(19) Octrooicentrum Nederland

(11) **2024979**

(12) B1 OCTROOI

(21) Aanvraagnummer: **2024979**

(22) Aanvraag ingediend: **24 februari 2020**

(51) Int. Cl.:
G01D 5/26 (2020.01) **G01P 15/093** (2020.01) **G01P 15/08** (2021.01)

(30) Voorrang:
-

(41) Aanvraag ingeschreven:
14 oktober 2021

(43) Aanvraag gepubliceerd:
-

(47) Octrooi verleend:
14 oktober 2021

(45) Octrooischrift uitgegeven:
4 november 2021

(73) Octrooihouder(s):
Laser Institute of Shandong Academy of Science te Jining City, China, CN

(72) Uitvinder(s):
Hua Zhang te Jinan (CN)
Binxin Hu te Jinan (CN)
Guangdong Song te Jinan (CN)
Feng Zhu te Jinan (CN)
Jiqiang Wang te Jinan (CN)
Tongyu Liu te Jinan (CN)

(74) Gemachtigde:
ir. H.A. Witmans c.s. te Den Haag

(54) Optical fiber grating acceleration sensor

(57) Optical fiber grating acceleration sensor including: a housing, a sensing component provided in the housing and a computing unit. The sensing component includes: a leaf spring connected to a bottom of the housing; a mass connected to a top of the leaf spring; a beam, including a first arm and a second arm, wherein the first arm and the second arm are connected via a rotating member fixed on a sidewall of the housing, and one end of the second arm far from the rotating member is connected to the top of the mass; and an optical fiber measuring device suspended above the beam, which includes a grating measuring device and an optical fiber connected respectively to the grating measuring device and the computing unit. The computing unit computes an acceleration of a structure to be measured according to a drift of the light parameter of the grating measuring device.

P126483NL00

Title: Optical fiber grating acceleration sensor

FIELD OF THE INVENTION

The present invention relates to the field of vibration monitoring technologies, and in particular, to an optical fiber grating acceleration sensor.

BACKGROUND OF THE INVENTION

For some large-scale geologic configuration with complex environment, for example, tunnels and mines, etc., vibration monitoring needs to be carried out periodically, and sensors for measuring vibration parameters are buried inside the geologic configuration in advance. When a seismic wave is generated in the geologic configuration, the seismic wave will be transmitted to the sensor, and the sensor will be able to measure the vibration parameter, so that a latent seismic activity may be found, thereby attaining the object of prewarning and disaster prevention.

Acceleration is one of the general vibration parameters, and it is used for reflecting the impact force of a seismic wave. At present, an optical fiber grating acceleration sensor is often employed to measure an acceleration. Optical fiber grating has the advantages of electromagnetic interference resistance, explosion-proof and high-temperature resistance, and it may be adapted to the complex and harsh environment of a geologic configuration. When an optical fiber grating acceleration sensor buried inside a geologic configuration detects a vibration signal, the light parameter of the optical fiber grating will change correspondingly, and the vibration acceleration of a large-scale structural engineering will be acquired by demodulating the change of the light parameter.

Fig.1 shows a structure of an optical fiber grating acceleration sensor, wherein an optical fiber grating 101 is adhered to the surface of a fixed end (Fi) of a cantilever beam 201, the free end (Fr) of the cantilever beam 201 is flexibly connected to a mass structure 301, and the vibration of the mass structure 301 makes the cantilever beam 201 bend, so that the central wavelength of the optical fiber grating 101 will drift. By detecting the drift of the central wavelength, the vibration acceleration of the geologic configuration can be computed. However, because the optical fiber grating 101 is directly adhered to the cantilever beam 201, the mechanical properties of the cantilever beam 201 will cause the grating period of the optical fiber grating 101 to change axially, that is, a grating chirp phenomenon will occur, which causes an inaccurate measurement result.

SUMMARY OF THE INVENTION

The present invention provides an optical fiber grating acceleration sensor, thereby solving the problem of low accuracy of acceleration measurement.

In the first aspect of the invention, there provides an optical fiber grating acceleration sensor, which includes: a housing, a sensing component provided in the housing, and a computing unit; wherein the sensing component includes:

a leaf spring connected to the bottom of the housing, which is plate-shaped elastic member formed by stacking at least one layer of spring steel;

a mass connected to the top of the leaf spring;

a beam, which includes a first arm and a second arm, wherein the first arm and the second arm are connected via a rotating member, the rotating member is fixed to the sidewall of the housing, and one end of the second arm far from the rotating member is connected to the top of the mass;

an optical fiber measuring device suspended above the beam, which includes a grating measuring device, and an optical fiber connected respectively to the grating measuring device and the computing unit.

The computing unit is configured to compute the acceleration of a structure to be measured according to a drift of the light parameter of the grating measuring device.

In the first aspect, the sensor is placed in the structure to be measured, when the structure to be measured vibrates due to external factors, the sensor vibrates with the structure to be measured, so that the mass vibrates under the action of an inertial force, and the first arm in the beam is driven to make a certain angular displacement around the rotating member, so that the grating measuring device will deform due to being stretched, thus the light parameter of the grating will drift, and the acceleration of the structure to be measured may be demodulated according to the drift of the light parameter. In the invention, the optical fiber grating is suspended in the housing, and no grating chirp phenomenon or reflected wave multimodal phenomenon will appear. The second arm is connected to the leaf spring via a mass, and the leaf spring is an elastic member with relatively large size and stiffness, thus the lateral vibration interference to the mass may be lowered, and the interference vibration in the leaf spring is transmitted to the second arm after being attenuated by the mass, so that the lateral vibration interference to the second arm is greatly lowered, the measurement precision of unidirectional vibration acceleration is increased, the frequency band is wide, and it has a high sensitivity and a large frequency response range.

In the second aspect of the invention, there provides an optical fiber grating acceleration sensor, which includes: a housing, a sensing component provided in the housing, and a computing unit; wherein the sensing component includes:

a leaf spring connected to the bottom of the housing, which is plate-shaped elastic member formed by stacking at least one layer of spring steel;

a beam, which includes a first arm and a second arm, wherein the first arm and the second arm are connected via a rotating member, the rotating member is fixed to the sidewall of the housing, the second arm is connected to the top of the leaf spring, and the length of the leaf spring and the length of the first arm are both less than that of the second arm;

an optical fiber measuring device suspended above the beam, which includes a grating measuring device, and an optical fiber connected respectively to the grating measuring device and the computing unit.

The computing unit is configured to compute the acceleration of a structure to be measured according to a drift of the light parameter of the grating measuring device.

In the second aspect, the second arm is a long arm, and a leaf spring is connected to the bottom of the long arm, and the leaf spring has large size and stiffness, which can provide a more stable support to the second arm and lower the lateral vibration interference in the vibration of the second arm, so that the measurement precision of unidirectional vibration acceleration is increased, the frequency band is wide, and it has a high sensitivity and a large frequency response range.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to more clearly illustrate the technical solutions of the embodiments of the invention or of the prior art, the drawings needed in the description of the embodiments or the prior art will be briefly introduced below. Apparently, the drawings in the description below are only some embodiments of the invention, and other drawings may also be obtained by one of ordinary skills in the art according to these drawings without creative work.

Fig.1 is a structural representation of an optical fiber grating acceleration sensor of the prior art;

Fig.2 is a structural representation of an optical fiber grating acceleration sensor shown in Embodiment 1 of the invention;

Fig.3 is an equivalent force model of the sensor shown in Embodiment 1;

Fig.4 is a structural representation of an optical fiber grating acceleration sensor shown in Embodiment 2 of the invention; and

Fig.5 is an equivalent force model of the sensor shown in Embodiment 2.

In the drawings: 1 housing; 2 sensing component; 21 leaf spring; 22 mass; 23 beam; 231 first arm; 232 second arm; 233 rotating member; 24 optical fiber measuring device; 241 grating measuring device; 242 optical fiber; 25 bolt; 3 computing unit.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The technical solutions in the embodiments of the invention will be described clearly and fully below in conjunction with the drawings in the embodiments of the invention. Apparently, the embodiments described are only a part of the embodiments of the invention, rather than being the whole embodiments. All the other embodiments obtained by one of ordinary skills in the art based on the embodiments of the invention without creative work pertain to the protection scope of the invention.

As shown in Fig.2, an optical fiber grating acceleration sensor according to Embodiment 1 of the invention may be buried inside a structure to be measured, for measuring an acceleration parameter a structure to be measured. The sensor overall includes a housing 1, a computing unit 3, and a sensing component 2 provided inside the housing 1. The housing 1 is configured to encapsulate the sensing component 2, and the sensing component 2 is configured to convert the vibration of the structure to be measured into the change of grating strain. Moreover, the light parameter of the grating on which strain occurs will also change. The light parameter may be wavelength, frequency, phase or polarization, etc. For different types of gratings, the light parameter sensitive to strain may be different. For example, Fiber Bragg Grating (FBG) may be selected as the specific grating. The computing unit 3 may be an external light signal demodulation device, and it is configured to demodulate the light parameter detected so as to obtain the acceleration of the structure to be measured.

In Fig.2, the sensing component 2 includes a leaf spring 21 fixedly connected to the bottom of the housing 1, a beam 23 connected to the top of the leaf spring 21 and an optical fiber measuring device 24 connected to the beam 23, wherein the optical fiber measuring device 24 is suspended above the beam 23.

The optical fiber measuring device 24 includes a grating measuring device 241 of which a light parameter changes when a structure to be measured vibrates, and an optical fiber 242 connected respectively to the grating measuring device 241 and the computing unit 3. The grating measuring device 241 may be a grating dedicated to acceleration measurement. In other possible implementation modes, the grating measuring device 241 is formed by directly engraving the grating into the fiber core of the optical fiber 242.

The beam 23 includes a first arm 231 and a second arm 232, wherein the first arm 231 and the second arm 232 are connected via a rotating member 233 fixed on the sidewall of the housing 1, and an end A of the first arm 231 is connected to the grating measuring device 241. If the mode that the grating is engraved into the optical fiber 242 is employed, the end A of the first arm 231 will be directly connected with the optical fiber 242, and in such a case, the optical fiber 242 and the grating have the same deformation. The beam 23 employs an L-shaped beam, and the second arm 232 is parallel to the optical fiber measuring device 24. If the vibration inertia of the second arm 232 is to be increased, a mass 22 may be additionally connected to the end B of the second arm 232.

The housing 1, the leaf spring 21 and the second arm 232 may be connected as a whole via a bolt 25, so that the housing 1, the leaf spring 21 and the beam 23 form a vibration sensing and transmitting structure in z direction. The vibration sensing and transmitting structure employs the leaf spring 21 as a support base and realizes rigid connection via a bolt 25, so that the vibration sensing and transmitting structure may be prevented from generating non-z direction displacement due to an external vibration, the measurement precision of acceleration may be increased, and structure stability may be ensured. Additionally, in such a bolt connection mode, it is convenient for removing and replacing a component. The housing 1, the leaf spring 21 and the second arm 232 are not limited to being connected via a bolt, and other rigid connection modes may also be employed, for example, the leaf spring 21 may be welded to the bottom of the housing 1, and the second arm 232 may be welded to the top of the leaf spring 21.

It is found by the inventors in practical application that, when the second arm 232 is supported by a common spring, because the size and elastic stiffness of the spring are both small, the support to the second arm 232 by the spring will not be stable enough, and the spring will be very sensitive to vibration. When the vibration of the structure to be measured is transmitted to the housing 1 and then transmitted to the second arm 232 via the spring, not only the second arm 232 and the mass 22 will vibrate up and down along z direction, but also lateral vibration interference will occur in the horizontal plane. That is, the mass 22 not only generates a displacement Δx_1 in z direction, but also generates a lateral displacement Δx_h due to lateral vibration interference. Thus the strain of the grating measuring device 241 will be a result of the combined action of Δx_1 and Δx_h. The strain generated on on the grating measuring device 241 will change its light parameter, thus a deviation will occur between the acceleration demodulated from the light parameter and the actual acceleration generated by the z direction vibration, which causes an inaccurate computation of the vibration acceleration in z direction.

Therefore, in this embodiment, a leaf spring 21 is employed to support the second arm 232. The leaf spring 21 is also referred to as a plate spring, which is a plate-shaped elastic member formed by stacking at least one layer of spring steel. The leaf spring 21 may be provided with large length and width, as well as a large elastic stiffness. The leaf spring 21 can provide a more stable support to the second arm 232 and have a stronger lateral vibration interference resistance. Because the leaf spring 21 is directly connected to the second arm 232, the length L_{bh} of the leaf spring 21 should be less than the length L_2 of the second arm 232, thus the obstruction of the leaf spring 21 to the rotating member 233 may be eliminated, and it may be guaranteed that the rotating member 233 can freely drive the first arm 231 to rotate under the drive of the vibration of the second arm 232, and the strain of the grating can conform to the actual vibration, thereby ensuring the measurement accuracy of the grating measuring device 241.

Preferably, the length L_{bh} of the leaf spring 21 is 4/5 of the length L_2 of the second arm 232, that is, a length difference of scale 0.2 is reserved. By such a design, not only flexible rotation of the rotating member 233 can be guaranteed, but also the leaf spring 21 and the second arm 232 can have a large contact area, so that the affect of interference vibration can be lowered greatly. The leaf spring 21 may be provided at any location on the bottom of the second arm 232, for example, at a location on the bottom of the second arm 232 near the mass 22. Preferably, in this embodiment, the leaf spring 21 is provided at the center of the bottom of the second arm 232. By such a configuration, the leaf spring 21 can more stably support the second arm 232, and the leaf spring 21 can more uniformly transmit the vibration, so that the lateral vibration interference to the second arm 232 and the mass 22 can be further lowered, and the accuracy of acceleration measurement of vibration in z direction can be increased. In Embodiment 1, the length L_2 of the second arm 232 is the distance from the axle center C of the rotating member 233 to the mass 22 (end B).

When vibration occurs in the environment of a structure to be measured, an acting force will be applied on the sensor by the structure to be measured, and the acting force will be transmitted to the second arm 232 via the housing 1 and the leaf spring 21 sequentially. The second arm 232 has a certain mass, and it vibrates because of inertia. The vibration of the second arm 232 will drive the first arm 231 to generate a certain angular displacement around the rotating member 233, so that a strain will be generated to the grating measuring device 241 due to being stretched, so that the light parameter of the grating measuring device 241 will drift, thus the computing unit 3 may demodulate the acceleration of the structure to be measured according to the drift of the light parameter.

A component such as a bearing and a rotating shaft, etc., may be employed as the rotating member 233. In this embodiment, the bearing is preferred. The bearing is configured to connect and support a mechanical rotating body (that is, the beam 23). It can lower the frictional coefficient in the rotation of the first arm 231, ensure a revolving precision of the first arm 231 and increase the mechanical sensitivity of the beam 23. Moreover, it is favorable for lowering the loss of vibration during transfer, thereby improving the measurement precision of the sensor.

Fig.3 shows an equivalent force model of the sensor in Embodiment 1. The displacement generated by the second arm 232 is Δx_1, the displacement generated by the grating in the grating measuring device is Δx_2, L_1 is the length of the first arm 231, and L_2 is the length of the second arm 232, wherein the length L_1 of the first arm 231 is less than the length L_2 of the second arm 232, that is, the first arm 231 is a short arm, and the second arm 232 is a long arm. By such a design, the displacement Δx_1 generated by the second arm 232 may be less than the displacement Δx_2 generated by the grating, that is, the deformation of the grating measuring device 241 due to stretching may be reduced, which is equivalent to signal reduction. Thus the sensor may be buried inside a structure to be measured with strong vibration, for example, railway and tunnel, etc., so that the deformation of grating in the grating measuring device 241 may be limited, and the grating may be prevented from being broken due to excessive stretching or bending.

As shown in Fig.4, an optical fiber grating acceleration sensor according to Embodiment 2 of the invention includes a housing 1, a computing unit 3, and a sensing component 2 provided inside the housing 1. The housing 1 is configured to encapsulate the sensing component 2, and the sensing component 2 is configured to convert the vibration of the structure to be measured into the change of grating strain. The light parameter of the grating on which strain occurs will also change. The light parameter may be wavelength, frequency, phase or polarization, etc. For different types of gratings, the light parameter sensitive to strain may be different, and Fiber Bragg Grating (FBG) may be selected as the grating. The computing unit 3 may be an external demodulation device, and it is configured to demodulate the light parameter detected so as to obtain the acceleration of the structure to be measured.

In Fig.4, the sensing component 2 includes a leaf spring 21 connected to the bottom of the housing 1, a mass 22 connected to the top of the leaf spring 21, a beam 23 connected to the top of the mass 22, and an optical fiber measuring device 24 connected to the beam 23, wherein the optical fiber measuring device 24 is suspended above the beam 23.

The optical fiber measuring device 24 includes a grating measuring device 241 of which a light parameter changes when a structure to be measured vibrates, and an optical fiber 242 connected respectively to the grating measuring device 241 and the computing unit 3. In other possible implementation modes, the grating is engraved into the fiber core of the optical fiber 242. The beam 23 includes a first arm 231 and a second arm 232, wherein the first arm 231 and the second arm 232 are connected via a rotating member 233 fixed on the sidewall of the housing 1. One end of the second arm 232 far from the rotating member 233 (that is, end B) is connected to the top of the mass 22, and the end A of the first arm 231 is connected to the grating measuring device 241. If the mode that the grating is engraved into the optical fiber 242 is employed, the end A of the first arm 231 will be directly connected with the optical fiber 242. In such a case, the optical fiber 242 and the grating have the same deformation.

The housing 1, the leaf spring 21, the mass 22 and the second arm 232 may be connected as a whole via a bolt 25, so that the housing 1, the leaf spring 21, the mass 22 and the beam 23 form a vibration sensing and transmitting structure in z direction. The vibration sensing and transmitting structure employs the leaf spring 21 as a support base and realizes rigid connection via a bolt 25, so that the vibration sensing and transmitting structure may be prevented from generating non-z direction displacement due to an external vibration, the measurement precision of acceleration may be increased, and structure stability may be ensured. Additionally, in such a bolt connection mode, it is convenient for removing and replacing a component. The housing 1, the leaf spring 21, the mass 22 and the second arm 232 are not limited to being connected via a bolt, and other rigid connection modes may also be employed, for example, the leaf spring 21 may be welded to the bottom of the housing 1, the mass 22 may be welded to the top of the leaf spring 21, and one end of the second arm 232 far from the rotating member 233 (that is, end B) may be welded to the top of the mass 22.

The leaf spring 21, the mass 22 and the second arm 232 are connected sequentially from the bottom to the top along z direction. After a force is applied on the sensor buried inside the structure to be measured, vibration (resonance) is generated on the leaf spring-mass 21, 22 structure. The leaf spring 21 has a lateral vibration interference resistance, so that the lateral vibration interference to the mass 22 directly connected with the leaf spring 21 may be lowered, and the mass 22 almost vibrates up and down along z direction. In comparison with the structure of Embodiment 1 in which the leaf spring 21 and the second arm 232 are connected directly, in Embodiment 2, after the remaining lateral vibration of the leaf spring 21 is transmitted to the mass 22, a certain degree of attenuation will be generated. Thus when the mass 22 transmits the vibration to the second arm 232 again, the lateral vibration interference to the second arm 232 will be further lowered, that is, the lateral vibration interference attenuates gradually from the bottom to the top, and the strain of the grating is approximately the action result of the displacement Δx_1 of the mass 22 in z direction, so that the accuracy and reliability of the acceleration measurement in z direction may be improved, and at the same time, the leaf spring 21 can also improve the sensitivity and frequency response range of the sensor.

Because the second arm 232 and the leaf spring 21 are connected via the mass 22, the leaf spring 21 will not affect the rotation of the rotating member 233, thus the size of the leaf spring 21 may not be specifically defined. The larger the size of the leaf spring 21 is, the larger the stiffness will be, and the more stable the supporting performance will be, and hence the stronger the lateral vibration interference resistance will be. The length of the leaf spring 21 is less than or equal to that of the housing 1, the width of the leaf spring 21 is less than or equal to that of the housing 1, the height of the leaf spring 21 depends on the number of spring steel layers stacked, and the height of the leaf spring 21 is less than that of the housing 1. The length and width of the housing 1 are the inside dimensions of the housing 1, that is, the external dimensions with the thickness of the housing 1 being subtracted.

Preferably, in Embodiment 2, the width of the leaf spring 21 is equal to that of the housing 1, and the length of the leaf spring 21 is equal to that of the housing 1, which is equivalent to that the housing 1 is used for limiting the leaf spring 21, so that the leaf spring 21 can truly vibrate in z direction only, thereby limiting the freedom of movement of the leaf spring 21, the mass 22 and the second arm 232. By such a size design, the lateral interference to the mass 22 may be totally eliminated, thus the deviation of acceleration measurement may be further lowered, and the measurement precision of unidirectional vibration acceleration of the sensor may be increased.

Components such as a bearing and a rotating shaft, etc., may be employed as the rotating member 233. In this embodiment, the bearing is preferred. The bearing is configured to connect and support a mechanical rotating body (that is, the beam 23), and it can lower the frictional coefficient in the rotation of the first arm 231, ensure a revolving precision of the first arm 231 and increase the mechanical sensitivity of the beam 23. Moreover, it is favorable for lowering the loss of vibration during transmission, thereby improving the measurement precision of the sensor.

The beam 23 employs an L-shaped beam, so that the beam 23 is equivalent to a lever mechanism. The rotating member 233 is equivalent to a lever fulcrum, so that a dynamic balance mechanism is established inside the housing 1 for vibration transmission. As shown in Fig.4, the second arm 232 is vertically connected to the mass 22, so that the second arm 232 keeps in a horizontal position, that is, the second arm 232 is a fixed arm, thus the second arm 232 will suffer vibration in z direction together with the mass 22, the inertial force of vibration may function as a driving force of the rotating member 233, so that the rotating member 233 drives the first arm 231 to generate a certain angular displacement. That is, the first arm 231 is a power arm for stretching the grating measuring device 241. When the optical fiber measuring device 24 is suspended along a direction parallel to the second arm 232, deformation in a horizontal direction occurs to the grating in the grating measuring device 241, that is, a leftward tension strain is generated on the grating in Fig.4, so that the displacement Δx_1 of the mass 22 in z direction is converted into a displacement Δx_2 of the grating in horizontal direction, and Δx_2 makes the light parameter of the grating measuring device 241 drift, and acceleration of the structure to be measured may be obtained by demodulating the light parameter

Fig.5 is an equivalent force model of the sensor structure shown in Fig.4. It is given that the elastic coefficient of the leaf spring 21 is k_1, the elastic modulus of the optical fiber 242 is E_2, the lateral area of the optical fiber

242 is A_2, and the length between fixed points A and M of the optical fiber 242 is L, then the elastic coefficient of the optical fiber 242 will be: $k_2 = E_2 \cdot A_2 / L$; the resultant force applied to the sensor is F, the displacement of the mass 22 in z direction is Δx_1, then the total stiffness k of the system is: $k = F / \Delta x_1$, and the resultant force F may be resolved into a component force F_1 acting on the leaf spring 21 and a component force F_2 acting on the second arm 232 by the mass 22, wherein F_1 makes the leaf spring 21 and the mass 22 to generate a displacement Δx_1, and after F_2 transmitted by the mass 22 is acted on the second arm 232, under the action of the L-shaped beam, F_T is generated in the optical fiber 242, wherein F_T makes the grating measuring device 241 generate a displacement Δx_2, that is, F_T is a component of F_2. Because the displacement of the grating measuring device 241 and the mass 22 is small, it may be regarded that F_1 and F_T is always vertical to the action line, then:

$$F_1 = k_1 \Delta x_1 \qquad (1)$$

$$F_T = k_2 \Delta x_2 \qquad (2)$$

According to lever principle and the geometric property of an L-shaped beam, it may be obtained that:

$$F_2 L_2 = F_T L_1 \qquad (3)$$

$$\frac{\Delta x_1}{L_2} = \frac{\Delta x_2}{L_1} \qquad (4)$$

Wherein, L_1 is the length of the first arm 231, L_2 is the length of the second arm 232. The length L_2 of the second arm 232 is the distance between the axle center C of the rotating member 233 and the central axis L_C of the mass 22 in x direction, the length L_2 of the second arm 232 is greater than zero, thus a space in x direction exists between the mass 22 and the rotating member 233, and the mass 22 will not affect the rotation of the rotating member 233. By subsequent computation, it may be obtained that:

$$\Delta x_2 = \frac{L_1}{L_2} \Delta x_1 \qquad (5)$$

$$F_2 = \frac{L_1}{L_2} F_T = \frac{L_1}{L_2} k_2 \Delta x_2 \qquad (6)$$

It may be known from formula (5) that, when the length L_1 of the first arm 231 is greater than the length L_2 of the second arm 232, that is, when the first arm 231 is a long arm and the second arm 232 is a short arm, the L-shaped beam may function to amplifying a signal, thereby improving the measurement precision of the sensor. The resultant force $F = F_1 + F_2$, then it may be obtained that:

$$k\Delta x_1 = k_1 \Delta x_1 + \frac{L_1}{L_2} k_2 \Delta x_2 \qquad (7)$$

From formula (7), the total stiffness k of the sensor may be obtained as:

$$\mathrm{k} = k_1 + k_2 (\frac{L_1}{L_2})^2 \qquad (8)$$

It may be known from formula (8) that, the total stiffness k of the sensor is related to the elastic coefficient of the leaf spring 21 and the optical fiber 242 and the arm length of the L-shaped beam. In this embodiment, Fiber Bragg Grating (FBG) is selected as the grating in the grating measuring device 241. When no affect of temperature is considered, the central wavelength of FBG has a linear relationship with strain. It is given that the strain of FBG is ε, the offset of the leaf spring 21 is ρ, wherein $\rho = F / k = ma / k$, the mass of the mass 22 is m, with a unit of Kg, and acceleration of the structure to be measured is a, then:

$$\varepsilon = \frac{L_1}{L_2} \rho = \frac{L_1}{L_2} \frac{ma}{k} \qquad (9)$$

Fiber Bragg Grating (FBG) has a strain sensing feature of:

$$\frac{\Delta\lambda}{\lambda_B} = (1-P_e)\varepsilon \qquad (10)$$

Wherein, $\Delta\lambda$ is wavelength drift of the grating measuring device 241, λ_B is initial wavelength of the grating measuring device 241, P_e is effective elastooptical coefficient of the optical fiber 242, which generally has a value of 0.22, then a relationship between acceleration a of the structure to be measured and wavelength drift $\Delta\lambda$ may be obtained as:

$$\Delta\lambda = \lambda_B(1-P_e)\varepsilon = \lambda_B(1-P_e)\frac{L_1}{L_2}\frac{ma}{k} \qquad (11)$$

After receiving a detection signal from the grating measuring device 241, the computing unit 3 may compute acceleration a of the structure to be measured according to the wavelength drift $\Delta\lambda$ via formula (11), wherein the acceleration is the acceleration corresponding to the vibration signal in z direction.

The sensitivity S of the sensor is the wavelength drift on unit acceleration, then the sensitivity S will be shown by formula (12):

$$S = \frac{\Delta\lambda}{a} = \frac{\lambda_B(1-P_e)\frac{L_1}{L_2}\frac{ma}{k}}{a} = \lambda_B(1-P_e)\frac{L_1}{L_2}\frac{m}{k_1+k_2(\frac{L_1}{L_2})^2} \qquad (12)$$

The resonance frequency ω_n of the sensor is shown by formula (13):

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{k_1L_2^2+k_2L_1^2}{mL_2^2}} \qquad (13)$$

In this embodiment, the length L_1 of the first arm 231 is greater than the length L_2 of the second arm 232, that is, the first arm 231 is a long arm, the second arm 232 is a short arm. The sensor is buried inside a structure to be measured with weak external vibration. For example, it is applied to the microseism monitoring of an ore structure, and an optical fiber grating acceleration sensor is buried inside an ore structure to which a microseism activity occurs. It may be known from the above formula (5) that, when the length L_1 of the first arm 231 is greater than the length L_2 of the second arm 232, the L-shaped beam may function to amplify a signal, thus an external weak vibration signal may be amplified inside the sensor. Because lateral vibration interference is eliminated by the sensor of Embodiment 2, it is the vibration signal in z direction that is amplified, rather than the interference vibration signal in non-z direction. Therefore, for a structure to be measured with microseism, the measurement precision of unidirectional vibration acceleration may also be improved.

It may be known from formula (12) and formula (13) that, when the length L_1 of the first arm 231 is greater than the length L_2 of the second arm 232, the sensitivity S and the resonance frequency ω_n of the sensor can also be increased, so that the performance of the sensor can be further improved. Additionally, in the invention, the optical fiber measuring device 24 is suspended inside the housing 1, thus no grating chirp phenomenon or reflected wave multimodal phenomenon will appear, it has a good lateral interference resistance, and the measurement precision of unidirectional vibration acceleration may be improved.

Reference may be made to each other for the same part in Embodiment 1 and Embodiment 2.

Other embodiments of the invention will readily occur to those skilled in the art after reading and practicing the invention disclosed herein. The invention intends to cover any variations, usages or adaptability changes, which conform to the general principles of the invention and include common sense or conventional technical means of the art that are not disclosed n the invention. The illustrations and embodiments are exemplary only, and the true scope and spirit of the invention are defined by the appended claims.

It should be understood that, the invention is not limited to the exact structures described above and shown in the drawings, and various modifications and variations may be made without departing from the scope thereof. The scope of the invention is merely limited by the claims appended.

CONCLUSIES

1. Een optische vezelrooster versnellingssensor, omvattende: een behuizing (1), een sensorcomponent (2) voorzien in de behuizing (1) en een rekeneenheid (3);

waarbij de sensorcomponent (2) omvat:

een bladveer (21) verbonden met een bodem van de behuizing (1), welke een plaatvormig elastisch deel is welke gevormd is door het stapelen van ten minste één laag van verenstaal;

een massa (22) verbonden met een bovenkant van de bladveer (21);

een balk (23), omvattende een eerste arm (231) en een tweede arm (232), waarbij de eerste arm (231) en de tweede arm (232) zijn verbonden via een roterend deel (233), waarbij het roterende deel (233) is bevestigd op een zijwand van de behuizing (1), en waarbij een einde van de tweede arm (232) ver van het roterende deel (233) is verbonden met een bovenkant van de massa (22);

een optische vezel meetinrichting (24) opgehangen boven de balk (23), omvattende een roostermeetinrichting (241) en een optische vezel (242) respectievelijk verbonden met de roostermeetinrichting (241) en de rekeneenheid (3);

waarbij de rekeneenheid (3) is geconfigureerd om een versnelling te berekenen van een te meten structuur volgens een afwijking van een lichtparameter van de roostermeetinrichting (241).

2. De optische vezelrooster versnellingssensor volgens conclusie 1, waarbij de lengte van de eerste arm (231) groter is dan die van de tweede arm (232).

3. De optische vezelrooster versnellingssensor volgens conclusie 1 of 2, waarbij de rekeneenheid (3) een versnelling van een te meten structuur berekent volgens de onderstaande formule:

$$\Delta\lambda = \lambda_B\left(1-P_e\right)\frac{L_1}{L_2}\frac{ma}{k}$$

waarbij $\Delta\lambda$ een golflengte afwijking van de roostermeetinrichting (241) is, λ_B een initiele centrale golflenfte van de roostermeetinrichting (241) is, P_e een effectieve elasto-optische coëfficiënt van de optische vezel (242) is, m een massa van de massa (22) is met een eenheid van Kg, k een totale stijfheid van de optische vezelrooster versnellingssensor is, a een versnelling van een te meten structuur is, L_1 een lengte van de eerste arm (231) is, en L_2 een lengte van de tweede arm (232) is;

waarbij de totale stijfheid k van de optische vezelrooster versnellingssensor wordt gegeven door:

$$\mathrm{k} = k_1 + k_2\left(\frac{L_1}{L_2}\right)^2$$

waarbij k_1 een elastische coëfficiënt van de bladveer (21) is, en k_2 is een elastische coëfficiënt van de optische vezel (242).

4. De optische vezelrooster versnellingssensor volgens conclusie 1, waarbij de balk (23) een L-vormige balk hanteert, en de tweede arm (232) parallel is aan de optische vezelmeetinrichting (24).

5. De optische vezelrooster versnellingssensor volgens conclusie 1, waarbij het roterende deel (233) een lagering gebruikt.

6. De optische vezelrooster versnellingssensor volgens conclusie 1, waarbij een breedte van de bladveer (21) gelijk is aan die van de behuizing (1), en een lengte van de bladveer (21) gelijk is aan die van de behuizing (1).

7. De optische vezelrooster versnellingssensor volgens conclusie 1, waarbij de behuizing (1), de bladveer (21), de massa (22) en de tweede arm (232) als een geheel zijn verbonden via een bout (25).

8. Een optische vezelrooster versnellingssensor, omvattende: een behuizing (1), een sensorcomponent (2) voorzien in de behuizing (1) en een rekeneenheid (3);

waarbij de sensorcomponent (2) omvat:

een bladveer (21) verbonden met een bodem van de behuizing (1), welke een plaatvormig elastisch deel is welke gevormd is door het stapelen van ten minste één laag van verenstaal;

een balk (23), omvattende een eerste arm (231) en een tweede arm (232), waarbij de eerste arm (231) en de tweede arm (232) zijn verbonden via een roterend deel (233), waarbij het roterende deel (233) is bevestigd op een zijwand van de behuizing (1), en waarbij de tweede arm (232) is verbonden met een bovenkant van de bladveer (21), en waarbij een lengte van de bladveer (21) en een lengte van de eerste arm (231) beide kleiner zijn dan die van de tweede arm (232); en

een optische vezel meetinrichting (24) opgehangen boven de balk (23), omvattende een roostermeetinrichting (241) en een optische vezel (242) respectievelijk verbonden met de roostermeetinrichting (241) en de rekeneenheid (3); en

waarbij de rekeneenheid (3) is geconfigureerd om een versnelling te berekenen van een te meten structuur volgens een afwijking van een lichtparameter van de roostermeetinrichting (241).

9. De optische vezelrooster versnellingssensor volgens conclusie 1, waarbij een lengte van de bladveer (21) 4/5 is van die van de tweede arm (232).

10. De optische vezelrooster versnellingssensor volgens conclusie 1, waarbij de bladveer (21) is voorzien in het midden van de onderkant van de tweede arm (232).

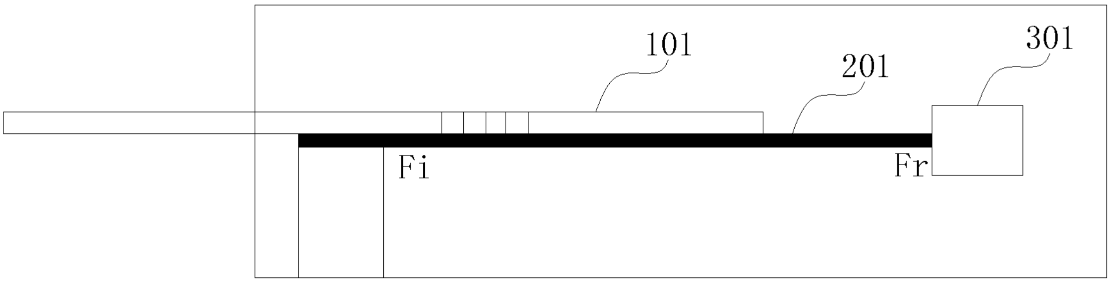
101
201
301
Fi
Fr

Fig. 1

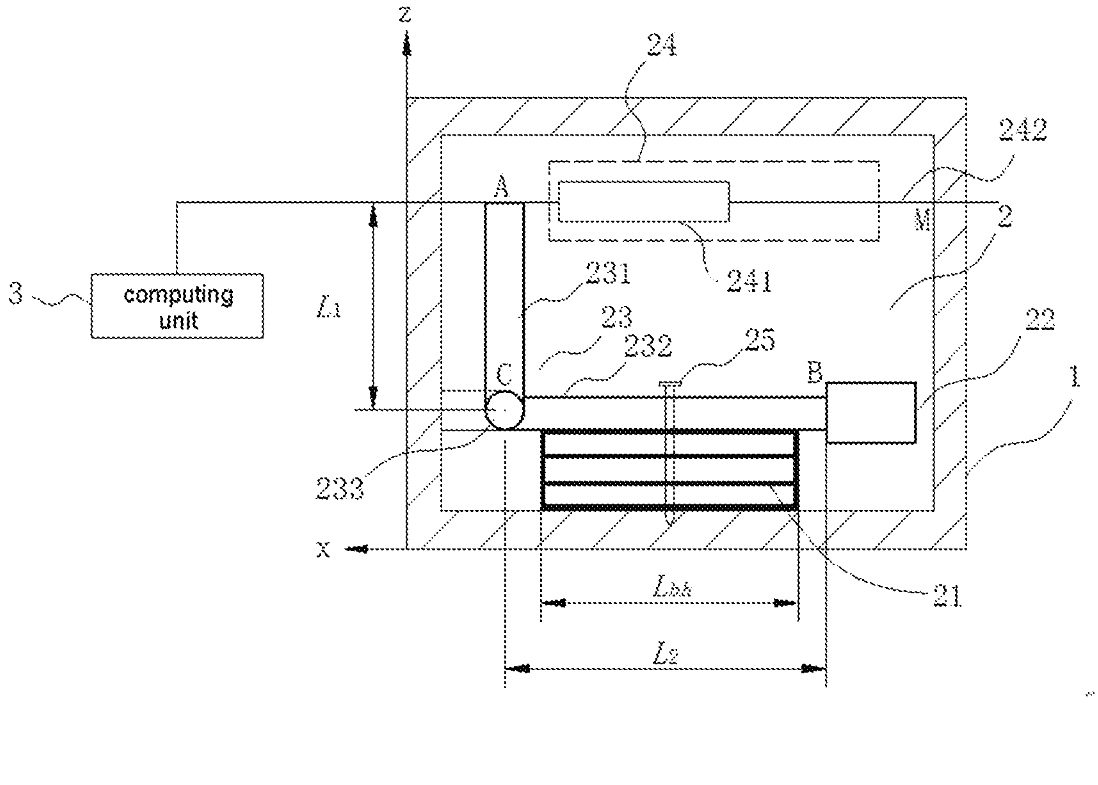
z
24
242
A
M
2
3
computing unit
231
L_1
23
232
25
22
B
C
1
233
x
L_{bb}
21
L_2

Fig. 2

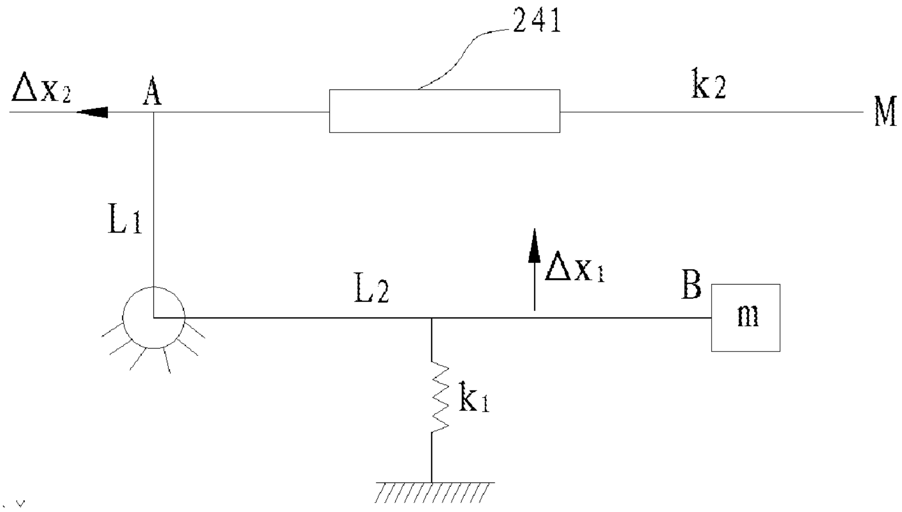

Fig. 3

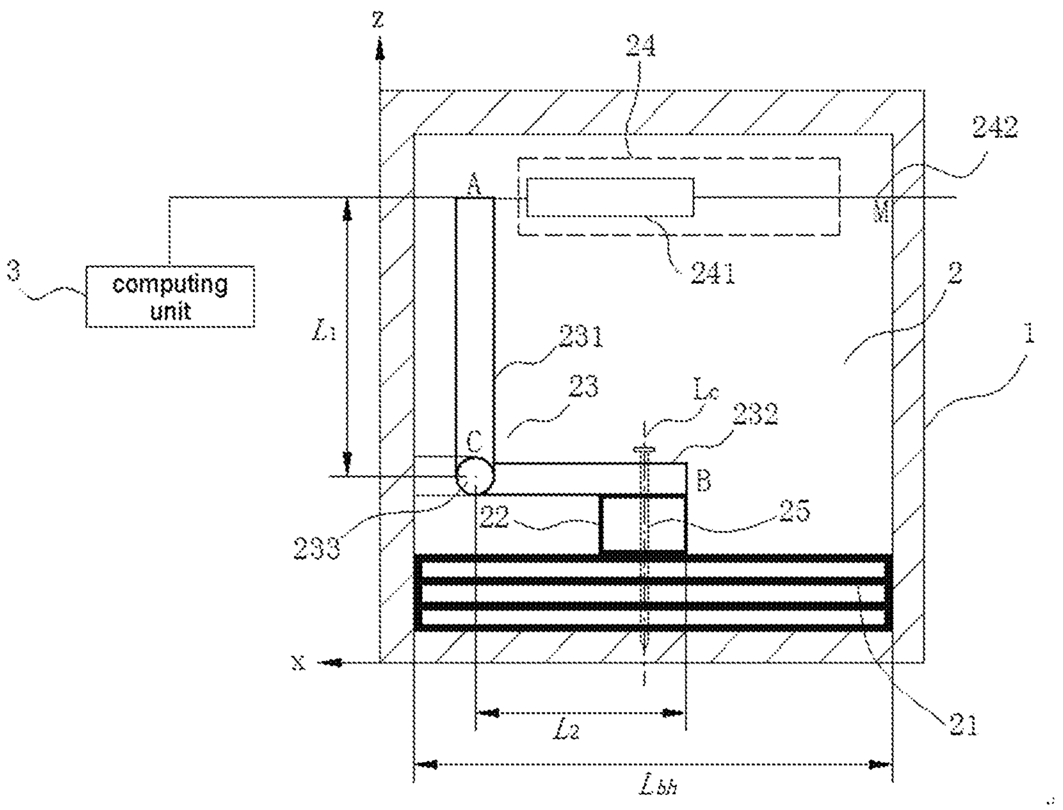
z
24
242
A
M
3
computing unit
241
2
L_1
231
1
23
L_c
232
C
B
22
25
233
x
21
L_2
L_{bh}

Fig. 4

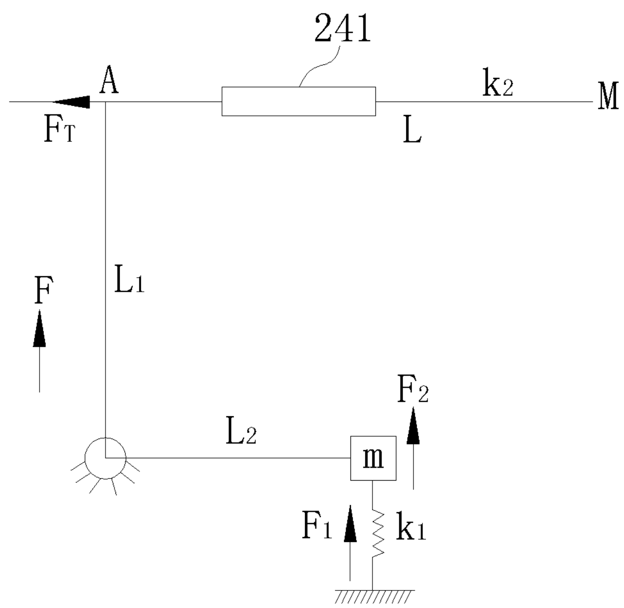

Fig. 5

Rijksdienst voor Ondernemend Nederland

OCTROOIAANVRAAG NR.:
NO 140647
NL 2024979

ONDERZOEKSRAPPORT

BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK

RELEVANTE LITERATUUR

Categorie[1]	Literatuur met, voor zover nodig, aanduiding van speciaal van belang zijnde tekstgedeelten of figuren.	Van belang voor conclusie(s) nr:	Classificatie (IPC)
Y	US 2015/135832 A1 (BLUMENKRANZ STEPHEN J [US] ET AL) 21 mei 2015 (2015-05-21) * bladzijde 1, alinea 11; figuur 1F * -----	1-10	INV. G01P15/093 G01D5/26
Y	DE 199 39 583 A1 (SIEMENS AG [DE]) 14 september 2000 (2000-09-14) * het gehele document * -----	8-10	ADD. G01P15/08
Y	CN 104 515 587 A (NUCTECH CO LTD) 15 april 2015 (2015-04-15) * het gehele document * -----	8-10	
Y	CN 107 946 887 A (CHANGZHOU INST TECHNOLOGY) 20 april 2018 (2018-04-20) * het gehele document * -----	1-4,6-10	
Y	CN 108 982 916 A (UNIV SHIJIAZHUANG TIEDAO) 11 december 2018 (2018-12-11) * het gehele document * -----	5	
A	WO 2016/182431 A1 (FUGRO TECH BV [NL]) 17 november 2016 (2016-11-17) * bladzijde 14, regel 26 - bladzijde 15, regel 23; figuren 6, 7 * -----	1-10	Onderzochte gebieden van de techniek G01P G01D G01L

Indien gewijzigde conclusies zijn ingediend, heeft dit rapport betrekking op de conclusies ingediend op:

Plaats van onderzoek:	Datum waarop het onderzoek werd voltooid:	Bevoegd ambtenaar:
München	12 oktober 2020	Springer, Oliver

[1] CATEGORIE VAN DE VERMELDE LITERATUUR

X: de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur
Y: de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht
A: niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft
O: niet-schriftelijke stand van de techniek
P: tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

T: na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding
E: eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven
D: in de octrooiaanvrage vermeld
L: om andere redenen vermelde literatuur
&: lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

AANHANGSEL BEHORENDE BIJ HET RAPPORT BETREFFENDE HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK, UITGEVOERD IN DE OCTROOIAANVRAGE NR.

NO 140647
NL 2024979

Het aanhangsel bevat een opgave van elders gepubliceerde octrooiaanvragen of octrooien (zogenaamde leden van dezelfde octrooifamilie), die overeenkomen met octrooischriften genoemd in het rapport.
De opgave is samengesteld aan de hand van gegevens uit het computerbestand van het Europees Octrooibureau per
De juistheid en volledigheid van deze opgave wordt noch door het Europees Octrooibureau, noch door het Bureau voor de Industriële eigendom gegarandeerd; de gegevens worden verstrekt voor informatiedoeleinden.

12-10-2020

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
US 2015135832 A1	21-05-2015	US 2015135832 A1	21-05-2015
		US 2018031600 A1	01-02-2018
		US 2019383851 A1	19-12-2019
DE 19939583 A1	14-09-2000	CN 1341208 A	20-03-2002
		DE 19939583 A1	14-09-2000
		EP 1157263 A1	28-11-2001
		JP 2002538426 A	12-11-2002
		KR 20010108257 A	07-12-2001
		PL 350130 A1	04-11-2002
		WO 0050864 A1	31-08-2000
CN 104515587 A	15-04-2015	GEEN	
CN 107946887 A	20-04-2018	GEEN	
CN 108982916 A	11-12-2018	GEEN	
WO 2016182431 A1	17-11-2016	EP 3295185 A1	21-03-2018
		US 2018156643 A1	07-06-2018
		WO 2016182431 A1	17-11-2016

SCHRIFTELIJKE OPINIE

DOSSIER NUMMER	INDIENINGSDATUM	VOORRANGSDATUM	AANVRAAGNUMMER
NO140647	24.02.2020		NL2024979
CLASSIFICATIE INV. G01P15/093 G01D5/26 ADD. G01P15/08			
AANVRAGER Laser Institute of Shandong Academy of Science			

Deze schriftelijke opinie bevat een toelichting op de volgende onderdelen:

- ☒ Onderdeel I Basis van de schriftelijke opinie
- ☐ Onderdeel II Voorrang
- ☐ Onderdeel III Vaststelling nieuwheid, inventiviteit en industriële toepasbaarheid niet mogelijk
- ☐ Onderdeel IV De aanvraag heeft betrekking op meer dan één uitvinding
- ☒ Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid
- ☐ Onderdeel VI Andere geciteerde documenten
- ☒ Onderdeel VII Overige gebreken
- ☒ Onderdeel VIII Overige opmerkingen

	DE BEVOEGDE AMBTENAAR
	Springer, Oliver

Aanvraag nr.:

SCHRIFTELIJKE OPINIE

NL2024979

Onderdeel I Basis van de Schriftelijke Opinie

1. Deze schriftelijke opinie is opgesteld op basis van de meest recente conclusies ingediend voor aanvang van het onderzoek.

2. Met betrekking tot **nucleotide en/of aminozuur sequenties** die genoemd worden in de aanvraag en relevant zijn voor de uitvinding zoals beschreven in de conclusies, is dit onderzoek gedaan op basis van:

   a. type materiaal:

   ☐ sequentie opsomming

   ☐ tabel met betrekking tot de sequentie lijst

   b. vorm van het materiaal:

   ☐ op papier

   ☐ in elektronische vorm

   c. moment van indiening/aanlevering:

   ☐ opgenomen in de aanvraag zoals ingediend

   ☐ samen met de aanvraag elektronisch ingediend

   ☐ later aangeleverd voor het onderzoek

3. ☐ In geval er meer dan één versie of kopie van een sequentie opsomming of tabel met betrekking op een sequentie is ingediend of aangeleverd, zijn de benodigde verklaringen ingediend dat de informatie in de latere of additionele kopieën identiek is aan de aanvraag zoals ingediend of niet meer informatie bevatten dan de aanvraag zoals oorspronkelijk werd ingediend.

4. Overige opmerkingen:

Aanvraag nr.:

SCHRIFTELIJKE OPINIE

NL2024979

Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid

1. Verklaring

Nieuwheid	Ja:	Conclusies	1-10
	Nee:	Conclusies	
Inventiviteit	Ja:	Conclusies	
	Nee:	Conclusies	1-10
Industriële toepasbaarheid	Ja:	Conclusies	1-10
	Nee:	Conclusies	

2. Citaties en toelichting:

Zie aparte bladzijde

Onderdeel VII Overige gebreken

De volgende gebreken in de vorm of inhoud van de aanvraag zijn opgemerkt:

Zie aparte bladzijde

Onderdeel VIII Overige opmerkingen

De volgende opmerkingen met betrekking tot de duidelijkheid van de conclusies, beschrijving, en figuren, of met betrekking tot de vraag of de conclusies nawerkbaar zijn, worden gemaakt:

Zie aparte bladzijde

Item V:

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 **Technical Field:**

The invention relates to an optical fiber grating acceleration sensor.

2 **Independent Claims:**

Claims 1 and 8 (apparatus).

3 **State of the Art:**

Reference is made to the following documents:

D1: US 2015/135832 A1 (BLUMENKRANZ STEPHEN J [US] ET AL) 21 May 2015

D2: DE 199 39 583 A1 (SIEMENS AG [DE]) 14 September 2000

D3: CN 104 515 587 A (NUCTECH CO LTD) 15 April 2015

D4: CN 107 946 887 A (CHANGZHOU INST TECHNOLOGY) 20 April 2018

D5: CN 108 982 916 A (UNIV SHIJIAZHUANG TIEDAO) 11 December 2018

D6: WO 2016/182431 A1 (FUGRO TECH BV [NL]) 17 November 2016

4 **Novelty and Inventive Step**

The subject-matter of claims 1 to 10 is lacking an inventive step in respect of the prior art:

4.1 **Independent Claim 1:**

Document **D1**, which is considered as closest prior art for the subject-matter of independent claim 1, shows (see e.g. page 1, paragraph 11, and figure 1F, and the references in parentheses applying to this document) an optical fiber grating acceleration sensor (140), comprising:

I. a housing and a sensing component (143, 144) provided in the housing (see e.g. p. 1, par. 11, and fig. 1F), wherein the sensing component (143, 144) comprises:

II. a spring connected to a bottom of the housing (see e.g. p. 1, par. 11, and fig. 1F);

III. a mass (141) connected to a top of the spring (see e.g. p. 1, par. 11, and fig. 1F);

IV. a beam, comprising a first arm and second arm (142), wherein the first arm and the second arm (142) are connected via a rotating member, the rotating member is fixed on a sidewall of the housing, and one end of the second arm (142) far from the rotating member is connected to a top of the mass (141) (see e.g. p. 1, par. 11, and fig. 1F);

V. an optical fiber measuring device (143, 144) suspended above the beam, comprising a grating measuring device (241), and an optical fiber (242) connected respectively to the grating measuring device (241) (see e.g. p. 1, par. 11, and fig. 1F).

The subject-matter of independent claim 1 differs from the closest prior art in, that the leaf spring is a plate-shaped elastic member formed by stacking at least one layer of spring steel and that the sensor further comprises a computing unit, wherein the computing unit is configured to compute an acceleration of a structure to be measured according to a drift of a light parameter of the grating measuring device.

A computing unit for calculating the acceleration according to the change of the light parameter is not disclosed in document **D1** but is implied as it is necessary for the evaluation of the measurement signals.

Thus, the remaining difference of a certain type of spring solves the objective technical problem of providing a leaf spring with optimum spring characteristics.

This feature is described in document **D4** (see e.g. page 5, paragraph 30, p. 7-8, par. 30, and figs. 4, 5) as providing the same advantages as in the present application. The skilled person would therefore regard it as a normal option to include this feature in the accelerometer described in document **D1** in order to solve the problem posed.

Thus, the subject-matter of independent claim 8 is not inventive.

4.2 **Independent Claim 8:**

Document **D2**, which is considered as closest prior art for the subject-matter of independent claim 8, shows (see the whole document and the references in parentheses applying to this document) an optical fiber grating acceleration sensor (see the abstract), comprising:

I. a housing (3), a sensing component (1, 11) provided in the housing (see e.g. column 8, line 56, to col. 9, l. 27, and fig. 6);

II. wherein the sensing component comprises:

III. a leaf spring (321) connected to a bottom of the housing (see e.g. col. 6, l. 65, to col. 7, l. 5, and fig. 6);

IV. a beam (20), comprising a first arm and second arm (250), wherein the first arm and the second arm are connected via a rotating member (21), the rotating member is fixed on a sidewall of the housing (see e.g. col. 7, l. 6-10, and fig. 6),

V. the second arm (250) is connect to a top of the leaf spring (321), and a length of the leaf spring (321) and a length of the first arm are both less than that of the second arm (250) (see e.g. col. 6, l. 65, to col. 7, l. 10, and fig. 6); and

VI. an optical fiber measuring device (1, 11) suspended above the beam (20), comprising a grating measuring device (11), and an optical fiber (1) connected respectively to the grating measuring device (11) (see e.g. col. 9, l. 3-9, and fig. 6).

The subject-matter of independent claim 1 differs from the closest prior art **D2** in, that the leaf spring is a plate-shaped elastic member formed by stacking at least one layer of spring steel and that the sensor further comprises a computing unit, wherein the computing unit is configured to compute an acceleration of a structure to be measured according to a drift of a light parameter of the grating measuring device.

Document **D3** shows a quite similar optical fiber grating acceleration sensor (see the whole document) and could therefore also serve as closest prior art.

A computing unit for calculating the acceleration according to the change of the light parameter is not disclosed in document **D2** nor **D3** but is implied as it is necessary for the evaluation of the measurement signals.

Thus, the remaining difference of a certain type of spring solves the objective technical problem of providing a leaf spring with optimum spring characteristics.

This feature is described in document **D4** (see e.g. page 5, paragraph 30, p. 7-8, par. 30, and figs. 4, 5) as providing the same advantages as in the present application. The skilled person would therefore regard it as a normal option to include this feature in the accelerometer described in document **D2** or **D3** in order to solve the problem posed.

Thus, the subject-matter of independent claim 8 is not inventive.

4.3 **Dependent claims 2 to 7, 9 and 10:**

Dependent claims 2 to 7, 9 and 10 do not appear to contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements with respect to inventive step. Dependent claims 2 to 7, 9 and 10 only suggest slight constructional changes to the arrangements of independent claim 1 to which they refer:

I. **Claim 2:** That the length of the first arm is greater than that of the second arm is a normal option for the skilled person.
II. **Claim 3:** Computing the acceleration using a formula as claimed in claim 3 is obvious since the arrangement of the optical acceleration sensor of document **D1** and the present application is identical (except the spring).

III. **Claim 4:** Document **D1** discloses the use of a L-shape beam where the second arm (142) is parallel to the optical fiber measurement device (143, 144) (see e.g. p. 1, par. 11, and fig. 1F).

IV. **Claim 5:** That "the rotating member employs a bearing" is known from document **D5** (see e.g. p. 5, par. 26, and figs. 1-4) and thus obvious.

V. **Claims 6, 9 and 10:** That the width and the length of the leaf spring is equal to that of the housing or that the length is 4/5 of that of the second arm or that the leaf spring is provided at the center of the bottom of the second arm is an obvious choice for the skilled person.

VI. **Claim 7:** Connecting the housing the leaf spring, the mass and the second arm via a bolt is a further normal option for the skilled person.

4.3.1 Consequently, the subject-matter of claims 2 to 7, 9 and 10 is lacking an inventive step, too.

5 **Industrial Applicability**

The invention as claimed in claims 1 to 10 is obviously industrially applicable in the field of optical fiber grating acceleration sensors.

<u>Item VII:</u>

Certain defects in the application

1 Independent claims 1 and 8 are not in the two-part form concerning document **D1** or **D2**, respectively.

2 Documents **D1** to **D5** are not identified in the description and the relevant background art disclosed therein is not discussed.

Item VIII:

Certain observations on the application

1 Claims 1 and 8 are not clear for the following reasons:

1.1 **Independent claim 1 and 8:**

It is not clear how the computing unit is able to compute the acceleration according to a drift of a light parameter of the grating measuring device because it is not defined how and where the optical fiber measuring device is suspended. One can derive from the description and the figures that the optical fiber measuring device is connected to the fist arm of the beam (see page 5, paragraph 28, 30; p. 9, par. 39, 40, and figures 2, 4, of the description).

Thus, independent claims 1 and 8 are unclear.