

**FIG. 9C**



EUROPEAN SEARCH REPORT

Application Number

EP 23 38 3249

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			E01D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 23 April 2024	Examiner Saretta, Guido
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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