

Dec. 14, 1971

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3,626,691

WATCH BALANCE

Filed Aug. 25, 1969

2 Sheets-Sheet 1

FIG. 1

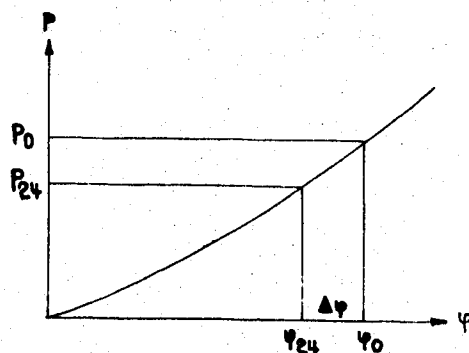


FIG. 2

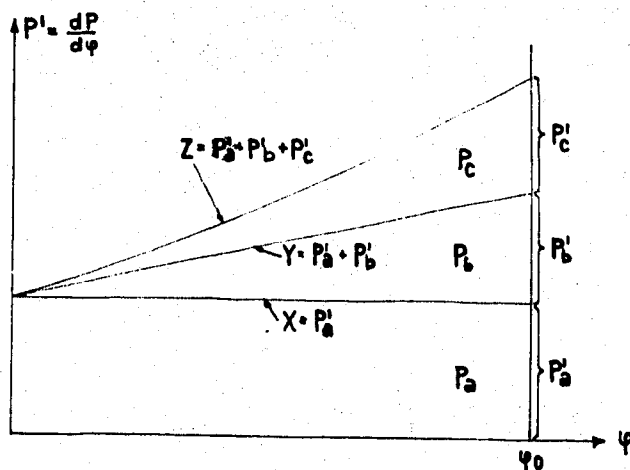
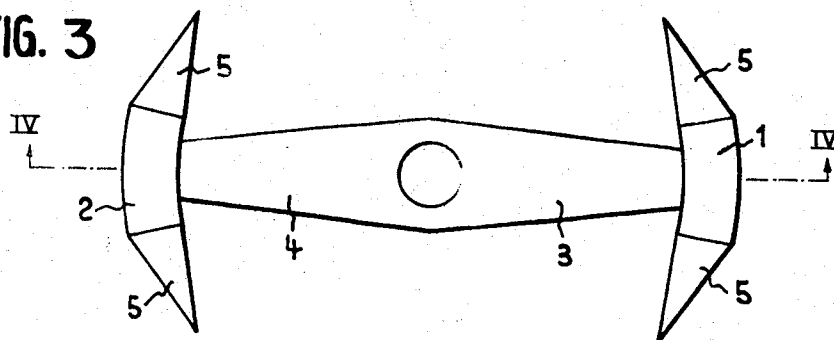


FIG. 4



FIG. 3



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FIG. 5

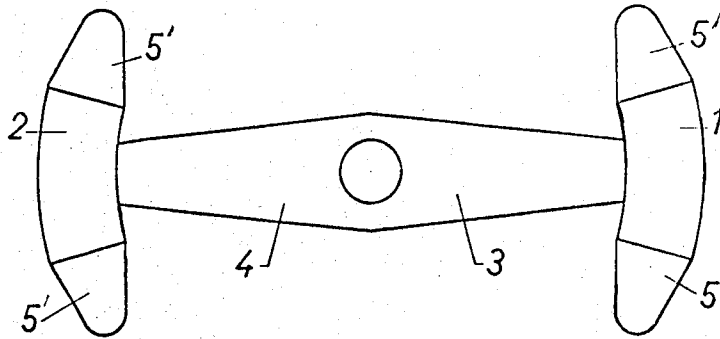


FIG. 6

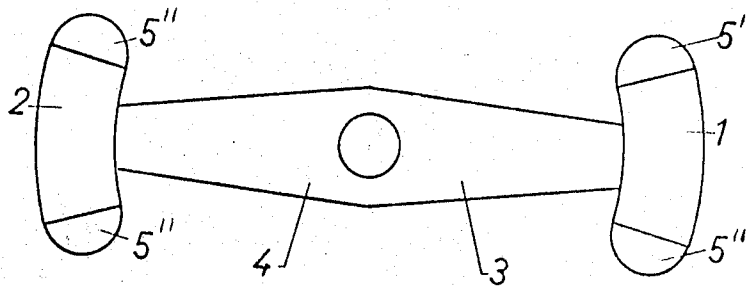
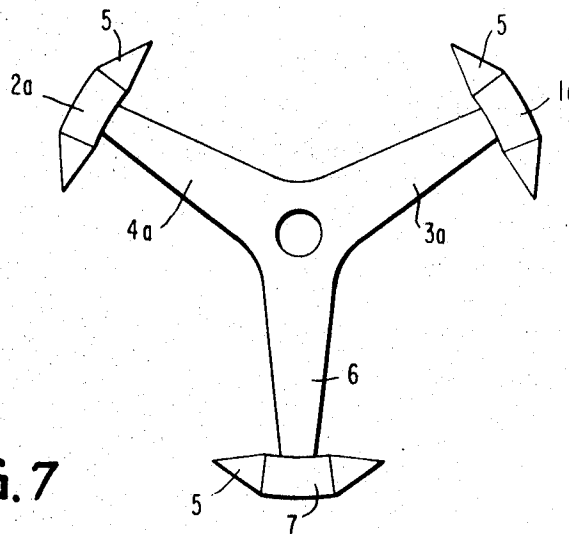


FIG. 7



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WATCH BALANCE

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6 Claims

ABSTRACT OF THE DISCLOSURE

A watch balance comprising at least two inertia-blocks having a streamlined shape carried by arms and extending on the whole over less than the half of the circumference of the balance, the rest of the circumference being free of material, characterized in that the compactness of the inertia-blocks in the range of from .310 to .455 and the material comprising the inertia-blocks a density exceeding 9 g./cm.³.

The present invention relates to a watch balance.

The energy consumed by a balance-hairspring assembly increases with the amplitude and, roughly, also with the moment of inertia. This is a well-known relation, and if an engineer notes that on a caliber the amplitude of the oscillation is too small, either he will endeavor to increase the force of the main spring, or else he will choose a smaller balance, having a smaller moment of inertia, which, for the same available energy, will oscillate with a larger amplitude.

On the contrary, if it is desired to increase the performances with respect to the stability and the precision of a watch, the moment of inertia of the balance is increased as far as possible, whereby the factor of quality Q of the oscillator can be increased. It is known that $Q = \pi N$, wherein N = number of the periods of a damped, non-sustained oscillator in order that its amplitude falls to $1/e$ of its initial value, e being the basis of the natural logarithms. For instance, on the marine chronometers, balances having a high moment of inertia are used, and these balances necessitate, therefore, in order that their oscillations can be sustained, a considerable power.

In a watch, especially for a small caliber (lady's watch), the available energy is limited. If it is sought to increase the moment of inertia and the factor of quality, one is rapidly stopped by the amplitude which becomes too small. This limitation has become particularly sensible with the present trend to increase the frequency of oscillation, for the purpose of increasing the factor of quality. Now, an oscillator of high frequency consumes more energy, and the engineer is induced to diminish the moment of inertia of the balance in order to keep a sufficient amplitude, so that the increase of the factor of quality is not as important as expected.

In short, the technical problem to be solved is the following:

How is it possible to minimize the consumption of energy of a balance having a given moment of inertia? As a matter of fact, any reduction of the consumption of energy for a given moment of inertia will enable the engineer to choose, for a given available power and a given frequency, balances of larger moment of inertia, and this will enhance or favor the factor of quality Q .

How is it possible to reduce the energy lost upon the oscillation of a balance?

It is at first important to know where the energy is going, by which physical processes it is dissipated. These losses are due:

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- (a) to the friction of the balance against air;
- (b) to the friction of the pivots;
- (c) to the internal friction of the hairspring.

The present invention aims at reducing the factor (a), i.e. the friction of the balance against air.

In the balances of conventional shape, which are uncut and have a circular rim, this friction is only lateral (for the rim), since the latter always occupies the same portion of space when the balance oscillates. A front resistance (resistance to the penetration) only occurs for the edges of the balance arms. It is reasonable to think that this friction will be proportional to the rim area and that it will also depend on the peripheral speed (which is itself proportional to the radius, for a given angular velocity). This explains why the balances having a high moment of inertia consume more energy; in order to increase the moment of inertia, it is necessary to increase either the mass (and this will, for a constant density, increase the rim area), or the radius and this will increase the peripheral speed). Other factors intervene, but the energy portion dissipated by friction against air roughly increases with the moment of inertia.

The engineer is, therefore, induced to think that an increase of the density of the material used will be favorable, since, for a given mass, the rubbing surface will diminish. On the other hand, there exists a radical method for eliminating the friction of air, and this consists in causing the balance to oscillate in the vacuum.

However, another difficulty is encountered. The friction of air has a stabilizing effect on the amplitude of the balance spring torque when the spring uncoils). The balances made of a very dense material or oscillating in the vacuum consume little energy, but their amplitude considerably diminishes between the moment when the mainspring is completely wound up and after 24 hours, and this finds expression in variations of the daily rate if only the period varies with the amplitude (lack of isochronism).

The engineer seeks, therefore, to obtain an oscillator the consumption of which is as low as possible, but which does not show a too large fall of amplitude when the available power diminishes by a given percentage.

The engineer is thus induced to study the curve giving the consumed power in function of the amplitude. The inventor has shown (in Journal Suisse d'Horlogerie, Swiss edition, No. 9/10, 1967, pages 339-345) that if the total friction torque F in function of the angular velocity θ is given by

$$F = a + b\theta + c\theta^2$$

the consumed power P in function of the amplitude φ is

$$P = \frac{2}{\pi} a\omega\varphi + \frac{1}{2} b\omega^2\varphi^2 + \frac{2}{\pi} c\omega^3\varphi^3$$

$\omega = 2\pi\nu$, ν = frequency of the oscillation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph depicting dissipated power P as a function of amplitude φ for an oscillating system of the type treated by the invention;

FIG. 2 is a graph depicting the derivative $dP/d\varphi$ as a function of φ where P and φ are the same parameters as in FIG. 1;

FIG. 3 is a top view of an embodiment of the invention; FIG. 4 is a cross-sectional view taken along line 4—4 of FIG. 3;

FIGS. 5, 6 and 7 are, respectively, plan views of further embodiments of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The curve giving P in function of the amplitude φ has the aspect shown in FIG. 1 of the accompanying drawing. In this figure, the letters have the following meanings:

P_0 =available power when the mainspring is wound up
 φ_0 =corresponding amplitude
 P_{24} =available power after working during 24 hours
 φ_{24} =corresponding amplitude
 Δ_ϕ =difference of amplitude

It will be seen immediately that the difference of amplitude Δ_ϕ will depend on the average slope of the curve in the domain of utilization; the larger is this slope, the smaller will be Δ_ϕ . This slope is given by:

$$\frac{dP}{d\varphi} = \frac{2}{\pi} a\omega + b\omega^2\varphi + \frac{6}{\pi} c\omega^3\varphi^2$$

The problem, therefore, amounts to reducing P_0 while keeping a sufficient slope between φ_0 and φ_{24} . But P_0 is connected with the slope:

$$P_0 = \int_0^{\varphi_0} \frac{dP}{d\varphi} d\varphi$$

If the curve of the derivative $dP/d\varphi$ in function of φ is represented, the curve Z shown in FIG. 2 of the accompanying drawing is obtained. In this representation, P_0 will be the area of the surface situated below the curve Z up to the abscissa φ_0 . The problem, therefore, amounts to diminishing the surface lying below the curve Z , while keeping the ordinate at the point of abscissa φ_0 .

The ordinate $dP/d\varphi$ at the point of abscissa φ_0 may be divided into three segments:

$$Pa' = \frac{2}{\pi} a\omega$$

$$Pb' = b\omega^2\varphi_0$$

$$Pc' = \frac{6}{\pi} c\omega^3\varphi_0^2$$

$$\left(\frac{dP}{d\varphi}\right)_{\varphi_0} = Pa' + Pb' + Pc'$$

In the same manner, the surface P_0 may be divided into three portions:

$$Pa = \frac{2}{\pi} a\omega\varphi_0$$

$$Pb = \frac{1}{2} b\omega^2\varphi_0^2$$

$$Pc = \frac{2}{\pi} c\omega^3\varphi_0^3$$

$$P_0 = Pa + Pb + Pc$$

The quantities Pa , Pb and Pc are connected in a simple manner with Pa' , Pb' and Pc' :

$$Pa = \varphi_0 \cdot Pa'$$

$$Pb = \frac{1}{2} \varphi_0 Pb'$$

$$Pc = \frac{1}{3} \varphi_0 Pc'$$

$$P_0 = \varphi_0 (Pa' + \frac{1}{2} Pb' + \frac{1}{3} Pc')$$

It is desired to keep $P'(\varphi_0) = Pa' + Pb' + Pc'$ constant. It is, therefore, only possible to carry out transfers between the Pa' , Pb' and Pc' (for instance subtract a certain quantity $\Delta P'$ from Pa' and distribute it over Pb' and Pc').

Since the purpose is to diminish the surface lying below the curve Z , i.e. P_0 it will immediately be seen in which manner these transfers have to be effected: For instance, the term Pa' has to be reduced (which has to be multiplied by φ_0 in order to obtain the corresponding surface portion) and the terms Pb' and Pc' have to be increased (these terms have to be multiplied only by $\varphi_0/2$ and $\varphi_0/3$, respectively, in order to obtain the corresponding surfaces).

The terms whose multiplicative factor is small have, therefore, to be favored at the expense of those whose multiplicative factor is large, i.e. Pc' and Pb' have to be favored at the expense of Pa' and Pc' has to be favored at the expense of Pb' .

Upon which geometric and physical characteristics of the balance depend these terms Pa , Pb and Pc , Pa' , Pb' and Pc' ? They are respectively proportional to a , b and c .

a =so-called "dry" coefficient of friction, proportional to the weight of the balance and to the radius of the pivot;

b =so-called "viscous" coefficient of friction, proportional (as concerns the part due to the friction of air on the rim), to S and to R_m^2 ;

c =so-called "quadratic" coefficient of friction, proportional to S and to R_m^3 .

There exists, therefore, a simple method for increasing Pb' and Pc' at the expense of Pa' without reducing the moment of inertia: R_m has to be increased, and this permits (for the same moment of inertia) reducing the mass (moment of inertia $= mR_m^2$), and therefore Pa' . Since Pb' and Pc' are proportional to R_m^2 and to R_m^3 , respectively, they will increase with the radius and the engineer will obtain what he desires, viz a reduction of P_0 without changing P' at φ_0 . The diminution of the mass results, I admit, for the same density and radius, in a diminution of the rim area, but since the radius is increased while reducing the mass, a slimmer rim, having a larger circumference, and therefore less compact, is obtained, so that the diminution of the mass does not produce a diminution of the area.

It is also sought to diminish the masses lying near the center and which, therefore, do not contribute to increase the moment of inertia nor to stabilize the amplitude: masses of the balance staff, of the roller and also of the arms. This permits reducing Pa' and accordingly increasing Pb' and/or Pc' .

The increase of the radius will also permit favoring Pc' at the expense of Pb' , since Pc' is proportional to R_m^3 , whereas Pb' is proportional to R_m^2 .

Summarizing, a reduction of the mass with an increase of the radius permits diminishing Pa' at the expense of Pb' and Pc' ; in addition, it permits increasing Pc' more than Pb' , but it does not permit diminishing Pb' . Now, a diminution of Pb' at the expense of Pc' would permit further reducing P_0 without altering $P'(\varphi_0)$.

In order to reduce b , it is necessary to diminish the rim area without diminishing its moment of inertia.

A first method is to increase the density of the material used for the rim. Thus, the rim area is reduced, so that Pb' and Pc' are diminished; then, the radius has to be increased in order to restore $P'(\varphi_0)$; since Pc' increases more quickly with the radius than Pb' , it is possible to obtain all things considered a diminution of Pb' at the expense of Pc' .

But, here too, there is a limitation: Since the volume of the rim diminishes and the radius increases, the engineer is led to very little compact shapes wherein the area becomes important with respect to the volume, so that an optimal radius is quickly attained, beyond which the consumption due to Pb and Pc becomes too important. The obstacle is, therefore, the little compactness; if this obstacle is to be overcome, it is necessary to try to use more compact shapes.

The engineer is, therefore, induced to wonder whether it would not be advantageous to abandon the continuous rim and to distribute the mass of inertia into separate portions, this introducing, I admit, front frictions (which may again be reduced by using stream-lined shapes), but permitting obtaining a larger compactness and, therefore, a smaller area for a given volume. The calculation and the experience have confirmed this supposition: The introduction of a front friction is largely

compensated by the diminution of the side friction consecutive to the diminution of the area. And this is precisely the subject-matter of the present invention. The invention proposes a balance having separate masses, preferably presenting a stream-lined profile, carried by arms. For reasons of equilibrium, at least two symmetrical masses are required. The engineer is even induced to provide for three masses in order to facilitate the poising of the balance, but the multiplication of the masses diminishes the compactness and, therefore, it is not desirable to multiply them beyond what is strictly necessary.

The stream-lined profile having to be symmetrical owing to the reciprocating motion of the balance and the rear profile being more conclusive than the front profile, it is advantageous to terminate it in the shape of a point rather than to round it off.

Definition of the compactness

The following quantity is defined as a measure for the compactness:

$\gamma = \sqrt[3]{V}/\sqrt{S}$ or, if several bodies are present, or, if several bodies are present,

$$\gamma = \frac{\sqrt[3]{\sum_1^3 V_i}}{\sqrt{\sum_1^3 S_i}}$$

wherein V=volume of the body, S=area of the body.

This measure offers the advantage that it depends only upon the shape, and not upon the size (γ is invariant if all of the linear dimensions of a body are multiplied by the same factor).

EXAMPLES

Compactness of a sphere (maximum compactness)

$$V = \frac{4\pi R^3}{3} \quad S = 4\pi R^2$$

$$\gamma = \frac{\sqrt[3]{V}}{\sqrt{S}} = \frac{\sqrt[3]{\frac{4\pi}{3}}}{\sqrt{4\pi}} = 0.455$$

Compactness of a cube

$$V = a^3 \quad S = 6a^2$$

$$\gamma = \frac{\sqrt[3]{V}}{\sqrt{S}} = \frac{1}{\sqrt{6}} = 0.408$$

Overall compactness of two spheres of the same radius

$$\gamma = \frac{\sqrt[3]{2 \cdot \frac{4\pi}{3}}}{\sqrt{2 \cdot 4\pi}} = 0.405$$

Compactness of an ordinary continuous rim of rectangular cross-section

$$V = 2\pi R_m h s \quad S = 2\pi R_m \cdot 2(h+s)$$

$$\gamma = \frac{\sqrt[3]{2\pi R_m h s}}{2\sqrt{\pi R_m (h+s)}} \\ = \frac{\sqrt[3]{2\pi} \sqrt[3]{R_m h s}}{2\sqrt{\pi} \sqrt{R_m (h+s)}}$$

R_m = average radius of the rim

h = height of the rim

s = width of the rim

$$= 0.52054 \cdot \frac{\sqrt[3]{R_m h s}}{\sqrt{R_m (h+s)}}$$

The compactnesses of the rim of the ordinary balances (dimensions according to the norms of the Swiss watch industry) are about .248-.264.

The present invention relates to a watch balance, consisting of at least two inertia-blocks or weights carried by arms and extending on the whole over less than the half of the circumference of the balance, the rest of the circumference being free of material, this balance being characterized in that the compactness of the inertia-blocks is greater than .310, and is preferably greater than .320. The compactness referred to as the compactness of the mass of inertia alone (inertia-blocks and possible balancing screws), the arms adapted to sustain this mass of inertia not included. If the inertia-blocks are pieces manufactured separately from the arms, the arm portion situated outside the inner radius of the inertia-block is considered as belonging to the mass of inertia.

The balance illustrated in FIGS. 3 and 4 includes two identical inertia-blocks or weights 1 and 2 carried by arms 3 and 4, respectively. Each of the inertia-blocks presents two pyramid-shaped ends 5, in order to reduce the front frictions on the oscillation of the balance. The width of the arms 3 and 4 is fairly larger than their thickness. Both inertia-blocks 1 and 2 extend on the whole over less than the half of the circumference of the balance, the rest of the circumference being free of material. In the example illustrated, the compactness of the inertia-blocks is about .35. The density of the inertia-blocks 1 and 2 is preferably rather large; it may for instance exceed 9 g./cm.³. The number of the inertia-blocks might be greater than two and may include three or more arms 3a, 4a and 6, carrying weights 1a, 2a and 7 respectively, as shown in FIG. 7. The pyramids 5, in which end the inertia-blocks may be more or less blunt or paraboloidal 5', FIG. 5, and might also be replaced by half-spheres 5'', FIG. 6.

1. A watch balance, consisting of at least two inertia-blocks carried by arms and extending on the whole over less than the half of the circumference of the balance, the rest of the circumference being free of material, characterized in that the compactness of the inertia-blocks is in the range of from .310 to .455, the material comprising said blocks having a density exceeding 9 g./cm.³, and said inertia-blocks having a streamlined shape which converges symmetrically toward the opposite ends thereof, whereby to establish streamline flow past said block and reduce the front friction during oscillation of the balance.

2. A watch balance according to claim 1, characterized in that the inertia-blocks are in the number of two.

3. A watch balance according to claim 1, characterized in that the inertia-blocks are in the number of three.

4. A watch balance according to claim 1, wherein said ends are of generally pyramidal shape and converge to points.

5. A watch balance according to claim 1, wherein said ends are of generally paraboloidal shape.

6. A watch balance according to claim 1, wherein said ends are half-spheres.

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