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(54) SYNCHRONIZING ARRANGEMENT FOR A TIMEKEEPING INSTRUMENT

(71) We, **TIMEX CORPORATION**, a Corporation organized 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 a synchronizing arrangement for a timekeeping instrument such as a wristwatch.

It is already known to feed driving pulses of constant frequency to timekeeping instruments that are customarily controlled by a control pulse generator. The driving pulses are usually employed to synchronize a mechanical oscillator which has a nominal frequency deviating from the synchronous frequency. In order to suppress said nominal frequency, the driving pulse is made so strong that the influence of the nominal frequency is suppressed. This arrangement has the undesirable characteristic that a large source of energy is required.

The synchronization of indexing devices is less complicated, but these are only utilizable for the drive of a time-keeping instrument in particular instances, because such an indexing device, due to lack of an oscillating mechanism proper, actually has no inherent oscillation, so that such oscillation need not be suppressed. But if such a device is subjected to an impact or jolt it has the disadvantage that a driving pulse might be skipped, detrimentally affecting the accuracy of the timepiece.

The present invention seeks to provide a synchronizing arrangement which makes it possible to adjust or tune a timekeeping instrument to a specific synchronous frequency and, in case of deviation from such frequency, to lead back the oscillating member to said frequency, whereby said synchronizing process requires a comparatively

small amount of energy.

According to the invention there is provided a synchronizing arrangement for a timekeeping instrument including a control system which includes at least one driving coil movable relative to a permanent magnet system, by means of which control system a mechanical oscillating member can be maintained in motion with constant synchronous frequency and synchronous amplitude, said oscillation being opposed by a spring member, said arrangement comprising: a pulse generator for generating electrical pulses, means for dividing down the frequency of the pulses and feeding said pulses to the driving coil, and, at least one ferromagnetic element mounted in a fixed geometric relation to the driving coil and positioned to coact with the permanent magnet system during the relative movement of said system and the driving coil so as to generate a correcting force for adjustment of the mechanical oscillating member to the synchronous condition.

The synchronizing force generated reduces the oscillating frequency when amplitude increases and increases the oscillating frequency when amplitude grows smaller, or vice versa. It is possible to dimension the counterforce on the oscillating member in such a manner that it is non-linear, so that in case of a deviation from the normal synchronous amplitude a rapid restoration of the synchronous amplitude and frequency takes place. It is not at all necessary in this case that greater driving pulses than usual be employed. The timekeeping instrument will thus be inert to jolts and impact or any other influences that result in a deviation from the synchronous frequency and amplitude.

The following discussion will attempt to describe the mode of operation of the synchronizing arrangement according to this invention. For the sake of simplicity, it is assumed that the driving coil is disposed on

the oscillating member, so as to coact with a stationary permanent magnet system and is energized with a driving pulse approximately in the zero position, i.e., in the condition of the maximum velocity for every half or full oscillation. The inherent oscillations of the oscillating member give rise to monitoring pulses which are combined with control pulses of synchronous frequency and having a fixed pulse duration, which control pulses are delivered from an outside pulse source. The magnitude of the driving pulses is dependent on the combination of the monitoring and control pulses so that the oscillating member will be adjusted to the synchronous frequency. In explaining this adjustment or tuning, it is first assumed that the oscillating member already oscillates synchronously with the synchronous frequency and receives driving pulses of such magnitude that the oscillations of the oscillating member are maintained at the constant synchronous frequency and constant synchronous amplitude.

In contrast to conventional watch movements, the arrangement according to the present invention is such that upon change in amplitude, e.g., due to a jolt or to impact, the counterforce acting against the oscillations generated by the movement does not remain constant, instead, it changes. For example, said counterforce increases or decreases continually within a definite amplitude range upon deviation from the synchronous amplitude. Contrary to the usual practice, where despite change in amplitude due to an unchanging counterforce, the frequency of oscillation of the oscillating member remains practically unchanged, the oscillating frequency now changes, thereby departing from the synchronous frequency either in an upward or downward direction. Due to the variations between the synchronous frequency and the oscillating frequency a corresponding phase displacement results between the monitoring pulses and the control pulses, with the result that the magnitude of the driving pulses is reduced at enlarged amplitude and increased at reduced amplitude. This results in a rapid tuning of the oscillating frequency to the synchronous frequency and to the synchronous amplitude.

This adjustment can be attained by comparing either the rear flank or the fore flank of the monitoring pulses with the control pulses. This occurs in connection with the selection of the changing counterforce, i.e. whether the frequency of the oscillating member decreases or increases with changing amplitude. In every case the driving pulse at an enlarged amplitude will grow smaller until the synchronous frequency and the synchronous amplitude are reached. With decreasing amplitude the process works vice versa.

It is advantageous, if in the adjusting range the change in the frequency of the oscillating member as a function of the amplitude change is comparatively large, as this results in an especially rapid adjustment. In this case conveniently in the adjusting range, the change in the frequency of the oscillating member can be approximately proportional to the change in amplitude i.e., the curve would be substantially a straight line.

As the ferromagnetic element is constantly unmagnetized it is preferable that it is of a material that has small hysteresis losses, e.g., ferrites.

The synchronizing arrangement according to this invention can be utilized for greatly varying synchronous frequencies, e.g., for frequencies of the oscillating member in the range of 1 to 30 cycles. Also the synchronous amplitudes may be varied over a wide range, e.g., between 280° and 30°.

A particularly favourable form of the ferromagnetic element is comprised of a thin plate, but it is also readily possible to provide this element in a different form, such as a ferromagnetic powder that is dispersed in a carrier.

Due to the bilateral vibrations of the oscillating member it is advisable that the ferromagnetic element is disposed symmetrically to the central plane of oscillation for generating identical conditions in both oscillating directions. Alternatively, a plurality of such ferromagnetic elements may be disposed in and/or bilaterally of this central plane of oscillation.

Further advantages and features of the invention will become apparent from the following description of preferred embodiments thereof, given with reference to the accompanying drawings in which:—

Figure 1 is an axial section through a first embodiment of the invention;

Figure 2 is a section along the line 2-2 of Figure 1;

Figure 2a is a schematic representation of a control pulse generator in connection with the drive of the oscillating member;

Figure 3 is a partial view showing a second embodiment of the invention; and

Figure 4 is a section along the line of 4-4 of Figure 3.

In the first exemplified embodiment of Figures 1 and 2, showing a synchronizing arrangement for a wristwatch, there is disposed a mechanical oscillating member in the form of a balance assembly 10 having a driving coil 26. The driving coil is energized by driving pulses of synchronous frequency. Any suitable pulse generator may be applied to generate these driving pulses, provided it is ensured that these pulses are of a constant frequency. A known generator of this type, which is preferably also used in connection

with the synchronizing arrangement according to this invention, is schematically shown in Figure 2a wherein 100 represents the pulse generator which may customarily be a crystal oscillator such as a quartz oscillator. The pulse generator 100 supplies control pulses to a number of frequency dividers 102, so that the control frequency is divided downwards and reduced to a desired low frequency, e.g., 1 to 30 cycles per second. These low frequency control pulses are then fed to an output circuit 104 where, in response to the control pulses, driving pulses of identical frequency are adjustably fed in and then conducted to a driving coil 106 that coacts with a magnet 108. In this case either the coil 106 or the magnet 108 may be stationary; it is only necessary that the two components move relative to each other.

In the description of the exemplified embodiment, it is assumed that driving pulses of synchronous frequency are fed to the driving coil as shown in the drawings.

Reference is also made to the fact that the mechanical and electromagnetic arrangements of the exemplified embodiments described hereinafter are to a great extent similar to already known types, so that a comparatively cursory description will be sufficient. In addition, such details of the wristwatch as are not shown or described herein can be of a conventional nature.

Thus, reverting to the exemplified embodiment of Figures 1 and 2, the balance assembly 10 includes a balance staff 12 mounted in bearings 14 and 16 of bridge members 18 and 20. The balance staff 12 carries a balance body 22 and also a hub 24 to which the driving coil 26 and an impulse pin 28 are secured. The balance body 22 is insulated from the balance staff 12 and a first spiral spring 30 acts between said body 22 and bridge member 20. A second spiral spring 32 is secured to the other end of the balance staff 12 and to a frame section (not shown).

Impulse pin 28 coacts with a stepping mechanism comprising a lever 34 pivotally mounted at 36 and with its pallet pins 38 engaging an indexing wheel 42 securely mounted on wheel staff 40.

Driving coil 26 has parallel lengthwise sides 26a and 26b and two arcuate sections 26c and 26d that join said sides together. Four pairs of permanent magnets 44, 46, 48 and 50 coact with said coil 26, with two pairs of said magnets being secured to each one of back plates 52, 54.

A ferromagnetic element 56 is secured to the one lengthwise magnetic coil side 26a on the peripheral surface and in the central plane of oscillation A-A.

When the balance is in oscillation and the driving pulses are fed to the driving coil, as described above, the effect of the

ferromagnetic element 56 is as follows. It is assumed that the balance wheel assembly 10 and with it the driving coil 26 oscillate with a constant synchronous frequency of 6 cycles per second and short driving pulses of identical frequency are conducted to driving coil 26 when passing through the zero point of oscillation. As a result, the balance assembly 10 oscillates with synchronous frequency and synchronous amplitude. The normal synchronous amplitude of oscillation of the coil 26 is, for example between 160° and 200°—i.e. from 80° to 100° on each side of the plane A-A. During this oscillation the ferromagnetic element 56 coacts sequentially with the several poles of the permanent magnets 44 to 50. For the sake of simplicity in the following discussion, only one magnet group with the pairs 44 and 46 will be considered, as the effect of the two other magnet pairs 48 and 50 is exactly the same.

As the element 56 is a member having soft iron characteristics and thus without any permanent magnetism, it is attracted by all magnets. For example, as the element 56 moves anticlockwise from the position shown in Figure 2, it is attracted first by the north pole and then by the south pole of the magnet pair 44. Since the oscillating velocity of the balance assembly is normally very high, the effect of the element 56 is insignificant. However, if for example due to a jolt, the element is caused to oscillate beyond the south pole of magnet pair 44, then the effect of the element 56 is much stronger due to the fact that the oscillating velocity of the balance assembly is now substantially smaller since it is close to its terminal position at which it reverses its direction of movement. If the element swings beyond the south pole of magnet pair 44, in a direction towards the central plane of oscillations A-A, a braking force is exerted upon the driving coil which tends to cause the balance assembly to return to its normal synchronous amplitude and frequency. If the element passes through the central plane of oscillation A-A, the magnetic attraction of the south pole of magnet pair 44 and the north pole of magnet pair 46 are approximately identical, so that their influence on the element is zero. Upon further oscillation towards the north pole of 46, the attraction of the element 56 by said north pole results in a boosting of the counterforce of the spiral springs 30 and 32. Thus the total counterforce acting on the driving coil in both directions is not linear, for example, rising or falling in a straight line over a certain range, but changes in direction at 180° deflection in either direction. The intersecting point of the booster force and the counterforce of the springs can be changed by altering the

spring force of the spiral springs, whereby the intersecting point also changes to ensure that the synchronous amplitude is not so great that the element 56 swings as far as the central plane of oscillation, i.e. 180° in either direction.

If, due to a jolt, an opposing force is imparted to the oscillating driving coil thus causing it to oscillate with reduced amplitude, then the element 56 acts to increase the amplitude by virtue of its attraction towards the north pole of magnet pair 44 or the south pole of magnet pair 46. For example if, in oscillating anticlockwise in Figure 2, the driving coil is caused to slow to such an extent that the effect of the element 56 becomes significant before the element has reached the north pole of magnet pair 44, then the element will be attracted to the south pole and tend to speed up the oscillation, thus ensuring a rapid return to the normal synchronous amplitude and frequency.

As stated above, if deviations from the synchronous amplitude occur, the frequency of the balance assembly changes and with that the magnitude of the driving pulses, which decreases with expanding amplitude and increases with contracting amplitude.

Figures 3 and 4 illustrate a further embodiment of the invention. In this case the pairs of magnets are omitted, but they can be arranged in a manner similar to the first embodiment. Substantially only the balance assembly is shown which, e.g., oscillates at 4 cycles per second. The whole unit is designated by 62 and is mounted in bearings 64 and 66. There is a balance staff 68 to which one end of the spiral springs 70 and 72 are secured, the other ends being secured to frame members 74 and 76. The balance body in toto is designated 78. It has a hub 80 and two forked arms 82 and 84 to which a driving coil 90 is secured by two cast resin infusions 86 and 88. One ferromagnetic element 92, 94 is included in each cast resin infusion. Opposite the driving coil is a web 96 to which an arcuate member 98 is attached as a weight equalizing means.

The mode of operating of the ferromagnetic elements 92 and 94 is the same as described in connection with the first embodiment. If the not shown pairs of magnets are disposed symmetrically to the central plane of oscillation B-B then, as with the previous embodiment the elements 92 and 94 have zero effect at an oscillation of 180°.

The arrangement of the magnets, the ferromagnetic elements, and, if desired, also multiple driving coils, may be diversified in a number of ways. Regard must be given to the fact that the effect of the ferromagnetic elements on either side of a specific

amplitude—the synchronous amplitude—is different and can result in an inverse change of frequency if amplitude changes.

The mode of operation of the ferromagnetic elements is independent of the type of relative oscillation between the magnetic coil and the magnets. For example, the driving coil may be stationary and the permanent magnets disposed on the balance assembly. In this case it is not necessary that the ferromagnetic elements be mounted on the driving coil proper, rather, they may be secured to any suitable stationary member.

WHAT WE CLAIM IS:—

1. A synchronizing arrangement for a timekeeping instrument including a control system which includes at least one driving coil movable relative to a permanent magnet system, by means of which control system a mechanical oscillating member can be maintained in motion with constant synchronous frequency and synchronous amplitude, said oscillation being opposed by a spring member, said arrangement comprising: a pulse generator for generating electrical pulses, means for dividing down the frequency of the pulses and feeding said pulses to the driving coil, and, at least one ferromagnetic element mounted in a fixed geometric relation to the driving coil and position to coact with the permanent magnet system during the relative movement of said system and the driving coil so as to generate a correcting force for adjustment of the mechanical oscillating member to the synchronous condition.

2. A synchronizing arrangement in accordance with Claim 1 wherein the ferromagnetic member is operable to generate a correcting force whose magnitude varies in a non-linear manner in dependence on the amplitude of oscillation of the oscillating member.

3. A synchronizing arrangement in accordance with either one of Claims 1 or 2 wherein the ferromagnetic element is of a material having a small hysteresis loss.

4. A synchronizing arrangement in accordance with any one of Claims 1 to 3 wherein the ferromagnetic element is of a ferrite material.

5. A synchronizing arrangement in accordance with any one of the preceding Claims wherein the mechanical oscillating member comprises a balance wheel on which the driving coil is mounted, and wherein the ferromagnetic element comprises separate elements mounted on the balance wheel and located symmetrically with respect to the central plane of oscillation.

6. A synchronizing arrangement in accordance with any one of the preceding Claims wherein the permanent magnet system includes at least two groups of pairs

spring force of the spiral springs, whereby the intersecting point also changes to ensure that the synchronous amplitude is not so great that the element 56 swings as far as the central plane of oscillation, i.e. 180° in either direction.

If, due to a jolt, an opposing force is imparted to the oscillating driving coil thus causing it to oscillate with reduced amplitude, then the element 56 acts to increase the amplitude by virtue of its attraction towards the north pole of magnet pair 44 or the south pole of magnet pair 46. For example if, in oscillating anticlockwise in Figure 2, the driving coil is caused to slow to such an extent that the effect of the element 56 becomes significant before the element has reached the north pole of magnet pair 44, then the element will be attracted to the south pole and tend to speed up the oscillation, thus ensuring a rapid return to the normal synchronous amplitude and frequency.

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2. A synchronizing arrangement in accordance with Claim 1 wherein the ferromagnetic member is operable to generate a correcting force whose magnitude varies in a non-linear manner in dependence on the amplitude of oscillation of the oscillating member.

3. A synchronizing arrangement in accordance with either one of Claims 1 or 2 wherein the ferromagnetic element is of a material having a small hysteresis loss.

4. A synchronizing arrangement in accordance with any one of Claims 1 to 3 wherein the ferromagnetic element is of a ferrite material.

5. A synchronizing arrangement in accordance with any one of the preceding Claims wherein the mechanical oscillating member comprises a balance wheel on which the driving coil is mounted, and wherein the ferromagnetic element comprises separate elements mounted on the balance wheel and located symmetrically with respect to the central plane of oscillation.

6. A synchronizing arrangement in accordance with any one of the preceding Claims wherein the permanent magnet system includes at least two groups of pairs



of magnets disposed symmetrically to the central plane of oscillation so that the ferromagnetic element coacts therewith.

5 7. A synchronizing arrangement in accordance with any one of the preceding Claims wherein the oscillating member has a synchronous frequency in the range of 1 to 20 cycles per second.

10 8. A synchronizing arrangement in accordance with any one of the preceding Claims wherein the oscillating member has a synchronous amplitude ranging from 280° to 30°.

9. A synchronizing arrangement for

a timekeeping instrument constructed, 15
arranged and adapted to operate substantially as hereinbefore described with reference to Figures 1 and 2 or Figures 3 and 4 of the accompanying drawings.

10. A timekeeping instrument incorporating the synchronizing arrangement as 20
claimed in any one of the preceding Claims.

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