Aug. 29, 1967 P. G. KUEFFER 3,338,047

FREQUENCY REGULATOR FOR TUNING FORK DRIVE SYSTEM

Filed Oct. 18, 1965

Fig. 1

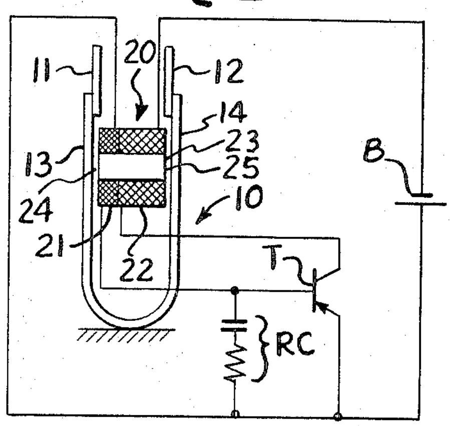


Fig. 2

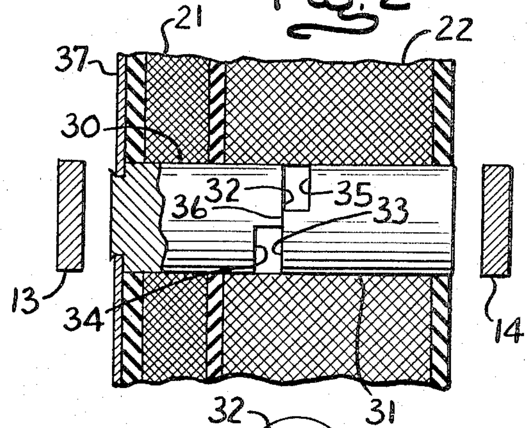


Fig. 3

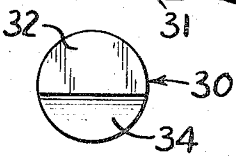


Fig. 4

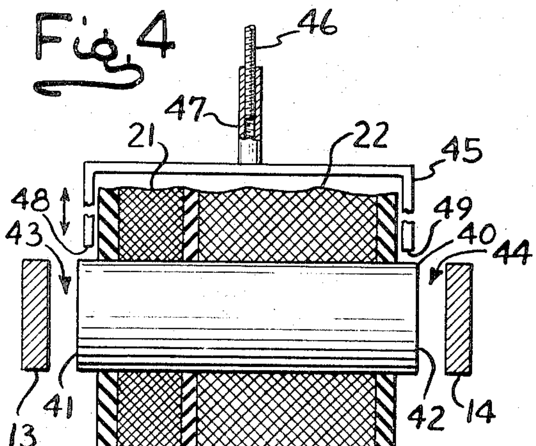


Fig. 5

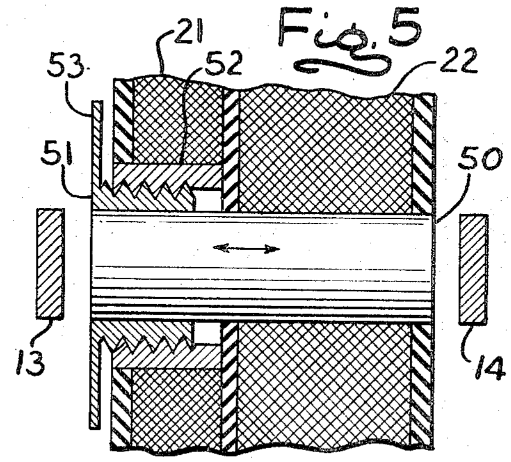
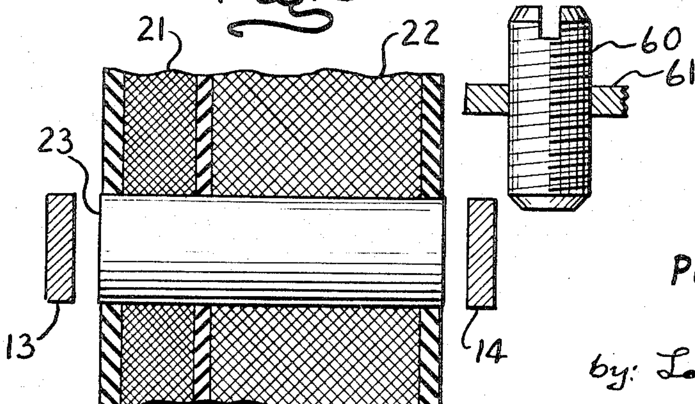


Fig. 6



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3,338,047
FREQUENCY REGULATOR FOR TUNING FORK DRIVE SYSTEM

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Filed Oct. 18, 1965, Ser. No. 497,236
3 Claims. (Cl. 58—23)

ABSTRACT OF THE DISCLOSURE

A frequency regulator for adjusting the frequency of a tuning fork in a timepiece driving system by adjusting the magnetic flux in the air gaps between the tines of the tuning fork and the ends of a magnetic core used to drive the tuning fork. The frequency regulator adjusts the magnetic flux by changing the magnetic reluctance of the magnetic core, by shunting a part of the magnetic flux between the ends of the core, or by moving the core back and forth along its axis.

This invention relates generally to timepiece driving systems and, more particularly, to an improved speed regulator for an electromagnetic drive system in which a tuning fork is used as the frequency or speed controlling element.

It is a primary object of the present invention to provide an improved timepiece driving system using a tuning fork as the speed controlling element and in which the vibratory frequency of the tuning fork can be accurately adjusted in order to adjust the speed of the timepiece. A related object of the invention is to provide such an improved tuning fork drive system in which the frequency regulator can be precisely adjusted by simple and convenient manual operation.

It is another object of one aspect of this invention to provide an improved frequency or speed regulator of the foregoing type which does not disturb the balance of the tuning fork being regulated. In this connection, it is yet another object of this invention to provide such an improved regulator device which does not increase the physical size of the drive system which vibrates the tuning fork.

It is a further object of the present invention to provide an improved frequency regulator of the type described above which regulates the driving forces applied to the tuning fork rather than superimposing an auxiliary load on the fork tines. Thus, it is a related object to provide such a regulator which does not interfere with the normal vibratory motion of the tuning fork tines.

Other objects and advantages of the invention will become apparent upon reading the following detailed description and accompanying drawings, in which:

FIGURE 1 is a schematic illustration of a tuning fork adapted to drive a rotary timepiece, and associated electromagnetic drive means for vibrating the tuning fork at a predetermined frequency;

FIG. 2 is a fragmentary section showing one embodiment of the improved regulator provided by this invention for controlling the frequency of the tuning fork in a system such as illustrated in FIG. 1;

FIG. 3 is an end view of one of the cooperating faces of the two core sections in the regulator device of FIG. 2;

FIG. 4 is a fragmentary section showing the core structure for another embodiment of the frequency regulator provided by this invention in a tuning fork drive system of the type illustrated in FIG. 1;

FIG. 5 is a fragmentary section of still another embodiment of the frequency regulator provided by this invention; and

FIG. 6 is a fragmentary section showing a fourth embodiment of the improved regulator of this invention.

While the invention will be described in connection with certain illustrated embodiments, it will be understood that it is not intended to limit the invention to these embodiments but, on the contrary, it is intended to cover all alternative embodiments, constructions and equivalent arrangements as may be included within the spirit and scope of the appended claims.

Turning now to the drawings, and referring to FIG. 1, there is shown a timekeeping standard in the form of a tuning fork **10** made of a magnetic flux conducting material and adapted to drive the indicating hands of a rotary timepiece via the pinions and gears which comprise the conventional timing train. In order to couple the tines of the tuning fork **10** to the timing train, two C-shaped magnets **11**, **12** are mounted on the ends of the respective fork tines **13**, **14** for cooperating with a toothed rotor (not shown) as described in more detail in copending application Ser. No. 492,793, entitled, Improved Drive System for Tuning Fork Timepiece, filed Oct. 4, 1965, which is assigned to the assignee of the present invention. It will suffice to say that the rotor is driven at a timed rate which depends upon the frequency of vibration of the fork. While the illustrative tuning fork includes a pair of magnets **11**, **12** cooperating with the rotor, it will be understood that only one magnet (mounted on one of the tines) may be used with a balancing mass mounted on the other fork tine.

For the purpose of driving the tuning fork, a coil assembly **20** is provided including a pickup coil **21** and drive coil **22** wound about a magnetic core **23**. As shown in FIG. 1, the pickup coil **21** is connected in the base or input circuit of a transistor T while the drive coil **22** is connected to the transistor output circuit which includes a battery B connected to the emitter. A capacitor-resistor series circuit RC is connected in parallel with the pickup coil as shown. Alternate half cycles of the voltage fluctuations induced in the pickup coil are amplified by the transistor to produce driving pulses in the drive coil **22** in proper phase relationship to sustain the tuning fork vibrations. The driving pulses produced in the drive coil **22** vary the magnetic flux in the air gaps **24**, **25** between the two outer ends of the core **23** and the respective fork tines **13**, **14**, these air gaps **24**, **25** forming part of an overall magnetic circuit which includes both the magnetic core **23** and the flux conducting tines **13**, **14** of the tuning fork. For the more detailed features of the electronic circuitry and a more complete discussion thereof, reference is made to the abovementioned copending application.

In accordance with the present invention, the electromagnetic drive system for vibrating the tuning fork is provided with an improved frequency regulator which comprises means for adjusting the magnetic flux in the air gaps between the ends of the magnetic core member and the respective opposed tines of the tuning fork so as to control the vibratory frequency of the tuning fork. Thus, referring to FIG. 2, the magnetic core consists of two cooperating magnetic core sections **30**, **31** having a pair of opposed abutting end faces **32**, **33** which are adapted to vary the magnetic reluctance of the core assembly upon relative rotation of the two sections **30**, **31**. More particularly, the two cooperating end faces **32**, **33** are generally D-shaped (FIG. 3) with each D extending beyond or encompassing the common axis of the two core sections and forming complemental D-shaped recesses or cavities **34**, **35**. As one of the core sections is rotated relative to the other sections, the two cooperating D faces **32**, **33** overlap more or less with each other so as to vary the contact area **36** between the two sections, thereby varying the flux-carrying capacity of the core assembly and of the magnetic circuit in which the core assembly is included.

In order to facilitate rotation of one of the core sections relative to the other, a serrated adjustment wheel **37** is secured to the outer end of the left-hand core section **30**. As the adjustment wheel **37** is turned through any given angular displacement, the left-hand core section **30** is rotated through the same angular distance so as to increase or decrease the contact area **36** between the two cooperating D faces **32, 33**. If the contact area **36** is increased, the magnetic reluctance of the core assembly is decreased with an attendant increase in its flux-carrying capacity. This increases the frequency of the vibratory motion of the tuning fork by increasing the magnetic flux in the air gaps between the two outside end faces of the magnetic core and the respective fork tines. Since the two D faces of the core sections **32, 33** extend beyond or encompass the common axis of the two core sections, it will be appreciated that the two cooperating faces will always be in contact with each other, with the contact area **36** being reduced or enlarged by simply rotating one of the two sections relative to the other.

Since the regulator of FIGS. 2 and 3 simply utilizes a drive core assembly made of two sections instead of one, it does not increase the physical size of the electromagnetic drive means. Moreover, the adjustment wheel **37** for rotating one of the core sections relative to the other can be made extremely thin and mounted along one face of the core assembly so that again the physical size of the unit is not substantially enlarged. These considerations are extremely important when one considers the limited space available for mounting a drive unit of this type between the tines of a miniature tuning fork. Of course, it will be understood that the cooperating core sections may be provided with configurations other than the D-shaped end faces used in the illustrative embodiment, as long as the contact area is varied as one core section is rotated relative to the other. Moreover, the cooperating ends of the core sections may be designed so as to move the two core sections axially relative to the fork tines as one or the other of the sections is rotated. In this latter case, the two core sections are preferably moved together through the same axial distance so as to maintain substantially equal air gaps between the outside ends of the core and the cooperating fork tines.

An alternative embodiment of the inventive regulator, illustrated in FIG. 4, varies the magnetic flux in the two air gaps without altering the magnetic reluctance of the core member. Thus, the regulator device of FIG. 4 includes a single core member **40** having a pair of outside end faces **41, 42** which cooperate with the fork tines **13, 14** to form a pair of substantially equal air gaps **43, 44**. In order to vary the magnetic flux within the air gaps, a C-shaped shunt member **45** made of a magnetic flux conducting material is operatively associated with the core member **40**. For the purpose of permitting adjustment of the magnetic shunt **45**, it is provided with a vertical mounting post **46**, the upper end of which is threaded into a corresponding threaded socket **47** so that the shunt **45** can be raised and lowered relative to the core member **40**. As the shunt **45** is raised, the air gaps between the two end faces **48, 49** and the core **40** are increased so that more flux is permitted to flow through the core member. This increases the frequency of the tuning fork by increasing the flux in the two air gaps **43, 44** between the core end faces **41, 42** and the cooperating fork tines. Conversely, if the shunt **45** is lowered closer to the magnetic core **40**, more magnetic flux is passed through the shunt so as to reduce the flux in the core member and thus in the two air gaps **43, 44**, thereby reducing the frequency of the vibrating fork.

In accordance with another aspect of this invention, a freqency regulator is provided for adjusting the magnetic

flux in the core-tine air gaps by the use of a single core member. Thus, referring to FIG. 5, a single magnetic core **50** is mounted for movement back and forth along its axis between the tuning fork tines **13, 14**. In the particular structure illustrated, one end of the core **50** is provided with a threaded sleeve **51** which cooperates with a complementally threaded sleeve **52** fitted within the central opening of the pickup coil **21**. In order to move the core **50** axially in either direction, a serrated adjustment wheel **53** is connected to the threaded sleeve **52**. Then as the adjustment wheel **53** is turned through a given angular displacement, the threaded sleeve **52** is turned through the same distance so as to move the magnetic core **50** along its axis toward one of the tuning fork tines **13, 14**. Of course, the particular direction in which the magnetic core **50** is moved depends on the direction in which the adjustment wheel **53** is turned.

It can be seen that the regulator of FIG. 5 does not modify the magnetic reluctance of the core member **50**, nor does it shunt any of the magnetic flux between the two ends of the core member. Of course, as one end of the core member **50** is moved a given distance toward one of the fork tines, the opposite end of the core will be moved away from the other fork tine by the same distance so that the air gaps between the ends of the core member and the fork tines are not always equal. Consequently, this particular embodiment of the inventive regulator is most useful in those applications where it is not essential to maintain perfect balance between the two tines of the tuning fork.

In FIG. 6, there is illustrated another type of regulator device which does not form part of the present invention, but which may be helpful for comparative purposes. In this device, the frequency of the tuning fork is not regulated by varying the magnetic flux in the air gaps between the two ends of the core member and the respective tuning fork tines, but rather by superimposing an auxiliary load on one of the tuning fork tines. Thus, a permanently magnetized screw **60** is threaded into a brass mounting bracket **61** alongside one of the tuning fork tines. By advancing or retracting this magnetized screw **60** within the mounting bracket **61**, a variable supplemental magnetic load is applied to the vibrating fork. In other words, the magnetized screw provides a damping effect on the vibrating fork, and the degree of damping applied may be varied by mechanical adjustment of the screw.

It can be seen from the foregoing detailed description that this invention provides an improved timepiece driving system using a tuning fork as the speed controlling element and in which the vibratory frequency of the tuning fork can be accurately adjusted in order to adjust the angular velocity of the timepiece. Precise adjustments can be made by simple and convenient manual operations, such as by turning the serrated adjustment wheel in the embodiments of FIGS. 2 and 5, or by turning the stem of the magnetic shunt in the embodiment of FIG. 4. Moreover, the preferred regulator devices provided by this invention maintain the symmetry of the magnetic circuit and thus do not disturb the balance of the tuning fork being regulated. Furthermore, the inventive regulator is relatively simple to manufacture at a low cost, and functions by regulating the driving forces applied to the tuning fork rather than superimposing an auxiliary load on the fork tines. This regulator is also extremely compact and does not substantially increase the physical size of the drive system, and does not interfere with the normal vibratory motion of the fork tines.

I claim as my invention:

1. In a timepiece driving system, the combination of a tuning fork having a pair of opposed tines made of a magnetic flux-conducting material for controlling the angular velocity of the driving system, electromagnetic drive means including a pair of coils and a magnetic core for vibrating the tuning fork tines, said magnetic core being operatively associated with the tuning fork tines so that the ends of said core and the tuning fork tines define predetermined symmetrical air gaps, and a frequency regulator comprising means for adjusting the magnetic reluctance of said core member and thereby adjusting the magnetic flux in said air gaps so as to control the vibratory frequency of the tuning fork.

2. In a timepiece driving system, the combination of a tuning fork having a pair of opposed tines made of a magnetic flux-conducting material for controlling the angular velocity of the driving system, electromagnetic drive means including a pair of coils and a magnetic core for vibrating the tuning fork tines, said magnetic core being positioned to define perdetermined symmetrical air gaps between the ends of said core and the tuning fork tines, said magnetic core including two cooperating core sections movable relative to each other and having opposed abutting end faces adapted to vary the contact area between the two sections as said sections are moved relative to each other, and means for moving said core sections relative to each other so as to vary the magnetic reluctance of said magnetic core by varying said contact area whereby the magnetic flux in said air gaps may be adjusted to control the vibratory frequency of the tuning fork.

3. In a timepiece driving system, the combination of

a tuning fork having a pair of opposed tines made of a magnetic flux-conducting material for controlling the angular velocity of the driving system, electromagnetic drive means including a pair of coils and a magnetic core for vibrating the tuning fork tines, said magnetic core being positioned to define predetermined symmetrical air gaps between the ends of said core and the tuning fork tines, said magnetic core consisting of two symmetrical core sections having opposed abutting D-shaped end faces, and means for rotating one of said core sections relative to the other section whereby the contact area between the abutting D-shaped end faces is varied so as to adjust the magnetic reluctance of said core and thereby adjust the magnetic flux in said air gaps to control the vibratory frequency of the tuning fork.

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