

TITLE OF THE INVENTION

Mounting Arrangement of Acceleration Detecting Elements

FIELD OF THE INVENTION

The present invention relates to an mounting arrangement of acceleration detecting elements used in detecting impact.

BACKGROUND OF THE INVENTION

There is an acceleration detecting element which is constituted by a bymorph element of a double end fixing type. For example, as a conventional example, as is shown in Fig.11 in a simplified manner, an acceleration sensor 20a includes a bymorph element 1 served as an acceleration element and an insulating case 2 containing the element after positioning it and is fixedly attached on an sensor attaching face 3 such as a circuit board.

The bymorph element 1 is formed in a rectangular plate shape and is integrated by laminating two piezoelectric ceramics plates 6 on the top and the bottom faces of each of which a signal electrode 4 and an intermediate electrode 5 are formed. Each of the piezoelectric ceramics plates 6 opposedly bonded via the intermediate electrode 5 is polarized along the thickness direction with a sense reverse

to that of the other piezoelectric ceramics plate 6. The broken line arrow marks in Fig.11 designate the directions of polarization. The respective signal electrodes 4 in this example are formed along the longitudinal direction of the respective piezoelectric ceramics plates 6 and are extended up to end portions different from each other.

Meanwhile, the insulating case 2 is constituted by a pair of clamp frames 7 having a channel like shape in a plane view cramping only both end portions along the longitudinal direction of the bymorph element 1 in the thickness direction and a pair of case lids 8 enclosing open faces formed by the bymorph element 1 and the clamp frames 7 opposedly arranged across the element. The respective signal electrodes 4 of the bymorph element 1 contained in the insulating case 2 are connected to external electrodes (not shown) formed at outer end faces of the insulating case 2 which are different from each other.

An outer surface of the clamp frames 7 or the case lids 8 constituting the insulating case 2 is positioned and fixed on the sensor attaching face 3 thereby attaching the acceleration sensor. The respective signal electrodes 4 of the bymorph element 1 are connected to wiring patterns (not shown) on the sensor attaching face 3 via the external

electrodes formed on the insulating case 2. These wiring patterns are connected to a signal processing circuit (not shown). The signal processing circuit detects acceleration caused by impact by processing electric signals outputted from the acceleration sensor.

Fig.12 shows another conventional example of such an acceleration detecting element which is different from the above-mentioned conventional example in view of polarization. Fig.12 illustrates electrodes and the like more in details than those of the acceleration detecting element in Fig.11.

The acceleration sensor 20b includes piezoelectric ceramics bodies 23 in a rectangular plate shape on the main surfaces of which signal output electrodes 21 are formed and wherein an inner electrode 22 in parallel with the signal output electrodes 21 are embedded. Each of the signal output electrodes 21 is constituted by three surface electrodes 24 arranged separately at a center location and end locations along the longitudinal direction of the piezoelectric ceramics bodies 23 and a connecting electrode 25 covering the surface electrodes 24 together.

An acceleration element is constituted by the signal output electrodes 21 and the piezoelectric ceramics bodies 23.

One side (top side in the figure 12) electrode of the signal output electrodes 21 is extended up to one outer end face (left side in the figure 12) of the piezoelectric ceramics bodies 23. Meanwhile, the other side (bottom side in the figure 12) one of the signal output electrodes 21 is extended up to the other outer end face (right side in the figure 12). Further, ceramics regions 26 and 27 constituting the piezoelectric ceramics bodies 23 by opposing each other across the inner electrode 22 are respectively divided into three portions in the longitudinal direction, namely, center portions 26a and 27a and both sides of end portions 26b and 27b via boundaries where a direction of stresses caused by the operation of acceleration are changed. The center portions 26a and 27a and the both sides of end portions 26b and 27b are polarized in the thickness direction with senses different from each other by using the inner electrode 22 and the surface electrodes 24.

Here, the center portion 26a and the end portions 26b constituting the ceramics region 26 are provided with senses H and I of polarization which are different from each other and the center portion 27a and the end portions 27b constituting the ceramics region 27 are provided with senses J and K of polarization which are different from each other.

Further, in this case, for example, the senses of polarization H and J of the center portions 26a and 27a are inward senses wherein the senses are directed to each other and the senses of polarization I and K of the end portions 26b and 27b are outward senses wherein the senses are directed apart from each other.

Both edges in the longitudinal direction of the acceleration sensor 20b are fixedly supported by a pair of cramp frames 28 in a channel like shape in a side view. The respective signal output electrodes 21 formed on main surfaces of the piezoelectric ceramics bodies 23 are connected to external output electrodes 29 and 30 formed on different outer end faces of the piezoelectric ceramics bodies 23 and the cramp frames 28.

The acceleration sensor 20b having such a structure is used by the following reason. When acceleration is operated on the acceleration sensor 20b, which includes the acceleration element constituted by the signal output electrodes 21 and the piezoelectric ceramics bodies 23, the center portions 26a and 27a and the end portions 26b and 27b in the ceramics regions 26 and 27 constituting the piezoelectric ceramics bodies 23 are deformed by the operation of inertia force. In this case the respective

portions 26a, 27a, 26b and 27b receive tensile stresses or compressive stresses caused by the deformation. In the respective portions 26a, 27a, 26b and 27b a charge generation amount is enhanced by a synergistic effect of the respective senses of polarization H through K and the received stresses and a charge generation amount of the total of the acceleration sensor 20b is enhanced which promotes the detection sensitivity of the acceleration sensor.

Meanwhile, a maximum electric signal is outputted in the acceleration sensor 20a or 20b when acceleration is operated in a direction orthogonal to the surface of the piezoelectric ceramics plates 6 or 23, that is, in the thickness direction. Further, the maximum electric signal having the same absolute value with an inversed plus/minus sign is outputted when acceleration is operated in a sense inverse thereto by 180°. That is, the direction of the operation of acceleration is in the direction causing the maximum sensitivity, that is, the maximum sensitivity direction P which is called a main axis of the acceleration sensor. No electric signal is outputted when acceleration is operated in a direction tangential to the surface of the piezoelectric ceramics plates 6 or 23 in the acceleration sensor 20a or 20b and accordingly, the detection sensitivity is nullified. Meanwhile, when

acceleration is operated in a direction between the orthogonal direction and the tangential direction, a detection sensitivity having an amount corresponding to an angle θ made by the maximum sensitivity direction P and the operational direction of acceleration, that is, a direction sensitivity having an amount of the maximum sensitivity $S \times \cos\theta$ is produced.

When the acceleration sensor 20a having the above-mentioned conventional structure is attached on the sensor attaching face 3 as shown in Fig.11, the maximum sensitivity direction P is in parallel with or orthogonal to the sensor attaching face 3. As shown in Fig.11 two-dimensional orthogonal coordinate axes (plane coordinate axes) x and y are set on the sensor attaching face 3 and three-dimensional orthogonal coordinate axes (space coordinate axes) x, y and z with the sensor attaching face 3 as x-y plane are set in case where one of the case lids 8 of the insulating case 2 integrated with the bymorph element 1 is attached on the sensor attaching face 3 and in case where the longitudinally disposed maximum sensitivity direction P of the acceleration sensor 20a is equal to the direction of y axis on the sensor attaching face 3, then acceleration along x axis or z axis, that is, acceleration operating in any direction in x-z plane

cannot be detected.

Further, although not illustrated, when one of the clamp frames 7 of the insulating case 2 is attached on the sensor attaching face 3 where the orthogonal coordinate axes x and y are set and the maximum sensitivity direction P of the acceleration sensor 20a is equal to the direction of z axis orthogonal to the sensor attaching face 3, acceleration in any direction in x - y plane constituted by x axis and y axis cannot be detected. Therefore, in detecting all of accelerations operating in the respective directions of the mutually orthogonal coordinate axes x , y and z , three acceleration sensors of which maximum sensitivity directions P are equal to the respective directions of x axis, y axis and z axis need to be attached on the sensor attaching face 3 which increases a number of acceleration sensors elements and installation space, giving rise to high cost and a complicated signal processing circuit processing electric signals outputted from the three acceleration sensors.

Further, the same problem is naturally caused when the acceleration sensor 20b in Fig.12 is attached on the sensor attaching face 3 in place of the acceleration sensor 20a.

To avoid such inconvenience there has been proposed an acceleration detecting element capable of detecting

acceleration operating in the three directions of the orthogonal coordinate axes x, y and z by previously inclining the maximum sensitivity direction of the acceleration detecting element upwardly from the sensor attaching face. Although not illustrated, such an acceleration detecting element is disclosed in Japanese Unexamined Patent Publication No.133974/1993 wherein the maximum sensitivity direction of an acceleration detecting element having a rectangular plate shape is inclined from an sensor attaching face by 45° and an edge line of the acceleration detecting element is further inclined from an edge line of an element attaching substrate by 45° . When the acceleration detecting element having such a structure in the acceleration sensor is adopted, accelerations operating in the directions of x axis, y axis and z axis (hereinafter, three directions in conformity with those shown in Fig.11) can certainly be detected by a single element.

However, even if accelerations operating in the directions of the three orthogonal coordinate axes x, y and z may be detected, accelerations in all of directions cannot be detected. It is impossible to detect acceleration operating in a plane orthogonal to the maximum sensitivity direction. Still further, although the maximum sensitivity

direction is naturally inclined from z axis by 45° in adopting the above structure, the directions of x axis and y axis in this case are inclined from the maximum sensitivity direction substantially by 60° and accordingly, the detection sensitivities in x axis, y axis and z axis are not substantially the same.

SUMMARY OF THE INVENTION

The present invention has been created in view of the inconvenience and it is an object of the present invention to provide an mounting arrangement of acceleration detecting elements capable of detecting acceleration in a wide range with the number thereof as few as possible and having substantially the same detection sensitivities with respect to accelerations operating in the respective directions of orthogonal coordinate axes.

To achieve the object the present invention provides an mounting arrangement of acceleration detecting elements comprising two acceleration detecting elements, wherein a first maximum sensitivity direction of one of the acceleration detecting elements is inclined from the y axis toward a z axis by 40° to 50° and a second maximum sensitivity direction of another of the acceleration

detecting elements is inclined from the x axis toward the z axis by 40° to 50° . Further, the acceleration detecting element in this case is a bymorph element of a double end fixing type made of a piezoelectric ceramics.

Further, to achieve the object the present invention provides an mounting arrangement of acceleration detecting elements comprising two acceleration detecting elements, a calculating means for calculating a sum of absolute values of electric signals outputted from the respective acceleration detecting elements and wherein a first maximum sensitivity direction of one of the acceleration detecting elements is inclined from the y axis toward a z axis by 20° to 30° and a second maximum sensitivity direction of another of the acceleration detecting elements is inclined from the x axis toward the z axis by 20° to 30° . Further, the acceleration detecting element in this case is a bymorph element of a double end fixing type made of a piezoelectric ceramics.

Further, the present invention provides an mounting arrangement of acceleration detecting elements wherein inner electrodes are provided at an inner portion of the piezoelectric ceramics bodies having a rectangular plate shape and arranged separately at a center location and end locations of the piezoelectric ceramics bodies along a

longitudinal direction, signal output electrodes are provided on main surfaces of the piezoelectric ceramics bodies and respective center portions and end portions along the longitudinal direction of the piezoelectric ceramics bodies opposed to each other via the inner electrodes are polarized in a thickness direction with different senses.

BRIEF DESCRIPTION OF DRAWINGS

Fig.1 is a partially broken perspective view showing a structure of an acceleration detecting element according to a first embodiment;

Fig.2 is an explanatory view showing the mounting arrangement of the acceleration detecting element of the first embodiment;

Fig.3 shows a function block diagram showing the operation of the mounting arrangement of the first embodiment;

Fig.4 is a partially broken perspective view showing the structure of an acceleration detecting element according to a second embodiment;

Fig.5 is an explanatory view showing the mounting arrangement of the acceleration detecting element of the second embodiment;

Fig.6 is a function block diagram showing the operation of the mounting arrangement of the second embodiment;

Fig.7 is a partially broken perspective view showing an acceleration detecting element according to a third embodiment;

Figs.8(a), 8(b) and 8(c) illustrate sectional views showing steps of a prestage of a manufacturing method in the third embodiment;

Figs.9(a) and 9(b) illustrate sectional views showing steps of a poststage of the manufacturing method in the third embodiment;

Figs. 10(a), 10(b) and 10(c) illustrate sectional views showing a modified example of steps of the prestage in the manufacturing method of the third embodiment;

Fig.11 is a partially broken perspective view showing the structure of an acceleration detecting element according to a conventional example;

Fig.12 is a partially broken perspective view showing the structure of a piezoelectric element according to another conventional example.

DETAILED DESCRIPTION OF REFERRED EMBODIMENTS

Embodiment 1

An explanation will be given of Embodiment 1 of the present invention in reference to the drawings.

Fig.1 is a partially broken perspective view showing an acceleration sensor, which is a partial mounting arrangement of an acceleration detecting element according to a first embodiment, Fig.2 is an explanatory view showing the general mounting arrangement of the acceleration detecting elements and Fig.3 is a function block diagram showing an operation of the mounting arrangement of the first embodiment. Further, the structure of the acceleration sensor including the acceleration detecting element is basically the same as that in the conventional example. Therefore, in Fig.1 and Fig.2 portions or parts the same as those in Fig.11 are attached with the same notations and a detailed explanation thereof will be omitted.

As shown in Fig.1 the acceleration sensor A or B in the first embodiment is constituted by a double end fixing type bymorph element 1 served as an acceleration detecting element and an insulating case 2 containing the bymorph element 1. The acceleration sensor A and B are attached on an sensor attaching face 3 such as a circuit board. The bymorph element 1 in this case is positioned and contained in the insulating case 2 in a state where the maximum sensitivity

direction P is inclined from the sensor attaching face 3. The maximum sensitivity direction P is set upwardly with an angle of inclination from the sensor attaching face 3 being 40° or more and 50° or less, for example, 45° hereinafter.

In the bymorph element 1 of the first embodiment a pair of piezoelectric ceramics plates 6 both in a rectangular plate shape on the top and the bottom surfaces of each of which a signal electrode 4 and an intermediate electrode 5 are formed, are opposed and bonded together and end portions thereof are cut off by planes inclined from the thickness direction by 45° corresponding to the angle of inclination. The respective piezoelectric ceramics plates 6 bonded via the intermediate electrodes 5 are polarized in the thickness direction with senses inverse to each other and the respective signal electrodes 4 are extended up to mutually different end portions along the longitudinal direction of the respective piezoelectric ceramics plates 6 which is the same as in the conventional example. Further, the insulating case 2 in this case is constituted by using clamp frames 7 and case lids 8 as those in the conventional example and the respective signal electrodes 4 of the bymorph element 1 are connected to external electrodes (not shown) of the insulating case 2 which are formed on outer end faces

different from each other.

Meanwhile, as shown in Fig.2, the mounting arrangement of acceleration detecting elements are provided with the two acceleration sensors A and B attached on the same sensor attaching face 3 in directions respectively equal to directions of the orthogonal coordinate axes x and y. Further, as shown in Fig.3 the mounting arrangement is connected to a first and a second comparator circuit X1 and X2 performing comparator processing of electric signals V_A and V_B respectively outputted from the electric elements A, B and a logical circuit X3 performing an OR logical processing of comparator signals V_{G1} and V_{G2} respectively outputted from the first and the second comparator circuits X1 and X2. The comparator circuits X1 and X2 and the logical circuit X3 are integrated in a signal processing circuit (not shown).

The acceleration sensors A and B are attached on the sensor attaching face 3 by positioning and fixing an outer surface of the case lids 8 constituting the insulating case 2. The respective signal electrodes 4 of the bymorph element 1 are connected to wiring patterns (not shown) which have been formed on the sensor attaching face 3 by soldering etc. via external electrodes (not shown) on the insulating case 2.

The maximum sensitivity direction P of the bymorph element 1, which is served as an acceleration detecting element and integrated in the acceleration sensor A, is in a direction upwardly inclined from y axis to z axis by 45° . The maximum sensitivity direction P of the bymorph element 1, which is also served as an acceleration detecting element and integrated in the acceleration sensor B, is in a direction upwardly inclined from x axis to z axis.

Now, an explanation will be given of the operation of the mounting arrangement of the acceleration detecting elements in this embodiment in reference to Fig.2 and Fig.3. In the following explanation the maximum sensitivity of the acceleration detecting elements (the acceleration sensors A and B) is $S(\text{mV/G})$ where G is gravitational acceleration and thresholds for detecting impacts at certain levels or more are designated as S_1 and S_2 .

Firstly, assume a case in which acceleration of 1G is operated from the positive direction of the orthogonal coordinate axis x to the mounting arrangement of the two acceleration sensors A and B arranged in the positional relationship shown in Fig.2. Then, the detection sensitivity of the acceleration sensor A arranged along a direction equal to the direction of y axis is nullified whereas the detection

sensitivity of the acceleration sensor B arranged along a direction equal to the direction of x axis is indicated by the maximum sensitivity S multiplied by $\cos 45^\circ$. Therefore, an electric signal V_A outputted from the acceleration sensor A in this case is 0(mV) and an electric signal V_B outputted from the acceleration sensor B is $S \times \cos 45^\circ \times 1(\text{mV})$. In the second comparator circuit X2 to which only the electric signal V_B is inputted, a comparator processing is performed with the predetermined S_2 as a threshold. That is, when $V_B > S_2$, a comparator signal $V_{S2}=1$ and when $V_B \leq S_2$, the comparator signal $V_{S2}=0$. The comparator signal V_{S2} is outputted from the second comparator circuit X2 to the logical circuit X3.

Further, when acceleration of 1G is operated from the positive direction of the orthogonal coordinate axis y, the detection sensitivity of the acceleration sensor A arranged along the direction equal to the direction of y axis is indicated by the maximum sensitivity S multiplied by $\cos 45^\circ$ whereas the detection sensitivity of the acceleration sensor B arranged along a direction equal to the direction of x axis is nullified. Accordingly, the electric signal V_A outputted from the acceleration sensor A in this case is indicated by $S \times \cos 45^\circ \times 1(\text{mV})$ and the electric signal V_B outputted from

the acceleration sensor B is 0 (mV). As a result in the first comparator circuit X1 to which only the electric signal V_A is inputted from the acceleration sensor A, the comparator processing is performed with the predetermined S_1 as the threshold. That is, when $V_A > S_1$, the comparator signal $V_{S1} = 1$ and when $V_A \leq S_1$, the comparator signal $V_{S1} = 0$. Thereafter, the comparator signal V_{S1} is outputted from the first comparator circuit X1 to the logical circuit X3.

Meanwhile, when the acceleration of 1G is operated from the positive direction of the orthogonal coordinate axis z, both of the detection sensitivities of the acceleration sensors A and B are indicated by the maximum sensitivity S multiplied by $\cos 45^\circ$ and the electric signals V_A and V_B outputted from the acceleration sensors A and B are indicated as $S \times \cos 45^\circ \times 1$ (mV). Further, in the first comparator circuit X1 to which only the electric signal V_A is inputted from the acceleration sensor A, the comparator processing is performed with S_1 as the threshold and in the second comparator circuit X2 to which only the electric signal V_B is inputted from the acceleration sensor B, the comparator processing is performed with S_2 as the threshold. Thereafter, the comparator signals V_{S1} and V_{S2} are outputted from the first and the second comparator circuits X1 and X2 to the

logical circuit X3.

Moreover, in the logical circuit X3 to which either one or both of the comparator signals V_{S1} and V_{S2} are inputted from the comparator circuits X1 and X2, an OR logical processing based on the comparator signals V_{S1} and V_{S2} , that is, the OR logical processing in which a logical circuit signal $V_L=1$ if $V_{S1}=1$ or $V_{S2}=1$ is performed. Thereafter, the logical circuit signal V_L is outputted to the outside.

As explained above, when the mounting arrangement of acceleration detecting elements in this embodiment is adopted, the detection sensitivities having substantially the same degree with respect to any one of the directions of the orthogonal coordinate axes x , y and z , that is, the detection sensitivities of the maximum sensitivities S multiplied by $\cos 45^\circ$ are provided. Further, in the mounting arrangement of this embodiment a direction in which the detection sensitivity is nullified is only a direction orthogonal to the maximum sensitivity directions P both of the acceleration sensors A and B thereby providing an advantage in which acceleration can be detected in a wide range.

Incidentally, although in the mounting arrangement of this embodiment the maximum sensitivity directions P of the bymorph elements 1 respectively integrated in the

acceleration sensors A and B are inclined from the sensor attaching face 3 by the angle of inclination of 45° . However, it has been recognized by the inventors of the present invention that the angle of inclination is not restricted to 45° but may be in a range of 40° or more and 50° or less in practice. A ratio of $\cos 40^\circ$ to $\cos 45^\circ$ in case of the angle of inclination of 40° is $\cos 40^\circ / \cos 45^\circ = 1.083 \dots$. A ratio of $\cos 50^\circ$ to $\cos 45^\circ$ in case of the angle of inclination θ of 50° is $\cos 50^\circ / \cos 45^\circ = 0.909 \dots$. Therefore, the ratios are within a range of substantially $\pm 10\%$ of the value in the case of the angle of inclination of 45° . Therefore, it is apparent that the detection sensitivities substantially the same as those in this embodiment can be provided in any directions of the orthogonal coordinate axes x, y and z.

Embodiment 2

Fig.4 is a partially broken perspective view showing an acceleration sensor, which is a partial mounting arrangement of an acceleration detecting element in a second embodiment, Fig.5 is an explanatory view showing the general mounting arrangement of the acceleration detecting elements and Fig.6 is a function block diagram showing the operation of the mounting arrangement of the second embodiment. Further, the structure of the acceleration sensor including the

acceleration detecting element per se is basically the same as those in the conventional example and the first embodiment and accordingly, in Fig.4 and Fig.5 portions or parts the same as those in Fig.11 and Fig.1 are attached with the same notations and a detailed explanation thereof will be omitted.

As shown in Fig.4 each of the acceleration sensors corresponding to the second embodiment are respectively constituted by a double end fixing type bymorph element 1 and an insulating case 2 containing the element and these acceleration sensors are attached on the sensor attaching face 3 such as a circuit board. The bymorph element 1 in this case is positioned and contained in the insulating case 2 in a state inclined from the sensor attaching face 3 and the maximum sensitivity direction P is set upwardly by the angle of inclination θ from the sensor attaching face 3 in a range of 20° or more and 30° or less, for example, 25° .

In the bymorph element 1, which is served as the acceleration detecting element of the second embodiment, a pair of piezoelectric ceramics plates 6 both in a rectangular plate shape on the top and the bottom faces of each of which a signal electrode 4 and a intermediate electrode 5 are formed, are opposed and bonded and edge portions thereof are cut off by planes inclined from the thickness direction by

25° corresponding to the angle of inclination θ . Further, the respective piezoelectric ceramics plates 6 bonded via the intermediate electrode 5, are polarized in the thickness direction with senses inverse to each other and the respective signal electrodes 4 are extended up to end portions different from each other along a longitudinal direction of the respective piezoelectric ceramics plates 6 which is the same as in the conventional example. Further, the insulating case 2 in this case is constituted by clamp frames 7 and case lids 8 as in the conventional example and the respective signal electrodes 4 of the bymorph element 1 are connected to external electrodes (not shown) formed on different outer end faces of the insulating case 2.

As shown in Fig.5 and Fig.6 the mounting arrangement of the acceleration detecting elements in the second embodiment, is connected to two acceleration sensors A' and B' attached on the same sensor attaching face 3 along directions equal to the directions of the orthogonal coordinate axes x and y, a calculating means X4 for calculating a sum ($|V'_A| + |V'_B|$) of absolute values of electric signals V'_A and V'_B outputted respectively from the acceleration sensors A' and B' and a comparator circuit X5. The structure of the calculating means X4 performing the above-mentioned calculation is well

known and a detailed explanation thereof will be omitted.

The outer surfaces of the case lids 8 constituting the insulating cases 2 are positioned and fixed thereby attaching the respective acceleration sensors A' and B' on the sensor attaching face 3. The respective signal electrodes 4 of the bymorph element 1 are connected to respective wiring patterns (not shown) formed on the sensor attaching face 3 by soldering etc. via external electrodes (not shown) formed on the insulating case 2. The maximum sensitivity direction P of the bymorph element 1 integrated in the acceleration sensor A' in this case is inclined upwardly from y axis to z axis by 25° and the maximum sensitivity direction P of the bymorph element 1 in the acceleration sensor B' is inclined upwardly from x axis to z axis by 25°.

Next, an explanation will be given of the operation of the mounting arrangement of the acceleration detecting elements in the second embodiment in reference to Fig.5 and Fig.6. In the following explanation the maximum sensitivities of the acceleration detecting elements (the acceleration sensors A' and B') are S' (mV/G) where G is gravitational acceleration.

Now, assume a case in which acceleration of 1G is operated from the positive direction of the orthogonal

coordinate axis x to the mounting arrangement constituted by the two acceleration sensors A' and B' arranged in the positional relationship shown in Fig.5. Then, the detection sensitivity of the acceleration sensor A' attached along a direction equal to the direction of y axis, is indicated by the maximum sensitivity S' multiplied by $\cos 90^\circ$ and the detection sensitivity of the acceleration sensor B' attached along a direction equal to the direction of x axis, is indicated by the maximum sensitivity S' multiplied by $\cos 25^\circ$. The electric signal $V_{A'}$ outputted from the acceleration sensor A' is indicated by $S' \times \cos 90^\circ \times 1(\text{mV})$ and the electric signal $V_{B'}$ outputted from the acceleration sensor B' is indicated by $S' \times \cos 25^\circ \times 1(\text{mV})$. In a calculating means X4 a sum ($|V_{A'}| + |V_{B'}|$) of absolute values of the electric signals $V_{A'}$ and $V_{B'}$ outputted respectively from the acceleration sensors A' and B', that is, $|S' \times \cos 90^\circ| + |S' \times \cos 25^\circ| = S' \times 0.91(\text{mV})$ is calculated as a synthesized signal V'_{AB} . The synthesized signal V'_{AB} which has been calculated in accordance with such a procedure, is outputted to the comparator circuit X5. In the comparator circuit X5 a comparator processing is performed with a predetermined S_0 as a threshold. In the comparator circuit X5, when $V'_{AB} > S_0$, the comparator signal $V_{S'} = 1$ and when $V'_{AB} < S_0$ the comparator

signal $V'_S=0$. Thereafter, the comparator signal V'_S is outputted to the outside. Further, although the above explanation has been given to a case in which acceleration of 1G is operated from the positive direction of the orthogonal coordinate axis x, the same is applicable to a case where acceleration of 1G is operated from the positive direction of the orthogonal coordinate axis y and $S' \times 0.91(\text{mV})$ is calculated as the synthesized signal V'_{AB} .

Further, in case where acceleration of 1G is operated from the positive direction of the orthogonal coordinate axis z to the mounting arrangement of Fig.5, the following operation is performed. The detection sensitivities of the acceleration sensors A' and B' in a direction equal to the direction of z axis, is indicated as the maximum sensitivity S' multiplied by $\cos 65^\circ$, that is, multiplied by $\cos(90^\circ - 25^\circ)$, since the angles of inclination of the acceleration sensors A' and B' from the sensor attaching face 3 are 25° . Therefore, both of the electric signals V'_A and V'_B outputted respectively from the acceleration sensors A' and B' in this case are indicated by $S' \times \cos 65^\circ \times 1(\text{mV})$. In the calculating means X4 a sum of absolute values of the electric signals V'_A and V'_B outputted respectively from the acceleration sensors A' and B', that is, $|S' \times \cos 65^\circ| + |S' \times \cos 65^\circ|$

$=S' \times 0.85(\text{mV})$ is calculated as the synthesized signal V_{AB} .

In the mounting arrangement of the acceleration detecting elements in the second embodiment, substantially the same detection sensitivities are provided in any direction of the orthogonal coordinate axes x , y and z . Further, in the mounting arrangement of the second embodiment a direction in which the detection sensitivity is nullified is a direction orthogonal respectively to the maximum sensitivity directions P of the acceleration sensors A' and B' thereby providing an advantage whereby acceleration can be detected in a wide range.

Incidentally, according to the second embodiment the synthesized signals V'_{AB} in case where acceleration is operated along directions of x axis and y axis are $S' \times 0.91(\text{mV})$ and the synthesized signal V'_{AB} in case where acceleration is operated along the direction of z axis is $S' \times 0.85(\text{mV})$. The difference is caused since the angle of inclination θ of the acceleration detecting elements (the bismorph elements 1) in the acceleration sensors A' and B' from the sensor attaching face 3 is set as 25° in view of the convenience of manufacturing. In calculation completely the same detection sensitivities are provided along any directions of x axis, y axis and z axis by setting the angle

of inclination θ as $26.565...^\circ$.

It has been confirmed by an investigation performed by the inventors of the present invention that when the angle of inclination from the sensor attaching face 3 of the maximum sensitivity directions P of the bymorph elements 1 respectively integrated to the two acceleration sensors A' and B' arranged along directions equal to the directions of orthogonal coordinate axes x and y on the sensor attaching face 3, is changed between 0° to 90° , the sums ($|V'_A| + |V'_B|$) of the absolute values of the electric signals V'_A and V'_B outputted from the acceleration sensors A' and B' change as shown in Table 1.

Table 1 inserted.

Table 1

Angle of inclination $\theta(^{\circ}\text{C})$	Detection sensitivity in x axis direction			Detection sensitivity in y axis direction			Detection sensitivity in z axis direction		
	A'	B'	$\text{IV}_{A'} + \text{IV}_{B'}$	A'	B'	$\text{IV}_{A'} + \text{IV}_{B'}$	A'	B'	$\text{IV}_{A'} + \text{IV}_{B'}$
0	0.00	1.00	1.00	1.00	0.00	1.00	0.00	0.00	0.00
5	0.00	1.00	1.00	1.00	0.00	1.00	0.09	0.09	0.17
10	0.00	0.98	0.98	0.98	0.00	0.98	0.17	0.17	0.35
15	0.00	0.97	0.97	0.97	0.00	0.97	0.26	0.26	0.52
20	0.00	0.94	0.94	0.94	0.00	0.94	0.34	0.34	0.68
25	0.00	0.91	0.91	0.91	0.00	0.91	0.42	0.42	0.84
30	0.00	0.87	0.87	0.87	0.00	0.87	0.50	0.50	1.00
35	0.00	0.82	0.82	0.82	0.00	0.82	0.57	0.57	1.14
40	0.00	0.77	0.77	0.77	0.00	0.77	0.64	0.64	1.28
45	0.00	0.71	0.71	0.71	0.00	0.71	0.71	0.71	1.41
50	0.00	0.64	0.64	0.64	0.00	0.64	0.76	0.76	1.53
55	0.00	0.58	0.58	0.58	0.00	0.58	0.82	0.82	1.63
60	0.00	0.50	0.50	0.50	0.00	0.50	0.86	0.86	1.73
65	0.00	0.43	0.43	0.43	0.00	0.43	0.90	0.90	1.81
70	0.00	0.35	0.35	0.35	0.00	0.35	0.94	0.94	1.88
75	0.00	0.26	0.26	0.26	0.00	0.26	0.96	0.96	1.93
80	0.00	0.18	0.18	0.18	0.00	0.18	0.98	0.98	1.97
85	0.00	0.09	0.09	0.09	0.00	0.09	1.00	1.00	1.99
90	0.00	0.01	0.01	0.01	0.00	0.01	1.00	1.00	2.00

Table 1 apparently shows that the detection sensitivities in mutually orthogonal three axes directions are substantially the same only in case where the maximum sensitivity directions P of the respective acceleration sensors A' and B' are inclined from the sensor attaching face 3 in a range of from 20° to 30°, by calculating the sums of the absolute values of the electric signals V'_A and V'_B outputted from the acceleration sensors A' and B'.

Embodiment 3

An explanation will be given of a third embodiment of the present invention. The third embodiment discloses the structure and the manufacturing method of an acceleration detecting element applicable to the first and second embodiments.

Fig.7 is a partially broken perspective view showing an acceleration sensor in the state of removing case lids, including an acceleration detecting element according to the third embodiment, Figs.8(a) through 8(c) illustrate sectional diagrams showing steps of a prestage in the manufacturing method of the acceleration detecting element, Figs.9(a) and 9(b) illustrate sectional views showing steps of a poststage in the manufacturing method thereof and Figs.10(a) to 10(c) illustrate sectional views showing steps of a modified

example of the prestage in the manufacturing method thereof.

An acceleration detecting element C including an acceleration detecting element is composed of the bymorph structure capable of realizing the same function as in the conventional example. As shown in Fig.7 the sensor includes piezoelectric ceramics bodies 32 in a rectangular plate shape having a predetermined thickness, for example, piezoelectric ceramics bodies 32 manufactured by a method of baking green sheets made of a piezoelectric ceramics. A signal output electrode 33 in one layer structure is formed on a main surface of each of the piezoelectric ceramics bodies 32. The signal output electrode 33 on one side (top side in the figure 7) is extended up to one side outer edge face (left side in the figure 7) of the piezoelectric ceramics body 32. Meanwhile, the signal output electrode 33 on the other side (bottom side in the figure 7) is extended up to the other side outer edge face (right side in the figure 7) of the piezoelectric ceramics body 32.

At an inner portion of the piezoelectric ceramics bodies 32 three inner electrodes 34 arranged separately at a center location and end locations along the longitudinal direction are embedded in parallel with the signal output electrodes 33. Ceramics regions 35 and 36 constituting the

piezoelectric ceramics bodies 32 by opposing each other across these inner electrodes 34, are respectively divided into three portions separated along the longitudinal direction of the piezoelectric ceramics bodies 32 similar to the inner electrodes 34, that is, center portions 35a and 36a and end portions 35b and 36b. Further, the respective of the center portions 35a and 36a and the end portions 35b and 36b in the ceramics regions 35 and 36 are polarized in the thickness direction with mutually different senses as in the conventional example.

The acceleration detecting element is constituted by the piezoelectric ceramics bodies 32, the signal output electrodes 33 and the inner electrodes 34.

The polarization with respect to the ceramics regions 35 and 36 are performed by using the signal output electrodes 33 and the inner electrodes 34. Here, the center portion 35a and the end portions 35b constituting the ceramics region 35 are provided with senses H and I of polarization. The center portion 36a and the end portions 36b constituting the ceramics region 36 are provided with senses J and K of polarization. Further, the both end edges along the longitudinal direction of the acceleration sensor C are fixedly supported by a pair of cramp frames 37 in a channel

like shape in a side view. The respective signal output electrodes 33 formed on the main surfaces of the piezoelectric ceramics bodies 32 are connected to respective external output electrodes 38 and 39 formed on mutually different outer end faces of the piezoelectric ceramics bodies 32 and the cramp frames 37.

Next, an explanation will be given of the manufacturing procedure of the acceleration sensor C including the acceleration detecting element shown in Fig. 7 in reference to sectional views of steps illustrated in Figs. 8(a) to 8(c) and Figs. 9(a) and 9(b). Further, in these views a range of the size and shape corresponding to those of each acceleration detecting element and the acceleration sensor C is partitioned by imaginary lines.

Firstly, as shown in Fig.8(a) green sheets in a rectangular plate shape having a size and a shape corresponding to those of a number of the piezoelectric ceramics bodies 32 constituting the acceleration detecting elements, that is, two green sheets made of a piezoelectric ceramics and to be finally transformed into the ceramics regions 35 and 36, are prepared. Further, a conductive paste of silver, silver-palladium or the like is applied by a method of screen printing or the like on one face of one

(bottom one in the figure 8(a)) of the green sheets 40, that is, applied at every center location and every end location on the one face corresponding to every piezoelectric ceramics body 32 along the longitudinal direction and the conductive paste is dried under a temperature of approximately 1000°C thereby forming inner electrode patterns 41 arranged separately from each other.

As shown in Fig.8(b) a face of the green sheet on the other side, that is, the green sheet 40 on which the inner electrode patterns 41 are not formed, is laminated on the face of the green sheet 40 on which the respective inner electrode patterns 41 have been formed and the assembly is baked under a temperature of approximately 100°C . Then, the two green sheets 40 in the laminated state are bonded together by the baking whereby an integrated piezoelectric ceramics basic body 42 is made. Further, the inner electrode patterns 41 interposed between the two green sheets 40 are simultaneously baked along with the baking treatment and the respective inner electrodes 34 arranged separately from each other are formed.

Next, as shown in Fig.8(c) the conductive paste is respectively applied on the main surfaces of the piezoelectric ceramics basic body 42, signal output electrode

patterns 43 are formed by drying the pasted basic body under a temperature of approximately 100°C and the assembly is baked under a temperature of approximately 800°C by which the respective signal output electrodes 33 are formed. Thereafter, the center portions 35a and 36a and the end portions 35b and 36b of the ceramics regions 35 and 36 constituting the piezoelectric ceramics bodies 32 are polarized by applying direct current electric fields among the signal output electrodes 33 and the inner electrodes 34. Further, the respective portions 35a, 36a, 35b and 36b are polarized to produce the senses of polarization H through K shown in Fig.7.

Thereafter, as shown in Fig.9(a) cramp frames basic bodies 45 in which recessed grooves 44 each having a predetermined width dimension are formed at every predetermined location on the inner surface side, are prepared and integrated by pasting the respective cramp frame basic bodies 45 on the main surfaces of the piezoelectric ceramics basic body 42 on which the signal output electrodes 33 have been formed. Further, the piezoelectric ceramics basic body 42 and the cramp frame basic bodies 45 are cut at the respective imaginary lines which are set by partitioning the ranges each having a size and a shape corresponding to

each piezoelectric ceramics body 32. Then, the acceleration sensor as shown in Fig.9(b), that is, the acceleration sensor constituted by a pair of the cramp frames 37 and the acceleration detecting element, which is constituted by the piezoelectric ceramics bodies 32, the signal output electrodes 33 and the inner electrodes 34.

Then, the external output electrodes 38 and 39 are formed on respective outer end faces of the acceleration detecting element, that is, on the outer end faces of the piezoelectric ceramics bodies 32 and the cramp frames 37 by which the acceleration sensor C of the bymorph structure as shown in Fig.7 is finished. Further, the respective signal output electrodes 33 are connected to the respective external output electrodes 38 and 39 in a T-like form and are conductive to each other.

Incidentally, the manufacturing method of the acceleration sensor C according to the third embodiment is not limited to the procedure shown in Figs. 8(a) through 8(c) and it is possible to adopt a procedure as shown in Figs. 10(a) through 10(c). Figs.10(a) through 10(c) show a modified example of the prestage in manufacturing the acceleration detecting element and parts and portions common to those in Figs.8(a) through 8(c) are attached with the same

notations in Figs.10(a) through 10(c).

As shown in Fig.10(a) in this modified example, firstly, piezoelectric ceramics plates in a rectangular plate shape which have previously been baked, that is, two piezoelectric ceramics plates 47 having a size and a shape corresponding to a number of the piezoelectric ceramics bodies 32 constituting the acceleration sensors, are prepared. The conductive paste is applied and dried on faces of the respective piezoelectric ceramics plates 47, that is, at the center locations and the end locations along the longitudinal direction of the faces each corresponding to a single piezoelectric ceramics body 32 whereby the respective inner electrode patterns 41 arranged separately from each other are formed.

Thereafter, as shown in Fig.10(b) the conductive paste is applied on the other faces of the respective piezoelectric ceramics plates 47 by which the signal output electrode patterns 43 are formed and the inner electrode patterns 41 and the signal output electrode patterns 43 are simultaneously baked by which the respective signal output electrodes 33 and the respective inner electrodes 34 are formed. Center portions 47a and end portions 47b disposed along the longitudinal direction of the respective piezoelectric ceramics plates 47 are polarized by applying

direct current fields among the respective signal output electrodes 33 and the inner electrode 34 in the respective piezoelectric ceramics plates 47. The respective piezoelectric ceramics plates 47 finally become the ceramics regions 35 and 36 and in this operation the center portions 35a and 36a and the end portions 35b and 36b in the ceramics regions 35 and 36 are polarized.

Further, as shown in Fig.10(c) the faces of the piezoelectric ceramics plates 47 on which the respective inner electrodes 34 have been formed are adhered by using a thermosetting adhesive agent (not shown) and the assembly is heated by which the piezoelectric ceramics plates 47 are integrated into the piezoelectric ceramics basic body 42. The piezoelectric ceramics basic body 42 which have been made in accordance with the above-mentioned procedure is provided with the same structure as that shown in Fig.8(c). Thereafter, the integrated piezoelectric ceramics basic body 42 is subjected to the procedure in the poststage of the manufacturing method as shown in Figs.9(a) and 9(b) by which the acceleration sensor C having the bymorph structure as shown in Fig.7 is finished.

According to the acceleration detecting element and the manufacturing method in the third embodiment, the

polarization treatment is performed after separating the inner electrodes. Accordingly, it is not necessary to perform the polarization treatment after previously forming separated surface electrodes and it is also not necessary to constitute signal output electrodes by forming connecting electrodes after the polarization treatment.

Further, it is naturally possible to form the acceleration sensor C in the third embodiment such that the acceleration detecting element constituted by the piezoelectric ceramics bodies 32, the signal output electrodes 33 and the inner electrodes 34, is inclined from the sensor attaching face as in the acceleration sensors used in the first and the second embodiments.

As explained above, according to the mounting arrangement of acceleration detecting elements in the present invention, it is possible to detect acceleration operating along any one of mutually orthogonal three axes directions with substantially the same detection sensitivity by using two acceleration detecting elements and acceleration can be detected over a wide range. As a result the present invention provides an effect whereby not only the mounting arrangement is simplified but the cost is reduced.

Further, according to the acceleration detecting element

and the manufacturing method in this invention, separately arranged inner electrodes are arranged at an inner portion of piezoelectric ceramics bodies and respective portions in ceramics regions are polarized by using the inner electrodes. Therefore, it is not necessary to perform polarization treatment after previously forming separated surface electrodes on main surfaces of the piezoelectric ceramics bodies and it is also not necessary to constitute signal output electrodes of a two layer structure by forming connecting electrodes after the polarization treatment. As a result the present invention provides an effect whereby various inconveniences in constituting the signal output electrodes of a two layer structure are not caused and time and labor in manufacturing the acceleration detecting elements can be saved.



WHAT IS CLAIMED IS:

1. A mounting arrangement of acceleration detecting elements with respect to mutually orthogonal x, y and z axes, including:

two acceleration detecting elements,

each of the acceleration detecting elements comprising a piezoelectric ceramics bimorph element fixed at both ends thereof,

wherein a first one of the acceleration detecting elements has a maximum sensitivity direction which is inclined from the y axis toward the z axis by 40° to 50° and a second one of the acceleration detecting elements has a maximum sensitivity direction which is inclined from the x axis toward the z axis by 40° to 50° , thereby providing substantially constant acceleration detection sensitivity along all three of said axes.

2. A mounting arrangement of acceleration detecting elements with respect to mutually orthogonal x, y and z axes, including:

two acceleration detecting elements,

each of the acceleration detecting elements comprising a piezoelectric ceramics bimorph element fixed at both ends thereof;

a calculating circuit for calculating a sum of absolute values of electric signals outputted from the respective acceleration detecting elements; and

wherein a first one of the acceleration detecting elements has a maximum sensitivity direction which is inclined from the y axis toward the z axis by 20° to 30° and a second one of the acceleration detecting elements has a maximum sensitivity direction which is inclined from the x axis toward the z axis by 20° to 30° , thereby providing substantially constant acceleration direction sensitivity along all three of said axes.



3. The mounting arrangement of acceleration detecting elements according to Claim 1 or 2, wherein said element comprises a pair of piezoelectric ceramic bodies having a rectangular plate shape; inner electrodes are provided at an inner portion between the piezoelectric ceramics bodies and arranged separately from each other at a center location and end locations along a longitudinal direction of the piezoelectric ceramics bodies; signal output electrodes are provided on outer main surfaces of the piezoelectric ceramics bodies; and respective center portions and end portions along the longitudinal direction of the piezoelectric ceramics bodies opposed to each other via the inner electrodes are polarized in a thickness direction with opposite senses.

4. A method of making an acceleration detecting element comprising the steps of:

preparing two green sheets having a rectangular plate shape made of piezoelectric ceramics;

applying a conductive paste on a center location and end locations along a longitudinal direction of a first face of a first one of the green sheets thereby forming respective inner electrode patterns;

laminating a first face of the second of the green sheets on the first face of the first one of the green sheets on which the inner electrode patterns have been formed;

baking to simultaneously form inner electrodes and piezoelectric ceramics bodies by a baking treatment;

forming signal output electrodes by a baking treatment after applying the conductive paste on main second surfaces of the piezoelectric ceramics bodies; and

polarizing center portions and end portions of the piezoelectric ceramics bodies by using the respective signal output electrodes and the respective inner electrodes.



5. A method of making an acceleration detecting element comprising the steps of:

preparing and baking two piezoelectric ceramics plates in a rectangular plate shape;

applying a conductive paste on center locations and end locations along a longitudinal direction of first faces of the respective piezoelectric ceramics plates thereby forming respective inner electrode patterns;

forming inner electrodes and signal output electrodes by a baking treatment after forming signal output electrode patterns by applying the conductive paste on second faces of the respective piezoelectric ceramics plates;

polarizing center portions and end portions of the respective piezoelectric ceramics plates by using the respective signal output electrodes and the respective inner electrodes; and

bonding the second faces of the piezoelectric ceramics plates on which the inner electrodes have been formed thereby forming the piezoelectric ceramics bodies.