

(19) **DANMARK**

(10) **DK/EP 3684672 T3**



(12)

Oversættelse af europæisk patentskrift

Patent- og
Varemærkestyrelsen

-
- (51) Int.Cl.: **B 61 L 23/04 (2006.01)** **B 61 L 1/16 (2006.01)** **G 01 D 5/353 (2006.01)**
- (45) Oversættelsen bekendtgjort den: **2022-01-17**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2021-10-20**
- (86) Europæisk ansøgning nr.: **18759979.0**
- (86) Europæisk indleveringsdag: **2018-09-05**
- (87) Den europæiske ansøgnings publiceringsdag: **2020-07-29**
- (86) International ansøgning nr.: **EP2018073820**
- (87) Internationalt publikationsnr.: **WO2019057491**
- (30) Prioritet: **2017-09-22 EP 17192644**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
- (73) Patenthaver: **Thales Management & Services Deutschland GmbH, Thalesplatz 1, 71254 Ditzingen, Tyskland**
- (72) Opfinder: **Oldewurtel, Kassen, Trollingerweg 13, 71706 Markgröningen, Tyskland**
Klemm, Rainer, Von-Weber-Str. 27, 71711 Steinheim, Tyskland
MUSCHAWECKH, Florian, Blumenstr. 58, 85774 Unterföhring, Tyskland
SCHICKER, Kai, Am Wiesengrund 9, 08539 Mehltheuer, Tyskland
Hoffmann, Lars, Fallmerayerstrasse 15, 80796 München, Tyskland
- (74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**
- (54) Benævnelse: **STRÆKNINGSMÅLEINDRETNING, ISÆR TIL EN AKSELTÆLLER**
- (56) Fremdragne publikationer:
EP-A1- 1 128 171
WO-A1-01/35133
DE-A1-102014 100 653
DE-B3-102015 115 925

Description

The invention relates to a strain gauge arrangement, in particular for an axle counter, comprising

- 5 - at least one strain sensor element, in particular an optical fiber with a fiber Bragg grating,
 - a carrier, to which the strain sensor element is fastened, and
 - a structure to be monitored, in particular a railroad track, to which the carrier has been fastened, wherein at least a part of the carrier is kept in an elastically
 - 10 deformed state by the structure when the carrier is fastened to the structure, wherein the carrier is embodied with a first carrier piece and a second carrier piece, which oppose one another in spaced apart fashion, wherein the strain sensor element is fastened to the first carrier piece with at least one first fixing point, to the second carrier piece with at least one second fixing point, and to
 - 15 neither the first nor the second carrier piece with a central section between the fixing points,
- wherein the part of the carrier which is kept in an elastically deformed state by the structure when the carrier is fastened to the structure comprises a leaf spring element.

20

Such a strain gauge arrangement for an axle counter has been disclosed by DE 10 2015 115 925 B3, in particular.

Axle counters are used to make rail traffic safer. Axle counters can be used to

25 check, in particular, whether the location of the axle counter has been completely passed by a train, for example to determine whether associated track sections have become completely free.

A possible measuring principle of axle counters is based on using a strain sensor

30 element to measure an elastic deformation at a rail caused by the weight of a train transferred by an axle.

In this respect, EP 3 069 952 A1 proposes to fasten a fiber Bragg grating (FBG), as a strain sensor element, to a rail under pretension. The reflection wavelength of the fiber Bragg grating depends on the elastic strain state of the FBG, on the basis of which the strain state can be measured. As a result of the pretension, the strain state of the FBG can be used to identify whether the FBG is still correctly fastened to the rail or has fallen off the rail. One variant proposes thermal application of the pretension by virtue of fastening a carrier to the rail under pretension.

Moreover, DE 10 2005 010 344 A1 has disclosed the practice of influencing damping properties in an optical waveguide via bending states.

Furthermore, strain sensor elements which are based on a change in resistance or capacitance due to a changing strain state, for example, have also been disclosed.

However, it is comparatively difficult to fasten strain sensor elements under pretension directly on a structure to be monitored, for instance a railroad track. A certain simplification can be achieved by applying the pretension via a carrier to which the strain sensor is affixed. However, it is also difficult in this case to set a defined strain state on the strain sensor element (for instance, to set a working point).

DE 10 2015 115 925 B3 describes a fiber optic sensor with a carrier structure. The carrier structure comprises two fastening elements between which an optical waveguide is pretensioned with fastening points. The carrier structure comprises an elastic element which has an arc-shaped design on two sides and introduces a pretension into the optical waveguide in the longitudinal direction. The carrier structure is fastened on an intermediate carrier via connecting surfaces.

EP 1 128 171 A1 describes a fiber optic load sensor for detecting rail vehicles, wherein an optical waveguide is braided around a carrier structure of rods.

Object of the invention

The invention is based on the object of presenting an easy-to-use strain gauge arrangement in which a fall-off can be reliably recognized and a strain state of the strain sensor element can be specified more easily.

5

Brief description of the invention

This object is achieved by a strain gauge arrangement of the type set forth at the outset, which is characterized

10 in that the following is formed on the leaf spring element

- a support element for support on the structure when the carrier is fastened to the structure, wherein, when the carrier is fastened to the structure, the support element pushes the leaf spring element upwardly away from the structure, as a result of which the leaf spring element is elastically
- 15 deformed, and
- a driver element for reaching behind the strain sensor element in the central section, wherein, following a detachment of the carrier from the structure, the leaf spring element springs back into an elastically non-deformed state and the driver element presses against the strain sensor element and
- 20 impresses an elastic strain on the latter.

Within the scope of the invention, provision is made for the strain sensor element not to be fastened to the carrier in linear fashion over its entire measuring length, but rather only to be fastened to a first carrier piece with a first fixing point and to a

25 second carrier piece with a second fixing point. The strain sensor element is kept free in the central section situated therebetween.

As a result, it is possible, as a matter of principle, to at least partially decouple the strain state of the strain sensor element from the elastic deformation state of the

30 carrier. In particular, it becomes possible to transfer an elastic deformation of the carrier resulting from a deformation of the monitored structure in a weakened or reinforced fashion, depending on the application, or to transfer said elastic

deformation to the strain sensor element only above certain thresholds, or to transfer certain types of deformation of the carrier to the strain sensor element in reinforced fashion. As a result, the strain sensor element can be operated in an optimal working range, and certain monitoring functions of the strain sensor element, for instance the detection of a fall-off from the structure, can be made more reliable. At the same time, the carrier can be fastened to the structure with an easily controllable elastic deformation of the carrier, without being excessively restricted by the strain sensor element.

10 A simple and direct access to the strain sensor element is possible at the central section, in particular without being fixed in the deformation of the strain sensor element by preforming an underlying carrier. In the central section there can be, e.g., additional tightening (for instance by means of a driver element) or an additional relief (for instance by excess length) of the strain sensor element with
15 respect to the carrier.

Fastening the carrier to the structure to be monitored, with at least a part of the carrier being kept in an elastically deformed state by the structure, enables a simple check to be made as to whether the strain gauge arrangement is still
20 correctly seated on the structure or has fallen off the structure; the latter leads to springing back into an elastically non-deformed state of the carrier or at least of said part. By way of example, falling-off from the structure may occur with aging or temperature-related softening of a fastening. The strain gauge arrangement is preferably embodied in such a way that the elastic deformation or bracing of the
25 carrier is ascertainable via a measured strain of the strain sensor element (i.e., the elastic deformation of the carrier lies in the monitored region of the strain sensor element). Alternatively, it is also possible to provide a measuring device or measurement which is separate from the strain sensor element or the strain thereof and by means of which the deformation of the carrier can be checked (for
30 instance using a further strain sensor element).

A strain gauge arrangement usually comprises only one strain sensor element; alternatively, it may comprise also two or even more strain sensor elements.

5 Within the scope of the invention, a strain sensor element is fastened to a first and second carrier piece with a first and second fixing point and not fastened to these carrier pieces (or to other parts of the carrier either) in a central section. In addition to the first and second carrier piece, the carrier usually also comprises one or more further pieces (for example a base element or a bracket).

10 The strain sensor element is preferably embodied as an optical fiber with a fiber Bragg grating (FBG); the FBG is located between the fixing points in the central section in this case. Typically, the strain sensor element is under a slight elastic strain when the carrier is fastened to the structure, and so both compression and extension of the structure to be monitored can easily be identified.

15

A strain gauge arrangement according to the invention can be used in an axle counter, in particular; such an axle counter comprises at least one strain gauge arrangement according to the invention. However, other applications for the strain gauge arrangement can also be envisaged, for instance for monitoring mechanical loads or wear on machine components. A strain sensor element can be disposed at an oblique angle, for instance at an angle of approximately 45 °, with respect to a neutral fiber of a structure to be monitored. By way of example, the carrier can be attached to the structure to be monitored by screwing, soldering or adhesive bonding. By way of example, the strain sensor element can be fastened to the carrier pieces by jamming, soldering or adhesive bonding.

20

25

In summary, the invention particularly easily allows, firstly, the strain sensor element (when the carrier is fastened to the structure) to be kept at a desired pretension, and, secondly, the monitoring by means of at least the part of the carrier as to whether the carrier is still (sufficiently) fastened to the structure to be monitored.

30

In the strain gauge arrangement according to the invention, provision is made for the part of the carrier which is kept in an elastically deformed state by the structure when the carrier is fastened to the structure to comprise a leaf spring element, and for the following to be formed on the leaf spring element:

- 5 - a support element for support on the structure when the carrier is fastened to the structure and
- a driver element for reaching behind the strain sensor element in the central section. An elastic deformation is impressed on the leaf spring element by the support element abutting against the structure. The driver element typically moves
- 10 substantially perpendicular to the direction of extension (measurement direction) of the strain sensor element and typically moves substantially perpendicular to the surface of the structure to which the carrier has been fastened. The driver element can be used to impress an elastic strain or a bend on the strain sensor element, depending on the deformation of the leaf spring element. This strain or bend can
- 15 be measured by the strain sensor element (for instance via the strain as such, or via a modified, usually increased damping), and the detachment of the carrier from the structure can thus be easily identified. The inventive structure particularly reliably detects a detachment of the strain sensor element from the structure to be monitored. All that is needed to detect the sensor falling off is an elastic
- 20 deformation of the leaf spring element; in particular, there is no need to fasten (for example, adhesively bond) carrier surfaces that are elastically braced against one another to the structure, which makes installation particularly easy.

Preferred embodiments of the invention

25

In one preferred embodiment of the strain gauge assembly in accordance with the invention, when the carrier is fastened to the structure, the driver element is lifted so far that the latter does not contact the strain sensor element.

30

In a further embodiment, the leaf spring element and the driver element are embodied in such a way that no strain, or only little strain, is applied to the strain sensor element by said leaf spring and driver elements in the elastically deformed

state of the leaf spring element when the carrier is fastened to the structure, and a greater strain is applied to the strain sensor element in an elastically relaxed state of the leaf spring element after the carrier has been detached from the structure. In its elastically relaxed state, the leaf spring element (together with the driver
5 element) tightens and/or bends the strain sensor element, which is usually easy to detect; conversely, the leaf spring element and the driver element (and the support element) are embodied in such a way that, in the elastically tensioned state, the strain sensor element is not or only slightly tightened by the driver element. Alternatively, it is also possible to relax the strain sensor element in the elastically
10 relaxed state of the leaf spring element.

Another preferred embodiment provides that the driver element has a driver projection projecting downwards towards the strain sensor element and that, in the elastically non-deformed state of the leaf spring element, the driver element
15 presses on the strain sensor element by way of the driver projection.

An embodiment which provides for the carrier to have a base element, by means of which the carrier is fastened to the structure to be monitored, and for the first carrier piece and the second carrier piece to be fastened on or at
20 the base element is preferred. Targeted and simplified fastening to the structure, in particular also over a large area, can be provided by the base element. As a rule, the carrier pieces are only fastened to the structure via the base element. A typical base structure is embodied as a closed ring ("frame") and the carrier pieces protrude inwards into the ring. Another typical base structure is embodied with a
25 closed surface, on which the carrier pieces are seated.

A preferred development of this embodiment provides for the first and second carrier pieces to each be fastened to the base element only in a rear region which faces away from the strain sensor element, and for the first and second carrier
30 pieces to each be fastened to the strain sensor element in a front region which faces away from the rear region. The carrier pieces are only attached to the structure via the base element, fastening being affected at the rear region of the

respective carrier piece. The carrier pieces typically exhibit no noticeable elastic deformation (between the front and rear region). As a result of the distance from the front region to the rear region, the elastic strain of the base body or the structure is transferred in reinforced fashion to the strain sensor element.

- 5 Typically, the total length GL of the carrier pieces between the front and rear regions is at least three times as long as the length AE of the strain sensor element between the fixing points.

Further advantages of the invention are apparent from the description and the
10 drawing. Likewise, the aforementioned features and the features yet to be explained below can, according to the invention, each find use individually or together in any combination. The embodiments shown and described should not be understood to be an exhaustive list, but rather have an exemplary character for the purpose of illustrating the invention.

15

Detailed description of the invention and drawing

The invention is illustrated in the drawing and explained in more detail on the basis of exemplary embodiments. In the figures:

20

fig. 1a shows a schematic plan view of a design of a strain gauge arrangement not according to the invention, with a frame-shaped base element for general explanation;

25

fig. 1b shows a schematic cross-sectional view of the strain gauge arrangement of figure 1a;

30

fig. 2a shows a schematic plan view of an embodiment of a strain gauge arrangement according to the invention, comprising a leaf spring element, support element and driver element;

fig. 2b shows a schematic side view of the strain gauge arrangement of figure 2a, comprising a carrier fastened to the structure;

5 fig. 2c shows a schematic side view of the strain gauge arrangement of figure 2a, comprising a carrier detached from the structure;

Figure 1a shows, for general explanation, a design of a strain gauge arrangement 1 not according to the invention in a plan view, and **figure 1b** shows an associated cross-sectional view, cf. plane Ib in figure 1a.

10

The strain gauge arrangement 1 comprises a carrier 2, which here comprises a substantially rectangular base element 3 that is closed in ring-shaped fashion, a first carrier piece T1, and a second carrier piece T2. The carrier pieces T1, T2 protrude inward from the base element 3, which forms an outer frame of the carrier 2.

15

By way of the frame-shaped base element 3, the carrier 2 is fastened to a structure 4 to be monitored in a manner not shown in detail, e.g., it adhesively bonds to the structure 4 with the entire underside of the base element 3; however, 20 the undersides of the carrier pieces T1, T2 are not adhesively bonded to the structure 4, but only rest on said structure 4. By way of example, the structure 4 to be monitored can be a railroad track of a train route.

A strain sensor element 5 is fastened to the carrier pieces T1 and T2 at fixing 25 points 7, 8. The fixing points 7, 8 each lie at the inner end of the pieces T1, T2. The central section 5a of the strain sensor element 5 located between the fixing points 7, 8 freely spans between the pieces T1, T2 in this case.

In the design shown, the strain sensor element 5 is embodied as an optical fiber 6 30 with a fiber Bragg grating (FBG) 6a in the central section 5a. It should be noted that the fiber 6 is only shown in the region of the central section 5a in figure 1a for simplification purposes; figure 1b also shows feed lines 6b of the fiber 6.

Alternatively, other types of strain sensor elements, such as electrical resistance-measuring strips, could also be used.

In a basic state for using the strain sensor element 5 for monitoring the strain of the structure 4, the strain sensor element 5 is typically slightly elastically strained in the direction of extension ER of the fiber 6 in the central section 5a in order to set the working point of the FBG. Here, the elastic strain of the strain sensor element 5 can be predetermined practically as desired when or by fastening the strain sensor element 5 to the fixing points 7, 8 (in the basic state).

10

If there is a deformation of the structure 4, the base element 3 fastened to the structure 4 is also deformed. This deformation of the base element 3 is transferred to the strain sensor element 5 via the carrier pieces T1, T2, as a result of which this deformation becomes measurable.

15

A total length GL of the pieces T1, T2, in each case from the rear region 9 to the front region 10 where the respective fixing point 7, 8 is arranged, with $GL = LT1 + LT2$, is significantly longer than the distance AE between the fixing points 7, 8 in this case. In the design shown, $GL = 2 * AE$ applies approximately; in general, $GL \geq 2 * AE$ or $GL \geq 3 * AE$ is preferred. As a result of the pieces T1, T2 protruding parallel to the direction of extension ER of the strain sensor element 5, which pieces move when the structure 4 is deformed along the direction of extension ER but are themselves hardly deformed, the deformation of the structure 4 or the frame in the direction of extension ER can be transferred in reinforced fashion to the strain sensor element 5, in accordance with the ratio $AE / (LT1 + AE + LT2)$.

25

In the basic state already mentioned, the frame-shaped base element 3 is in an elastically deformed state, in which it is kept by the underlying structure 4 to which the base element 3 is fastened. In the present case, the base element 3 is strained slightly elastically with respect to the direction of extension ER. Should the base element 3 or the carrier 2 fall off the structure 4, the elastic deformation of the base element 3 would spring back; i.e., the base element 3 would contract in the

30

direction of extension ER in this case. This would also change the elastic strain state of the strain sensor element 5, as a result of which the fall-off from the structure 4 can be uncovered.

5 In the embodiment of the strain gauge arrangement according to the invention described below, it is primarily the differences from the design of figures 1a, 1b that are explained.

The embodiment of a strain gauge arrangement 1 according to the invention is
10 illustrated in a plan view in **figure 2a** and, in a side view, in the state fastened to the structure 4 in **figure 2b** and in the detached state in **figure 2c**.

The strain gauge arrangement 1 has a carrier 2, which also comprises a leaf
spring element 21 in addition to the pieces T1, T2. In the embodiment shown, the
15 leaf spring element 21 connects the two carrier pieces T1, T2 to one another, the leaf spring element 21 being fastened with its ends 22, 23 to the pieces T1, T2 in each case; the end regions of the leaf spring element 21 extending over the pieces T1, T2.

20 A support element 24 is formed on the leaf spring element 21, said support element extending over the strain sensor element 5 in this case and being supported with a support projection 24a on the structure 4 to be monitored as a stop partner. When the carrier 2 is fastened to the structure 4 (cf. figure 2b), the support element 24 presses the leaf spring element 21 away from the structure 4
25 in the upward direction, as a result of which the leaf spring element 21 is elastically deformed, specifically strained in this case.

Moreover, a driver element 25 is formed on the leaf spring element 21, said driver element likewise extending over the strain sensor element 5 in this case and
30 having a driver projection 25a which projects downward in the direction towards the strain sensor element 5 in this case. Thus, the driver projection 25a engages behind the strain sensor element 5 from above. In a state where the leaf spring

element 21 is elastically deformed by the support on the structure 4 (cf. Figure 2b), the driver element 25 (or its driver projection 25a) is raised so far in the embodiment shown that it does not touch the strain sensor element 5. Accordingly, the strain sensor element 5 has its normal strain state, which is provided for
5 normal measurement operation (for strain monitoring of the structure 4).

Should the strain gauge arrangement 1 fall off the structure 4, the leaf spring element 21 springs back into an elastically non-deformed state, which is shown in figure 2c, since the support element 24 no longer has a stop partner at the front
10 end. In this state, the driver projection 25a of the driver element 25 presses on the strain sensor element 5 and impresses a significant elastic strain thereon. This significant elastic strain is easy to measure, as a result of which the strain gauge arrangement 1 falling from the structure 4 can easily be detected.

15 In the embodiment of figures 2a-2c, the carrier pieces T1, T2 or the carrier 2 can be fastened to the structure 4 to be monitored without any significant shear stress, which simplifies the assembly.

List of reference signs:

	1	Strain gauge arrangement
	2	Carrier
5	3	Base element
	4	Structure to be monitored
	5	Strain sensor element
	5a	Central section
	6	Optical fiber
10	6a	Fiber Bragg grating
	6b	Feed line
	7	First fixing point
	8	Second fixing point
	9	Rear region
15	10	Front region
	21	Leaf spring element
	22	End (leaf spring element)
	23	End (leaf spring element)
	24	Support element
20	24a	Support projection
	25	Driver element
	25a	Driver projection
	AE	Fixing point spacing
	ER	Direction of extension (strain sensor element)
25	GL	Total length of pieces T1, T2
	FBG	Fiber Bragg grating
	LT1	Length of piece T1
	LT2	Length of piece T2
	T1	First piece (strain sensor element)
30	T2	Second piece (strain sensor element)

Patentkrav

1. Strækningssmåleindretning (1), især til en akseltæller (91), omfattende

- mindst et strækningssensorelement (5), især en optisk fiber (6) med et fiber-Bragg-gitter (6a, FBG),

5 - en bærer (2), på hvilken strækningssensorelementet (5) er fastgjort, og
 - en struktur (4), der skal overvåges, især en jernbaneskinne, på hvilken bæreren (2) er fastgjort, idet mindst en del af bæreren (2) i bærerens (2) på strukturen (4) fastgjorte tilstand holdes i en elastisk deformeret tilstand af strukturen (4),

10 idet bæreren (2) er udformet med et første bærerstykke (T1) og et andet bærerstykke (T2), der ligger over for hinanden i afstand fra hinanden, idet strækningssensorelementet (5) er fastgjort i det mindste med et første fastgørelsespunkt (7) til det første bærerstykke (T1), og i det mindste med et andet fastgørelsespunkt (8) til det andet bærerstykke (T2), og med et
15 midterafsnit (5a) mellem fastgørelsespunkterne (7, 8) hverken til det første eller til det andet bærerstykke (T1, T2),

 idet den del af bæreren (2), der i bærerens på strukturen (4) fastgjorte tilstand (2) af strukturen (4) holdes i en elastisk deformeret tilstand, omfatter et bladfjederelement (21),

20 **kendetegnet ved,**

at der på bladfjederelementet (21) er dannet

- et støtteelement (24) til at støtte på strukturen (4) i bærerens (2) på strukturen (4) fastgjorte tilstand, idet støtteelementet (24) i bærerens (2) på strukturen (4) fastgjorte tilstand trykker bladfjederelementet (21) opad
25 bort fra strukturen (4), hvorved bladfjederelementet (21) deformeres elastisk, og

- et medbringerelement (25) til at gribe bag om strækningssensorelementet (5) i midterafsnittet (5a), idet bladfjederelementet (21) efter løsning af bæreren (2) fra strukturen (4) fjedrer tilbage til en elastisk udeformeret tilstand og trykker
30 medbringerelementet (25) mod strækningssensorelementet (5) og påtrykker dette en elastisk strækning.

2. Indretning (1) ifølge krav 1, **kendetegnet ved, at** medbringerelementet (25) i bærerens (2) på strukturen (4) fastgjorte tilstand er løftet så langt, at det ikke berører strækningssensorelementet (5).

- 5 **3.** Indretning (1) ifølge krav 1 eller 2, **kendetegnet ved, at** bladfjeder-elementet (21) og medbringer-elementet (25) er udformede således, at der af disse i bladfjeder-elementets (21) elastisk deformerede tilstand, når bæreren (2) er fastgjort på strukturen (4), ikke påtrykkes nogen eller kun en mindre strækning på strækningssensorelementet (5), og i en elastisk afspændt tilstand af
- 10 bladfjeder-elementet (21) efter løsning af bæreren (2) fra strukturen (4) påtrykkes en større strækning på strækningssensorelementet (5).

- 4.** Indretning ifølge et af kravene 1 til 3, **kendetegnet ved, at** medbringer-elementet (25) har et på strækningssensorelementet (5) nedad
- 15 ragende medbringerfrem-spring (25a), og at medbringer-elementet (25) i bladfjeder-elementets (21) elastisk udeformerede tilstand trykker på strækningssensorelementet (5) med medbringerfrem-springet (25a).

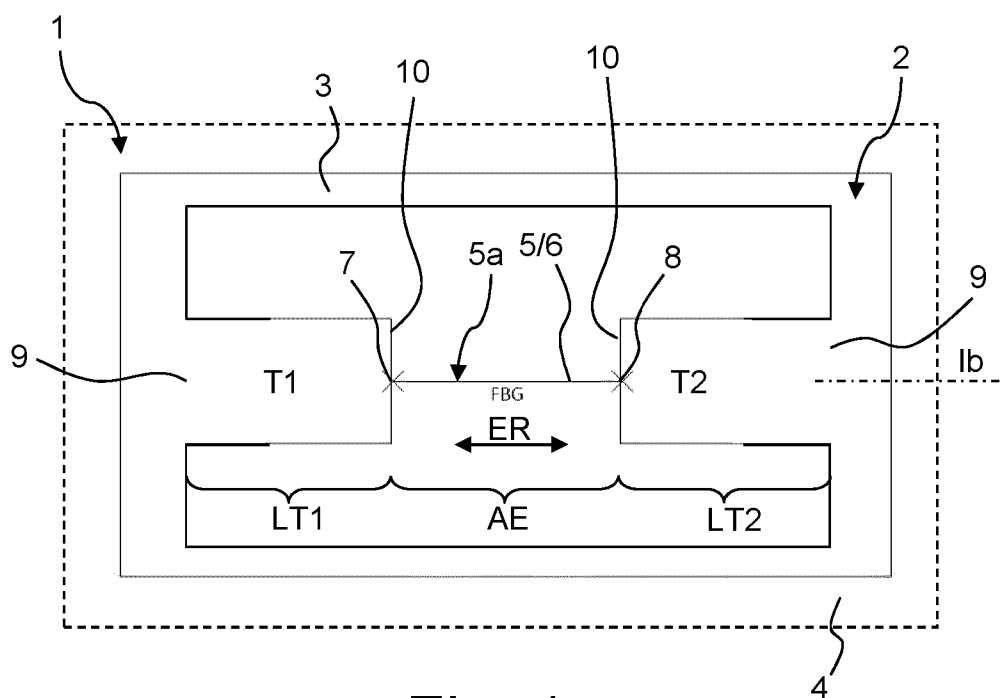


Fig. 1a

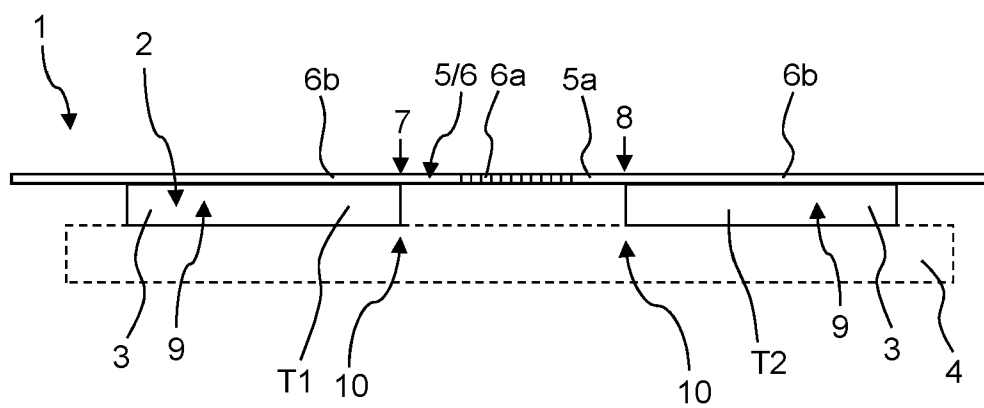


Fig. 1b

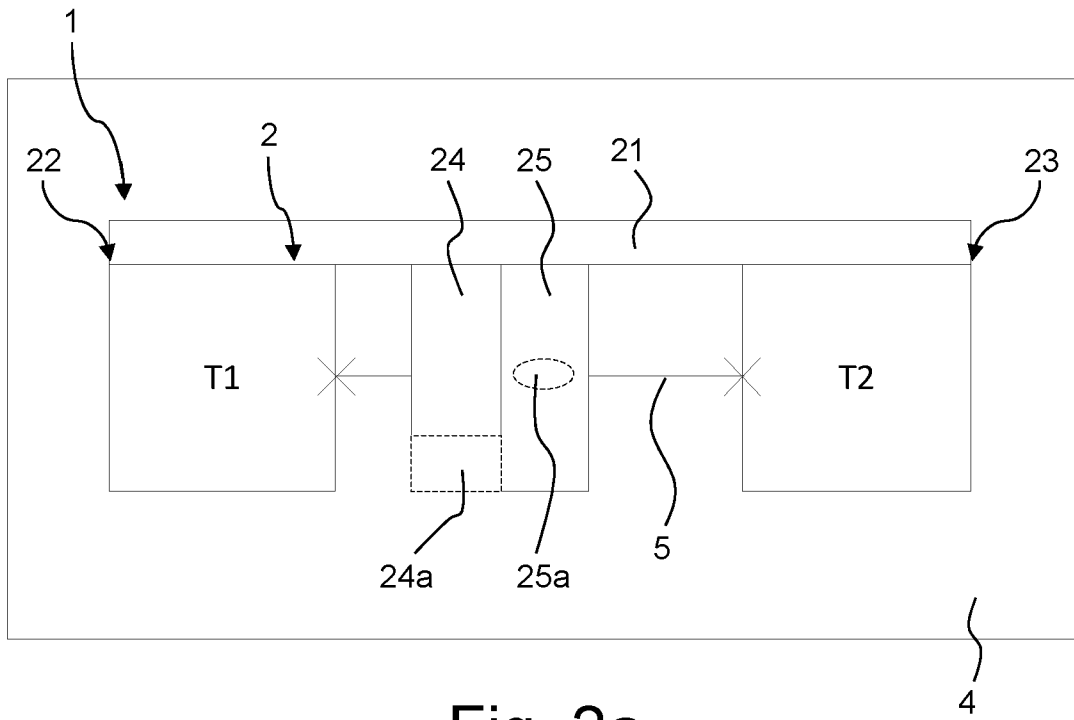


Fig. 2a

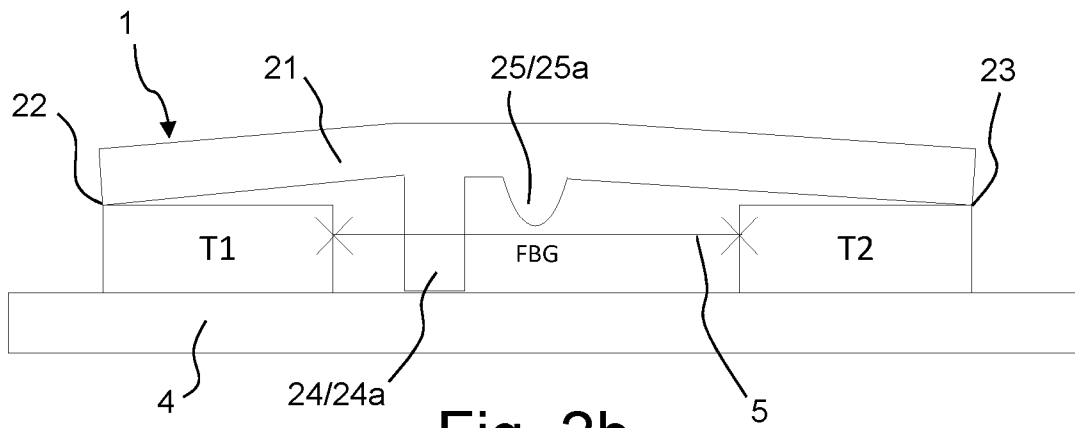


Fig. 2b

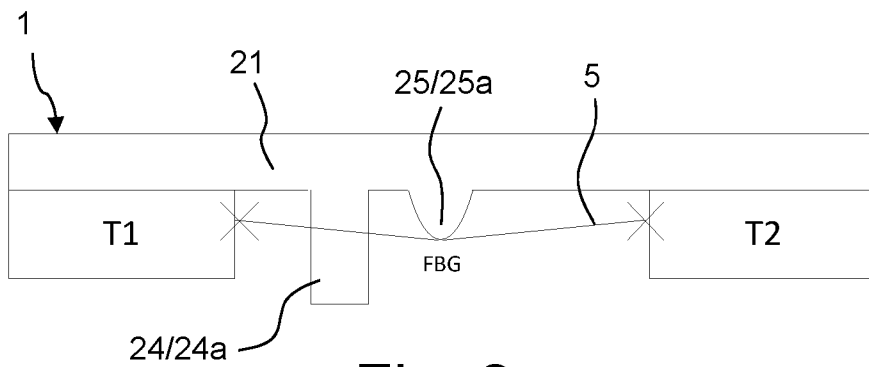


Fig. 2c