

Singapore

PATENT SPECIFICATION

(11) 1360546

1360546

- (21) Application No. 5185/72 (22) Filed 3 Feb. 1972
(31) Convention Application No. 114277 (32) Filed 10 Feb. 1971 in
(33) United States of America (US)
(44) Complete Specification published 17 July 1974
(51) International Classification G04B 17/06 G04C 3/04
(52) Index at acceptance
G3T A5B1 A6A



(54) BALANCE WHEEL AND METHOD OF POISING

(71) We, TIMEX CORPORATION, a Corporation organised under the Laws of the State of Delaware, United States of America, of Waterbury 20, Connecticut, United States of America, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to horology and more particularly to a balance wheel and a method of poising a balance wheel.

It is an object of this invention to provide a new and improved balance wheel.

It is another object of this invention to provide a unique method of poising balance wheels.

A further object of this invention is to provide a balance wheel having a unsymmetrical configuration which facilitates the poising thereof.

A still further object of this invention is to provide an economical and expeditious method of poising balance wheels of an unsymmetrical design.

According to the invention there is provided a horological balance comprising an outer rim, and a spoke extending inwardly from the rim and having a yoke at the end thereof, a body mounted in the yoke offset from the axis of rotation of the balance, and the rim an enlarged counterweight portion comprising a crescent shape determined by calculating conditions ranging from maximum to minimum dipoise due to variations in the weight of said body between a maximum value and a minimum value with dimensions of said portion being determined by the amount of counterweight to be removed to poise the assembly under various dipoise conditions, said balance having such amount of the counterweight portion removed as is necessary due to the actual weight of the body to poise the balance.

Also according to the invention there is provided a horological balance comprising a balance wheel having an axis, a counterweight portion and a body mounted on the

other side of said axis from said counterweight portion and which causes rotation of the body to a particular angular position when the axis is horizontal and the wheel is not properly poised, said angular position being related to the amount of dipoise, said counterweight portion comprising a crescent shape determined by calculating conditions ranging from maximum to minimum dipoise due to variations in the weight of said body between a maximum value and a minimum value with dimensions of said portion being determined by the amount of counterweight to be removed to poise the assembly under various dipoise conditions, said balance having such amount of the counterweight portion removed as is necessary due to the actual weight of the body to poise the balance.

Still further according to the invention there is provided a method of poising a horological balance comprising the steps of providing a balance having a rim and a spoke extending inwardly from the rim and terminating in a yoke having a body mounted between arms thereof, the body being offset from the axis of rotation of the balance, forming a contoured portion of the balance rim to serve as a counterweight, the contour of said counterweight portion being determined by developing a curve between positions corresponding to the maximum and minimum dipoise conditions due to variations in the weight of said body rotatably supporting the balance wheel at its said axis with said axis horizontal so that variations in weight of said body cause the wheel to take up a particular angular position with respect to a fixed tool to remove a portion of the counterweight portion to at least partly poise the balance wheel.

One embodiment of the present invention is envisaged as including a balance wheel carrying a body, e.g. a coil or magnet, mounted thereon. The body is mounted unsymmetrically with respect to the axis of rotation of the balance wheel, that is, the centre of the body is displaced a predetermined distance from a reference plane through the balance wheel axis. Variations in body weight or wheel

design, therefore, cause rotation about the axis of the balance wheel when the wheel is freely suspended with its axis horizontal. The rotation of the balance wheel stations a particular segment of the counterweight portion of the rim opposite a fixed tool. Activation of the tool removes sufficient material to correctly poise the balance wheel. The balance wheel may thus be readily poised without the use of complex and expensive machines.

Features and advantages of the present invention will now be further described with reference to the accompanying drawings, in which:—

Figure 1 is a top view of an embodiment comprising a balance wheel carrying a coil;

Figures 2 and 3 show the position of such a balance wheel having respectively a light coil and a heavy coil;

Figure 4 is a schematic diagram related to the torsion force diagram of Figure 5 and the torsion triangle of Figure 6;

Figures 7 and 8 illustrate the conditions of maximum and minimum material removal;

Figure 9 shows the amount of cut "h" to be computed; and

Figure 10 is a sketch disclosing a balance wheel carrying magnets.

Referring now to Figure 1 of the drawings, a balance wheel 10 comprises a substantially annular rim portion 11 having a gap 12 within which part of a coil 13 is fixed to the tapered faces 14 and 16 of the rim 11 by means of a suitable adhesive compound 17. The opposite side of the coil 13 is nested between the arms 18 and 19 of a yoke 21 and is held in position by adhesive 22. The yoke 21 comprises one end of a spoke 23 which extends inwardly from the rim 11 of the balance wheel 10. The rim 11 also includes a slightly enlarged portion 24 extending on both sides of the spoke 23 and an enlarged counterweight portion 26 having an inner curved surface 27 of predetermined configuration.

The balance wheel 10 depicted in Figure 1 represents only one possible embodiment of balance, and it is to be understood that the balance could have a completely annular rim, a rim comprised by a segment only of an annulus or comprise other variations thereof. Furthermore, the balance wheel 10 may carry magnets as shown in Figure 10 rather than the coil 13 illustrated in Figure 1. In conventional balance wheel design, the spoke 23 would generally be joined to the base 25 of the yoke 23 with the centre line of the spoke 23 coinciding with the plane Y—Y through the axis of rotation 28 and the centre 35 of coil 13.

The balance wheel 10 is designed so that an unbalanced wheel 10 supported with its axis

horizontal will rotate a predetermined amount with respect to a fixed tool 29, such as a punch or drill, see Figures 2 and 3, depending upon variations in coil weight and wheel design. The movement of the balance wheel presents a section of the counterweight 26 to the tool 29. Since the counterweight 26 decreases from a maximum in size and weight at one end to a minimum at the other end, the segment removed by the tool 29 is related to the amount of rotation about the axis 28. It is, therefore, possible to employ the same cutter or tool 29 and cutting depth for different balance wheels 10. The counterweight 26 and particularly the crescent shaped surface 27 thereof must be specifically designed to accomplish this effect.

The theory of the invention is shown schematically in Figures 2 and 3 which depict two extreme conditions. Under normal manufacturing conditions, a typical coil weight may vary $\pm 5\%$, the conditions represented by Figures 2 and 3. Figure 2 illustrates a light coil 13 of minimum weight which rotates the balance 10 an angle α min about the axis 28 so that a maximum amount of counterweight material 31 is removed by the tool 29. On the other hand, the heavy coil 13 (5% over specified weight) rotates the balance 10 a maximum amount, i.e. by angle α max, with respect to the fixed tool 29 so that a minimum amount of material 32 is removed. The amount of material take-off is controlled by the coil position or angle α which is taken up due to coil weight, and by the crescent shape of the counterweight 26.

In order to design the balance wheel 10 of Figure 1 formulas must be developed for the angle of dipose α and the amount of dipose M_x . Thus, Figure 4 is a schematic representation of a portion of the balance wheel 10 while Figure 5 shows the various torsional forces acting on the balance wheel 10 and Figure 6 represents the force or torsion triangle derived therefrom. The tolerance 35 due chiefly to variations in coil weight is also illustrated in Figure 5.

The torsional forces about the axis 28 of the balance wheel 10 are as follows:

$$\text{Coilside: } M_c (\text{torsion}) = G_c \cdot a$$

$$\text{Counterside: } M_c (\text{torsion}) = G_c \cdot b$$

where:

G_c = coil weight; a = distance from wheel centre

G_c = counterweight; b = distance from wheel centre

The direction of dipose $\tan \alpha$ and the amount of dipose M_x may be determined by

applying the sine rule to the torsion triangle of Figure 6 to obtain the following relationships:

$$(1) \quad \tan \alpha \text{ (direction of dipoise)} = \frac{\sin \beta}{\frac{M_x}{M_0} - \cos \beta}$$

$$(2) \quad M_x \text{ (amount of dipoise)} = M_0 \frac{\sin \beta}{\sin \alpha}$$

- 5 The angle β is selected to be as small as possible, say 1 to 10° in view of production tolerances and the distances a and b are known for a particular balance wheel. The maximum and minimum coil weights are substituted in the torsion formulas to obtain the maximum and minimum angle of dipoise and amount of dipoise are then arrived at by computation using the respective maximum and minimum torsion values.

10 Figure 7 illustrates, again in schematic fashion, the maximum amount of material to be removed from a typical balance wheel 10 for poising purposes with an angle α min of approximately 25° while Figure 8 illustrates a condition of minimum dipoise with an angle α max of say 88.5° and angle β is selected to be 3°. In designing the balance wheel 10, values of α and M_x between the two extremes should be calculated. Since the tool diameter and cutting depth are known the area of the material to be removed can be determined.

15 The crescent shaped surface 27 of the wheel 10 is arrived at by calculating the depth of cut h for various values of M_x . Since a fixed tool having a diameter of approximately 2 mm may be used, the amount of material take off is determined by the curve of the balance wheel.

20 With reference to Figure 9 the depth of cut h may be computed for various values of M_x as follows:

$$M_x = (a + Y_0) F \cdot d \cdot W$$

and

$$40 \quad Y_0 = \frac{S^2}{12F}$$

where

F = area of segment

d = cutting depth of segment

W = specific weight of material (density)

$$45 \quad M_x = d \cdot W \cdot r^2 \left[\frac{a(\phi - \sin \phi)}{2} + \frac{2r \sin^3 \frac{\phi}{2}}{3} \right]$$

where

r = radius from axis 28 to centre of gravity of segment.

Solving for M_x results in the formula above where angle ϕ is unknown. Preferably using a computer, M_x (amount of dipoise) is calculated for one degree steps of angle thereby determining the crescent shape 27; the relationship of angle ϕ to height "h" can be found in common mathematical tables. The chord of the segment So is used rather than the actual bow design of the crescent and therefore, the poising method is used sometimes only for rough poising. If there is to be a fine poising operation, the first material take-off is somewhat less than required in order to ensure that the remaining dipoise for fine poising is still within the area of counterweight 26 and not on the coil side.

The balance wheel 10 itself is designed by dividing the wheel into small calculable areas where s_1, s_2 etc, are the centres of gravity, see Figure 1. The sum of all torsions about the axis 28, M right side, M left side, M above and M below must balance. The wheel 10 will be balanced when the material comprising So is removed since in the illustration a minimum coil weight is used. For calculation purposes, the unknown quantities are area s_0 (spoke) and angle δ , the angle between the centerline of the spoke 23 and the y axis. The unknowns, s_0 and δ are computed by summing the forces as follows:

$$(4) \quad \begin{aligned} \epsilon M \text{ (below)} &= \epsilon M \text{ (above)} \\ \epsilon M \text{ (left)} &= \epsilon M \text{ (right)} \\ \tan \delta &= \frac{\epsilon M \text{ (above, below)}}{\epsilon M \text{ (right, left)}} \end{aligned}$$

Having solved the force summations for angle δ and spoke area s_0 , the width of the spoke 23 can be computed since the spoke material, length, and thickness are already known.

The balance wheel 10 and method of manufacture described above simplify the poising operation which now often requires two or three separate drillings merely for rough poising. The present invention also eliminates the costly machines and constant adjustments formerly required in the industry for poising conventionally designed balance wheels. Using known techniques, it is also possible to automatically feed these new-type balance wheels 10 to a poising station at high speed thereby facilitating the mass production process.

It is understood, of course, that the arrangements discussed above are merely illustrative in nature. Numerous other arrangements may be readily devised by those skilled in the

art, for example designs following the condition of formulas (1), (2) and (4) and also formula (3) where a round tool is employed. In another embodiment instead of the coil 13 described above, one or more magnets 40 can be used on balance wheel 41. This arrangement is illustrated in Figure 10.

While the crescent-shaped contour 27 is positioned inside of the rim 26 in the coil-carrying balance wheel 10, it can also be located on the outside as shown with magnet-carrying balance wheel 41. Recesses 43 and 44 are provided for balance compensation. The maximum and minimum material take offs are also illustrated in dotted lines on the outer crescent surface 42.

WHAT WE CLAIM IS:—

1. A horological balance comprising an outer rim, and a spoke extending inwardly from the rim and having a yoke at the end thereof, a body mounted in the yoke offset from the axis of the balance, and the rim having an enlarged counterweight portion comprising a crescent shape determined by calculating conditions ranging from maximum to minimum dispose due to variations in the weight of said body between a maximum value and a minimum value with dimensions of said portion being determined by the amount of counterweight to be removed to poise the assembly under various dispose conditions, said balance having such amount of the counterweight portion removed as is necessary due to the actual weight of the body to poise the balance.
2. A balance in accordance with Claim 1, wherein the rim is substantially annular in shape having a gap between the opposite ends thereof, the yoke includes a main body portion having a base joined to the spoke and a pair of spaced apart arms projecting from the base, the said body comprising a coil mounted between the arms of the yoke, a portion of said coil extending into and being mounted within the gap in the rim.
3. A balance in accordance with Claim 1 or Claim 2 wherein the enlarged counterweight portion extends inwardly from the rim.
4. A balance in accordance with Claim 1 or Claim 2 wherein the enlarged counterweight portion extends outwardly of the rim.
5. A horological balance comprising a

balance wheel having an axis, a counterweight portion and a body mounted on the other side of said axis from said counterweight portion and which causes rotation of the body to a particular angular position when the axis is horizontal and the wheel is not properly poised, said angular position being related to the amount of dispose, said counterweight portion comprising a crescent shape determined by calculating conditions ranging from maximum to minimum dispose due to variations in the weight of said body between a maximum value and a minimum value with dimensions of said portion being determined by the amount of counterweight to be removed to poise the assembly under various dispose conditions, said balance having such amount of the counterweight portion removed as is necessary due to the actual weight of the body to poise the balance.

6. A method of poising a horological balance comprising the steps of providing a balance having a rim and a spoke extending inwardly from the rim and terminating in a yoke having a body mounted between arms thereof, the body being offset from the axis of rotation of the balance, forming a contoured portion of the balance rim to serve as a counterweight, the contour of said counterweight portion being determined by developing a curve between positions corresponding to the maximum and minimum dispose conditions due to variations in the weight of said body, rotatably supporting the balance wheel at its said axis with said axis horizontal so that variations in weight of said body cause the wheel to take up a particular angular position with respect to a fixed tool, and actuating the tool to remove a portion of the counterweight portion to at least partly poise the balance wheel.

7. A balance substantially as hereinbefore described with reference to the accompanying drawings.

8. A method of poising a balance substantially as hereinbefore described with reference to the accompanying drawings.

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balance wheel having an axis, a counterweight portion and a body mounted on the other side of said axis from said counterweight portion and which causes rotation of the body to a particular angular position when the axis is horizontal and the wheel is not properly poised, said angular position being related to the amount of dispoise, said counterweight portion comprising a crescent shape determined by calculating conditions ranging from maximum to minimum dispoise due to variations in the weight of said body between a maximum value and a minimum value with dimensions of said portion being determined by the amount of counterweight to be removed to poise the assembly under various dispoise conditions, said balance having such amount of the counterweight portion removed as is necessary due to the actual weight of the body to poise the balance.

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