ELECTRONIC TIMEPIECE

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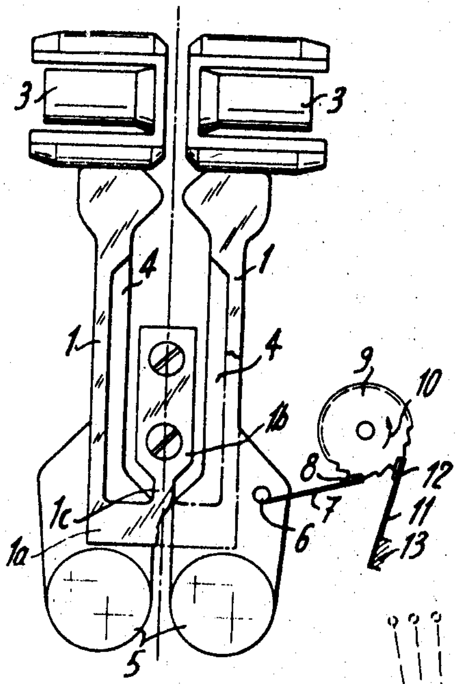

Fig. 1

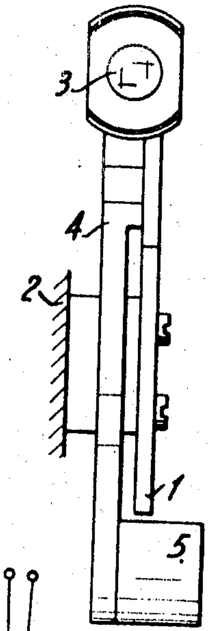

Fig. 2

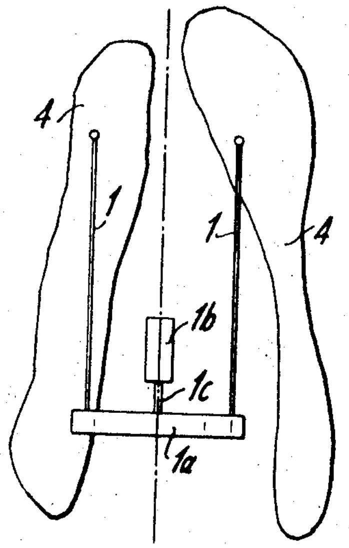

Fig. 3

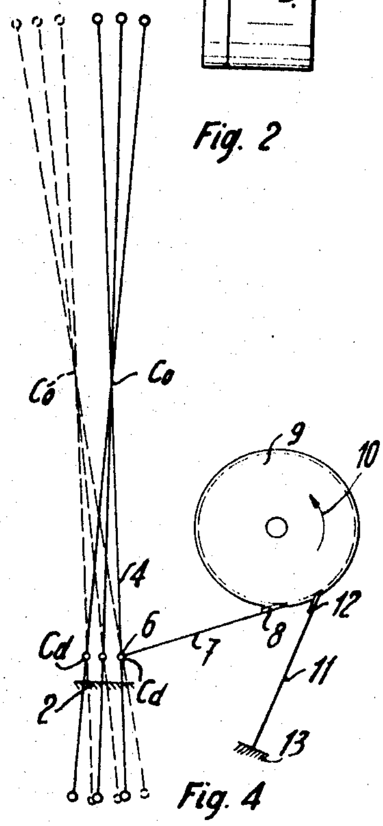

Fig. 4

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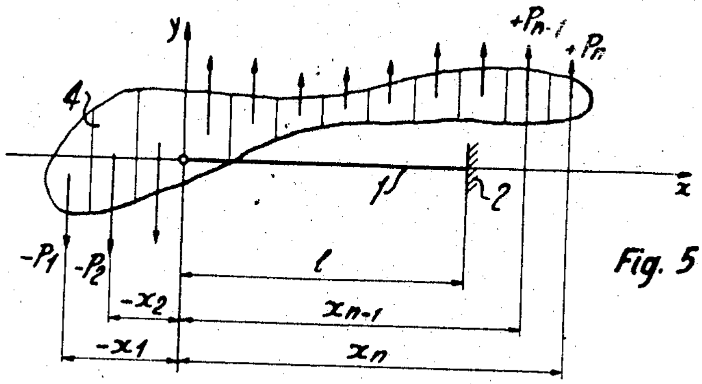

Fig. 5

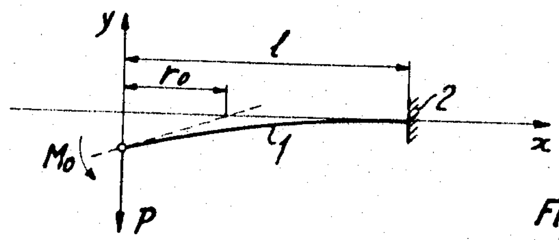

Fig. 6

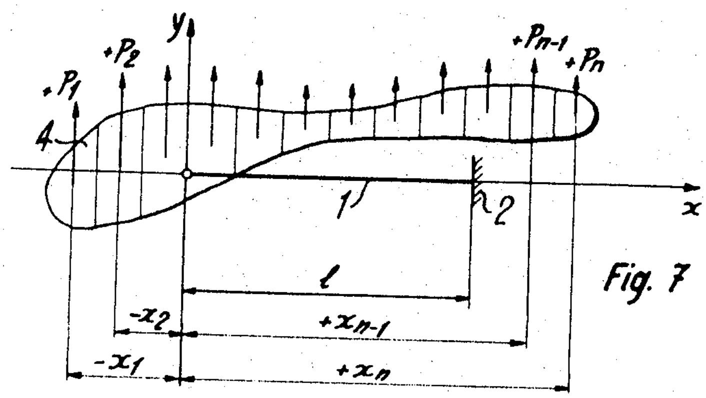

Fig. 7

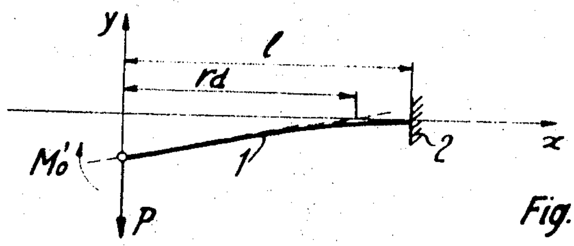

Fig. 8

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3,447,311
ELECTRONIC TIMEPIECE

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U.S. Cl. 58—23 4 Claims

ABSTRACT OF THE DISCLOSURE

An electronic timepiece including mechanical resonator, the oscillations of which are maintained electronically, a counting device actuated by the resonator that transforms the oscillating movements of the resonator into rotary movements of a counting wheel, the resonator being constituted by a symmetrical flexion-type oscillator having a U-shaped portion with two arms thereof participating in flexion in the fashion of a tuning fork and with two rigid limbs thereof adapted to compensate for gravity position effects, each rigid limb being connected to one of the flexible arms in the vicinity of the free end thereof, the counting device being attached to the resonator at a selected point of at least one of the rigid limbs of such resonator as the limb is submitted to a vibratory oscillating movement under the effect of the vibrations of the flexible arm with which such rigid limb is associated, the counting device being practically insensitive to accelerations resultant from shocks to which the timepiece is subjected.

The present invention relates to an electronic timepiece comprising a mechanical resonator, the oscillations of which are maintained electronically, and actuating a counting device which transforms the oscillating movements of the resonator into rotary movements of a counting wheel.

Timepieces of the above-mentioned type are already known, in particular timepieces in which the resonator comprises a tuning fork which, by means of the click, actuates a ratchet-wheel which constitutes the counting wheel. The drawback of such known timepieces rests in the fact that they are sensitive to shocks, which are liable to cause the click to jump several teeth on the counting wheel, thereby obviously rendering the counting inaccurate.

To remedy this drawback, it has been proposed that such devices be fitted with two driving clicks, respectively associated with two flexible arms and operating alternatively, each one for one half-oscillation of the resonator, the retaining click then being omitted.

This solution, however, has serious disadvantages when regulating, repairing and testing the timepiece. In fact, when the counting wheel is retained by a so-called "fixed" click, it is easy to adjust this click by slight displacement thereof in order to determine a position therefor in which the counting wheel recoil is such that the mechanism operates harmoniously and without jerks. In the case in which the counting wheel is subjected to the action of two driving clicks, without a fixed retaining click, such a type of adjustment is not possible and regulating has to be effected by manipulating one or the other of the driving clicks, which is a very delicate operation.

An object of the present invention is to provide a timepiece, the running of which is practically insensitive to sudden accelerations arising due to the effect of shocks, and which nevertheless does not suffer from the disadvantages mentioned above.

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In the present timepiece, the resonator is constituted by a symmetrical flexion-type oscillator having a U-shaped part, the two arms of which participate in flexion in the fashion of a tuning fork, and also having two rigid limbs adapted to compensate for changes in the position or orientation of the oscillator in the field of gravity, each such limb being connected to one of the flexible arms in the vicinity of the free end of the latter.

Such an arrangement has the advantage that the resonator is practically insensitive to "gravity position effects," that is, to modifications in frequency which, under the effect of gravity, are brought about by alterations in positions or orientation of the resonator.

Thus, the present invention provides a timepiece the running of which is insensitive both to gravity position effects, by reason of the design of the resonator equipped with rigid compensating limbs, and to shocks.

The timepiece is characterized by the fact that the counting device is attached to the resonator at a point of at least one of the rigid limbs of the latter, which limb is actuated by a vibratory oscillating movement, under the effect of the vibrations of the flexible arm with which this rigid limb is associated, the arrangement being such that the counting device is practically insensitive to acceleration effects, more especially those due to shocks, to which the timepiece is subjected.

The accompanying drawings show, by way of example, one embodiment of the resonator of the invention.

In these drawings,

FIG. 1 is a plan view of a portion of a timepiece in which only those elements necessary for an understanding of the invention are shown,

FIG. 2 is a view in elevation of a detail in FIG. 1, and

FIGS. 3 to 8 illustrate the principle on which the invention is based.

FIG. 1 represents a mechanical resonator comprising two arms formed by elastic flexible blades **1** connected by a median portion **1***a* rigid with a tongue **1***b*, attached at **2** to the frame of the timepiece. The tongue **1***b* is connected to the median portion **1***a* by an elastic portion **1***c* the purpose of which is to suppress any type of eddy vibrations of a frequency corresponding to the frequency of the desired type of vibrations, during which the two flexible blades **1** vibrate in opposite phase. These blades **1** bear, at their free ends, electro-dynamic transducers **3** which serve to maintain the resonator's oscillations. As the means for maintaining these oscillations is extraneous to the present invention, it will not be described herein.

Each of the flexible blades **1** bears, attached to its free end, a rigid limb **4** which vibrates with the blade with which it is associated and which is itself equipped, at its free end, with a balancing mass or counter-weight **5**. As is shown in FIG. 2, the blades **1** and the limbs **4** are located in two different planes, for the purpose of reducing the surface dimensions of the resonator.

It should be noted that the transducers **3** may be located instead at the position of the balancing masses **5**, that is, at the free ends of the rigid limbs **4**. In this case, the elastic blades **1** will bear balancing masses at their free ends. It would likewise be possible to have, located at the free ends of the elastic blades and the rigid limbs, four transducer parts which would balance each other.

One of the rigid limbs **4** bears, attached to it at **6**, a click formed by an elastic blade **7** provided with a beak **8** that engages with the toothing of a ratchet-wheel **9** which constitutes a counting wheel. This counting wheel is driven step by step, in the direction of the arrow **10**, in the course of the oscillations of the resonator, and is held back by a fixed click, formed by an elastic blade **11** bearing a beak **12**, attached at **13** to the frame of the timepiece clockwork. The beaks **8** and **12** may be constituted by jewels, for example. The counting wheel **9** transmits its movement to the indicating element of the timepiece through the intermediary of a gear train, not shown herein.

Due to the fact that the elastic blade **7** of the driving click is attached to the rigid limb **4** of the resonator, and not to the flexible arm **1** of such resonator, and, furthermore, is connected to a particular point on such rigid limb, the running of the timepiece is not affected by acceleration effects, more especially those due to shocks, to which the timepiece may be subjected.

This feature is explained in the following manner:

The resonator may be shown diagrammatically in the manner represented in FIG. 3, in which the same reference numbers have been employed as in FIGS. 1 and 2.

In this figure, there will again be noted, therefore, a mechanical resonator formed of two elastic blades **1**, each fixed at one end and free at the other, and two rigid masses **4**, each connected rigidly to the free end of one of the elastic blades **1**.

It will easily be seen that, when such a resonator vibrates, the parts **4** turn about a point C_o (FIG. 4) which constitutes a node of vibration and which may be called the instantaneous centre of oscillation.

If said assembly is subjected to acceleration effects of any kind, the resonator becomes deformed. It is possible to determine, on each rigid mass **4**, a stationary point C_d (FIG. 4) about which such mass turns, and which may be called the instantaneous centre of deformation.

The effects of normal vibration and of displacements due to shocks, as applied to a single blade, are shown in FIG. 4.

In order that the device, applied to the driving of the indicator elements of a timepiece through the intermediary of a counting device, may function in the desired maner, that is, may be insensitive to shocks, it is necessary for the point of attachment of the counting device to the resonator to be located on the centre of deformation C_d and, furthermore, for the centre of oscillation C_o not to coincide with the centre C_d.

Thus, in FIG. 1, if the point of attachment **6** of the counting device coincides with the centre of deformation C_d, it is clear that said device will not be influenced by shocks. However, so that the mechanism may work, that is, so that the counting wheel may be driven by the resonator while the normal vibration of the latter is proceeding, the counting device must not be attached to the resonator at a point **6** coinciding with the centre of oscillation C_o of the latter. Thus, the condition set out above, that the centres of oscillation and of deformation should not coincide, can be fulfilled by a judicious selection of the shape and the size of the rigid masses **4**, in correlation with the characteristics of the elastic portions of the resonator.

It should be noted that the condition set out above is compatible with the demands the resonator must meet for its frequency to be independent of its position in the field of gravity.

It is to be demonstrated that the centre of oscillation and the centre of deformation do not coincide. With this in view, said centres will be calculated hereinafter. In these calculations, only one half of the resonator is considered, this latter being symmetrical and its central portion being without effect on the calculations, as will be explained hereinafter.

(1) Calculation of the centre of oscillation C_o, that is calculation of the distance r_o between such centre and the free end of the resonator

As is shown in FIG. 5, each rigid mass **4** may be broken down into elementary weights P_i applied to the centres of gravity of elements of elementary surfaces and separated from the free end ($x=0$) of the flexible blade **1** by a distance x_i.

The system of forces thus arising can be reduced to the resulting couple (M_o) applied about $x=0$, that is:

$$M_o=P_1x_1+P_2x_2+\ldots+P_{n-1}x_{n-1}+P_nx_n=\sum_{i=1}^{n}p_ix_i \text{ where}$$

$$P=\sum_{i=1}^{n}P_i$$

In applying Rayleigh's method, which assumes the hypothesis that the static deformation is equal to the dynamic deformation, it is possible to calculate the elastic line of the blade **1** by the general flexion formula:

$$\frac{d^2y}{dx^2}=\frac{M(x)}{EJ}$$

in which:

E=modulus of elasticity (Young modulus) of the blade **1**

J=inertial moment of the blade **1**

$M(x)=M_o+Px$ (in the particular case)

By a double integration, and assuming that for $x=l$ (FIG. 6), $y=0$ and $dy/dx=0$, it is possible to calculate the function $y=f(x)$.

Calculation of the position of centre of oscillation C_o is reduced to calculation of the distance r_o, which may therefore be expressed by:

$$r_o=\frac{(y)_{x=o}}{\left(\frac{dy}{dx}\right)_{x=o}}$$

Calculation leads to:

$$r_o=\frac{\frac{1}{2}M_ol+\frac{1}{3}Pl^2}{M_o+\frac{1}{2}Pl}$$

(2) Calculation of the centre of deformation C_d, that is calculation of the distance r_d between such centre and the free end of the resonator

It being assumed that the initial acceleration applied to the assembly is G, the effect of said acceleration is that shown in FIG. 7.

As in the preceding case, the system of forces shown can be reduced to the resulting moment applied about $x=0$, that is:

$$M'_o=-P_1x_1-P_2x_2+\ldots+P_{n-1}x_{n-1}+P_nx_n\sum_{i=1}^{n}P_ix_i \text{ and}$$

$$P=\sum_{i=1}^{n}P_i$$

Calculations for determining the centre of deformation C_d, that is, the distance r_d (FIG. 8), are in all points identical with the preceding calculations, with the sole difference that M'_o is different from M_o, due to the fact that the forces located to the left of the y axis in FIG. 7 have altered sign.

Thus, by a judicious selection of the parameters occuring in the formulae, it is possible to arrange that $r_o \neq r_d$ and, consequently, that C_o does not coincide with C_d.

(3) Observations concerning the calculations

The calculations above suppose that the amplitude of the vibrations is extremely small in relation to the length of the vibrating portion of the resonator, and this is always the case in practice.

Likewise, no account has been taken of the elasticity of the median portion **1c**, since this can be considered to be negligible in relation to the elasticity of the flexible arms **1**. Additionally, it is sufficient that said elastic portion **1c** should be located, by design, at the level of the centre of deformation C_d, measured in the direction of the ordinates, in order that the effect of said elastic portion on the position of the centre of deformation should be nil, which is further justification for not taking such elastic portion into account in the calculations.

(4) Practical example

In the case in which $l=0.91$ cm. and M_0 in the vibrational state=515 dynes×cm. and M'_0 with shocks= −229 dynes×cm., calculation leads to $r_o=0.5$ cm. and $r_d=1.0$ cm.

Thus, r_o and r_d do not coincide, so that, in the vibrational state, the amplitude C_d is not nil, and so that the position of C_d in relation to a fixed point on the frame remains unaltered, whatever the size and direction of the acceleration effects to which the complex may be subjected.

What we claim is:

1. In an electronic timepiece comprising a mechanical resonator, the oscillations of which are maintained electronically, a counting device actuated by the said resonator, that transforms the oscillating movements of the resonator into rotary movements of a so-called counting wheel, and in which said resonator is constituted by a symmetrical flexion-type oscillator having a U-shaped portion the two arms of which participate in flexion, in the fashion of a tuning fork, and having two rigid limbs adapted to compensate for gravity position effects and each connected to one of the said flexible arms, in the vicinity of the free end of the latter, in such a timepiece, the said counting device attached to the said resonator at a selected point of at least one of said rigid limbs of such resonator, which limb is submitted to a vibratory oscillating movement, under the effect of the vibrations of the flexible arm with which this rigid limb is associated, the arrangement being such that the counting device is practically insensitive to accelerations, more especially those due to shocks, to which the timepiece is subjected.

2. In a timepiece as claimed in claim **1**, the point of attachment of the said counting device to the said resonator coincides with the center of deformation of the complex formed by the rigid limb actuating said counting device and the flexible arm associated with it, in the displacements of such complex which are due to the effects of accelerations, such center of deformation being distinct from the center of oscillation of said complex in its displacements that are due to vibratory oscillations.

3. In a timepiece as claimed in claim **1**, in which the said counting device is constituted by a click mechanism that actuates a ratchet wheel which constitutes the said counting wheel, (a center of deformation on each rigid limb about which the mass turns in deformation of the resonator under subjection to acceleration effects, such click mechanism comprises at least one click attached to one of the rigid limbs at a point which coincides with said center of deformation of the complex formed by said rigid limb and the flexible arm bearing such rigid limb.

4. In a timepiece as claimed in claim **1**, including an elastic portion interconnecting the two arms of the oscillator and the respective rigid limb for supressing eddy vibrations of a frequency corresponding to the frequency of the desired vibrations, the resonator being fixed on its support through the intermediary of the elastic portion terminating in the U-shaped transverse portion which connects the flexible arms, the said elastic portion being located at the level of the point of attachment of the counting device to the resonator, along the axis of symmetry of the latter.

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