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(54) Title: METHOD FOR MONITORING MECHANICAL DEFORMATION OF A SURFACE OF A MANUFACTURING PRODUCT, MECHANICAL DEFORMATION SENSOR AND MANUFACTURING PRODUCT COMPRISING SAID SENSOR

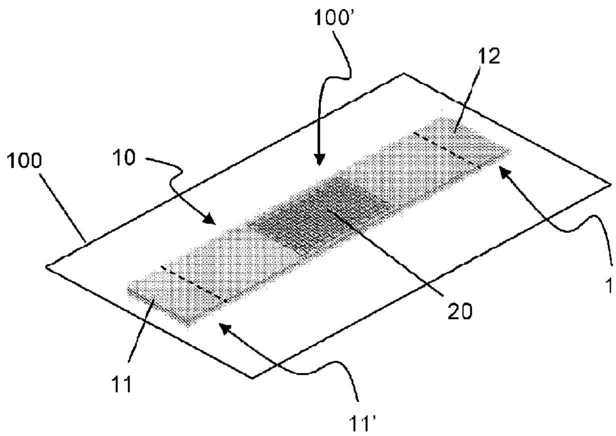

FIG. 2

(57) Abstract: Described herein is a method for monitoring the deformation of a surface (100) of a manufactured product, comprising: applying an elastic material layer (10) on said surface (100), covering it at least partially, wherein said elastic material layer (10) has a substantially rectangular shape and is engaged on said surface (100) at two opposite ends (11, 12); wherein said elastic material layer (10) has an active zone (20) comprising a plurality of through apertures (21); each aperture (21) having a substantially elongated shape, wherein each aperture (21) is adapted to deform, as a function of the elastic or plastic deformation of said surface (100), between: a first configuration, substantially closed, wherein said plurality of through apertures (21) block the view of said covered surface (100); and a second configuration, substantially open, wherein said plurality of through apertures (21) allow viewing, at least partly, said covered

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surface (100); wherein said active zone (20) shows an auxetic behaviour.

TITLE

Method for monitoring the mechanical deformation of a surface of a manufactured product, mechanical deformation sensor, and manufactured product comprising such sensor

DESCRIPTION

Field of the invention

The present invention relates, in general, to the monitoring of mechanical deformations of solid bodies. In particular, the present invention concerns a method for monitoring the elastic and/or plastic deformation of a surface; for example, said surface is the surface of a manufactured product.

Background art

Nowadays many devices are available for estimating the elastic or plastic deformation of a body. For example, deformation sensors are known in the art, which are also referred to as strain gauges, which can monitor the deformation of a surface of an object.

For example, known deformation sensors comprise a resistive element that permits detecting, as a function of a change in its own resistance, a variation that has occurred in the original length of the body.

Mechanochromic sensors are also known, which are based on a film of polymeric material comprising mechano/piezochromic materials. Such a film of polymeric material provides a means suitable for quantitatively measuring, through a change in colour, the local deformation of an interface.

Another category of products having similar functionality includes crackmeters used, for example, for measuring the progress of cracks and clefts in walls.

The Applicant noticed that the methods and devices known in the art for monitoring surface deformations have a number of drawbacks.

In particular, the Applicant noticed that the methods and devices known in the art for monitoring surface deformations do not allow for naked-eye monitoring, and may require the use of dedicated acquisition systems such as strain gauges or MEMs.

Even more importantly, such dedicated acquisition systems require, in order to work properly, a power supply system that results in increased space occupation.

Furthermore, disadvantageously, the sensitivity of known devices like crackmeters is not adequate for small deformations.

Summary of the invention

The Applicant has tackled the problem of providing an alternative method for monitoring and/or assessing surface deformations which can overcome the above-mentioned problems.

According to a further aspect, the Applicant has tackled the problem of providing a metal band equipped with an element that permits monitoring any elastic and/or plastic deformation of such band.

In particular, the present invention provides a method for monitoring the deformation of a surface of a manufactured product, comprising:

- applying an elastic material layer on said surface, covering it at least partially,
  wherein said elastic material layer has a substantially elongated shape and is engaged on said surface at two opposite ends, covering at least a portion of said surface;
  wherein said elastic material layer has an active zone comprising a plurality of through apertures; each aperture having a substantially elongated shape,
  wherein each aperture is adapted to deform, as a function of the elastic or plastic deformation of said surface, between:
    - a first configuration, substantially closed, wherein said plurality of through apertures block the view of said covered surface; and
    - a second configuration, substantially open, wherein said plurality of through apertures allow viewing, at least partially, said covered surface.

The expression “surface of a manufactured product” refers to a surface of an object produced by a human or by a machine. For example, said manufactured product may be a building structure; an aerodynamic structure; an industrial container; a duct for liquids; an electric line; a band.

Advantageously, by applying the elastic material layer on the surface of the above-listed manufactured products the following can be attained:

- considering a building structure (e.g. buildings, bridges, tunnels, etc.), the elastic layer makes it possible to monitor the deformation of the structure in order to prevent the occurrence or propagation of cracks or clefts;
- considering an aerodynamic structure, the elastic layer provides visual monitoring of the instantaneous elongation of aerodynamic surfaces;
- considering an industrial container (e.g. a container under pressure), the elastic layer makes it possible to monitor the deformation caused by, for example, corrosion and internal temperature or pressure;
- considering a duct, the elastic layer makes it possible to monitor the deformation caused by, for example, corrosion, mechanical stress, internal temperature or pressure;
- considering an electric line, the elastic layer provides contactless monitoring of the elongation of electric cables, e.g. of the catenary type.

Preferably, said active zone shows an auxetic behaviour. In other words, when said active zone is deformed, the apertures will move and/or widen and/or deform, thereby causing an expansion of the active zone in a direction substantially transversal to the direction of deformation.

Preferably, said elastic material layer has a first colour and said method comprises, before applying said elastic material layer on said surface, colouring said surface with at least a second colour.

Preferably, said second colour is in chromatic contrast with said first colour.

Preferably, said plurality of through apertures comprise a plurality of first apertures and a plurality of second apertures, said first apertures and said second apertures being perpendicular to each other.

Preferably, each aperture of said plurality of apertures has, in said first configuration, a length equal to at least half the thickness of the active zone.

Preferably, each aperture of said plurality of apertures has, in said first configuration, a length equal to at least 0.5 mm.

Preferably, at least a part of said first apertures lie on a straight line disposed parallel to a longitudinal development direction of said elastic material layer;

wherein a second aperture is interposed between two successive first apertures of said at least a part of said first apertures.

Preferably, the minimum distance between a respective first aperture and an adjacent second aperture is in the range of 0.1 to 0.8 mm and the active zone has a thickness in the range of 0.7 to 1 mm.

Preferably, said elastic material layer has at least two reinforced sections at said opposite ends attached to said surface. In particular, said at least two reinforced sections correspond to a respective portion of said elastic material layer without apertures.

Advantageously, said reinforced sections are made of the same material as the elastic material layer, and therefore permit a deformation of the elastic material layer and of the active zone.

Preferably, said elastic material layer has a plurality of active zones. In particular, adjacent active zones are separated by a portion of said elastic material layer without apertures.

Preferably, said elastic material layer comprises a lateral perimeter without apertures on at least one side of said active zone.

According to a further aspect, the present invention provides a manufactured product comprising a surface having, on a portion thereof, an elastic material layer;

wherein said elastic material layer comprises an active zone comprising a plurality of through apertures; each through aperture having a substantially elongated shape and being adapted to deform, as a function of the elastic and/or plastic deformation of said outer surface portion, between:

- a first configuration, substantially closed, wherein said plurality of through apertures block the view of said outer surface portion; and
- a second configuration, substantially open, wherein said plurality of through apertures allow viewing, at least partially, said outer surface portion;

wherein said active zone shows an auxetic behaviour. In other words, when said active zone is deformed, the apertures will move and/or widen and/or deform, thereby causing an expansion of the active zone in a direction substantially transversal to the direction of deformation.

According to a third aspect, the present invention provides a surface deformation sensor for a manufactured product. Said sensor comprises an elastic material layer having an elongated shape; said elastic material layer comprising first and second ends which can be engaged with an outer surface of said manufactured product;

wherein said elastic material layer has an active zone interposed between said ends and comprising a plurality of through apertures;

each through aperture having a substantially elongated shape and being adapted to deform, as a function of the elastic and/or plastic deformation of said outer surface portion, between:

- a first configuration, substantially closed, wherein said plurality of through apertures block the view of said outer surface portion; and
- a second configuration, substantially open, wherein said plurality of through apertures allow viewing, at least partially, said outer surface portion;

wherein said active zone shows an auxetic behaviour.

Brief description of the drawings

The present invention will become more apparent in the light of the following detailed description, wherein reference will be made to the annexed drawings, provided merely by way of non-limiting example, wherein:

- Figure 1 is a block diagram of the method according to the present invention;
- Figure 2 shows an elastic material layer according to the present invention, applied on a generic surface;
- Figure 3 shows a detail of the pattern of an elastic material layer according to one embodiment of the present invention;
- Figure 4 shows a detail of the pattern of an elastic material layer according to a further embodiment of the present invention;
- Figure 5 shows an elastic material layer equipped with one deformable zone;
- Figure 6 shows an elastic material layer equipped with two deformable zones;
- Figure 7 shows an elastic material layer equipped with three deformable zones;
- Figure 8 shows the transition of an elastic material layer from a substantially closed first configuration to a substantially open second configuration;
- Figure 9 shows a band provided with an elastic material layer according to the present invention.

In the drawings, those items which perform substantially the same function are designated by the same reference numerals.

The drawings are not in scale.

Detailed description of some embodiments

As shown in Figure 2, the monitoring method according to the present invention is based on an elastic material layer 10.

Preferably, the elastic material layer 10 is made of an elastomeric material. In particular, the elastic material layer 10 is preferably made of a material selected from: styrene butadiene rubber (SBR), silicone, latex or natural rubber, polyvinyl chloride (PVC), polyurethane (PU) and butyl rubber. Even more preferably, the elastic material layer 10 is made of polyurethane (PU) or butyl rubber.

The elastic material layer 10 has a substantially elongated shape, and has a first end 11 and a second end 12. The first end 11 and the second end 12 are opposite to each other.

For example, as shown in Figure 2, the elastic material layer 10 has a substantially rectangular shape, wherein the first end 11 and the second end 12 substantially correspond to the minor sides of the elastic material layer 10.

According to the present invention, the elastic material layer 10 has an active zone 20.

As shown in Figures 3 and 4, the active zone 20 comprises a plurality of through apertures 21. Each aperture 21 has a substantially elongated shape. Preferably, the length of each aperture 21 is one to three times the thickness of the elastic material layer 10, more preferably greater than at least 150% of the thickness of the elastic material layer 10.

It should be noted that the active zone 20 corresponds to a portion of the elastic material layer 10 where a plurality of cuts have been made, thereby forming the plurality of apertures 21. Such through cuts may be made, for example, by water cutting.

Preferably, the active zone 20 has a substantially rectangular shape.

Preferably, each aperture 21 in the active zone 20 is adapted to deform, at least perpendicularly to its longitudinal axis. In particular, each aperture 21 will deform when the elastic material layer 10 is stretched along a generic axis, thus becoming wider.

Preferably, the elastic material layer 10 has, when it is not subject to tension, a thickness in the range of 0.5 mm to 2 mm, more preferably 0.7 mm to 1 mm.

Preferably, the elastic material layer 10 has a constant thickness when it is not subject to tension. In other words, when the elastic material layer 10 is not subject to tension, the first end 11, the second end 12 and the active zone 20 have substantially the same thickness.

As shown in Figure 2, for example, the elastic material layer 10 has a substantially rectangular shape and is engaged on a surface 100, thus covering it at least partially, i.e. covering a surface portion 100'. Such surface 100 is the surface of a manufactured product; for example, the surface 100 is the surface of: a building structure; or an aerodynamic structure; or an industrial container; or a duct for liquids; or a conductor of an electric line, or a band (e.g. such band may be a band used in the automotive industry, in the shipbuilding industry, in household appliances, in production machinery, etc.).

The elastic material layer 10 is engaged on the surface 100 at its opposite ends 11, 12. In other words, the first end 11 and the second end 12 are engaged on the surface 100, leaving a central portion of the elastic material layer 10 free. Said central portion comprises the active zone 20.

In particular, the first end 11 and the second end 12 of the elastic material layer 10 are glued to the surface 100; preferably, the glue is applied – outside the active zone 20 – onto a respective portion 11', 12' of the elastic material layer 10.

The Applicant observes that, when the surface 100 undergoes an elastic or plastic deformation, also the elastic material layer 10 will become deformed. In particular, the elastic material layer 10 will deform at least in the active zone 20.

As a function of the elastic or plastic deformation of the surface 100, the plurality of apertures 21 – created in the active zone 20 – will become deformed between:

- a first configuration, substantially closed, wherein the through apertures 21 are substantially closed and prevent viewing the surface 100' covered by the active zone 20; and
- a second configuration, substantially open, wherein the through apertures 21

allow viewing, at least partially, the surface 100’ covered by the active zone 20.

The Applicant observes that a thickness of the active zone 20 of 0.7 mm to 1 mm ensures an adequate tensile strength while providing a good view of the surface 100’ covered by the active zone 20, even from different angles.

Preferably, each aperture of the plurality of apertures 21 has an idle length equal to or greater than 0.5 mm. Note that the term “idle length” refers to the length of a generic aperture 21 when the elastic material layer 10 is not stretched or deformed.

Moreover, advantageously, considering apertures 21 having an idle length (i.e. the length in the absence of any elastic deformation) in excess of 0.5 mm, the change occurring in the active zone 20 between the first configuration and the second configuration will also be visible to the naked eye.

The Applicant observes that, advantageously, a ratio between the thickness of the active zone 20 and the idle length of the apertures 21 having a value in the range of 1 to 3, preferably of 2, ensures a deformation of the elastic material layer 10 with no fractures in the active zone 20, while also ensuring the proper operation of the active zone 20, i.e. the switching of said active zone 20 between a substantially closed first configuration and a substantially open second configuration.

According to a particularly preferred embodiment, the elastic material layer 10 has a first colour. Preferably, the surface 100 has a second colour. Such second colour is preferably in contrast with the first colour of the elastic material layer 10.

If the surface 100 does not have a colour in contrast with the first colour of the elastic material layer 10, prior to applying the elastic material layer 10 and covering at least a portion of the surface 100 it is preferable to colour said portion of the surface 100 with at least a second colour in contrast with the colour of the elastic material layer 10.

The Applicant observes that, in this manner, the chromatic contrast between the first and second colours will make it even easier to perceive a deformation of the active zone 20, and hence a plastic and/or elastic deformation of the surface 100’ covered by it.

With reference to Figures 3 and 4, one can notice that the apertures 21 may be arranged in accordance with different geometric configurations.

For example, Figure 3 shows a substantially "triangle-shaped" configuration, while Figure 4 shows a substantially "rectangle-shaped" configuration of the apertures 21.

Note that Figure 3 and Figure 4 are not in scale; in particular, the active zone 20 has been suitably magnified to better show the arrangement of the apertures 21.

In particular, according to the embodiment shown in Figure 3, the apertures 21 are grouped into groups including three apertures 21a, 21b, 21c. Preferably, the three apertures 21a, 21b, 21c are made in such a way as to form a mutual angle of 120°. Preferably, the three apertures 21a, 21b, 21c are made in such a way as to form a mutual angle of 120° and to have one end in common at the central point of symmetry C.

Preferably, a plurality of groups of three apertures 21a, 21b, 21c are made as described above in the active zone 21. Preferably, said plurality of groups of three apertures 21a, 21b, 21c are made in such a way as to obtain the utmost deformation due to the rotation of the triangular structures comprised between the apertures.

For example, considering four points of symmetry C1, C2, C3, C4 of respective groups of three apertures, such points of symmetry C1, C2, C3, C4 are arranged at the vertices of a rhombus. Preferably, considering a thickness of the active zone 20 of 0.7 mm to 2 mm, the sides of said rhombus have a length equal to or greater than the length of a single aperture 21 plus at least 10% of the length of said aperture 21, preferably plus 20% of the length of said aperture 21.

Alternatively, according to the embodiment shown in Figure 4, the plurality of apertures 21 comprise substantially horizontal first apertures 21' and substantially vertical second apertures 21''. The term "substantially horizontal apertures" refers to apertures 21 obtained by cutting parallelly to the longitudinal development axis Y-Y of the elastic material layer 10; the term "substantially vertical apertures" refers to apertures 21 obtained by cutting perpendicularly to the longitudinal development axis Y-Y of the elastic material layer 10.

In other words, the plurality of through apertures 21 comprise a plurality of first apertures 21' and a plurality of second apertures 21'', wherein the first apertures 21' and the second apertures 21'' are perpendicular to each other.

Preferably, as shown in Figure 4, at least a part of said first apertures 21' lie on a straight line A-A disposed parallel to the longitudinal development axis Y-Y of the elastic material layer 10. Preferably, a respective second aperture 21” is interposed between two successive first apertures 21’.

According to the “rectangle-shaped” embodiment described above, and considering a thickness of the elastic material layer 10 of 0.7 mm to 2 mm, the minimum distance X1 between a first aperture 21’ and an adjacent second aperture 21” is in the range of 0.1 to 0.8 mm, preferably 0.15 to 0.2 mm.

Preferably, the straight line A-A passes through a number of second apertures 21”, preferably crossing them at the median point of each second aperture 21”.

The Applicant observes that, by making the apertures 21 in such a way as to obtain the above-described “triangle-shaped” or “rectangle-shaped” patterns, an active zone 20 is formed which has an auxetic behaviour. In other words, when said active zone 20 is deformed, e.g. longitudinally, the apertures 21 will move and/or widen and/or deform, thus causing an expansion of the active zone 20 in a direction substantially transversal to the direction of deformation.

With reference to Figure 5, the elastic material layer 10 preferably includes at least two reinforced sections 15, 16.

The term “reinforced section” refers to a zone of the elastic material layer 10 where there are no through apertures 21, and whereon the glue for attaching the elastic material layer 10 to the surface 100 is applied.

The reinforced sections 15, 16 are provided at least at the opposite ends 11,12 of the elastic material layer 10.

Preferably, as shown in Figure 5, the active zone 20 does not extend up to the lateral perimeter 18 of the elastic material layer 10. In particular, preferably, considering a thickness of the active zone 20 of 0.7 mm to 2 mm, the apertures 21 start at a minimum distance of 0.5 mm from the lateral perimeter 18, preferably at a minimum distance of 1 mm from the lateral perimeter 18.

It should be noted that, when the elastic material layer 10 has a substantially rectangular shape, the expression “lateral perimeter 18” refers to the major sides of the elastic material layer 10.

The Applicant observes that, if no cuts (i.e. apertures 21) are made in a perimetric region of the elastic material layer 10, tensile strength is improved without reducing the visual effect when the elastic material layer 10 is deformed longitudinally or along other directions. In particular, the perimetric zone 18 without apertures 21 prevents the occurrence of undesired fractures or tears starting from the perimetric zone 18 and developing towards the active zone 20, i.e. it prevents fractures from developing inwards from the perimeter of the elastic material layer 10 when the latter is subjected to a deformation.

With reference to Figures 6 and 7, the elastic material layer 10 preferably has a plurality of active zones 20a, 20b, 20c.

Preferably, adjacent active zones 20a, 20b, 20c are separated by a separation portion 28a, 28b, i.e. by a portion of the elastic material layer 10 without apertures 21.

Preferably, the active zones 20a, 20b, 20c have the same pattern. In other words, the active zones 20a, 20b, 20c have all the same geometric arrangement of the respective apertures 21.

For example, each active zone 20a, 20b, 20c has a "rectangle-shaped" pattern of its plurality of apertures 21 and the same area of the patterned surface.

Alternatively, the active zones 20a, 20b, 20c may have different patterns. For example, the active zones 20a, 20b, 20c on the same elastic material layer 10 may have the respective apertures 21 arranged in a "rectangle" or "triangle" configuration. Moreover, should it be necessary to use active zones 20a, 20b, 20c having different sensitivity, adjacent apertures in the active zones 20a, 20b, 20c may have different lengths and different distances.

Preferably, the active zones 20a, 20b, 20c are disposed along the longitudinal development axis Y-Y of the elastic material layer 10.

According to one embodiment, the portions of the surface 100 that are covered by different active zones 20 have different colours.

For example, considering the embodiment shown in Figure 7, the colour of the surface 100 covered by the external active zones 20a, 20c is different from the colour used for the surface covered by the central active zone 20b. In particular, for example, the elastic material layer 10 has a substantially black colour; the surface under the first external active zone 20a is green, the surface under the central active zone 20b is red; the surface under the second external active zone 20c is green.

The Applicant observes that, the pattern being equal, the central active zone 20b will require a greater deformation of the surface 100 to switch from the substantially closed first configuration to the substantially open second configuration; therefore, the appearance of a different colour will allow the user to immediately realize that an undesired deformation of the surface 100 has occurred.

The Applicant observes that the elastic material layer 10 provides visual feedback even for small deformations of the surface 100. For example, Figure 8 shows the state of an active zone 20 under different tensile stress conditions; in particular, it shows:

- a first configuration D1, wherein the active zone 20 is substantially closed, i.e. no aperture 21 has undergone any longitudinal or perpendicular deformation;
- a second configuration D2, wherein the surface 100 (and hence the elastic material layer 10) shows a 2% deformation caused by tension along the longitudinal axis Y-Y; the second configuration D2 shows that every aperture 21 has undergone a deformation parallel and/or perpendicular to their respective development axes;
- a third configuration D3, wherein the surface 100 (and hence the elastic material layer 10) shows a 4% deformation caused by tension along the longitudinal axis Y-Y; the third configuration D3 shows that every aperture 21 has undergone a longitudinal and/or perpendicular deformation greater than the deformation occurred in the second configuration D2.

The Applicant observes that the transition from the first configuration D1 (i.e. from a substantially null deformation condition) to a deformed configuration D2, D3 (i.e. to a condition in which the surface 100, and hence the elastic material layer 10, has undergone a deformation along at least one direction) causes a deformation of a plurality of apertures 21 of the active zones 20 and an angular displacement of the structures comprised between the apertures 21 of the active zone 20. In particular, as the deformation of each aperture 21 increases, the surface 100 shown through the active zone 20 will also increase, thereby providing quick feedback about the elastic and/or plastic deformation undergone by the surface 100.

The Applicant also observes that it is possible to obtain active zones 20 having different sensitivity by placing adjacent apertures 21 at different mutual distances. For example, an active zone 20 where adjacent apertures 21 are farther spread apart will be less sensitive to deformations of the surface 100; an active zone 20 where adjacent apertures 21 are closer to each other will provide greater sensitivity to deformations of the surface 100.

The Applicant observes that the above-described method for monitoring the mechanical deformation of a surface can advantageously be used on different devices in that:

- it has a low production cost;
- it is easy to implement;
- it returns immediate and easy-to-understand visual feedback;
- it can be used in electronic/optic systems with no modifications;
- it has no dependencies on ambient conditions (e.g. temperature and pressure);
- the active zones 20 can be easily calibrated;
- it permits detecting deformations of a surface in the range of 2% to 10%.

As aforementioned, with reference to Figure 9, the above-described monitoring method is applicable to a surface of a manufactured product. Hereafter is described, by way of example, the application of the monitoring method to the surface of a band 200.

The band 200 comprises a main body 210 and, preferably, a tensioning element 220. The main body 210 has a substantially annular conformation. For example, the main body 210 is made of metallic material.

The tensioning element 220 is adapted to reduce the diameter of the main body 210. For example, the tensioning element 220 may be a screw-type mechanism adapted to tighten the band 200 by moving the ends of the main body 210 closer to each other, thereby reducing the diameter of the main body 210.

According to the embodiment shown in Figure 9, the main body 210 has, on an outer surface portion 100, an elastic material layer 10.

The elastic material layer 10 includes an active zone 20 comprising a plurality of through apertures 21 made as previously described herein, and has a first end 11 and a second end 12.

It should be noted that the length of the elastic material layer 10, i.e. the distance between the first end 11 and the second end 12 in the idle condition, can be chosen as a function of the portion of the surface 100 to be monitored, and may even cover the whole outer surface of the main body 210 of the band 200.

Each through aperture 21 has a substantially elongated shape and is adapted to deform, as a function of the elastic and/or plastic deformation of the outer surface portion 100, between:

- a first configuration, substantially closed, wherein said plurality of through apertures 21 block the view of said outer surface portion 100; and
- a second configuration, substantially open, wherein said plurality of through apertures 21 allow viewing said outer surface portion 100.

Preferably, the elastic material layer 10 is attached to the portion of the surface 100 by means of a glue applied to the first and second ends 11, 12 of the elastic material layer 10.

Preferably, the portion of the surface 100 which is covered by at least the active zone 21 has a colour in contrast with the colour of the elastic material forming the active zone 20.

In order to prepare the band 200 as described above, the following steps must be carried out (Figure 1):

- preparing an elastic material layer 10 as described above, preferably having a colour in contrast with the surface 100 of the main body of the band 200;
- optionally, applying a second colour in contrast with the colour of the elastic material layer 10 on the surface 100 to be monitored;
- applying a glue to the ends 11, 12 of the elastic material layer 10, avoiding the application of any glue within the active zone 20;
- positioning the elastic material layer 10 on the surface 100 to be monitored.

The Applicant observes that the behaviour of the active zone 20, i.e. its capability of showing a portion of the surface it covers as a function of the deformation of the active zone 20 and/or of the covered surface portion, is similar to a quasi-piezochromic effect. This property is based on a perceived colour change triggered by planar deformation (in one or more directions) of the active zone 20.

The Applicant observes that the quasi-piezochromic effect derives from the arrangement of the apertures 21 in the active zone 20 and from the deformation of two surfaces:

- the external one, i.e. the outer surface of the active zone 20, with a pattern of apertures 21 not visible at idle; and
- the internal one, whose colour is different from that of the material of the active zone 20.

When such surfaces are deformed, the apertures 21 will move and/or widen and/or deform, thus revealing what lies underneath the active zone 20, i.e. the covered surface 100 and, optionally, a colour in contrast with the colour of the active zone 20.

As aforementioned, the apertures 21 are preferably made in such a way that the active area 20 will show an auxetic behaviour; in particular, during the deformation of the active zone 20, the apertures 21 will become wider and/or deformed, while the surface between adjacent apertures 21 (e.g. the one visible in Figure 6, which has a geometric shape similar to a small rectangle 22) will move and rotate, showing the underlying surface 100.

The use of metamaterials having the above-described characteristics for making the elastic material layer 10 will ensure an accurate response of the latter as a deformation sensor also in a region of the surface to be monitored which is small in size and which is subject to small deformations.

Advantageously, as previously described herein, the colour under the active zone 20 is shown gradually during a deformation of the surface 100, and permits an immediate interpretation by an observer.

Lastly, the Applicant observes that the above-described band 200 offers the following advantages:

- the band 200 is provided with a deformation monitoring device, but its cost does not increase much;
- the band 200 can be installed without using specific electromechanical tools;
- the band 200 does not need to be installed by a skilled technician;
- the band 200 provides a monitoring function without interfering with the system that comprises the band 200 itself;
- the band 200 permits continuous monitoring over time;

- the band 200 is suitable for people suffering from daltonism problems, when the surface 100 has a colour in contrast with the elastic material layer 10.

CLAIMS

1. A method for monitoring the deformation of a surface (100) of a manufactured product, comprising:
   - applying an elastic material layer (10) on said surface (100), covering it at least partially,
     wherein said elastic material layer (10) has a substantially elongated shape and is engaged, on said surface (100), at two opposite ends (11, 12), covering at least a portion (100') of said surface (100);
     wherein said elastic material layer (10) has an active zone (20) comprising a plurality of through apertures (21); each aperture (21) having a substantially elongated shape,
     wherein each aperture (21) is adapted to deform, as a function of the elastic or plastic deformation of said surface (100), between:
     - a first configuration, substantially closed, wherein said plurality of through apertures (21) block the view of said covered surface (100); and
     - a second configuration, substantially open, wherein said plurality of through apertures (21) allow viewing, at least partially, said covered surface (100);
     wherein said active zone (20) shows an auxetic behaviour.
2. The method according to the preceding claim, wherein said elastic material layer (10) has a first colour and said method comprises, before applying said elastic material layer (10) on said surface (100), colouring said surface (100) with at least a second colour.
3. The method according to the preceding claim, wherein said second colour is in chromatic contrast with said first colour.
4. The method according to any one of the preceding claims, wherein said plurality of through apertures (21) comprise a plurality of first apertures (21') and a plurality of second apertures (21"), said first apertures (21') and said second apertures (21") being perpendicular to each other.

5. The method according to any one of the preceding claims, wherein each aperture of said plurality of apertures (21) has, in said first configuration, a length equal to at least half the thickness of said active zone (20).
6. The method according to any one of claims 4 to 5, wherein at least a part of said first apertures (21') lie on a straight line (A-A) disposed parallel to a longitudinal development direction (Y-Y) of said elastic material layer (10); wherein a second aperture (21") is interposed between two successive first apertures (21') of said at least a part of said first apertures (21').
7. The method according to the preceding claim, wherein, in said first configuration, the minimum distance between a respective first aperture (21') and an adjacent second aperture (21") is in the range of 0.1 to 0.8 mm and the active zone (20) has a thickness in the range of 0.7 to 1 mm.
8. The method according to any one of the preceding claims, wherein said elastic material layer (10) has at least two reinforced sections (15, 16) at said opposite ends (11,12) attached to said surface (100); wherein said at least two reinforced sections (15, 16) correspond to a respective portion of said elastic material layer (10) without apertures (21).
9. The method according to any one of the preceding claims, wherein said elastic material layer (10) has a plurality of active zones (20a, 20b, 20c); wherein adjacent active zones (20a, 20b) are spaced by a reinforced separation portion (28a); wherein said reinforced separation portion (28a) corresponds to a portion of said elastic material layer (10) without apertures (21).
10. The method according to any one of the preceding claims, wherein said elastic material layer (10) comprises a lateral perimeter (18) without apertures (21) on at least one side of said active zone (21).
11. The method according to any one of the preceding claims, wherein said surface 100 is a surface of: a building structure; or an aerodynamic structure; or an industrial container; or a duct for liquids; or a conductor of an electric line, or a band.
12. A manufactured product comprising a surface (100);

wherein said surface (100) has, on an outer portion thereof, an elastic material layer (10);
wherein said elastic material layer (10) has an active zone (20) comprising a plurality of through apertures (21);
each through aperture (21) having a substantially elongated shape and being adapted to deform, as a function of the elastic and/or plastic deformation of said outer surface portion (100), between:

- a first configuration, substantially closed, wherein said plurality of through apertures (21) block the view of said outer surface portion (100); and
- a second configuration, substantially open, wherein said plurality of through apertures (21) allow viewing, at least partially, said outer surface portion (100);

wherein said active zone (20) shows an auxetic behaviour.

13. A surface deformation sensor for a manufactured product, said sensor comprising an elastic material layer (10) having an elongated shape; said elastic material layer (10) comprising first and second ends which can be engaged with an outer surface (100) of said manufactured product;
wherein said elastic material layer (10) has an active zone (20) comprising a plurality of through apertures (21);
each through aperture (21) having a substantially elongated shape and being adapted to deform, as a function of the elastic and/or plastic deformation of said outer surface portion (100), between:

- a first configuration, substantially closed, wherein said plurality of through apertures (21) block the view of said outer surface portion (100); and
- a second configuration, substantially open, wherein said plurality of through apertures (21) allow viewing, at least partially, said outer surface portion (100);

wherein said active zone (20) shows an auxetic behaviour.

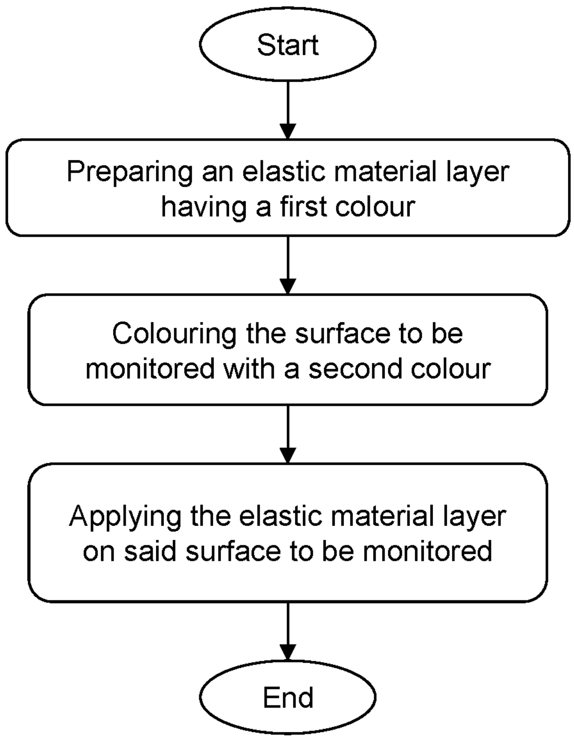
Start
Preparing an elastic material layer having a first colour
Colouring the surface to be monitored with a second colour
Applying the elastic material layer on said surface to be monitored
End

FIG. 1

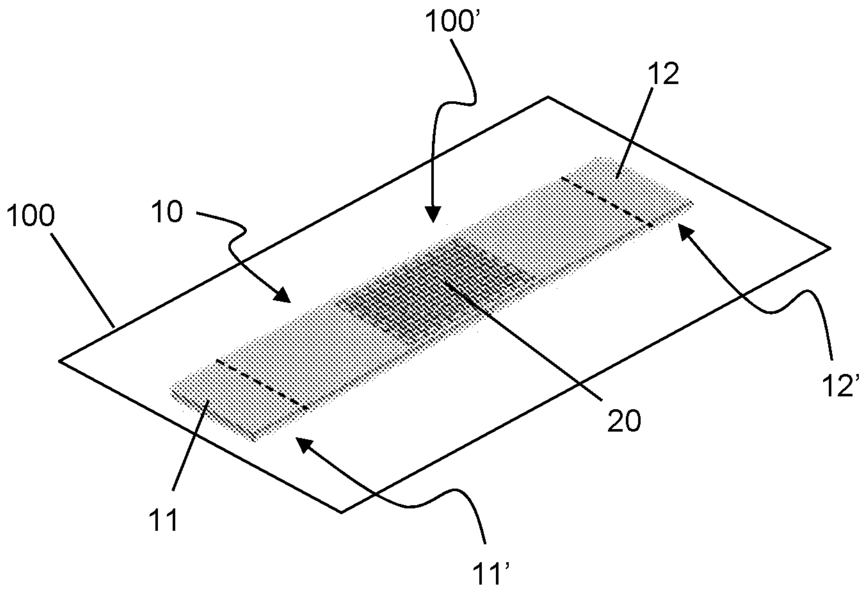
100'
12
100
10
12'
20
11
11'

FIG. 2

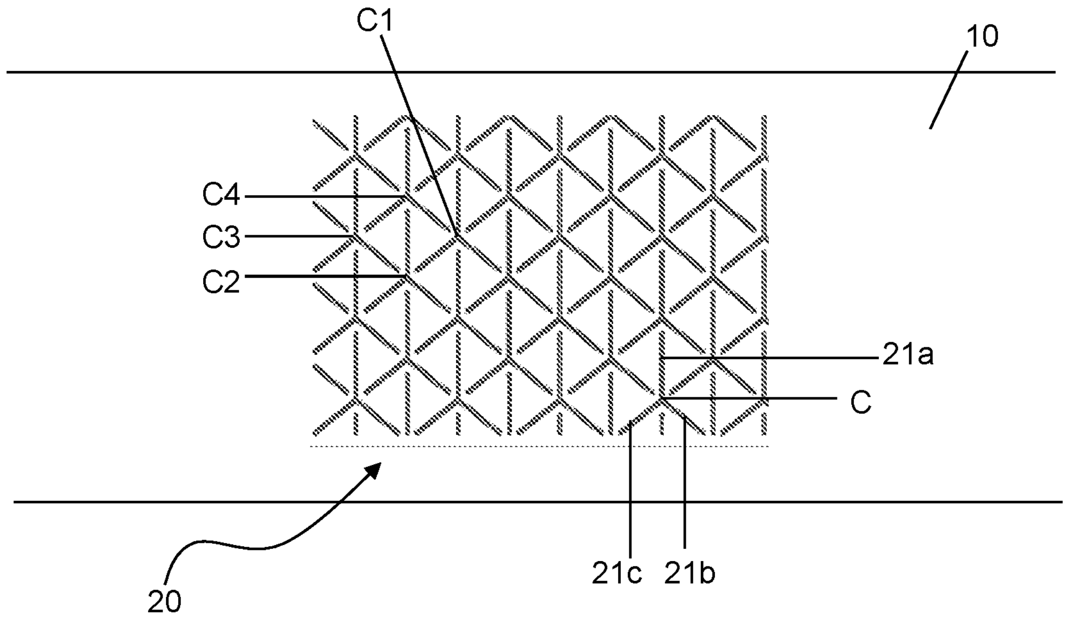

FIG. 3

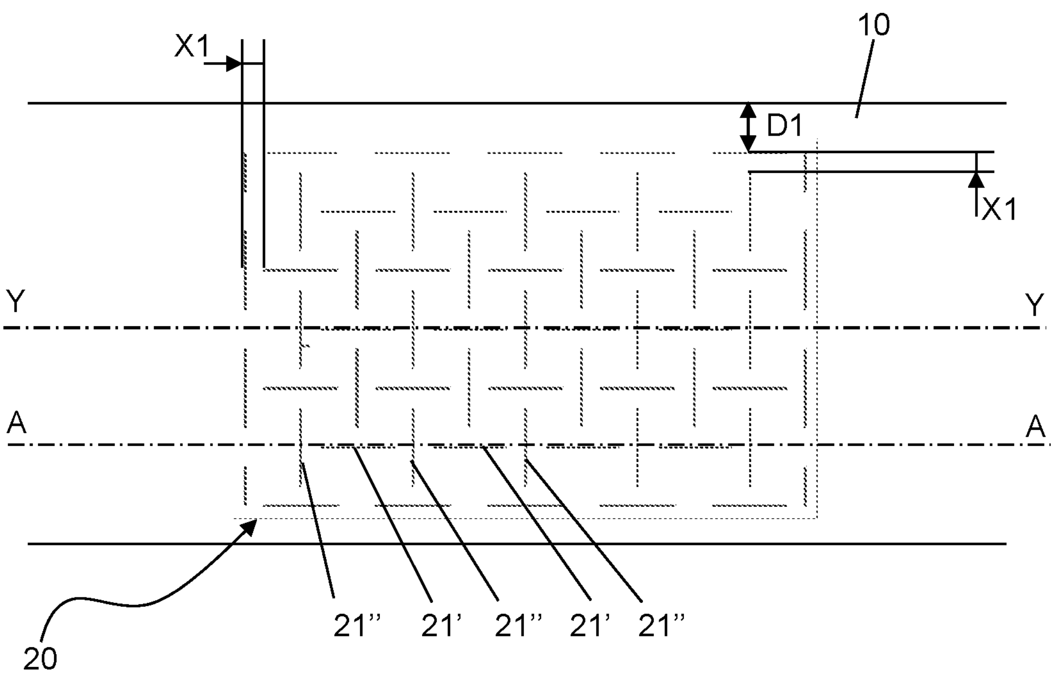

FIG. 4

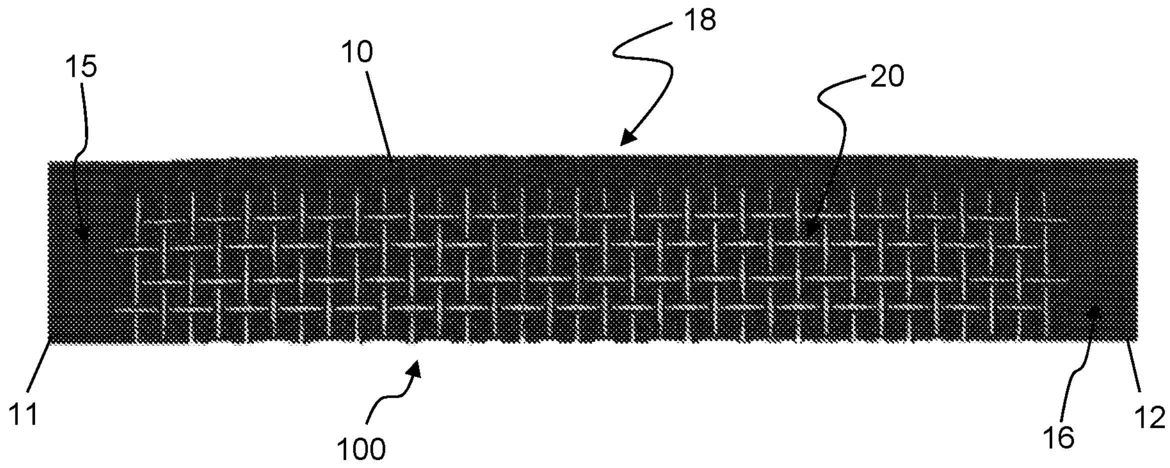

FIG. 5

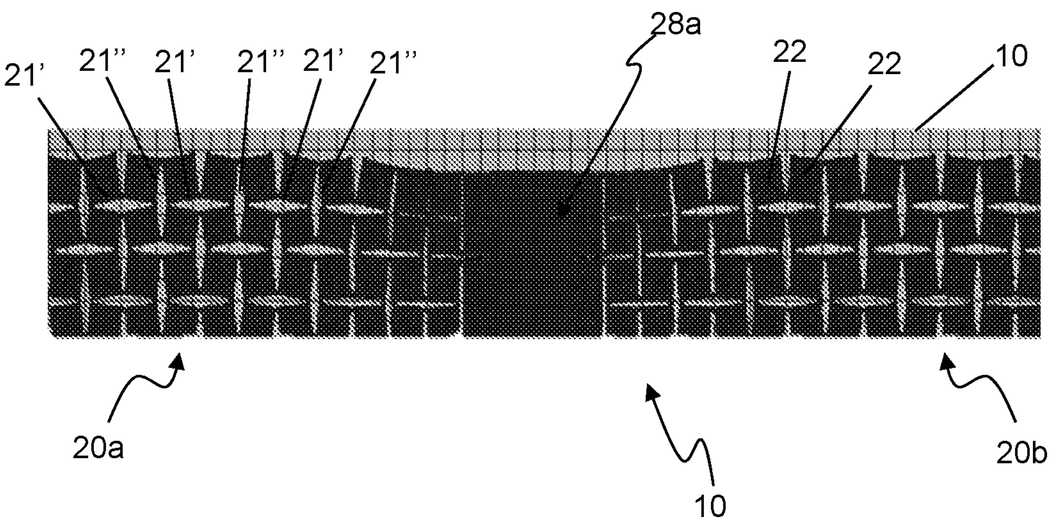

FIG. 6

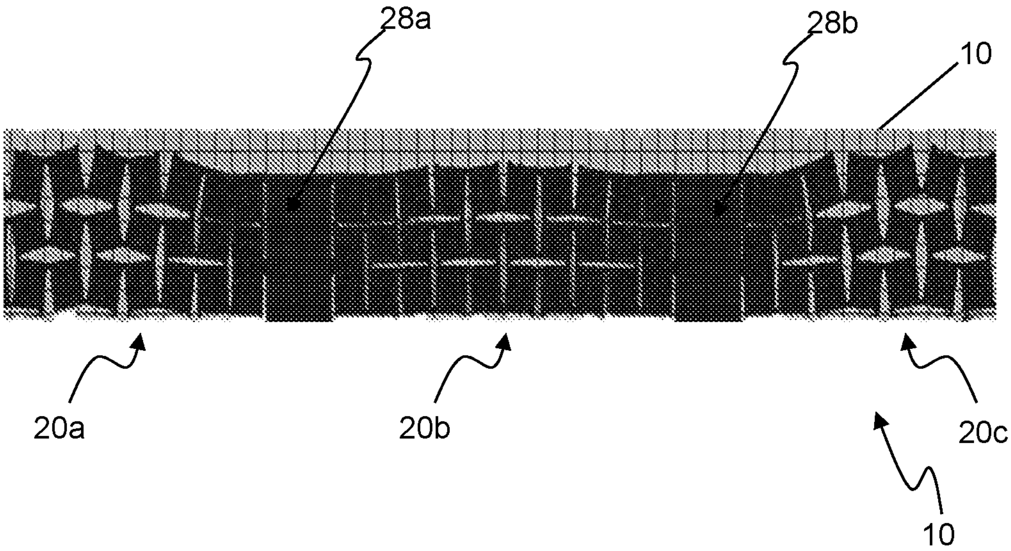

FIG. 7

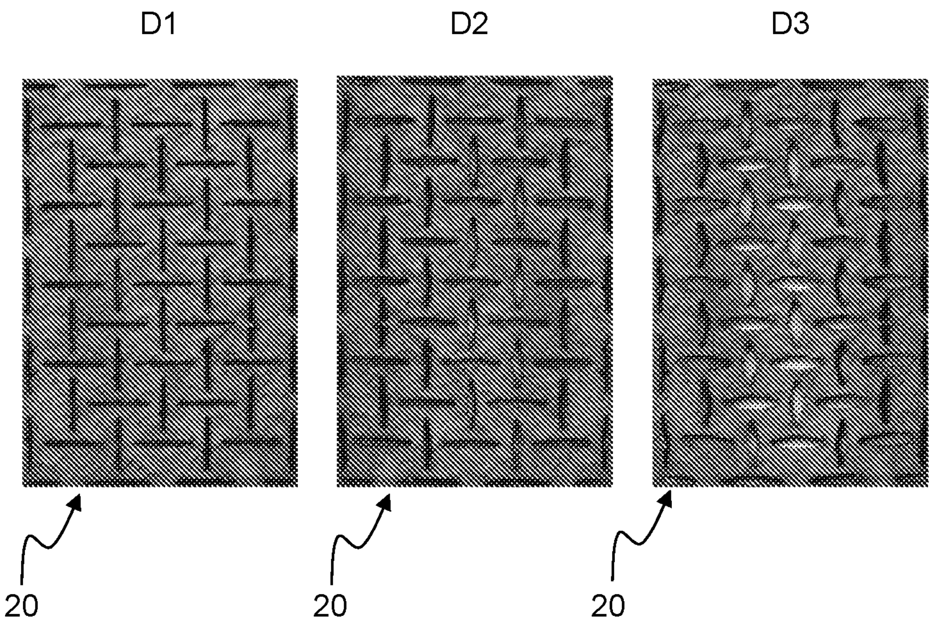

FIG. 8

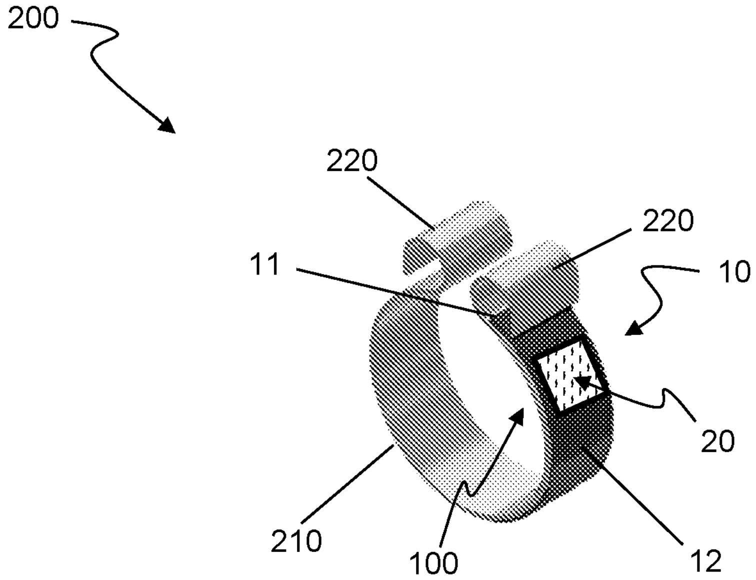

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2022/057051

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01B5/30 G01B11/16
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 4 700 715 A (LEVINE ROBERT A [US] ET AL) 20 October 1987 (1987-10-20) column 3, lines 10-65; figures 1-4	1,4-8, 10-13 2,3,9
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A	US 2021/085335 A1 (DAHL CAROLINE [SE]) 25 March 2021 (2021-03-25) figures 3,4	1-13
A	US 10 345 179 B2 (GEN ELECTRIC [US]) 9 July 2019 (2019-07-09) the whole document	1-13

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[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 November 2022	14/11/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Fazio, Valentina

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International application No
PCT/IB2022/057051

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 2016/370164 A1 (LOUVIGNÉ PIERRE-FRANÇOIS [FR] ET AL) 22 December 2016 (2016-12-22) the whole document -----	1-13

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2022/057051

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