

"Strain gauges weighing apparatus"

The present invention relates to a weighing machine, such as a machine for weighing people or foodstuffs or any other weighing machine with a tray or platform or the like.

In the prior art according to Article 54[3] EPC, a weighing machine comprising a base and a tray which is substantially parallel to this base and is designed to receive the load to be weighed is known from European Patent Application EP-A1-0 126 745 (corresponding to WO-A1-84/02186). A metal bar of circular or square cross-section is disposed between the base and the tray and has its opposite ends rigidly secured to the base and to the tray so that the bar can yield under the load acting on the tray.

The bar bears four stress gauges whose axes are parallel to the axis of the bar and which are electrically connected as a Wheatstone bridge.

Two of the adjacent gauges in the Wheatstone bridge are located on one surface of the bar, for example the surface facing the tray, and the two remaining gauges are located on the opposite surface.

This arrangement of the stress gauges makes it possible to measure, at the output terminals of the Wheatstone bridge, a signal which is in theory proportional to the force acting on the tray.

Given that the resultant of the forces acting on the tray may be situated at a point which is remote from the bending axis of the bar, the latter may be subject to torsional stresses which may lead to errors of measurement which may be as much as 5 or 6%.

This drawback has been remedied in this machine by connecting two torsion-responsive gauges, whose axes are disposed at 45° from the axis of the bar, in series with the electrical supply terminals of the Wheatstone bridge formed by the four bending-responsive stress gauges and by connecting a variable resistance in parallel with the two said gauges and one of the terminals measuring the signal supplied by the Wheatstone bridge.

This arrangement makes it possible to cancel out the torsion effects to which the bending-responsive stress gauges are subject.

However, the arrangement of the four bending-responsive stress gauges on two opposite surfaces of the bar greatly complicates the mass production of the machine and its calibration.

The object of the present invention is to remedy this drawback in accordance with the means set out in claim 1.

The applicants have established that the above-described method of connecting the four bending-responsive stress gauges makes it possible to dispose them on the same surface of the bar which considerably facilitates the mass production of bars equipped with such gauges.

This method of connecting the gauges also makes it possible to dispose the stress gauges on the same support strip and therefore to align them almost perfectly along the axis of extension of the bar, which makes it possible in principle to eliminate any torsion component likely to affect the measurement result.

Even in this case, experience has shown that it is nevertheless advantageous to dispose the torsion-responsive gauges symmetrically with respect to the centre of the bar, connecting them in series and respectively to the electrical supply terminals of the Wheatstone

bridge and to connect a variable resistance between the common point of the two torsion-responsive gauges and one of the signal-measuring terminals of the Wheatstone bridge.

In accordance with a preferred embodiment of the invention, the two torsion-responsive gauges are located on the same surface as the four bending-responsive gauges and have their axis inclined at 45° to the axis of alignment of the aforesaid four gauges.

Consequently, all the gauges and the electrical circuit supplying and interconnecting these gauges can be disposed on a single electrically insulating support (or at most two supports) which is secured to the surface facing the tray or to the surface facing the base.

As a result, the bars designed to be fitted in weighing machines of the invention can be manufactured under optimum economic conditions.

Further features and advantages of the invention will be set out in the following description.

In the attached drawings, given by way of non-limiting example:

Fig. 1 is a diagrammatic longitudinal section through a weighing machine of the invention;

Fig. 2 is a top view of the bar, showing the arrangement of the stress gauges;

Fig. 3 is a view showing the electrical circuit interconnecting the gauges;

Fig. 4 is a diagrammatic view similar to Fig. 3 showing the Wheatstone bridge in conventional form, to which two gauges measuring torsion and the variable resistance have been added;

Fig. 5 is a longitudinal section through a weighing machine of the invention, and

Fig. 6 is a top view of this machine;

Fig. 7 is a plan view of a bar in accordance with a variant of the invention;

Fig. 8 shows a Wheatstone bridge with two additional gauges and a variable resistance.

In Fig. 1, the weighing machine of the invention comprises a base 1 and a tray 2 parallel thereto which is designed to receive the load to be weighed, for example the weight of a user.

A metal bar 3 of square section, for example of quenched steel, is arranged between the tray 2 and the base 1, the opposite ends 3a, 3b of the bar being rigidly secured to the tray 2 and the base 1 respectively, so that the bar 3 can yield under the effect of the load acting on the tray 2.

As can be seen from Fig. 2, the bar 3 bears on its plane surface 3c disposed to face the tray 2 two pairs of bending-responsive stress gauges 4, 6; 5, 7 aligned on the longitudinal axis X-X' of the bar 3 and disposed symmetrically with respect to the centre M of this bar.

These stress gauges 4, 6; 5, 7 are formed by planar electrical resistances having parallel resistive filaments such as 4a (see Fig. 3) describing a winding path. These filaments 4a are aligned with the axis X-X' of the bar 3.

The four stress gauges 4, 6; 5, 7 are connected as a Wheatstone bridge 8 (see Figs. 3 and 4).

In the diagrams of Figs. 3 and 4, the points A and B disposed between the gauges 4 and 6 and the gauges 5 and 7 respectively are the electrical supply terminals of the Wheatstone bridge 8.

The points C and D located between the gauges 4 and 5 and the gauges 6 and 7 are the terminals between which the electrical signal resulting from an imbalance of the bridge caused by the bending of the bar 3 is measured, as will be described below in detail.

Two torsion-responsive gauges 9, 10 are disposed, symmetrically with respect to the centre M of the bar, on the same surface 3c of the bar 3 and between the bending-responsive gauges 4, 5; 6, 7. The axis of these gauges 9, 10 is inclined at 45° to the axis X-X' of the bar 3 (see Fig. 2). The same result may be obtained by inclining the parallel filaments 9a (see Fig. 3) at 45° to the filaments 4a of the other gauges.

These two torsion-responsive gauges are (see Fig. 4) connected in series and connected to the supply terminals A and B respectively of the Wheatstone bridge 8.

A variable electrical resistance 11 is connected in parallel between the two gauges 9, 10 and to one of the terminals C or D measuring the signal emitted by the Wheatstone bridge 8, in the direction of deflection of the parasite torsion component appearing on the gauges 4, 5; 6, 7 of the bridge.

Figs. 5 and 6 show a weighing tray embodied in accordance with the invention.

The bar 3 which extends between the base 1 and the upper tray 2 has its end 3a secured to the tray 2 by means of two screws 12 passing through the tray and by a counter-plate 13 disposed opposite the head of the screws 12.

Similarly, the end 3b of the bar 3 is fixed to the base 1 by means of two screws 14 passing through the base and by a counter-plate 15 disposed opposite the head of the screws 14.

All the gauges 4, 5, 6, 7, 9, 10 are disposed on the surface 3c facing the tray 2. All these gauges are located on a one-piece insulating support 16, constituted for example by a sheet of polyimide glued to the surface of the bar 3.

The above-described weighing machine operates as follows.

When a load is placed on the tray 2, the bar 3 tends to bend towards the base 1. This bending of the bar 3 causes an expansion or contraction of the resistive filaments of the gauges 4, 5, 6, 7 which has the effect of modifying their ohmic value thereby causing an imbalance in the Wheatstone bridge 8 and generating an electrical signal between the terminals C and D of the latter.

This signal measurement is converted into a measurement of the load acting on the tray 2 using known means.

More precisely, the signal measured between the terminals C and D of the Wheatstone bridge 8 is proportional to the algebraic sum of the following stresses:

in which relationship $\vec{s}_4, \vec{s}_5, \vec{s}_6, \text{ and } \vec{s}_7$ represent the stresses to

which the gauges 4, 5, 6 and 7 are respectively subject.

This signal is consequently proportional to the following sum of the bending moments:

$$\begin{aligned} & [F.(x + d) - F . d] + [F.(x' + d') - F . d'] \\ & = F . x + F(x') \\ & = F (x + x') \end{aligned}$$

in which F (see Fig. 1) is the force acting on the tray 2,

x is the distance between the gauges 4 and 5,

x' is the distance between the gauges 6 and 7,

d is the distance between the gauge 5 and the point at which the force F is applied, and

d' is the distance between the gauge 7 and the point at which the force F is applied.

Given that x and x' are constants, the signal measured is proportional to the force F wherever this force is applied to the tray 2.

This result is thus obtained with the four bending-responsive gauges 4, 6; 5, 7 aligned on the same surface 3c of the bar 3.

In the case of the machine disclosed in the aforesaid European Patent Application, the positions of the gauges 6 and 7 in the Wheatstone bridge were the opposite of those proposed by the present invention.

Consequently, in order to ensure that the signal emitted by the Wheatstone bridge was proportional to the stresses to which the gauges were subject, the two pairs of gauges had to be disposed on two opposite sides of the bar which considerably complicated the mass production of the bars.

In the case of the present invention, it is possible to achieve an almost perfect alignment of the gauges 4, 6; 5, 7 on the axis X-X' of the bar 3.

Experience shows, however, that an alignment error, even very slight, of these gauges creates a parasite signal which may lead to a slight error in the measurement. This drawback is remedied by the two torsion-responsive gauges 9 and 10. When the bar 3 is subject to slight torsion, these gauges emit a signal which corrects the signal measured between the terminals C and D of the Wheatstone bridge. The signal generated by the torsion is regulated by adjusting the resistance 11, which is connected to the terminal C or D during the assembly of the machine, in the direction of the parasite torsion signal.

In addition, the arrangement of the stress gauges on the same surface of the bar 3 makes it possible clearly to separate the pair of gauges 4, 6 from the pair of gauges 5, 7. The gradient of the signal proportional to the stress, i.e. the sensitivity of the weighing machine, is consequently increased.

This gradient is equivalent to the relationship:

$$a = 3 . K . \frac{x}{E . H} \quad \text{in } V . V^{-1} . \text{kg}^{-1}$$

wherein K is the constant of the gauges, x is the distance between the gauges, H is the thickness of a bar of square section and E is

the Young's modulus of this bar.

Thus, for a bar with a length L of 149 mm, a height H of 18 mm, a Young's modulus of 22 000 daN/mm² and where $x = 109$ mm, a gradient a of $5.097 \cdot 10^{-6} \text{ V V}^{-1} \text{ kg}^{-1}$ is obtained.

The gradient measured is slightly less than the theoretical gradient calculated from the above relationship as the two torsion compensation gauges 9 and 10 slightly reduce the signal amplitude.

The signal measured between the terminals C and D of the Wheatstone bridge reaches, however, a maximum value and has a low temperature drift since the gauges are arranged as a complete Wheatstone bridge.

In the embodiment described above, a particular arrangement of the stress gauges as a Wheatstone bridge makes it possible to obtain a linear signal proportional to the weight acting on the tray 2 and independent of the point at which this weight acts on the tray.

There is, however, a drawback when very great accuracy is required from the weighing machine, since a displacement along the longitudinal axis of the bar 3 of the point of application of the force is reflected by a variation of the signal on both sides of a central point.

This phenomenon is due to a displacement of the neutral fibre of the bar such that the moments of inertia perpendicular to the stress gauges are not constant during the displacement of the force along the longitudinal axis of the test body.

A weight acting on the tray 2 can in fact be broken down into a component parallel to the tray (compression or tension) and a perpendicular component.

There is a displacement of the neutral fibre, which generates the signal variations measured when the weight is applied to each end of the sensor in the case of a bar 3 of rectangular section:

if ξ = relative elongation

F = force

a = width

h = bar height

l = bar length

E = Young's modulus

V = distance between the longitudinal axis of the bar and a point

I = moment of inertia

$$\xi = \frac{F l}{E I} + \frac{F}{E b h}$$

which, if developed, provides: $\xi = \frac{P (12 l V \cos \alpha + E h \sin \alpha)}{E b h^3}$

$$\xi = 0 \Leftrightarrow 12 l V \cos \alpha = - E h \sin \alpha$$

$$V = - \frac{E h \sin \alpha}{12 l \cos \alpha}$$

It can be seen that the sign and the value of V depend on α and thus on the position of the weight.

In order to remedy the above drawback, the improvement of the

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invention consists in placing two gauges 17 and 18 close to the centre M of the bar 3 (see Fig. 7), the gauge 17 being aligned on X-X' and the gauge 18 being perpendicular to this axis.

Fig. 8 shows how these gauges 17 and 18 are connected to the Wheatstone bridge. The gauge 17 is connected to the terminal A and the gauge 18 is connected to the terminal B. They are also connected together and connected to the terminal D by means of a resistance 19 which enables the displacement along the longitudinal axis X-X' of the bar 3 to be adjusted.

This resistance is adjusted as follows:

- the same weight is disposed successively at each end of the bar 3 and the signal variation is recorded:
- depending on the sign of this variation, the adjustment bridge is connected to the terminal C or D,
- the ohmic value of the resistance 19 is adjusted proportionally to the signal amplitude such that there is no variation in the value of this signal according to the position of application of the force along the axis of the bar 3.

The invention is obviously not limited to the example described above and many modifications could be made thereto without departing from the scope of the invention.

Several identical bars could therefore be disposed between the base 1 and the tray 2 depending on the loads or forces designed to be applied to this tray.

In addition, the devices intended to measure the electrical signal at the terminals of the Wheatstone bridge may either be disposed within the weighing machine or externally thereto.

The bar 3 could also have a section other than square, for example rectangular or circular or any shape, provided that the moments of inertia plumb with the gauges are strictly equal.



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CLAIMS

1. A weighing machine comprising a base (1) and, disposed substantially parallel thereto, a tray or platform or the like (2) adapted to receive the load to be weighed, at least one metal bar (3) being disposed between the base (1) and the tray or the like (2) and having its opposite ends (3a, 3b) rigidly secured to the base (1) and tray (2) so that one bar (3) can yield under the load acting on the tray, the bar having on a single plane surface (3c) two pairs (4, 6; 5, 7) of bending-responsive stress gauges aligned substantially on the longitudinal axis (X-X') of the bar and electrically connected as a Wheatstone bridge (8) and two torsion-responsive stress gauges (9, 10) connected to the Wheatstone bridge (8) to cancel out torsion efforts detected by the bending-responsive strain gauges, the gauges of each pair (4, 6; 5, 7) being connected in opposition to the Wheatstone bridge while the two torsion-responsive gauges (9, 10) are connected in series and connected to the input terminals (A, B respectively) of the Wheatstone bridge (8), a variable resistance (11) being connected in parallel between the two torsion-responsive gauges (9, 10) and to one (C or D) of the signal-measuring terminals of the Wheatstone bridge.

2. A machine according to claim 1, characterised in that the two torsion-responsive gauges (9, 10) are disposed on the same surface (3c) as the four bending-responsive gauges (4, 6; 5, 7) and



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have their axis inclined at 45° to the axis of alignment (X-X') of the aforesaid four gauges.

3. A machine according to claim 2, characterised in that the two torsion-responsive gauges (9, 10) are arranged symmetrically of the centre of the bar (3) and between or outside the two pairs of bending-responsive gauges (4, 6; 5, 7).

4. A machine according to claim 2 and/or 3, characterised in that all the gauges (4, 6; 5, 7; 9, 10) and the electrical circuit (8) supplying and interconnecting the same are disposed on a single electrically insulating support secured to the bar surface (3c).

5. A machine according to claim 4, characterised in that the surface (3c) is the surface disposed opposite the tray (2) or opposite the base (1).

6. A machine according to any of claims 1 - 5, characterised in that it also comprises near the centre (M) of the bar (3) a gauge (17) aligned along the bar axis (X-X') and a gauge (18) perpendicular thereto, the two gauges (17, 18) being connected in series and connected to the Wheatstone bridge terminals (A, B respectively); and a variable resistance (19) is connected in parallel between the two gauges (17, 18) and to one (C or D) of the signal-measuring terminals of the Wheatstone bridge.